

## Advanced Features 2 x 75A Variable Frequency Drive for AC Induction Motors



Roboteq's HIM2360 is a feature-packed, high-current, dual or single channel controller for AC Induction motors. The controller can operate in one of several modes in order to sense the rotor position and sequence power on the motors' three windings in order to generate smooth continuous rotation. The controller also uses the 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 or torque modes. The HIM23xx features several Analog, Pulse and Digital I/Os which can be remapped as command or feedback inputs, limit switches, or many other function. The HIM23xx 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.

Various 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 AC Induction Motors at up to 75A
- Field Oriented Control
- Multiple Motor Operating mode
- RS485
  - Open Loop Volts per Hertz
  - Fixed Slip Control
  - FOC Torque Mode
  - FOC Speed Mode
- 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 for protecting controller, motors, wiring and battery.
- Accurate speed and Odometry measurement using Hall Encoder data
- Up to 11 Analog Inputs for use as command and/or feedback
- Up to four 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 two 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
- Dimensions: 9" (228.5mm) L, 5.5" W (140mm), 1.6" (40mm) H
- A -40°C to +85°C operating environment
- Weight: 2.95 lbs (1,340g)
- Easy configuration, tuning and monitoring using provided PC utility
- Field upgradeable software for installing latest features via the Internet

## Orderable Product References

Reference	Number of Channels	Amps/Channel	Volts	Ethernet	Resolver
HIM2360	2	75	60	No	No
HIM2396	2	75	96	No	No

## 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 their 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, as seen in Figure 1.

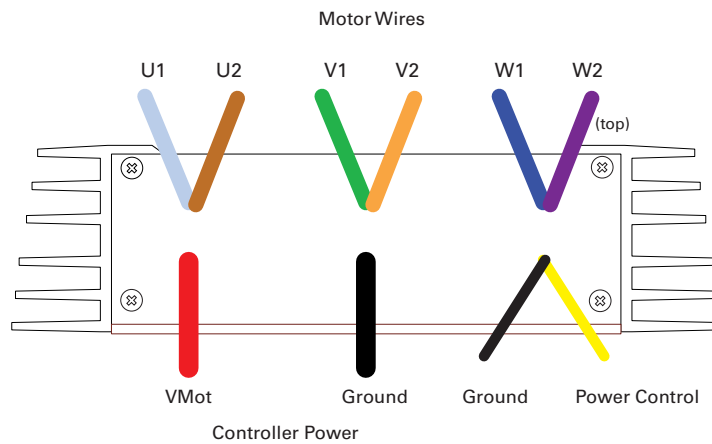


FIGURE 1. Rear Controller Layout

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

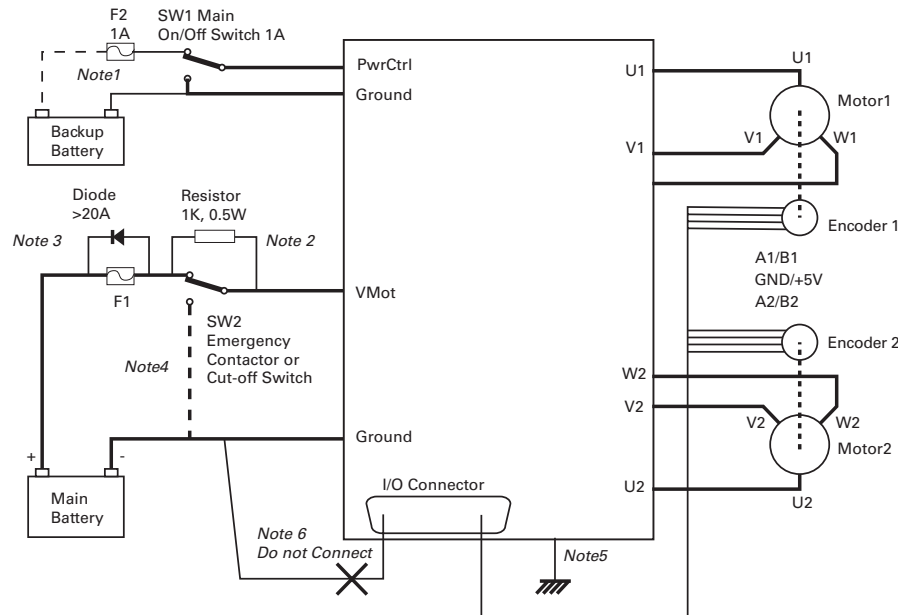


FIGURE 2. Powering the Controller. Thick lines identify MANDATORY connections

## 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 above diagram in order to ensure a safe and trouble-free operation. All connections shown as thick black lines are mandatory. The controller must be powered On/Off using switch SW1 on 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.
- 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.
- 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.

### 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.

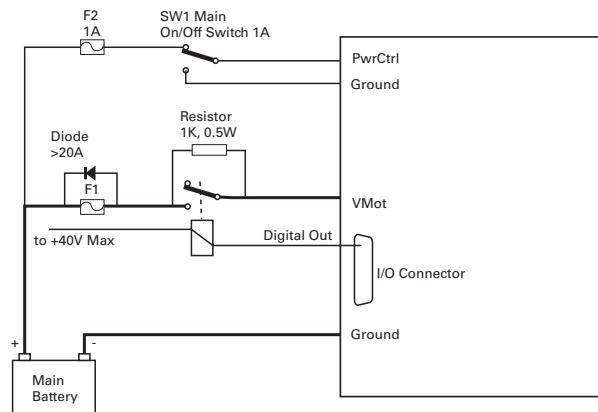


FIGURE 3. Contactor Wiring Diagram

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 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).

### Encoder Connection

Connection to the Encoder is done using a the 25-pin DSub connector. Encoder with 128 Pulses Per Revolution of less typically have open drain outputs and therefore need pull up resistors. Encoder wires must be placed away from the motor phase wires to avoid electrical noise. Capacitors may be required if the encoders pick up noise.

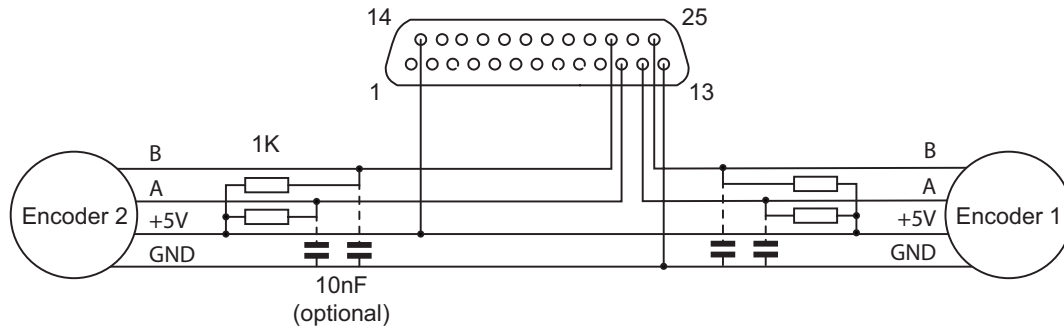


FIGURE 4. Encoder Wiring

TABLE 1.

Pin Number	14 and 25	12	24	11	23	1 and 14
	5V	Enc 1A	Enc 1B	Enc 2A	Enc 2B	Ground

## 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 the Table 2, below.

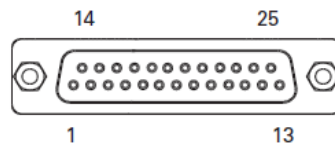


FIGURE 5. Main Connector Pin Locations

TABLE 2.

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		Contactur
7		DOUT4				DIN15		Unused
20		DOUT5				DIN16		Unused
8		DOUT6				DIN17		Unused
21					ANA5	DIN5		Unused
9	GND							
22					ANA6	DIN6		Unused
10					ANA7	DIN7		Unused
23			RS485+					RS485
11			RS485-					RS485
24					ANA10	DIN10	ENC1B	Unused
12					ANA11	DIN11	ENC1A	Unused
25	5VOut							
13	GND							

Note 1: Analog command is disabled in factory default configuration.

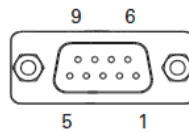


FIGURE 6. Secondary Connector Pin Locations

TABLE 3.

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

Note 1: RS485 is only available on hardware v2.3 or greater of the HIM23xx controllers

### 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.

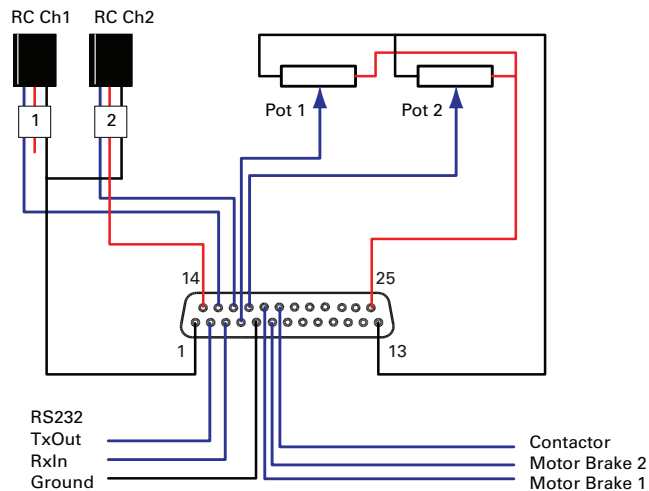


FIGURE 7. Factory default Pin Assignment

### 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.

## 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. USB and CAN can operate at the same time on the HIM23xx. Plugging USB to a computer will not disable the CAN interface.

## RS485 Communication

RS485 is only available on HIM23xx controllers that are hardware version 2.3 or greater. RS485 is an industry standard for defining serial communication. Due to its balanced signaling, RS485 is effective over distances, even if other electrical signals are present. Its stability makes it well suited to connect multiple receivers to a single network.

You can operate RS485 in half-duplex mode and it is well suited for use with the Modbus protocol. On the 25-pin connector, 2-pins are present.

## Status LED Flashing Patterns

After the controller is powered on, the Power LED will turn on, indicating that the controller is On. The Status LED will be flashing at a 2 seconds interval. The flashing pattern and color provides operating or exception status information.



FIGURE 8. Normal Operation Flashing Patterns

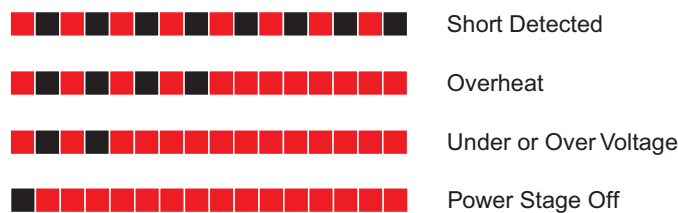


FIGURE 9. Exception or Fault Flashing Patterns

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

## Battery Backed Clock and Variables

The controller includes a real-time clock/calendar and RAM storage for user variables. Both the clock and the RAM storage require a battery to continue running in order 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 6 screws that are holding the cover. Lift the cover to reach the board and insert a 3V, 12.5mm coin-style battery. Use battery type CR1225 or equivalent.

## Measured Amps

Including Amps sensors on the wires allows for fast and efficient information. Both motor and battery amps are measured in real time.

## Secure Connection to Faston™ Tabs

Power Motor and Battery connections are made via standard 250mils (6.35mm) AMP FASTON™ Tabs. FASTON connectors provide a high current and very secure connection, proven over decades of use in the automotive industry. For maximum current handling, use connectors for AWG10 wires recognizable by their yellow plastic insulator.

FASTON connectors have an extremely tight fit and will not come off on their own. It is recommended, nevertheless, that the wiring is made so that the cables are never pulling the connector outward.

Frequent disconnects and reconnects will eventually loosen the connector's grip on the tab. If frequent disconnection is required, consider using Positive Lock connectors from TE Connectivity or their equivalent. These connectors have a spring loaded tab latch a pin that will lock into the hole of the male tab.

## Electrical Specifications

### Absolute Maximum Values

The values in Table 4, below, should never be exceeded, permanent damage to the controller may result.

TABLE 4.

Parameter	Measure point	Models	Min	Typical	Max	Units
Battery Leads Voltage	Ground to VMot	All			60	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-	All			60 (1)	Volts
Digital Output Voltage	Ground to Output pins	All			40	Volts
Analog and Digital Inputs Voltage	Ground to any signal pin on 25 and 9-pin connectors	All			30	Volts
RS232 I/O pins Voltage	External voltage applied to Rx pin (2)	All			30	Volts
Case Temperature	Case	All	-40		85	°C
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 source must be applied to Tx pin Note 3: Non condensing						

**Power Stage Electrical Specifications (at 25°C ambient)**

TABLE 5.

<b>Continuous Max Current per channel</b>	<b>Measure point</b>	<b>Models</b>	<b>Min</b>	<b>Typical</b>	<b>Max</b>	<b>Units</b>
Battery Leads Voltage	Ground to VMot	All	0 (1)		60	Volts
Motor Leads Voltage	Ground to U, V, W wires	All	0 (1)		60 (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	All	5	60 (4)	60	Volts
Under Voltage protection range	Ground to VMot	All	0	5 (4)	60	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	All			75 (6)	Amps
Continuous Max Current per channel	Motor current	All			40 (7)	Amps
Current Limit range	Motor current	All	10	50 (8)	75	Amps
Stall Detection Amps range	Motor current	All	10	75 (8)	75	Amps
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 6.

Parameter	Measure point	Min	Typical	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		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		1000	Hz
Encoder count	Internal	-2.147		2.147	10 <sup>9</sup> Counts
Encoder frequency	Encoder input pins			250	kHz
Note 1: Sum of all 5VOut outputs					
Note 2: Total average current on all outputs not to exceed 4.5A					

## Operating and Timing Specifications

TABLE 7.

Parameter	Measure Point	Min	Typical	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 and 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					

### 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 8.

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
Minimum load inductance/resistance ratio (1)	0 - 96	1	msec
Maximum operating electric speed (2)	0 - 96	15000	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.			
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 9.

Parameter	Measure Point	Min	Typical	Max	Units
Scripting Flash Memory	Internal		32000		Bytes
Max Basic Language programs	Internal	2000		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 10.

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						
Note 2: Max allowed power out starts lowering at minimum of range, down to 0 at max of range						

## Mechanical Specifications

TABLE 11.

Parameter	Measure Point	Min	Typical	Max	Units
Weight	Case		1340 (2.95)		g (lbs)
Wire Length	Case	43 (8.97)			cm (inches)
Power Wire Gauge	Wire		8		AWG
Power Wire Diameter	Outside diameter		6.6 (0.26)		mm (inches)

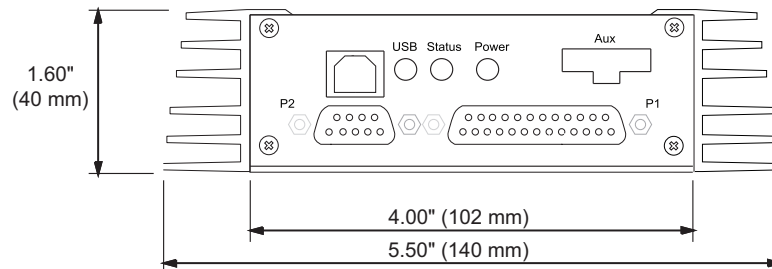


FIGURE 10. HIM23xx Front View and Dimensions

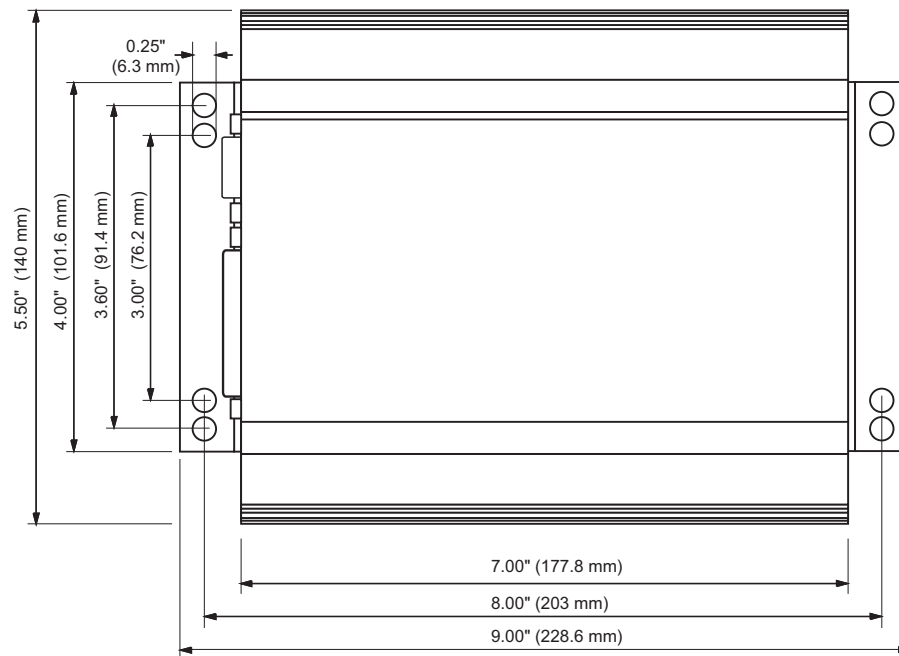


FIGURE 11. HIM23xx Top View and Dimensions