# High Performance Brushless DC Motor Controller with USB, and CAN Interface


Roboteq's HBL23xx is a high-power, dual channel controller for hall-sensor equipped Brushless DC motors. The controller uses the position information from the sensors to sequence power on the motors' 3 windings in order to generate smooth continuous rotation. The controller also uses the Hall sensor and/or Encoder information to compute speed and measure traveled distance inside a 32-bit counter. The motors may be operated in open or closed loop speed mode. The HBL23xx features several Analog, Pulse and Digital I/Os which can be remapped as command or feedback inputs, limit switches, or many other function. The HBL23xx accepts commands received from an RC radio, Analog Joystick, wireless modem, or microcomputer. For mobile robot applications, the controller's two motor channels can either be operated independently or mixed to move and steer a vehicle. Using CAN bus, up to 127 controllers can be networked at up to 1Mbit/s on a single twisted pair.

Numerous safety features are incorporated into the controller to ensure reliable and safe operation. The controller's operation can be extensively automated and customized using Basic Language scripts. The controller can be configured, monitored and tuned in real-time using a Roboteq's free PC utility. The controller can also be reprogrammed in the field with the latest features by downloading new operating software from Roboteq.

**Applications**

- Industrial Automation
- Small Electric Vehicles, Electric Bikes
- Terrestrial and Underwater Robotic Vehicles
- Automatic Guided Vehicles
- Police and Military Robots
- Hazardous Material Handling Robots
- Balancing Robots
- Telepresence Systems
- Animatronics

**Key Features**

- USB, RS232, 0-5V Analog, or Pulse (RC radio) command modes
- CAN bus interface up to 1Mbit/s
- Auto switch between USB, RS232, Analog, or Pulse based on user-defined priority
- Built-in dual 3-phase high-power drivers for two brushless DC motor at up to 75A
- Orderable in single channel 150A version (A-version only)
- Available in 60V and 96V versions
- Trapezoidal switching based on Hall Sensor position information
- Advanced Operating mode (A-version only)
  - Trapezoidal Sensorless
  - Sinusoidal with Encoders
  - Sinusoidal with Hall Sensors
- Support for absolute angle encoders (A-version only)
  - Sin/Cos analog
  - SSI
- Field Oriented Control in Sinusoidal modes (A-version only)
- Full forward and reverse control on each channel. Four quadrant operation. Supports regeneration
- Operates from a single power source
- Built-in programming language for automation and customization
- Programmable current limit for each channel up to 2x75A or 1x150A for protecting controller, motors, wiring and battery.
- Separate connector for Hall Sensors
- Accurate speed and Odometry measurement using Hall Sensor data
- Up to 11 Analog Inputs for use as command and/or feedback

- Up to six Pulse Length, Duty Cycle or Frequency Inputs for use as command and/or feedback
- Up to 21 Digital Inputs for use as Deadman Switch, Limit Switch, Emergency stop or user inputs
- Dual Quadrature Encoder inputs with 32-bit counters
- Eight general purpose 24V, 1A output for brake release or accessories
- Selectable min/max, center and deadband in Pulse and Analog modes
- Selectable exponentiation factors for each command inputs
- Trigger action if Analog, Pulse or Encoder capture are outside user selectable range (soft limit switches)
- Open loop or closed loop speed control operation
- Closed loop position control with analog or pulse/frequency feedback
- Precise speed and position control when Encoder feedback is used
- PID control loop with separate gains for each channel
- Optional Mixed control (sum and difference) for tank-like steering
- Configurable Data Logging of operating parameters on RS232 Output for telemetry or analysis
- Built-in Battery Voltage and Temperature sensors
- Optional 12V backup power input for powering safely the controller if the main motor batteries are discharged
- Power Control wire for turning On or Off the controller from external microcomputer or switch
- No consumption by output stage when motors stopped
- Regulated 5V output for powering Encoders, RC radio, RF Modem or microcomputer
- Separate Programmable acceleration and deceleration for each motor
- Separate Programmable maximum forward and reverse power
- Support for CANopen and three simplified CAN protocols
- Ultra-efficient 3 mOhm ON resistance MOSFETs
- Auto stop if no motion is detected
- Stall detection and selectable triggered action if Amps is outside user-selected range
- Short circuit protection with selectable sensitivity levels
- Overvoltage and Undervoltage protection
- Programmable Watchdog for automatic motor shutdown in case of command loss
- Overtemperature protection
- Diagnostic LED indicators
- Extruded aluminum, heat sinking enclosure for operation harsh shock and temperature environment
- Efficient heat sinking. Operates without a fan in most applications
- Dustproof and weather resistant. IP51 NEMA rating
- Power wiring via AWG8 battery cables and AWG10 motor cables
- Dimmensions: 9" (228.5mm) L, 5.5" W (140mm), 1.6" (40mm) H
- A -40° to +85° C operating environment
- Weight: 3 lbs (1,340g)
- Easy configuration, tuning and monitory using provided PC utility
- Field upgradeable software for installing latest features via the Internet

## Orderable Product References

| Reference | Number of Channels | Amps/Channel | Volts | Sinusoidal |
|---|---|---|---|---|
| **HBL2360** | 2 | 75 | 60 | No |
| **HBL2396** | 2 | 50 | 96 | No |
| **HBL2360A** | 2 | 75 | 60 | Yes |
| **HBL2360AS** | 1 | 150 | 60 | Yes |
| **HBL23120** | 2 | 40 | 120 | Yes |

# Important Safety Disclaimer

**Dangerous uncontrolled motor runaway condition can occur for a number of reasons, including, but not limited to: command or feedback wiring failure, configuration error, faulty firmware, errors in user script or user program, or controller hardware failure.**
**The user must assume that such failures can occur and must make his/her system safe in all conditions. Roboteq will not be liable in case of damage or injury as a result of product misuse or failure.**

## Hardware Revisions

The HBL23xx family has undergone two updates and a major redesign since its introduction. The original and its updated revisions share the HBL23xx product reference, plus the codes RC5 and RC53 marked on the label located on the bottom side of the case. The new design is refered as HBL23xxA. Newer versions are hardware and functionality backwards compatible with earlier versions. Unless otherwise noted, information in this datasheet applies to all hardware versions.

## Power Wires Identifications and Connection

Power connections are made by means of heavy gauge wires located at the back of the controller, as shown in Figure 1.

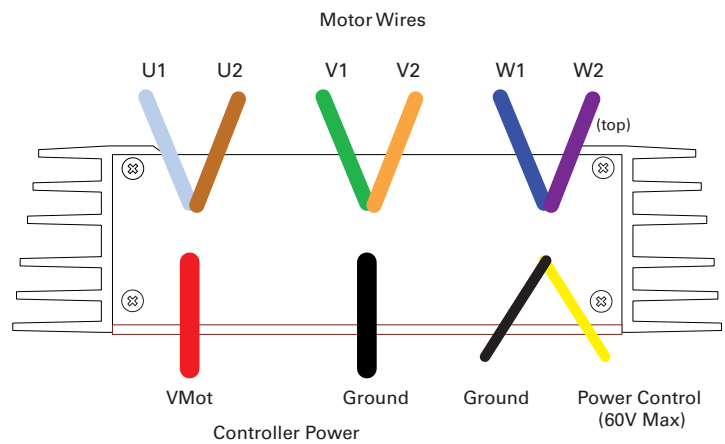


FIGURE 1. Rear Controller Layout

Figure 2, below, shows how to wire the controller and how to turn power On and Off.

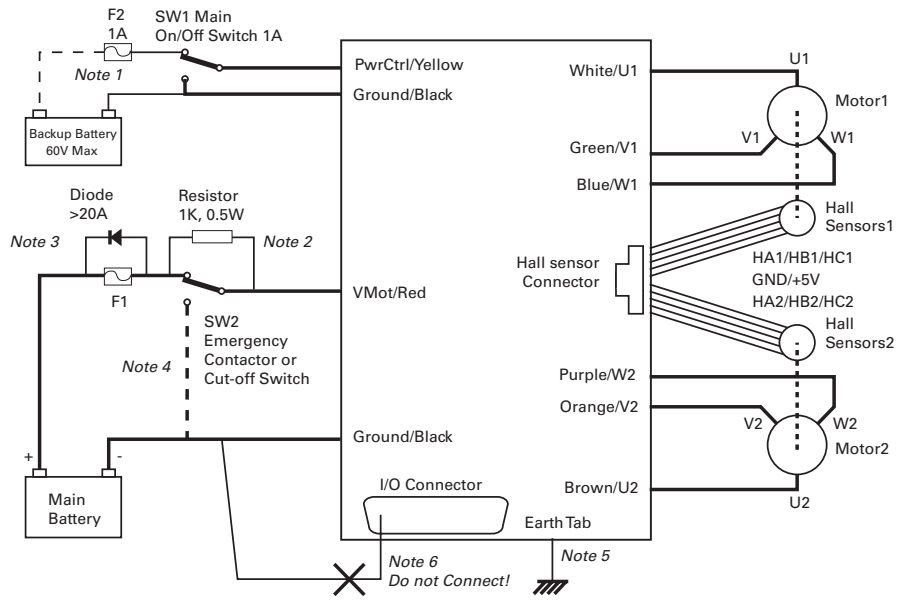


FIGURE 2. Powering the Controller. Thick lines identify MANDATORY connections

# Important Warning

**Carefully follow the wiring instructions provided in the Power Connection section of the User Manual. The information on this datasheet is only a summary.**

## Mandatory Connections

It is imperative that the controller is connected as shown in the diagram in Figure 2, above, in order to ensure a safe and trouble-free operation. All connections shown as thick black lines line are mandatory. The controller must be powered On/Off using switch SW1on the Yellow wire. Use a suitable high-current fuse F1 as a safety measure to prevent damage to the wiring in case of major controller malfunction.

## Emergency Switch or Contactor

The battery must be connected in permanence to the controller's Red wires via a high-power emergency switch or contactor SW2 as additional safety measure. The user must be able to deactivate the switch or contactor at any time, independently of the controller state.

## Electrostatic Discharge Protection

In accordance with IEC 61000-6-4, Roboteq Motor Controllers are designed to withstand ESD up to 4kV touch and 8kV air gap. This protection is implemented without any additional external connections required.

Some specifications, such as EN12895, require a higher level of protection. To maximize ESD protection, up to 8kV touch and 15kV air gap, you may connect the metallic heatsink of the controller to your battery negative terminal. See App Note 062918 for example connections.

### Precautions and Optional Connections

Note 1: Backup battery to ensure motor operation with weak or discharged batteries, connect a second battery to the Power Control wire/terminal via the SW1 switch. For 96V and 120V version controllers, the maximum voltage that should be applied to Power Control (PwrCtrl) is 60V. Applying a voltage >60V to PwrCtrl will damage the controller.
Note 2: Use precharge 1K, 0.5W Resistor to prevent switch arcing.
Note 3: Insert a high-current diode to ensure a return path to the battery during regeneration in case the fuse is blown.
Note 4: Optionally ground the VMot wires when the controller is Off if there is any concern that the motors could be made to spin and generate voltage in excess of 60V (HBL2360), 96V (HBL2396) or 120V (HBL23120).
Note 5: Connect the controller's earth tab to a wire connected to the Earth while the charger is plugged in the AC main, or if the controller is powered by an AC power supply.
Note 6: Beware not to create a path from the ground pins on the I/O connector and the battery minus terminal.

## Single Channel Wiring (A-Version only)

On the Single Channel HBL23xxAS, each of the motor wires must be connected to both wires of the same letter as shown in Figure 3 below. Use the Encoders and/or Hall sensors of Channel 1 for operation.

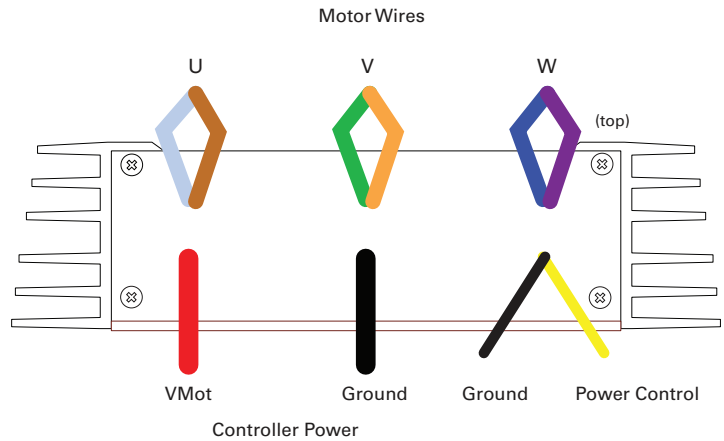


FIGURE 3. Single Channel Wiring Diagram

## Important Warning

**Single channel operation is only possible on the newer, A version of the controller. This wiring must be done only on the single channel version of the controller. Paralleling the wires on a dual channel product will cause permanent damage. Verify that your controller is an HBL2360AS or HBL2396AS before you wire in this manner.**

## Use of Safety Contactor for Critical Applications

An external safety contactor must be used in any application where damage to property or injury to person can occur because of uncontrolled motor operation resulting from failure in the controller's power output stage.

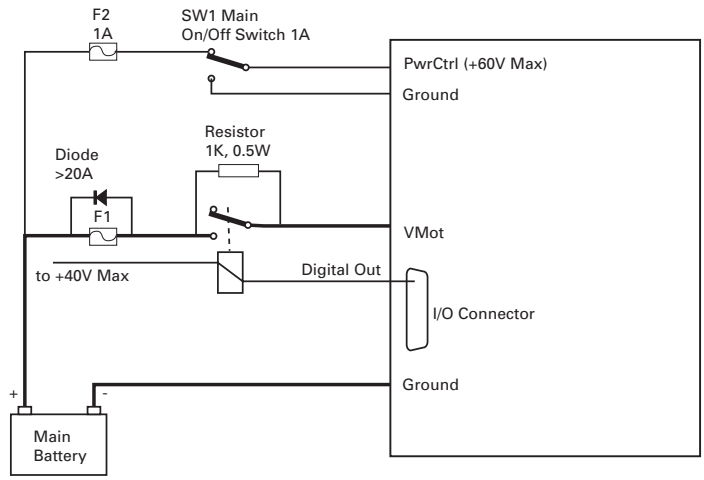


FIGURE 4. Contactor Wiring Diagram

Note: This wiring should not be used for 96V or 120V version controllers HBL2396 or HBL23120. This would apply a voltage >60V to PwrCtrl and damage the controller. The wiring shown in FIGURE 2 is recommended for the HBL2396.

The contactor coil must be connected to a digital output configured to activate when "No MOSFET Failure". The controller will automatically deactivate the coil if the output is expected to be off and battery current of 1A or more is measured for more than 0.5s. This circuit will not protect against other sources of failure such as those described in the "Important Safety Disclaimer" on Page 3.

## Controller Mounting

During motor operation, the controller will generate heat that must be evacuated. The published amps rating can only be fully achieved if adequate cooling is provided. Always operate the controller in a well ventilated space so that air can flow between the heat-sink fins. Additional conduction cooling can be achieved by having the bottom edges of the case making contact with a metallic surface (chassis, cabinet).

## Hall Sensors Connection

Connection to the Hall Sensors is done using a special connector on the front side of the controller. Figure 5, below, shows the location of the various low-voltage connectors and LEDs on the controller.

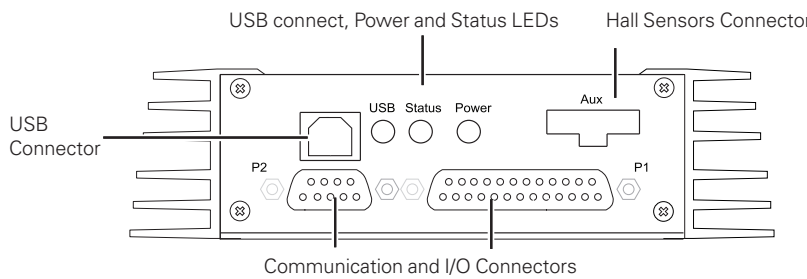


FIGURE 5. Front Controller Layout

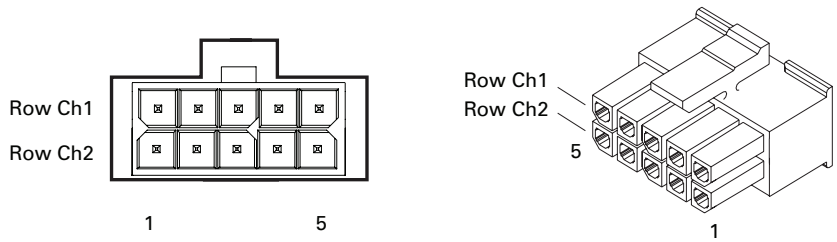


FIGURE 6. Hall Sensors Connector

TABLE 1.

| Pin Number | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Row Ch1 | 5V | Hall1 C | Hall1 B | Hall1 A | Ground |
| Row Ch2 | 5V | Hall2 C | Hall2 B | Hall2 A | Ground |

## Hall Sensor vs Motor Output sequencing

The controller requires the Hall sensors inside the motor to be 120 degrees apart. The controller's 3-phase bridge will activate each of the motor winding according to the sequence shown in Figure 7, below.

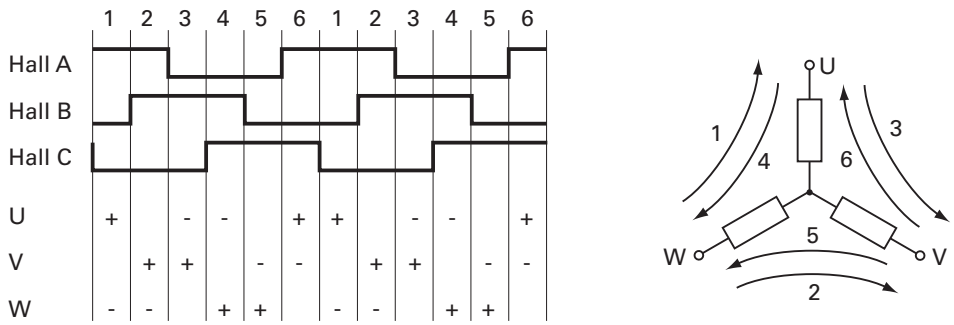


FIGURE 7. Hall Sensors Sequence

## Connection to SSI Absolute Encoder

On models HDC23xxA, when operating in Sinusoidal Mode, the controller can use motors equipped with absolute angle sensors with SSI interface. When enabled, the SSI signals are found on the 10-pin Molex connector that is otherwise used for the Hall Sensors. The controller issues a differential clock signal and expects a 12-bit differential data signal from the encoder. When two motors are used, the clock must be connected to both sensors. Serial data from each sensor is captured on separate input pins.

TABLE 2.

| Pin Number | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Row 1 | 5V | CLK – | Data 2 – | Data 1 – | GND |
| Row 2 | 5V | Clock + | Data 2 + | Data 1 + | GND |

## Connection to Analog Sin/Cos Absolute Encoder

The HBL23xxA has 4 high-speed analog inputs that can be used to capture absolute angle positions from resolvers or magnetic sensors with Sin/Cos voltage outputs. The signal must be 0-5V max with the 0 at 2.500V. Table 3 shows the signal assignments on the 25- pin connector.

TABLE 3.

| Signal | Pin Number | Pin Name |
|---|---|---|
| Sin1 | 12 | ASIN1 |
| Cos1 | 24 | ACOS1 |
| Sin2 | 11 | ANA7/ASIN2 |
| Cos2 | 23 | ANA8/ACOS2 |

## Commands and I/O Connections

Connection to RC Radio, Microcomputer, Joystick and other low current sensors and actuators is done via the 25 and 9 pin connectors located in front of the connector. The functions of many pins vary depending on controller model and user configuration. Pin assignments are found in Table 4, below.

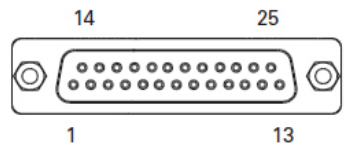


FIGURE 8. Main Connector Pin Locations

TABLE 4.

| Connector Pin | Power | Dout | Com | Pulse | Ana | Dinput | Enc | Default Config |
|---|---|---|---|---|---|---|---|---|
| 1 | GND | | | | | | | |
| 14 | 5VOut | | | | | | | |
| 2 | | | TxData | | | | | RS232Tx |
| 15 | | | | PIN1 | ANA1 | DIN1 | | RCRadio1 |
| 3 | | | RxData | | | | | RS232Rx |
| 16 | | | | PIN2 | ANA2 | DIN2 | | RCRadio2 |
| 4 | | | | PIN3 | ANA3 | DIN3 | | AnaCmd1 (1) |
| 17 | | | | PIN4 | ANA4 | DIN4 | | AnaCmd2 (1) |
| 5 | GND | | | | | | | |
| 18 | | DOUT1 | | | | DIN12 | | Motor Brake 1 |
| 6 | | DOUT2 | | | | DIN13 | | Motor Brake 2 |
| 19 | | DOUT3 | | | | DIN14 | | Contactor |
| 7 | | DOUT4 | | | | DIN15 | | Unused |
| 20 | | DOUT5 | | | | DIN16 | | Unused |
| 8 | | DOUT6 | | | | DIN17 | | Unused |
| 21 | | | | PIN5 (2) | ANA5 | DIN5 | | Unused |
| 9 | GND | | | | | | | |
| 22 | | | | PIN6 (2) | ANA6 | DIN6 | | Unused |

TABLE 4.

| Connector Pin | Power | Dout | Com | Pulse | Ana | Dinput | Enc | Default Config |
|---|---|---|---|---|---|---|---|---|
| 10 | | | | | ANA7 | DIN7 | | Unused |
| 23 | | | | | ANA8<br>COS2 (2) | DIN8 | ENC2B | Unused |
| 11 | | | | | ANA9<br>SIN2 (2) | DIN9 | ENC2A | Unused |
| 24 | | | | | ANA10<br>COS1 (2) | DIN10 | ENC1B | Unused |
| 12 | | | | | ANA11<br>SIN1 (2) | DIN11 | ENC1A | Unused |
| 25 | 5VOut | | | | | | | |
| 13 | GND | | | | | | | |
| Note 1: Analog command is disabled in factory default configuration.<br>Note 2: Available only on HBL2xxxA | | | | | | | | |

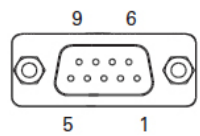


FIGURE 9. Secondary Connector Pin Locations

TABLE 5.

| Connector Pin | Power | Dout | Com | Pulse | Ana | Dinput | Default Config |
|---|---|---|---|---|---|---|---|
| 5 | | DOUT7 | | | | DIN18 | Unused |
| 9 | 5VOut | | | | | | |
| 4 | | | RS485+ (1) | | | | RS485+ |
| 8 | | | RS485- (1) | | | | RS485- |
| 3 | GND | | | | | | |
| 7 | | | CANH | | | | CAN High |
| 2 | | | CANL | | | | CAN Low |
| 6 | GND | | | | | | |
| 1 | | DOUT8 | | | | DIN19 | Unused |
| Note 1: Available only on HBL2xxxA | | | | | | | |

## Default I/O Configuration

While the controller can be configured so that practically any Digital, Analog and RC pin can be used for any purpose, the controller's factory default configuration provides an assignment that is suitable for most applications. The figure below shows how to wire the controller to two analog potentiometers, an RC radio, and the RS232 port. It also shows how to connect two outputs to motor brake solenoids and another output to an external status LED. You may omit any connection that is not required in your application. The controller automatically arbitrates the command priorities depending on the presence of a valid command signal in the following order: 1-RS232, 2-RC Pulse, 3-None. If needed, use the Roborun+ PC Utility to change the pin assignments and the command priority order.

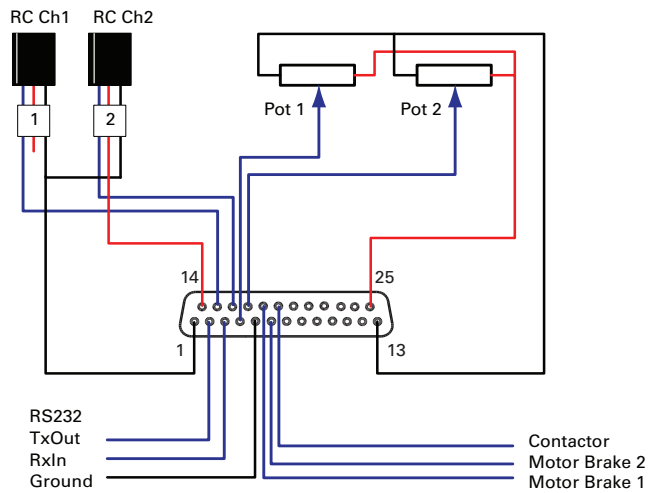


FIGURE 10. Factory default pins assignment

## Enabling Analog Commands

For safety reasons, the Analog command mode is disabled by default. To enable the Analog mode, use the PC utility and set Analog in Command Priority 2 or 3 (leave Serial as priority 1). Note that by default the additional securities are enabled and will prevent the motor from starting unless the potentiometer is centered, or if the voltage is below 0.25V or above 4.75V. The drawing shows suggested assignment of Pot 1 to ANA1 and Pot 2 to ANA4. Use the PC utility to enable and assign analog inputs.

## Serial Communication

The controller has a full RS232 compatible serial interface. In HBL23xxA models, the serial port can can also easily be connected to devices with TTL serial using a simple resistor and diodes circuit. See user manual for details.

## CAN Bus Operation

The controller can interface to a standard CAN Bus network, using three possible protocols: Standard CANOpen, and three proprietary schemes (MiniCAN, RoboCAN and RawCAN). Please refer to the User Manual for details. Note that version labeled R5, USB and CAN cannot operate at the same time. The controller starts up with CAN available, but CAN will be disabled as soon as the controller is plugged into USB. To re-enable CAN, disconnect USB and restart the controller. On HBL23xxA models and models labeled R53, USB and CAN can be operated simultaneously.

## RS485 Communication

The HBL23xxA has a half-duplex RS485 interface. Two signals are present on the 9-pin DSub connector for connecting to RS485 networks. Connecting these two wires with the correct polarity is all that is needed to establish a connection. The RS485+ is the positive signal and RS485- is the inverted signal. Once enabled, the RS485 can be used to communicate data under the Modbus protocol, or Roboteq's native serial commands.

## Status LED Flashing Patterns

After the controller is powered on, the Power LED will tun on, indicating that the controller is On. The Status LED will be flashing at a two seconds interval. The flashing pattern and color provides operating or exception status information. Note that earlier versions of the HBL23xx hardware labeled r5 have a monochrome status LED.

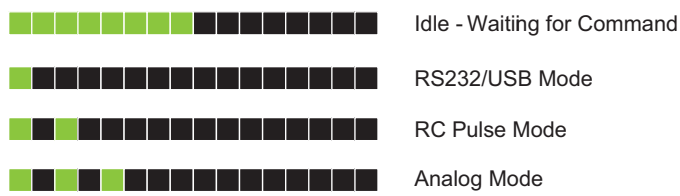


FIGURE 11. Normal Operation Flashing Patterns

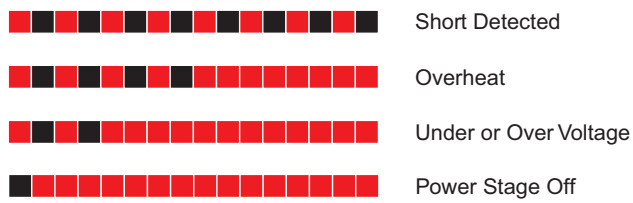


FIGURE 12. Exception or Fault Flashing Patterns

Additional status information may be obtained by monitoring the controller with the PC utility.

The communication LED gives status information on the CAN and USB.

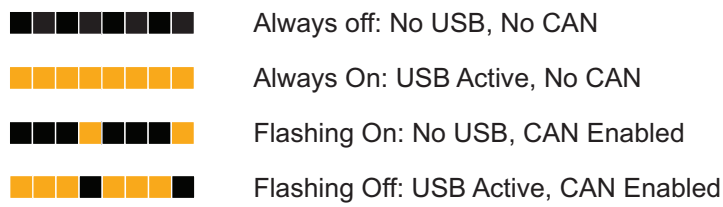


FIGURE 13. Com LED

## Measured and Calculated Amps

HBL23xx models include Amps sensor in line with the battery ground wires. Battery Amps are therefore measured with precision. Motor Amps are estimated using the formula Motor Amps = Battery Amps / PWM. This formula produces accurate results from 20% PWM and above. No Motor Amps are reported at 0% PWM.

HBL23xxA models include Amps sensors in line with the motor terminals and on the battery ground terminals. On these models, both Motor Amps and Battery Amps are therefore measured with precision.

## Battery Backed Clock and RAM

The controller includes a real-time clock/calendar and Non-Volatile RAM storage for user variables. Both the clock and the RAM storage require a battery to continue running and for the stored data not to be lost while the controller is powered down. The battery is not installed by Roboteq. Users who wish to use the clock and/or battery backed RAM variables must install a battery themselves. The battery socket can be reached by removing the bottom cover to reach the board and insert a 3V, 12.5mm coin-style battery. Use battery type CR1225 or equivalent. Battery holder is present only in the HBL23xxA version

## Electrical Specifications

### Absolute Maximum Values

The values in Table 6, below, should never be exceeded. Permanent damage to the controller can result

TABLE 6.

| Parameter | Measure point | Models | Min | Typical | Max | Units |
|---|---|---|---|---|---|---|
| | | HBL2360 | | | 60 | Volts |
| | | HBL2396 | 36 | | 100 | Volts |
| | | HBL23120 | 36 | | 130 | Volts |
| Reverse Voltage on Battery Leads | Ground to VMot | All | -1 | | | Volts |
| Power Control Voltage | Ground to Pwr Control wire | All | | | 60 | Volts |
| Motor Leads Voltage | Ground to M1+, M1-, M2+, M2- | HBL2360 | | | 60 (1) | Volts |
| | | HBL2396 | 36 | | 96 (1) | Volts |
| | | | | | | |
| Digital Output Voltage | Ground to Output pins | All | | | 40 | Volts |
| Analog and Digital Inputs Voltage | Ground to any signal pin on 25 & 9-pin connectors | All | | | 30 | Volts |
| RS232 I/O pins Voltage | External voltage applied to Rx pin | All | | | 30 (2) | Volts |
| Case Temperature | Case | All | -40 | | 85 | ºC |
| Humidity | Case | All | | | 100 (3) | % |

Note 1: Maximum regeneration voltage in normal operation. Never inject a DC voltage from a battery or other fixed source

Note 2: No voltage must be applied to the RS232 Tx pin

Note 3: Non condensing

## Power Stage Electrical Specifications (at 25ºC ambient)

TABLE 7.

| Continuous Max Current per channel | Measure point | Models | Min | Typical | Max | Units |
|---|---|---|---|---|---|---|
| Battery Leads Voltage | Ground to VMot | HBL2360 | 0 (1) | | 60 | Volts |
| | | HBL2396 | 36 (1) | | 100 | Volts |
| | | HBL23120 | 36 (1) | | 120 | Volts |
| Motor Leads Voltage | Ground to U, V, W wires | HBL2360 | 0 (1) | | 60 (2) | Volts |
| | | HBL2396 | 36 (1) | | 100 (2) | Volts |
| | | HBL23120 | 36 (1) | | 120 (2) | Volts |
| Power Control Voltage | Ground to Power Control wire | All | 0 (1) | | 60 | Volts |
| Minimum Operating Voltage | VMot or Pwr Ctrl wires | All | 9 (3) | | | Volts |
| Over Voltage protection range | Ground to VMot | HBL2360 | 5 | 60 (4) | 60 | Volts |
| | | HBL2396 | 5 | 100 (4) | 100 | Volts |
| | | HBL23120 | 5 | 120 (4) | 130 | Volts |
| Under Voltage protection range | Ground to VMot | HBL2360 | 0 | 5 (4) | 60 | Volts |
| | | HBL2396 | 0 | 5 (4) | 100 | Volts |
| | | HBL23120 | 0 | 5 (4) | 100 | Volts |
| Idle Current Consumption | VMot or Pwr Ctrl wires | All | 50 | 100 (5) | 150 | mA |
| ON Resistance (Excluding wire resistance) | VMot to U, V or W. Ground to U, V or W | All | | 6 | | mOhm |
| Max Current for 30s | Motor current | HBL2360 | | | 75 (6) | Amps |
| | | HBL2360S | | | 150 (6) | |
| | | HBL2396 | | | 50 (6) | |
| | | HBL2396S | | | 100 (6) | |
| | | HBL23120 | | | 40 | |
| | | HBL23120S | | | 80 | |
| Continuous Max Current per channel | Motor current | HBL2360 | | | 50 (7) | Amps |
| | | HBL2360S | | | 100 (7) | |
| | | HBL2396 | | | 35 (7) | |
| | | HBL2396S | | | 70 (7) | |
| | | HBL23120 | | | 25 (7) | |
| | | HBL23120S | | | 50 (7) | |

TABLE 7.

| Continuous Max Current per channel | Measure point | Models | Min | Typical | Max | Units |
|---|---|---|---|---|---|---|
| Current Limit range | Motor current | HBL2360 | 10 | 50 (8) | 75 | Amps |
| | | HBL2360S | 10 | 100 (8) | 150 (7) | |
| | | HBL2396 | 10 | 40 (8) | 50 | |
| | | HBL2396S | 10 | 80 (8) | 100 | |
| | | HBL23120 | 10 | 30 (8) | 40 | |
| | | HBL23120S | 10 | 60 (8) | 80 | |
| Stall Detection Amps range | Motor current | HBL2360 | 10 | 75 (8) | 75 | Amps |
| | | HBL2360S | 10 | 150 (8) | 150 (7) | |
| | | HBL2396 | 10 | 50 (8) | 50 | |
| | | HBL2396S | 10 | 100 (8) | 100 | |
| | | HBL23120 | 10 | 40 (8) | 40 | |
| | | HBL23120S | 10 | 40 (8) | 80 | |
| Stall Detection timeout range | Motor current | All | 1 | 500 (9) | 65000 | milli-seconds |
| Short Circuit Detection threshold (10) | Between Motor wires or Between Motor wires and Ground | All | 140 (11) | | 400 (11) | Amps |
| Short Circuit Detection threshold | Between Motor wires and VMot | All | No Protection. Permanent damage will result | | | |
| Motor Acceleration/ Deceleration range | Motor Output | All | 100 | 500 (12) | 65000 | milli-seconds |

Note 1: Negative voltage will cause a large surge current. Protection fuse needed if battery polarity inversion is possible
Note 2: Maximum regeneration voltage in normal operation. Never inject a DC voltage from a battery or other fixed source
Note 3: Minimum voltage must be present on VMot or Power Control wire
Note 4: Factory default value. Adjustable in 0.1V increments
Note 5: Current consumption is lower when higher voltage is applied to the controller's VMot or PwrCtrl wires
Note 6: Max value is determined by current limit setting. Duration is estimated and is dependent on ambient temperature cooling condition
Note 7: Estimate. Limited by case temperature. Current may be higher with better cooling
Note 8: Factory default value. Adjustable in 0.1A increments
Note 9: Factory default value. Time in ms that Stall current must be exceeded for detection
Note 10: Controller will stop until restarted in case of short circuit detection
Note 11: Sensitivity selectable by software
Note 12: Factory default value. Time in ms for power to go from 0 to 100%

## Command, I/O and Sensor Signals Specifications

TABLE 8.

| Parameter | Measure point | Min | Typical | Max | Units |
|---|---|---|---|---|---|
| Main 5V Output Voltage | Ground to 5V pins on | 4.6 | 4.75 | 5.1 | Volts |
| 5V Output Current | 5V pins on RJ45 and DSub15 | | | 100 (1) | mA |

TABLE 8.

| Parameter | Measure point | Min | Typical | Max | Units |
|---|---|---|---|---|---|
| Digital Output Voltage | Ground to Output pins | | | 30 | Volts |
| Digital Output Current | Output pins, sink current | | | 1 (2) | Amps |
| Output On resistance | Output pin to ground | | 0.75 | 1.5 | Ohm |
| Output Short circuit threshold | Output pin | 1.05 | 1.4 | 1.75 | Amps |
| Input Impedances | AIN/DIN Input to Ground | | 53 | | kOhm |
| Digital Input 0 Level | Ground to Input pins | -1 | | 1 | Volts |
| Digital Input 1 Level | Ground to Input pins | 3 | | 30 | Volts |
| Analog Input Range | Ground to Input pins | 0 | | 5.1 | Volts |
| Analog Input Precision | Ground to Input pins | | 0.5 | | % |
| Analog Input Resolution | Ground to Input pins | | 1 | | mV |
| Pulse durations | Pulse inputs | 20000 | | 10 | us |
| Pulse repeat rate | Pulse inputs | 50 | | 250 | Hz |
| Pulse Capture Resolution | Pulse inputs | | 1 | | us |
| Frequency Capture | Pulse inputs | 100 | | 2000 | Hz |
| Encoder count | Internal | -2.147 | | 2.147 | 10^9 Counts |
| Encoder frequency | Encoder input pins | | | 250 | kHz |
| Note 1: Sum of all 5VOut outputs<br>Note 2: Total average current on all outputs not to exceed 4.5A | | | | | |

## Operating & Timing Specifications

TABLE 9.

| Parameter | Measure Point | Min | Typical | Max | Units |
|---|---|---|---|---|---|
| Command Latency | Command to output change | 1 | 0.5 | 1 | ms |
| PWM Frequency | Ch1, Ch2 outputs | 10 | 16 (1) | 20 | kHz |
| Closed Loop update rate | Internal | | 1000 | | Hz |
| USB Rate | USB pins | | | 12 | MBits/s |
| RS232 baud rate | Rx & Tx pins | | 115200 (2) | | Bits/s |
| RS232 Watchdog timeout | Rx pin | 1 (3) | | 65000 | ms |
| Note 1: May be adjusted with configuration program<br>Note 2: 115200, 8-bit, no parity, 1 stop bit, no flow control<br>Note 3: May be disabled with value 0 | | | | | |

## Motor Characteristics Requirement for FOC current control

For proper FOC current control and motor operation under sinusoidal commutation, it is necessary for the motor to meet a minimum load inductance, minimum load L/R and maximum electric operating speed requirements. The minimum required inductance is necessary in order to ensure low Total Harmonic Distortion (THD) of the motor current. Furthermore, to achieve proper current response and stability, the controller's current loop sampling rate will limit the minimum permissible motor time constant $\tau$=L/R and the maximum operating electric speed.

TABLE. 10

| Parameter | Input DC Voltage (V) | Value | Units |
|---|---|---|---|
| Minimum load phase inductance (1) | 12 | 25 | uH |
| | 24 | 40 | uH |
| | 48 | 60 | uH |
| | 60 | 80 | uH |
| | 96 | 110 | uH |
| | 120 | 150 | uH |
| Minimum load inductance/resistance ratio (1) | 0 - 120 | 0.063 | msec |
| Maximum operating electric speed (2) | 0 - 120 | 96000 | RPM |
| Note 1: Star connected three phase load considered. In case the motor phase inductance does not fulfill the above requirements (minimum phase inductance and inductance/resistance ratio) an external AC inductor with proper inductance value is recommended to be added.<br>Note 2: Maximum rotor speed is calculated from the maximum operating electric speed and pole pairs. For example, in a motor with 4 pole pairs the maximum operating rotor speed is 15000/4 = 3750 rpm. | | | |

## Scripting

TABLE 11.

| Parameter | Measure Point | Min | Typical | Max | Units |
|---|---|---|---|---|---|
| Scripting Flash Memory | Internal | | 32000 | | Bytes |
| Max Basic Language programs | Internal | 1000 | | 3000 | Lines |
| Integer Variables | Internal | | 4096 | | Words (1) |
| Boolean Variables | Internal | | 8192 | | Symbols |
| Execution Speed | Internal | 50 000 | 100 000 | | Lines/s |
| Note 1: 32-bit words | | | | | |

## Thermal Specifications

TABLE 12.

| Parameter | Measure Point | Model | Min | Typical | Max | Units |
|---|---|---|---|---|---|---|
| Case Temperature | Case | All | -40 | | 85 (1) | °C |
| Thermal Protection range | Case | All | 80 | | 90 (2) | °C |
| Power Dissipation | Case | All | | | 70 | Watts |
| Thermal resistance | Power MOSFETs to case | All | | | 0.6 | °C/W |
| Note 1: Thermal protection will protect the controller power<br>Note 2: Max allowed power out starts lowering at minimum of range, down to 0 at max of range | | | | | | |

## Mechanical Specifications

TABLE 13.

| Parameter | Measure Point | Min | Typical | Max | Units |
|---|---|---|---|---|---|
| Weight | Case | | 1340 (2.95) | | g (lbs) |
| Wire Length | Case | 17 (43) | | | inches (cm) |
| Power Wires Gauge | Wire | | 8 | | AWG |
| Motor Wires Gauge | Wire | | 10 | | AWG |

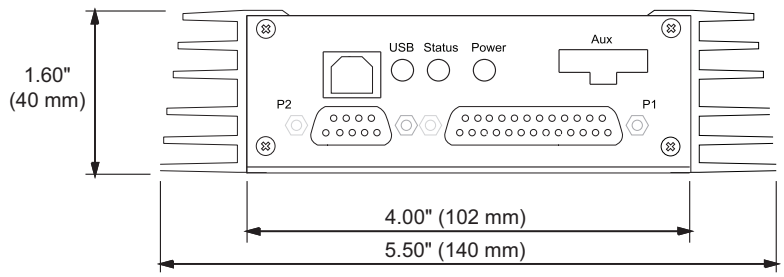


FIGURE 14. HBL23xx Front View and Dimensions

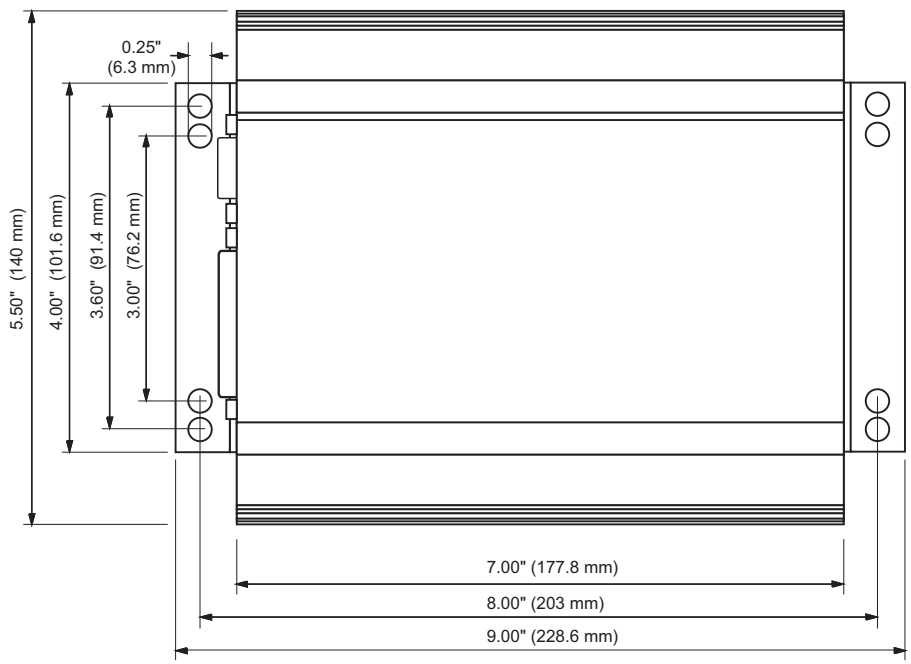


FIGURE 15. HBL23xx Top View and Dimensions