# RoboteQ

# HDC24xx

## 2x150A High Performance Dual Channel Brushed DC Motor Controller with USB, Encoder Inputs and CAN Interface

Roboteq's HDC24xx controller is designed to convert commands received from a RC radio, Analog Joystick, wireless modem, PC (via RS232 or USB) or microcomputer into high voltage and high current output for driving one or two DC motors. Designed for maximal ease-of-use, it is delivered with all necessary cables and hardware and is ready to use in minutes. Using CAN bus, up to 127 controllers can be networked at up to 1Mbit/s on a single twisted pair.

The controller features a high-performance 32-bit microcomputer and quadrature encoder inputs to perform advanced motion control algorithms in Open Loop or Close Loop (Speed or Position) modes. The HDC24xx features a high number of Analog, Pulse and Digital I/Os which can be remapped as command or feedback inputs, limit switches, or many other functions. The controller's two motor channels can either be operated independently or mixed to set the direction and rotation of a vehicle by coordinating the motion of each motor.

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 reprogrammed in the field with the latest features by downloading new operating software from Roboteq.

### Applications

- Industrial Automation
- Tracking, Pan & Tilt systems
- Terrestrial and Underwater Robotic Vehicles
- Automatic Guided Vehicles
- Police and Military Robots
- Flight simulators
- Telepresence Systems
- Animatronics

### Features List

- USB, RS232, 0-5V Analog, or Pulse (RC radio) command modes
- Available in version with CAN bus up to 1Mbit/s
- Auto switch between USB, RS232, CAN, Analog, or Pulse based on user-defined priority
- Built-in high-power power drivers for two brushed DC motors at up to 150A output per channel
- Full forward & reverse control on each channel. Four quadrant operation. Supports regeneration
- Built-in programming language for automation and customization
- Operates from a single power source
- Programmable current limit for each channel up to 2x150A for protecting controller, motors, wiring and battery.
- Up to 11 Analog Inputs for use as command and/or feedback
- Up to 4 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
- 8 general purpose 24V, 1A output for brake release or accessories
- Custom scripting in Basic language. Execution speed 50,000+ lines per second
- 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
- Multi-range PID gains changing on-the-fly according to motor speed
- 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 two simplified CAN protocols
- Ultra-efficient 1.5 mOhm ON resistance MOSFETs

- Orderable as single channel version up to 300A
- 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
- 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 heavy AWG8 cables
- 9" (228.5mm) L, 5.5" W (140mm), 1.6" (40mm) H
- -40o to +85o C operating environment
- 3 lbs (1,350g)
- Easy configuration, tuning and monitory using provided PC utility
- Field upgradeable software for installing latest features via the internet

## Orderable Product References

TABLE 1.

| Reference | Number of Channels | Amps/Channel | Volts |
|---|---|---|---|
| HDC2450 | 2 | 150 | 50 |
| HDC2450S | 1 | 300 | 50 |
| HDC2460 | 2 | 150 | 60 |
| HDC2472 | 2 | 120 | 72 |
| HDC2472S | 1 | 240 | 72 |

# 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.**

## Power Wires Identifications and Connection

Power connections are made by means of heavy gauge wires located at the back of the controller.
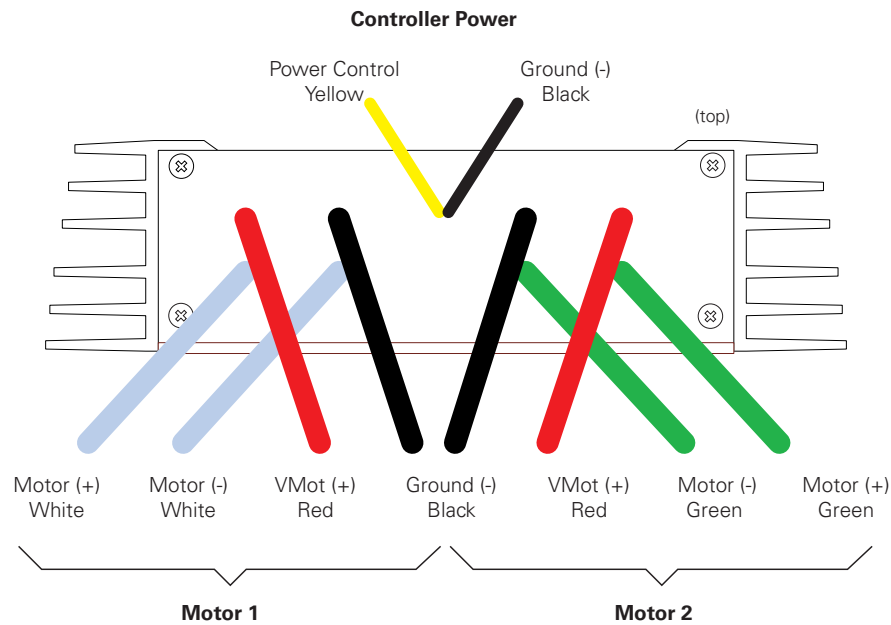
**Controller Power**

FIGURE 1. Rear Controller Layout

The diagram below shows how to wire the controller and how to turn power On and Off.
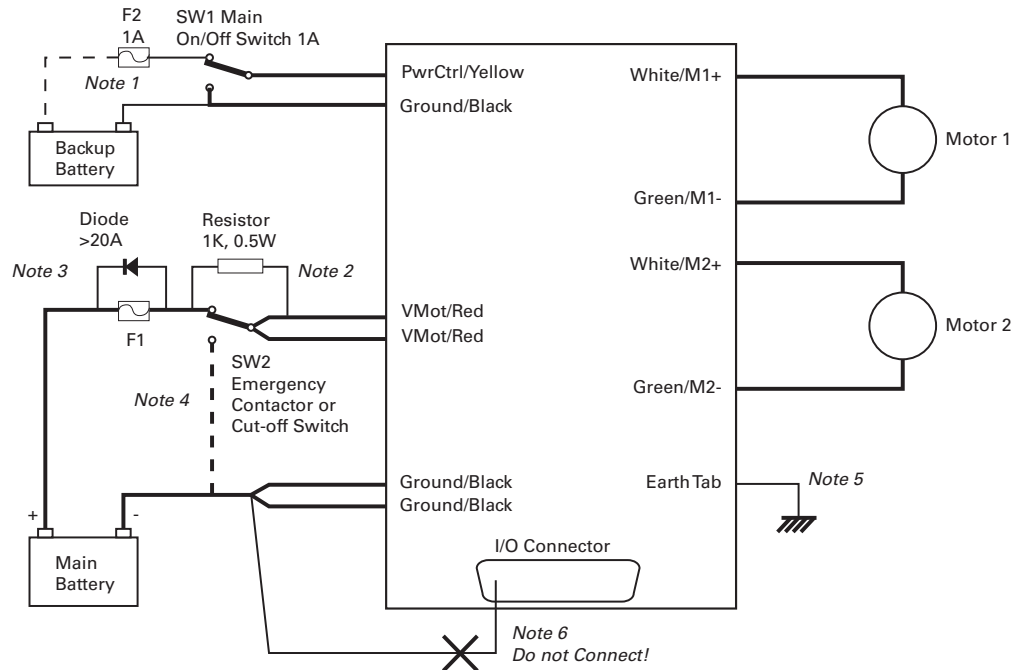


FIGURE 2.  Powering the controller. Thick lines identify **MANDATORY** connections

# 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.**

## Power Control Wiring for 72V Controllers

Power control line can only be used for powering off when grounded.

## Mandatory Connections

It is imperative that the controller is connected as shown in the above diagram 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.

## 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 72V version controllers, the power control and ground connection will only be used as the controller on/off switch. Applying voltage on this line will no longer power on

the controller. Some controllers already out in the field will not apply, but all recent purchases made from Roboteq as of 10/2/15 will have this change in effect

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 50V (HDC2450(S)) or 75V (HDC2472(S)).

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's minus terminal.

## 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.
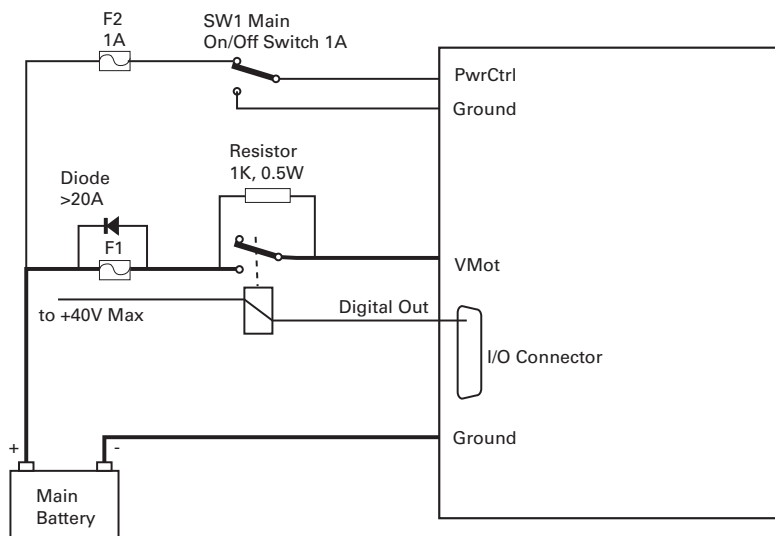


FIGURE 3. Contactor wiring diagram

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 2.5A 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 heatsink fins. Additional conduction cooling can be achieved by having the bottom edges of the case making contact with a metallic surface (chassis, cabinet).

## Sensor and Commands Connection

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 assignment is found in the table below.
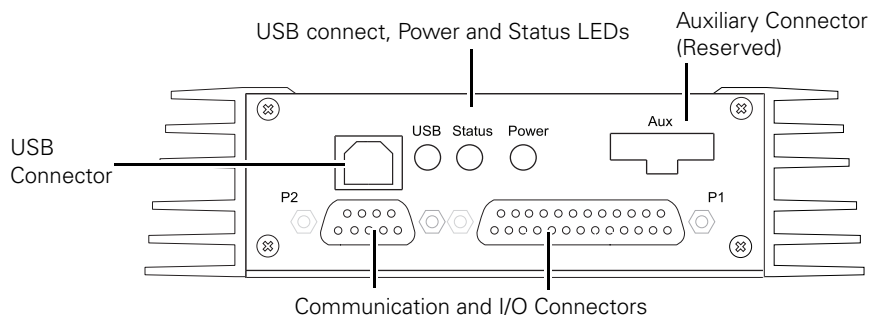


FIGURE 4. Front Controller Layout
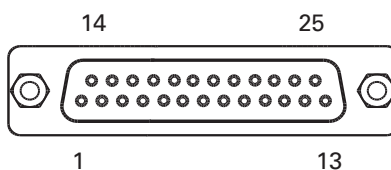


FIGURE 5. Main Connector pin locations

TABLE 4.

| Connector Pin | Power | Dout | Com | Pulse | Ana | Dinput | Enc | Default Config |
|---|---|---|---|---|---|---|---|---|
| 1 | GND | | | | | | | |
| 14 | 5VOut | | | | | | | |
| 2 | | | TxData | | | | | RS232Tx |
| 15 | | | | RC1 | ANA1 | DIN1 | | RCRadio1 |
| 3 | | | RxData | | | | | RS232Rx |
| 16 | | | | RC2 | ANA2 | DIN2 | | RCRadio2 |
| 4 | | | | RC3 | ANA3 | DIN3 | | AnaCmd1 (1) |
| 17 | | | | RC4 | ANA4 | DIN4 | | AnaCmd2 (1) |
| 5 | GND | | | | | | | |
| 18 | | DOUT1 | | | | DIN12 | | Motor Brake 1 |
| 6 | | DOUT2 | | | | DIN13 | | Motor Brake 2 |
| 19 | | DOUT3 | | | | DIN14 | | Safety Contactor |
| 7 | | DOUT4 | | | | DIN15 | | Unused |
| 20 | | DOUT5 | | | | DIN16 | | Unused |
| 8 | | DOUT6 | | | | DIN17 | | Unused |
| 21 | | | | | ANA5 | DIN5 | | Unused |
| 9 | GND | | | | | | | |
| 22 | | | | | ANA6 | DIN6 | | Unused |

TABLE 4.

| Connector Pin | Power | Dout | Com | Pulse | Ana | Dinput | Enc | Default Config |
|---|---|---|---|---|---|---|---|---|
| 10 | | | | | ANA7 | DIN7 | | Unused |
| 23 | | | | | ANA8 | DIN8 | ENC2B | Unused |
| 11 | | | | | ANA9 | DIN9 | ENC2A | Unused |
| 24 | | | | | ANA10 | DIN10 | ENC1B | Unused |
| 12 | | | | | ANA11 | DIN11 | ENC1A | Unused |
| 25 | 5VOut | | | | | | | |
| 13 | GND | | | | | | | |
| Note 1: Analog command is disabled in factory default configuration. | | | | | | | | |
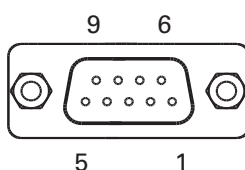
FIGURE 6. Secondary Connector pin locations

TABLE 5.

| Connector Pin | Power | Dout | Com | Pulse | Ana | Dinput | Default Config |
|---|---|---|---|---|---|---|---|
| 5 | | DOUT7 | | | | DIN18 | Unused |
| 9 | 5VOut | | | | | | |
| 4 | | | SCLI | | | | Reserved |
| 8 | | | SDAI | | | | Reserved |
| 3 | GND | | | | | | |
| 7 | | | CANH | | | | CAN High |
| 2 | | | CANL | | | | CAN Low |
| 6 | GND | | | | | | |
| 1 | | DOUT8 | | | | DIN19 | Unused |

## 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.
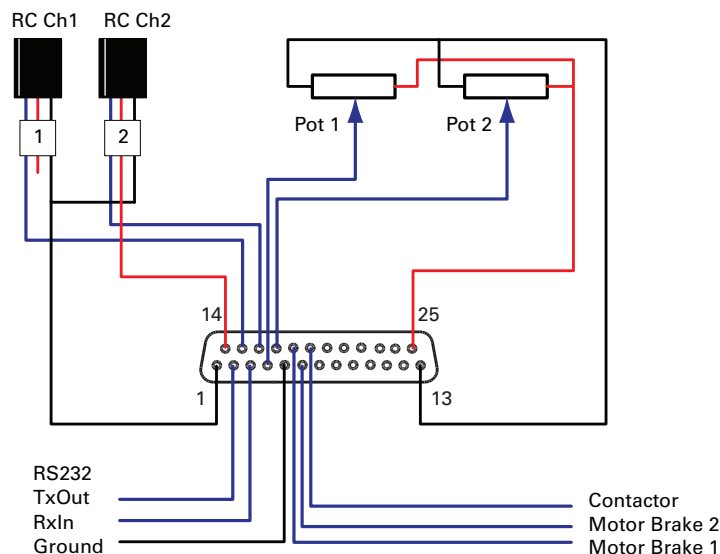
FIGURE 7. Factory default pins assignment

## 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.

## CAN Bus Operation

The controller can interface to a standard CAN Bus network, using 3 possible protocols: Standard CANOpen, and two simplified proprietary schemes (MiniCAN and RawCAN). Please refer to the User Manual for details. 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.

## USB communication

Use USB only for configuration, monitoring and troubleshooting. USB is not a reliable communication method when used in a electrically noisy environments and communication will not always recover after it is lost without unplugging and replugging the connector, or restarting the controller. Always prefer RS232 communication when interfacing to a computer.

## 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 2 seconds interval. The flashing pattern provides operating or exception status information.

Idle - Waiting for Command

RS232/USB Mode

RC Pulse Mode

Analog Mode

FIGURE 8.  Normal Operation Flashing Patterns

Short Detected

Overheat

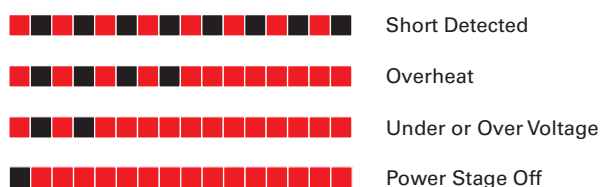Under or Over Voltage

Power Stage Off

FIGURE 9.  Exception or Fault Flashing Patterns

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

## Electrical Specifications

## Absolute Maximum Values

The values in the table below should never be exceeded, Permanent damage to the controller may result.

TABLE 6.

| Parameter | Measure point | Models | Min | Typ | Max | Units |
|-----------|---------------|--------|-----|-----|-----|-------|
| Battery Leads Voltage | Ground to VMot | HDC2450(S) | | | 50 | Volts |
| | | HDC2460 | | | 60 | Volts |
| | | HDC2472(S) | 36 | | 75 | Volts |
| Reverse Voltage on Battery Leads | Ground to VMot | All | -1 | | | Volts |
| Power Control Voltage | Ground to Pwr Control wire | All | | | 65 | Volts |
| Motor Leads Voltage | Ground to M1+, M1-, M2+, M2- | HDC2450(S) | | | 50 (1) | Volts |
| | | HDC2460 | | | 60 (1) | Volts |
| | | HDC2472(S) | 36 | | 75 (1) | Volts |
| Digital Output Voltage | Ground to Output pins | All | | | 30 | Volts |
| Analog and Digital Inputs Voltage | Ground to any signal pin on 25 & 9-pin connectors | All | | | 15 | Volts |
| RS232 I/O pins Voltage | External voltage applied to Rx/Tx pins | All | | | 15 | Volts |
| Case Temperature | Case | All | -40 | | 85 | oC |
| Humidity | Case | All | | | 100 (2) | % |

TABLE 6.

| Parameter | Measure point | Models | Min | Typ | Max | Units |
|-----------|---------------|--------|-----|-----|-----|-------|
| Note 1: Maximum regeneration voltage in normal operation. Never inject a DC voltage from a battery or other fixed source | | | | | | |
| Note 2: Non-condensing | | | | | | |

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

TABLE 7.

| Parameter | Measure point | Models | Min | Typ | Max | Units |
|-----------|---------------|--------|-----|-----|-----|-------|
| Battery Leads Voltage | Ground to VMot | HDC2450(S) | 0 (1) | | 50 | Volts |
| | | HDC2460 | 0 (1) | | 60 | Volts |
| | | HDC2472(S) | 36 (1) | | 75 | Volts |
| Motor Leads Voltage | Ground to M1+, M1-, M2+, M2- | HDC2450(S) | 0 (1) | | 50 (2) | Volts |
| | | HDC2460 | 0 (1) | | 60 (2) | Volts |
| | | HDC2472(S) | 36 (1) | | 75 (2) | Volts |
| Power Control Voltage | Ground to Power Control wire | All | 0 (1) | | 65 | Volts |
| Minimum Operating Voltage | VMot or Pwr Ctrl wires | All | 9 (3) | | | Volts |
| Over Voltage protection range | Ground to VMot | HDC2450(S) | 5 | 50 (4) | 50 | Volts |
| | | HDC2460 | 5 | 60 (4) | 60 | Volts |
| | | HDC2472(S) | 5 | 72 (4) | 75 | Volts |
| Under Voltage protection range | Ground to VMot | HDC2450(S) | 0 | 5 (4) | 50 | Volts |
| | | HDC2460 | 0 | 5 (4) | 60 | Volts |
| | | HDC2472(S) | 0 | 5 (4) | 75 | Volts |
| Idle Current Consumption | VMot or Pwr Ctrl wires | All | 50 | 100 (5) | 150 | mA |
| ON Resistance (Excluding wire resistance) | VMot to M+, plus M- to Ground at 100% power. Per channel | HDC2450/60/72 | | 3 | | mOhm |
| | | HDC2450S/72S | | 1.5 | | mOhm |
| Max Current per channel for 30s | Ch1 or Ch2 Motor current | HDC2450/60 | | | 150 (6) | Amps |
| | | HDC2472 | | | 120 (6) | Amps |
| | | HDC2450S | | | 300 (6)(7) | Amps |
| | | HDC2472S | | | 240 (6)(7) | Amps |
| Continuous Max Current per channel | Ch1 or Ch2 Motor current | HDC2450/60/72 | | | 80 (8) | Amps |
| | | HDC2450S/72S | | | 160 (7)(8) | Amps |
| Current Limit range | Ch1 or Ch2 Motor current | HDC2450 | 10 | 100 (9) | 150 | Amps |
| | | HDC2460 | 10 | 100 (9) | 150 | Amps |
| | | HDC2472 | 10 | 100 (9) | 120 | Amps |
| | | HDC2450S | 10 | 200 (9) | 300 (7) | Amps |
| | | HDC2472S | 10 | 200 (9) | 240 (7) | Amps |
| Stall Detection Amps range | Ch1 or Ch2 Motor current | HDC2450 | 10 | 100 (9) | 150 | Amps |
| | | HDC2460 | 10 | 100 (9) | 150 | Amps |
| | | HDC2472 | 10 | 100 (9) | 120 | Amps |
| | | HDC2450S | 10 | 200 (9) | 300 (7) | Amps |
| | | HDC2472S | 10 | 200 (9) | 240 (7) | Amps |

TABLE 7.

| Parameter | Measure point | Models | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Stall Detection timeout range | Ch1 or Ch2 Motor current | All | 1 | 65000 (10) | 65000 | milli-seconds |
| Short Circuit Detection threshold (11) | Between Motor wires or Between Motor wire and Ground | HDC2450/60/72 | 550 (12) | | 1600 (12) | Amps |
| | | HDC2450S/72S | 1100 | | 3000 (7) | Amps |
| Short Circuit Detection threshold | Between Motor wires and VMot | All | No Protection. Permanent damage will result | | | |
| Motor Acceleration/ Deceleration range | Ch1 or Ch2 | All | 100 | 500 (13) | 65000 | millisec-onds |

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: Current is sum of both synchronized channels. Current must be balanced between channel to obtain max current.

Note 8: Estimate. Limited by case temperature. Current may be higher with better cooling

Note 9: Factory default value. Adjustable in 0.1A increments

Note 10: Factory default value. Time in ms that Stall current must be exceeded for detection

Note 11: Controller will stop until restarted in case of short circuit detection

Note 12: Sensitivity selectable by software

Note 13: 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 | Typ | Max | Units |
|---|---|---|---|---|---|
| Main 5V Output Voltage | Ground to 5V pins on | 4.6 | 4.75 | 4.9 | Volts |
| 5V Output Current | 5V pins on RJ45 and DSub15 | | | 50 (1) | mA |
| 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 (except DIN12-19) | AIN/DIN Input to Ground | | 53 | | kOhm |
| Input Impedance (DIN12-19) | Input to 5V | | 50 | | kOhm |
| Digital Input 0 Level | Ground to Input pins | -1 | | 1 | Volts |
| Digital Input 1 Level | Ground to Input pins | 3 | | 15 | 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 |

TABLE 8.

| Parameter | Measure point | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| Pulse Capture Resolution | Pulse inputs | | 1 | | us |
| Frequency Capture | Pulse inputs | 100 | | 10000 | Hz |
| Encoder count | Internal | -2.147 | | 2.15 | 10^9 Counts |
| Encoder frequency | Encoder input pins | | | 1 | MHz |
| Note 1: Sum of all 5VOut outputs | | | | | |
| Note 2: Total average current on all outputs not to exceed 4.5A | | | | | |

## Operating & Timing Specifications

TABLE 9.

| Parameter | Measure Point | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| Command Latency | Command to output change | 1 | 0.5 | 1 | ms |
| PWM Frequency | Ch1, Ch2 outputs | 10 | 18 (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 | | | | | |
| Note 2: 115200, 8-bit, no parity, 1 stop bit, no flow control | | | | | |
| Note 3: May be disabled with value 0 | | | | | |

## Scripting

TABLE 10.

| Parameter | Measure Point | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| Scripting Flash Memory | Internal | | 8192 | | Bytes |
| Max Basic Language programs | Internal | 1000 | | 1500 | Lines |
| Integer Variables | Internal | | 1024 | | Words (1) |
| Boolean Variables | Internal | | 1024 | | Symbols |
| Execution Speed | Internal | 50 000 | 100 000 | | Lines/s |
| Note 1: 32-bit words | | | | | |

## Thermal Specifications

TABLE 11.

| Parameter | Measure Point | Model | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Case Temperature | Case | All | -40 | | 85 (1) | oC |
| Thermal Protection range | Case | All | 80 | | 90 (2) | oC |
| Power Dissipation | Case | All | | | 70 | Watts |
| Thermal resistance | Power MOSFETs to case | All | | | 0.6 | oC/W |

TABLE 11.

| Parameter | Measure Point | Model | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Note 1: Thermal protection will protect the controller power | | | | | | |
| Note 2: Max allowed power out starts lowering at minimum of range, down to 0 at max of range | | | | | | |

## Mechanical Specifications

TABLE 12.

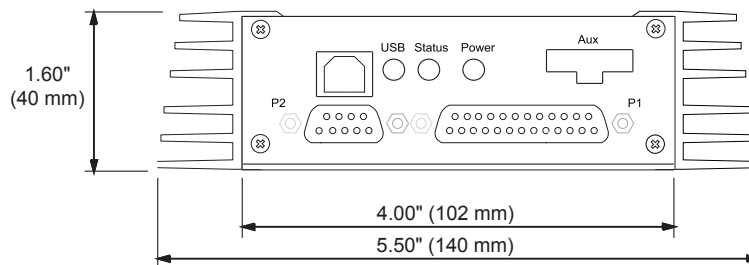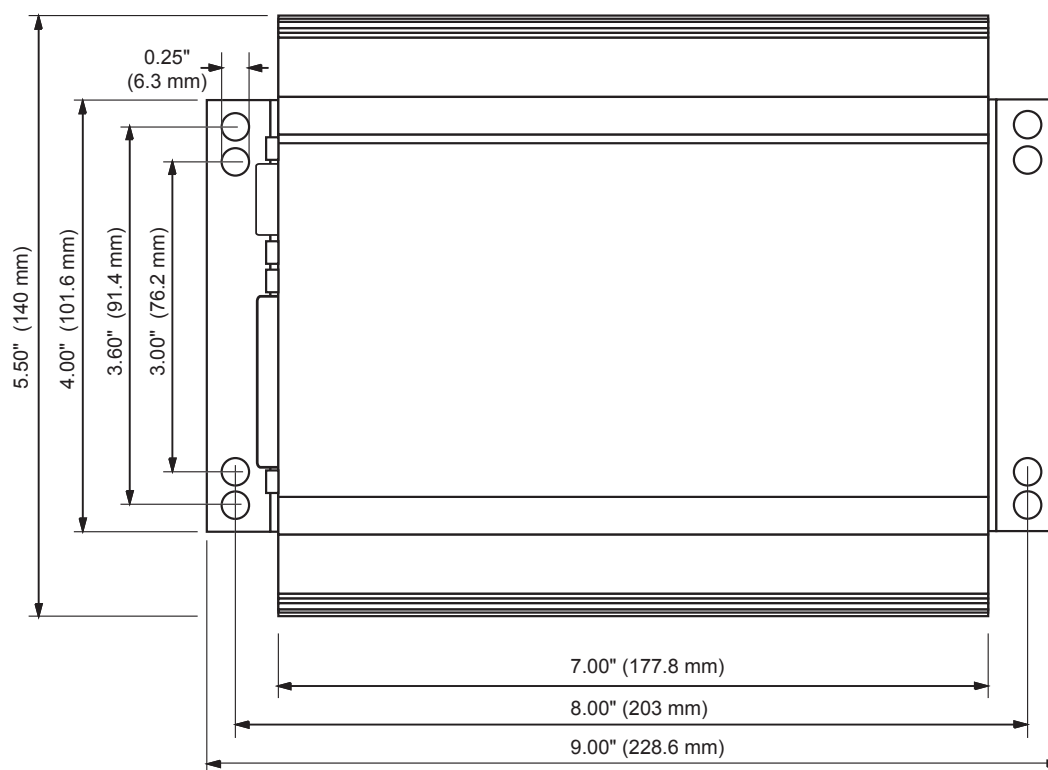| Parameter | Measure Point | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| Weight | Case | | 1.0 (2.0) | | kg (lbs) |
| Wire Length | Case | | 17 (43) | | inches (mm) |
| Power Wire Gauge | Wire | | 8 | | AWG |
| Power Wire Diameter | Outside diameter | | 0.26 (6.6) | | inches (mm) |



FIGURE 10.  HDC24xx front view and dimensions

FIGURE 11.  HDC24xx top view and dimensions