

# **Kelly HPM High Power Full Bridge Permanent Magnet DC Motor Controller User's Manual**

**HPM07601**

**HPM07801**

**HPM12401**

**HPM12601**

**HPM12901**

**HPM14301**

**HPM14501**

**HPM14701**

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# Chapter1 Introduction

## 1.1 Overview

This manual introduces the Kelly HPM motor controllers' features, their installation and their maintenance. Read the manual carefully and thoroughly before using the controller. If you have any questions, please contact the support center of Kelly Controls, LLC.

Kelly's programmable motor controllers provide high efficient, smooth and quiet controls for electric vehicles like golf carts, forklifts and hybrid vehicles, as well as electric boats and industrial motor speed control. It uses high power MOSFET's and, PWM to achieve efficiencies of up to 99% in most cases. A powerful microprocessor brings in comprehensive and precise control to the controllers. It also allows users to adjust parameters, conduct tests, and obtain diagnostic information quickly and easily.

Kelly's HPM high power motor controller is full bridge or 4 quadrant controller. It provides fast and reliable electronic direction control. There is no arc, spark, or life limit on motor direction changes.

# Chapter2 Main Features and Specifications

## 2.1 General functions

- (1) Extended fault detection and protection. The LED flashing pattern indicates the fault sources. Green LED indicates normal operation. Controller will shut down in some fault conditions.
- (2) Monitoring battery voltage. It will stop driving if the battery voltage is too high and it will progressively cut back motor drive power as battery voltage drops until it cuts out altogether at the preset "Low Battery Voltage" setting.
- (3) Built-in current loop and over current protection.
- (4) Configurable motor temperature protection range.
- (5) Current cutback at low temperature and high temperature to protect battery and controller. The current begins to ramp down at 90° C case temperature, shutting down at 100° C .
- (6) Two RS232 ports. Both can be used for configuration.
- (7) Configurable and programmable with a host computer though RS232 or USB. Provide free GUI which can run on Windows XP/2000, Windows 7 and Vista (recommend using Kelly Standard USB To RS232 Converter).
- (8) Provision of a +5 volt output to supply various kinds of sensors, including Hall effect type.
- (9) 4 switch inputs which are activated by connection to Ground. Default to throttle switch, brake switch, reversing switch and Boost/Economy switch input.
- (10) 3 analog 0-5V inputs that default to throttle input, brake input and motor temperature input.
- (11) Pulsed reverse alarm output.
- (12) Main contactor driver. Cutting off the power if any fault is detected.
- (13) Current meter to display both drive and regen current. Save shunt.
- (14) Configurable boost switch. Enables the maximum output power achievable if the switch is turned on.
- (15) Configurable economy switch. Limits the maximum current to half if the switch is turned on.
- (16) Maximum reverse power is configurable to half power.
- (17) Enhanced regen brake function. A novel ABS technique provides powerful and smooth regen.
- (18) Configurable 12V brake signal input, in lieu of motor temperature sensor.
- (19) Optional joystick throttle. A bi-symmetrical 0-5V signal for both forwarding and reversing.
- (20) Configurable motor over-temperature detection and protection with the recommended thermistor KTY83-122.
- (21) Using battery-powered.
- (22) Optional CAN bus.
- (23) Supply voltage 8V-30V.

## 2.2 Features

- Opto-isolated technology achieve stability.
- Intelligence with powerful microprocessor.
- Synchronous rectification, ultra low drop, and fast PWM to achieve very high efficiency.
- Electronic reversing, no reversing contactor needed, fast direction change, high reliability and efficiency, low noise, no arc, no wearing, no life limit, easy maintenance.
- Voltage monitoring on voltage source 12V and 5V.
- Current limit and torque control. Configurable torque mode and speed mode.
- Low EMC.
- LED fault code.
- Battery protection: current cutback, warning and shutdown at configurable high and low battery voltage.
- Rugged aluminum housing for maximum heat dissipation and harsh environment. Support fan or water cooling.
- Rugged high current terminals, and rugged aviation connectors for small signal.
- Thermal protection: current cut back, warning and shutdown at high temperature.
- Configurable high pedal protection: Disable operation if power up with high throttle.
- Brake switch is used to start regen.
- Support three modes of regenerative braking: brake switch regen, release throttle regen, 0-5V analog signal variable regen.
- An RS232 port allows for configuration, programming and software upgrades using the free Windows GUI with your PC.
- Standard PC/Laptop computer is used to do programming. No special tools needed.
- User program provided. Easy to use. No cost to customers.
- No adjustment.

## 2.3 Specifications

- Frequency of Operation: 16.6kHz.
- Standby Battery Current depending on the model: usually less than 2mA.
- 5V Sensor Supply Current: 40mA.
- Controller supply voltage range, PWR, 8 to 30V (24V preferred)
- Controller input power, PWR: less than 10W.
- Standard Throttle Input: 0-5 Volts(3-wire resistive pot), 1-4 Volts(hall active throttle).
- Analog Brake and Throttle Input: 0-5 Volts.
- Reverse Alarm, Main Contactor Coil Driver, Meter.
- Full Power Temperature Range: 0°C to 50°C (controller case temperature).
- Operating Temperature Range: -30°C to 90°C, 100°C shutdown(controller case temperature).
- Motor Current Limit, 1 minutes: 300A-900A. depending on the model.
- Motor Current Limit, continuous: 135A-450A, depending on the model.
- Max Battery Current : Configurable.

Kelly Full Bridge Permanent Magnet DC Motor Controller				
Model	1 minute Current	Continuous Current	Rated Voltage	Regen
HPM07601	600A	300A	72V	Yes
HPM07801	800A	400A	72V	Yes
HPM12401	400A	200A	120V	Yes
HPM12601	600A	300A	120V	Yes
HPM12901	900A	450A	120V	Yes
HPM14301	300A	135A	144V	Yes
HPM14501	500A	225A	144V	Yes
HPM14701	700A	315A	144V	Yes
Female plugs of J1&J2 will be shipped for free.				

## Chapter 3 Wiring and Installation

### 3.1 Mounting the Controller

The controller can be oriented in any position which should be as clean and dry as possible, if necessary, shielded with a cover to protect it from water and contaminants.

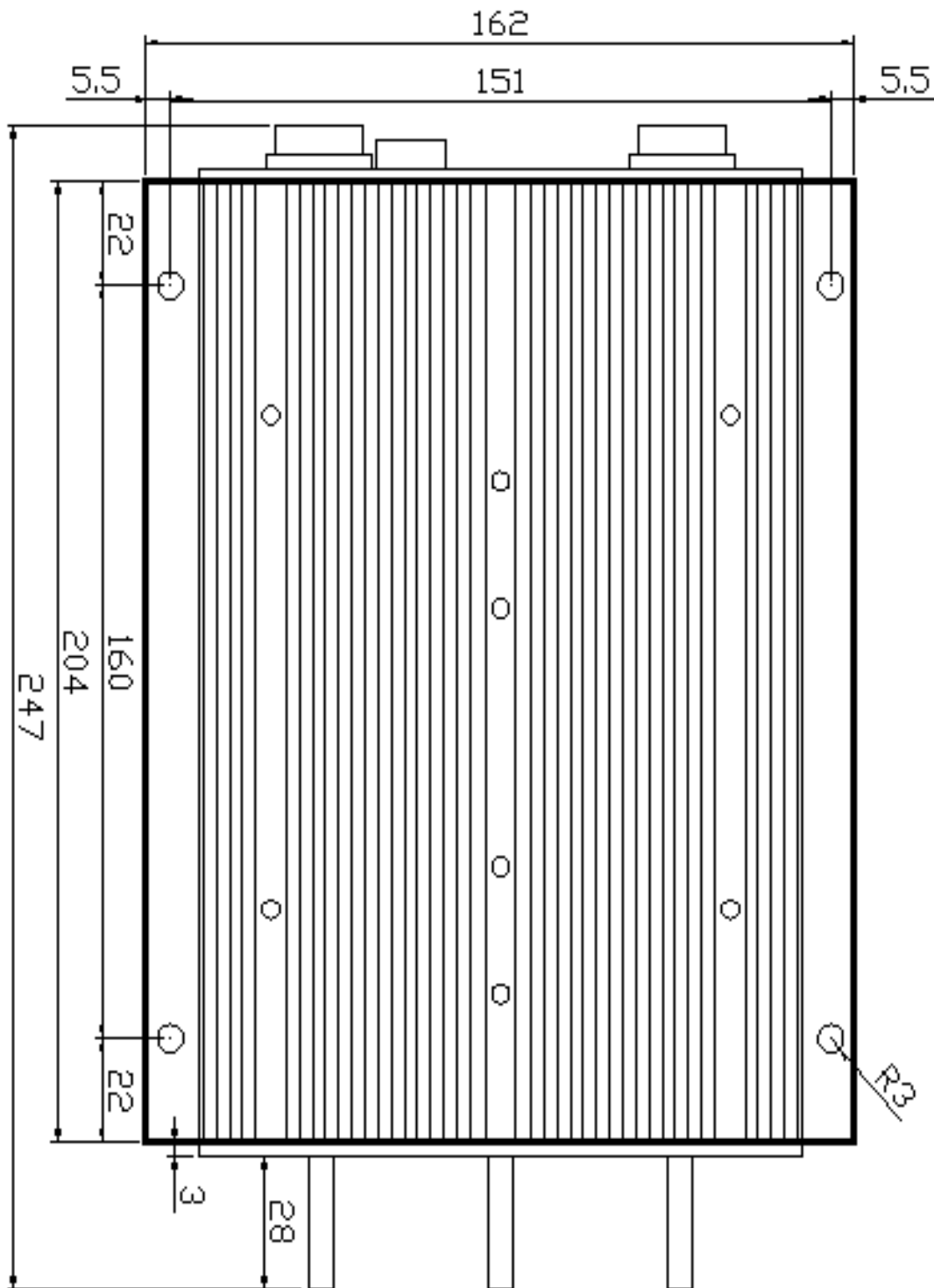
To ensure full rated output power, the controller should be fastened to a clean, flat metal surface with four or six screws. Applying silicon grease or some other thermal conductive material to contact surface will enhance thermal performance.

Proper heat sinking and airflow are vital to achieve the full power capability of the controller.

The case outline and mounting holes' dimensions are shown in Figure 1 and 2.

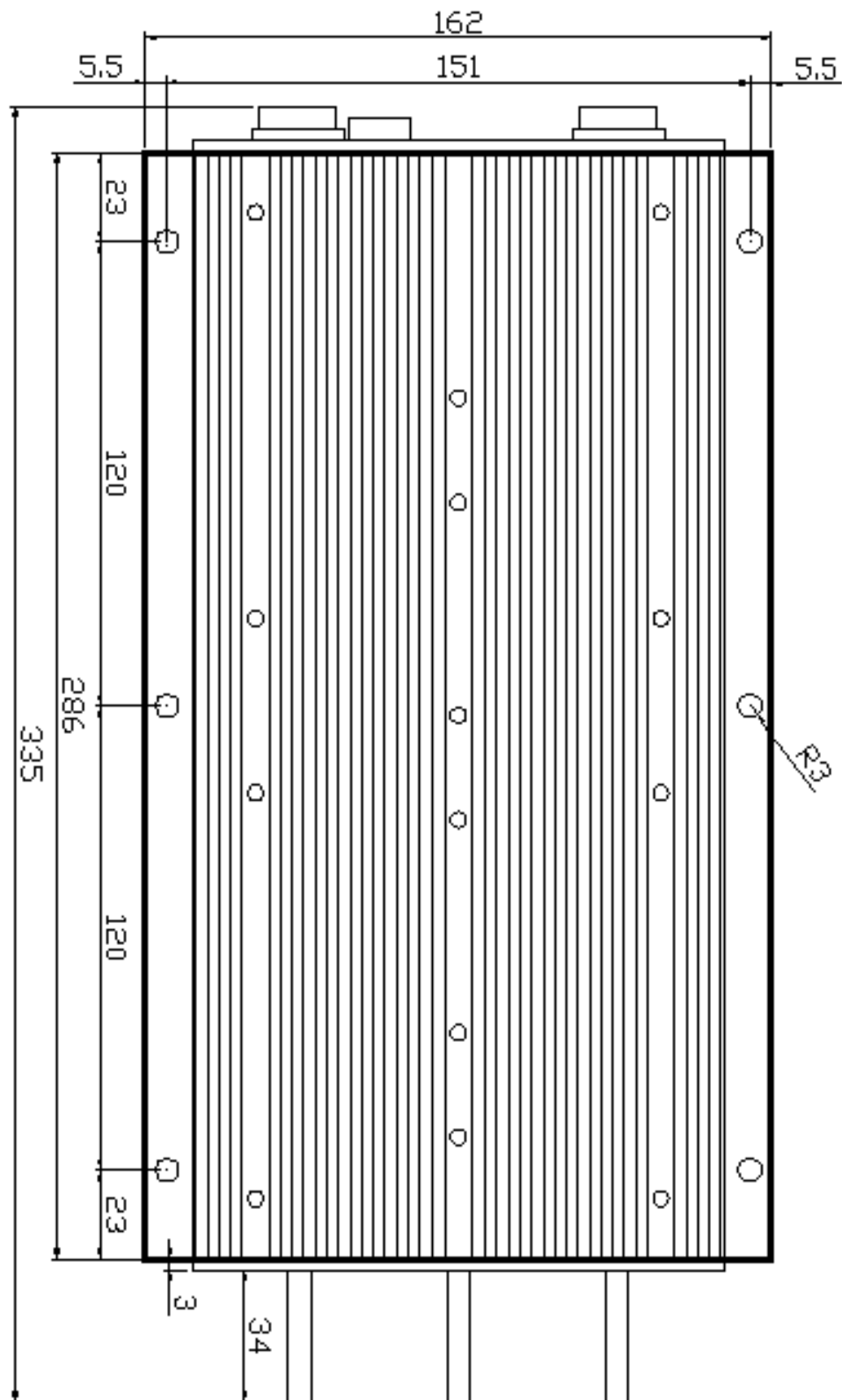
#### Caution:

- **RUNAWAYS** — Some conditions could cause the vehicle to run out of control. Disconnect the motor, or jack up the vehicle, and get the drive wheels off the ground before attempting any work on the motor control circuitry.
- **HIGH CURRENT ARCS** — Electric vehicle batteries can supply very high power, and arcs can occur if they are short circuit. Always turn off the battery circuit before working on the motor control circuit. Wear safety glasses, and use properly insulated tools to prevent short circuit.



**Figure 1:** Height: 84 millimeters  
 Length: 204 millimeters

Controller models with above dimension: HPM72601, HPM72801, HPM12401  
 HPM12601, HPM14301, HPM14501



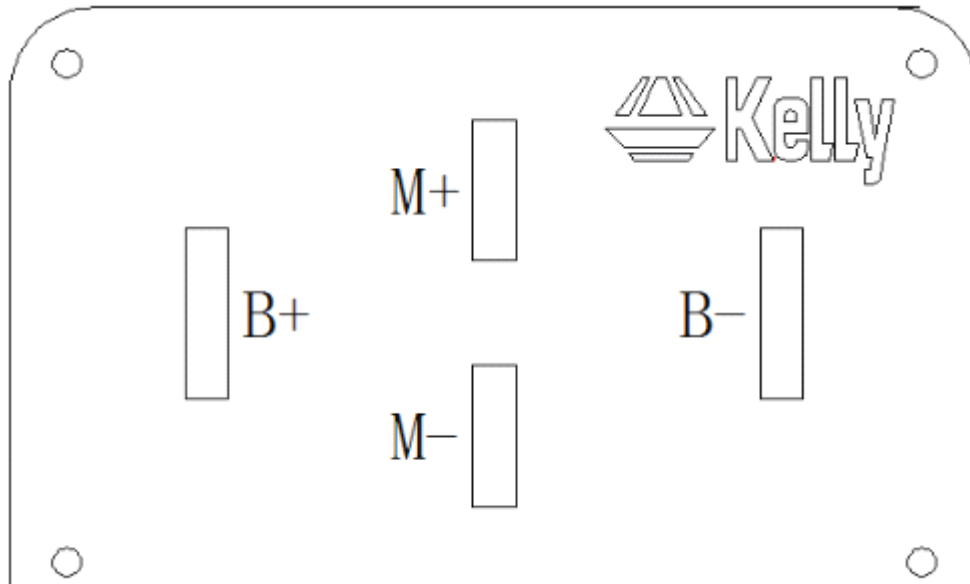
**Figure 2:** Height: 84 millimeters  
Length: 286 millimeters

Controller models with above dimension: HPM12901, HPM14701

## 3.2 Connections

### 3.2.1 Front and Back Panels of PM Motor Controller:

Four metal bars and two plugs (J1, J2) are provided for connecting to the battery, motor and control signals in the front and back panels of the controller shown as Figure 3 and 4



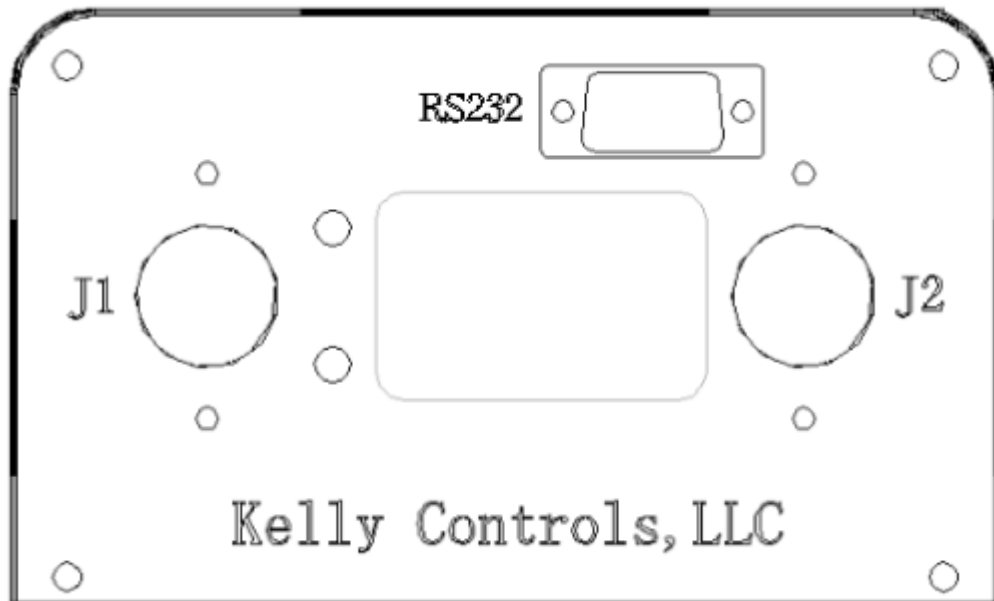
**Figure 3:** Front panel of HPM motor controller

**B+:** Battery positive

**B-:** Battery negative

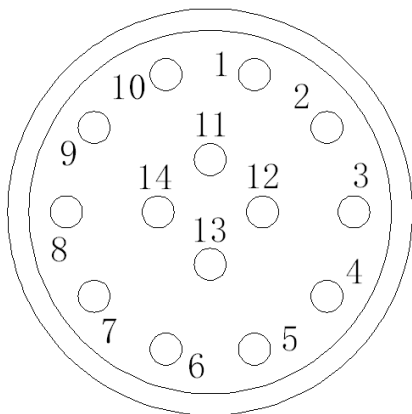
**M+:** armature positive

**M-:** armature negative



**Figure 4:** Back panel of HPM motor controller

**Figure 5:** The connecting diagram of J1 and J2



**J1 Pin Definition**

- 1- PWR: Controller power supply (output).**
- 2- Current meter. <200mA**
- 3- Main contactor driver. <2A**
- 4- Alarm: To drive reverse beeper, <200mA.**
- 5- GND: Signal return**
- 6- Green LED: Running indication**
- 7- GND: Signal return**
- 8- Reserved**
- 9- Reserved**
- 10- CAN bus high. Optional**
- 11- CAN bus low. Optional**
- 12- Reserved**
- 13- GND: Signal return, or power supply ground**
- 14- Red LED: Fault code.**

## J2 Pin Definition

- 1- PWR: Controller power supply (input)
- 2- GND: Signal return, or power supply ground
- 3- GND: Signal return
- 4- Motor temperature input.
- 5- Throttle analog input, 0-5V
- 6- Brake analog input, 0-5V
- 7- 5V: 5V supply output. <50mA
- 8- Micro\_SW: Throttle switch input
- 9- Reversing switch input
- 10- Brake switch input
- 11- Reserved
- 12- Reserved
- 13- Reserved
- 14- GND: Signal return

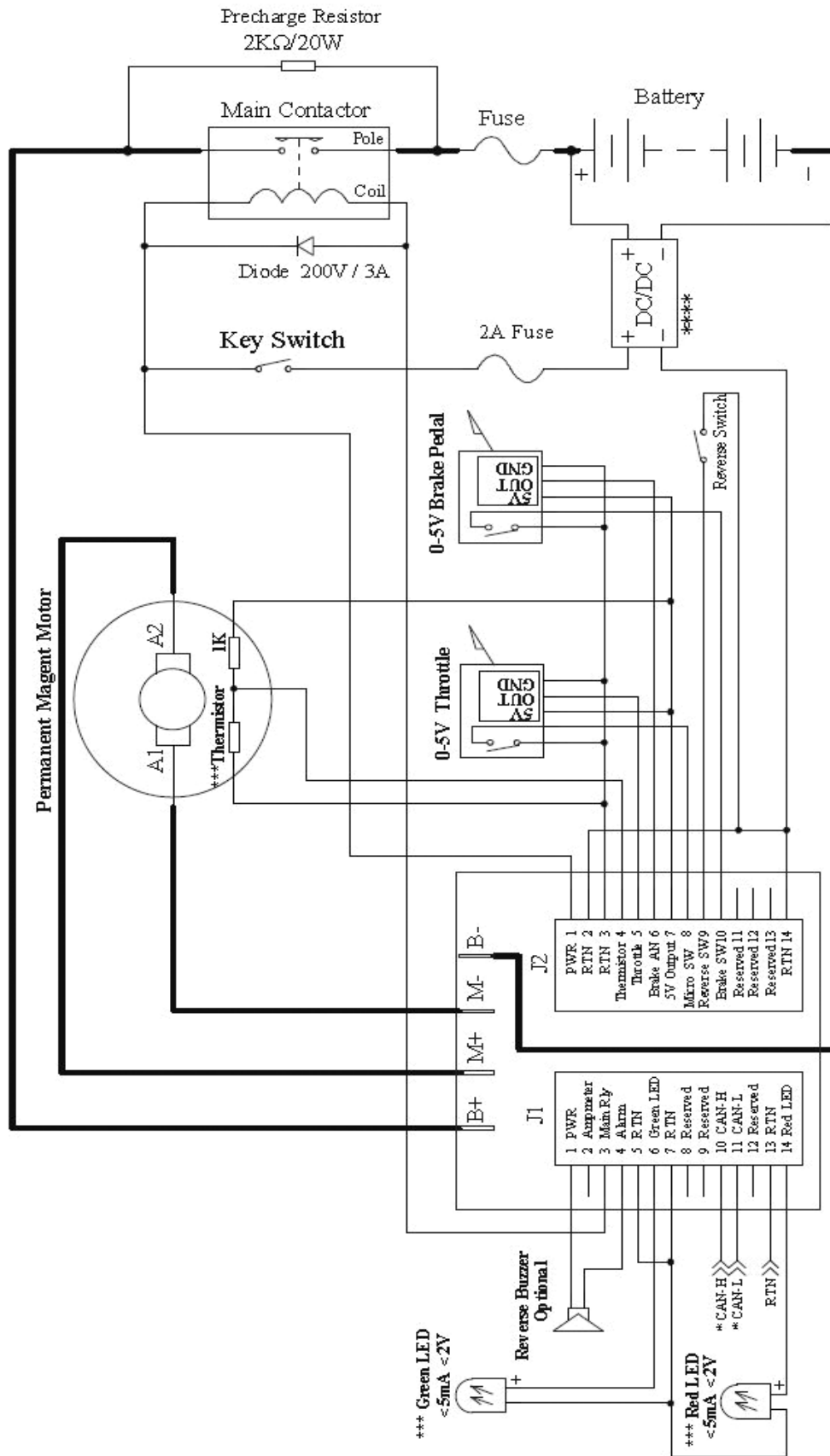
### Notes:

1. All RTN and GND pins are internally connected, but isolated from B-.
2. Two PWR pins, J1-1 and J2-1, are internally connected. It's recommended to use J1-1 to supply peripherals like alarm and contactor. Twist peripheral wires with PWR is the preferred for EMC.
3. Kelly Ammeter positive connect to 5V power supply of controller, negative to J1-2.
4. Switch to ground is active. Open switch is inactive.

### Caution:

- Do not apply power until you are certain the controller wiring is correct and has been double checked. Wiring faults will damage the controller.
- Ensure that the B- wiring is securely and properly connected before applying power.
- The preferred connection of the system contactor or circuit breaker is in series with the B+ line.
- All contactors or circuit breakers in the B+ line must have precharge resistors across their contacts. Lack of even one of these precharge resistors may severely damage the controller at switch-on.

### 3.2.2 Standard Wiring of HPM Motor Controller

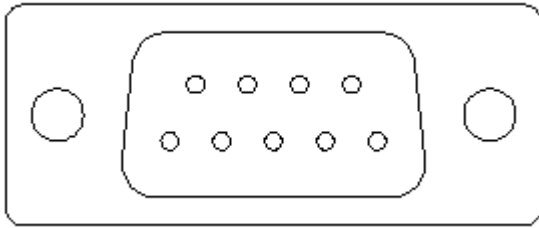


**NOTE:** Potentialmeter can be used to output 0-5V.  
 Please securely wire B- before any other wiring. Never put contactor or break on B-. Don't connect RTN to B-.  
 \* CAN bus is depopulated by default.  
 \*\* When you connect an external LED, the LED front panel brightness will be reduced.  
 \*\*\* Thermistor is optional item, default is KTY83-122.  
 \*\*\*\* 12V Isolated DC/DC Converter is Preferred.

Figure 6: HPM motor controller standard wiring

### 3.2.3 Communication Port

A RS232 port of controller is provided to communicate with host computer for calibration and configuration.



**Figure 7:** standard RS232 interface

## 3.3 Installation Checklist

Before operating the vehicle, complete the following checkout procedures. Use LED code as a reference as listed in Table 1.

### Caution:

- **Put the vehicle up on blocks to get the drive wheels off the ground before beginning these tests.**
- **Do not allow anyone to stand directly in front of or behind the vehicle during the checkout.**
- **Make sure the PWR switch and the brake is off**
- **Use well-insulated tools.**

- Make sure the wire is connected correctly.
- Turn on the PWR switch, the Red flashes once and the Green is off. After the start-up delay, normally the Red will stay off and the Green will turn on. If there is error, the Red LED will flashes for fault codes.  
**If the S/N less: 11xxxxxx:** Turn on the PWR switch, the Red flashes once and the Green is on. Normally, the Red will stay off. If there is error, the Red LED will flashes for fault codes.
- The fault code will be detected automatically at restart.
- With the brake switch open, select a direction and operate the throttle. The motor should spin in the selected direction. Verify wiring or voltage and the fuse if it does not. The motor should run faster with increasing throttle. If not, refer to the Table 1 LED code, and correct the fault as determined by the fault code.
- Take the vehicle off the blocks and drive it in a clear area. It should have smooth acceleration and good top speed.

# Chapter 4 Maintenance

There are no user-serviceable parts inside the controllers. Do not attempt to open the controller as this will void your warranty. However, periodic, exterior cleaning of the controller should be carried out.

The controller is a high powered device. When working with any battery powered vehicle, proper safety precautions should be taken that include, but are not limited to, proper training, wearing eye protection, avoidance of loose clothing, hair and jewelry. Always use insulated tools.

## 4.1 Cleaning

Although the controller requires virtually no maintenance after properly installation, the following minor maintenance is recommended in certain applications.

- Remove power by disconnecting the battery, starting with battery positive.
- Discharge the capacitors in the controller by connecting a load (such as a contactor coil, resistor or a horn) across the controller's B+ and B- terminals.
- Remove any dirt or corrosion from the bus bar area. The controller should be wiped down with a moist rag. Make sure that the controller is dry before reconnecting the battery.
- Make sure the connections to the bus bars, if fitted, are tight. To avoid physically stressing the bus bars use two, well-insulated wrenches.

## 4.2 Configuration

You can configure the controller with a host computer through either an RS232 or USB port.

- Disconnect motor wiring from controller.
- Do not connect B+, throttle and so on. The controller may display fault code in some conditions, but it doesn't affect programming or configuration.
- Use a straight through RS232 cable or Kelly USB To RS232 Converter to connect to a host computer. Provide 10V-30V (either J2 pin1 or J1 pin1) to PWR. Wire power supply return to any RTN pin, isolated from B-.

Download the free configuration software from:

<http://www.kellycontroller.com/support.php>

**Caution:**

- **Make certain that the motor is disconnected before trying to run the Configuration Software!**
- **Configuration software will be regularly updated and published on the website. Please Update your Configuration Software regularly. You must uninstall the older version before updating.**

# Table 1: LED CODES

## Green LED Code

LED Code	Explanation	Solution
Green Off	No power or switched off	1. Check if all wires are correct. 2. Check fuse and power supply.
Green On	Normal operation	That's great! You got solution!
Green & Red are both On		1. Software still upgrading. 2. Supply voltage too low or battery too high 3. The controller is damaged. Contact Kelly about a warranty repair.

## Red LED Code

1,2	α αα	Over voltage error	1. Battery voltage is too high for the controller. Check battery volts and configuration. 2. Regeneration over-voltage. Controller will have cut back or stopped regen. 3. This only accurate to $\pm 2\%$ upon Overvoltage setting.
1,3	α ααα	Low voltage error	1. The controller will clear after 5 seconds if battery volts returns to normal. 2. Check battery volts & recharge if required.
1,4	α αααα	Over temperature warning	1. Controller case temperature is above 90°C. Current will be limited. Reduce controller loading or switch Off until controller cools down. 2. Clean or improve heatsink or fan.
2,2	αα αα	Internal voltage fault	1. Measure that B+ & PWR are correct when measured to B- or RTN. 2. There may be excessive load on the +5V supply caused by too low a value of Regen or throttle potentiometers or incorrect wiring. 3. Controller is damaged. Contact Kelly about a warranty repair.
2,3	αα ααα	Over temperature	The controller temperature has exceeded 100 °C . The controller will be stopped but will restart when temperature falls below 80°C .
2,4	αα αααα	Throttle error at power-up	Throttle signal is higher than the preset 'dead zone' at Power On. Fault clears when throttle is released.
3,1	αααα α	Frequent reset	May be caused by over-voltage, bad motor intermittent earthing problem, bad wiring, etc.

3,2	□□□ □□	Internal reset	May be caused by some transient fault condition like a temporary over-current, momentarily high or low battery voltage. This can happen during normal operation.
3,3	□□□ □□□	Hall throttle is open or short-circuit	When the throttle is repaired, a restart will clear the fault.
3,4	□□□ □□□□	Non-zero throttle on direction change	Controller won't allow a direction change unless the throttle or speed is at zero. Fault clears when throttle is released.
4,1	□□□□ □	Regen or Start-up over-voltage	Motor drive is disabled if an over-voltage is detected at start-up or during regen. The voltage threshold detection level is set during configuration. The max threshold is about 1.25 times of controller rated voltage. I.e. you may set threshold lower than 60V for 48V controller.
4, 3	□□□□ □□□	Motor over-temperature	Motor temperature has exceeded the configured maximum. The controller will shut down until the motor temperature cools down.

The Red LED flashes once at power on as a confidence check and then normally stays Off. "1, 2" means the Red flashes once and after a second pause, flashes twice. The pause time between multiple flash code groups is two seconds.

# Table 2: HPM Controller CAN Commands List

## Version 1.1

### You should specify when sending:

**ID:**Our default ID is 0x6B, so only the data frame with ID 107 can be received by our controller. However, it can be set by configuration program.

**Frame type:**data frame

**Frame format:**standard 11 bits ID

**Length:**the number of data field bytes

**Data field:**data[0] is the command which indicates the operation.

### Controller response:

**ID:**The controller sends data frames with ID 115, 0x73. It also can be set by configuration program.

**Frame type:**data frame

**Length:**the number of data field bytes

**Data field:**The controller sends one or two data frames in response.

### Commands definitions

Command **CCP\_FLASH\_READ**

Length 3

data[0] 0xF2

data[1] INFO\_MODULE\_NAME

data[2] 8

Controller response

Length 8

data[0]~data[7] Controller's model in ASCII format, 8 bytes.

Description: Getting controller's model no. E.g. 0x4B,0x42,0x4C is 'K' , 'B', 'L', 0x30 is '0' . INFO\_MODULE\_NAME constant is defined as 64.

Command **CCP\_FLASH\_READ**

Length 3

data[0] 0xF2

data[1] INFO\_SOFTWARE\_VER

data[2] 2

Controller response

Length 2

data[0]~data[1] software version in BCD alike format, two bytes.

Description: Getting controller's software version, it also define as the controller's version, BCD alike format storage. E.g. 0x0A,0x01 should be parsed to ASCII characters '0' 'A' '0' '1' as the software version. INFO\_SOFTWARE\_VER constant is defined as 83.

Command **CCP\_FLASH\_READ**

Length 3

data[0] 0xF2

data[1] CAL\_TPS\_DEAD\_ZONE\_LOW

data[2] 1

Controller response

Length 1

data[0] TPS\_Dead\_Zone\_Low

Description: Getting controller's Throttle low-end dead zone. CAL\_TPS\_DEAD\_ZONE\_LOW constant is defined as 4.

Command **CCP\_FLASH\_READ**  
 Length 3  
 data[0] 0xF2  
 data[1] CAL\_BRAKE\_DEAD\_ZONE\_LOW  
 data[2] 1

Controller response

Length 1  
 data[0] Brake\_Dead\_Zone\_Low

Description: Getting controller's Brake low-end dead zone. CAL\_BRAKE\_DEAD\_ZONE\_LOW constant is defined as 5.

Command **CCP\_FLASH\_READ**  
 Length 3  
 data[0] 0xF2  
 data[1] CAL\_TPS\_DEAD\_ZONE\_HIGH  
 data[2] 1

Controller response

Length 1  
 data[0] TPS\_Dead\_Zone\_High

Description: Getting controller's Throttle high-end dead zone. CAL\_TPS\_DEAD\_ZONE\_HIGH constant is defined as 38.

Command **CCP\_FLASH\_READ**  
 Length 3  
 data[0] 0xF2  
 data[1] CAL\_BRAKE\_DEAD\_ZONE\_HIGH  
 data[2] 1

Controller response

Length 1  
 data[0] Brake\_Dead\_Zone\_High

Description: Getting controller's Brake high-end dead zone. CAL\_BRAKE\_DEAD\_ZONE\_HIGH constant is defined as 39.

Command **CCP\_A2D\_BATCH\_READ1**

Length 1  
 data[0] 0x1b  
 Controller response  
 Length 5  
 data[0] Brake A/D  
 data[1] TPS A/D  
 data[2] Operation voltage A/D  
 data[3] Vs A/D  
 data[4] B+ A/D

Description: Data batch reading.

- 1) For operation voltage, B+, A/D value and voltage mapping relation is:  
 $V = V_{ad} / 1.84$ . (For 120V controller).  
 $V = V_{ad} / 1.39$ . (For 144V controller).
- 2) Vs is defined as the 5V power supply for Hall sensor, control panel, ect. A/D value and voltage mapping relation is: 120 ~ 134 mapping to 4.75 ~ 5.25V.
- 3) Brake and TPS are defined as the Brake and the Throttle analog input. A/D value and voltage mapping relation is: 0 ~ 255 mapping to 0 ~ 5V.

Command **CCP\_A2D\_BATCH\_READ2**

Length 1  
 data[0] 0x1a  
 Controller response  
 Length 4  
 data[0] Ib A/D  
 data[1] Ic A/D  
 data[2] Vb A/D  
 data[3] Vc A/D

Description: Data batch reading.

- 1) For Vb, Vc, A/D value and voltage mapping relation is:  
 $V = Vad / 1.84.$  (For 120V controller).  
 $V = Vad / 1.39.$  (For 144V controller).
- 2) Ib and Ic are defined as the two phase current.

Command **CCP\_MONITOR1**

Length 1  
 data[0] 0x33  
 Controller response  
 Length 6  
 data[0] PWM  
 data[1] enable motor rotation  
 data[2] motor temperature  
 data[3] Controller's temperature  
 data[4] temperature of high side FETMOS heat sink  
 data[5] temperature of low side FETMOS heat sink

Description: Data batch reading.

3. PWM is output duty cycle, from 0 to 100.
4. data[1] indicates enabling motor rotation or disabling. 1 - enable, 0 - disable.
5. data[2] is defined as the temperature of motor in Celsius temperature. If the temperature sensor is not connected, the controller returns 0xFF.
6. data[3]-data[5] are defined as controller inside temperature in Celsius temperature. The value of data[4] and data[5] are inaccurate below 30°C.

Command **CCP\_MONITOR2**

Length 1  
 data[0] 0x37  
 Controller response  
 Length 3  
 data[0] MSB of error status code  
 data[1] LSB of error status code  
 data[2] present current accounts for percent of the rated current of controller

Description: Data batch reading.

- 1) Controller error status:  $(data[0] \ll 8) | data[1],$

data[0]M	7	6	5	4	3	2	1	0	data[0]L
	0x44	0x43	0x42	0x41	0x34	0x33	0x32	0x31	
data[1]M	7	6	5	4	3	2	1	0	data[1]L
	0x24	0x23	0x22	0x21	0x14	0x13	0x12	0x11	

if  $(data[0] \ll 8) | data[1]=0x4008,$  The corresponding error code is 0x43 and 0x14.

Command **COM\_SW\_ACC**

Length 2  
 data[0] 0x42  
 data[0] COM\_READING

Controller response

Length 1

data[0] Current throttle switch status

Description: Getting Throttle switch status, 1 – active, 0 – inactive. COM\_READING constant is defined as 0.

Command **COM\_SW\_BRK**

Length 2

data[0] 0x43

data[0] COM\_READING

Controller response

Length 1

data[0] Current Brake switch status

Description: Getting Brake switch status, 1 – active, 0 – inactive. COM\_READING constant is defined as 0.

Command **COM\_SW\_REV**

Length 2

data[0] 0x44

data[0] COM\_READING

Controller response

Length 1

data[0] Current Reverse switch status

Description: Getting Reverse switch status, 1 – active, 0 – inactive. COM\_READING constant is defined as 0.

#### **NOTICE:**

1. CAN bus rate should be configured to 1Mbit/s.

2. If the command is out of above commands

Controller response

Length 1

data[0] CCP\_INVALID\_COMMAND

Description: CCP\_INVALID\_COMMAND constant is defined as 0xe3.

## **Contact Us:**

**Kelly Controls, LLC**

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