30A Forward/Reverse Brushless DC Motor Controller with Hall and Encoder Inputs, USB and CAN

Roboteq's SBL13xx is a high-current controller for hall-sensor equipped Brushless DC motors. The controller uses the position information from the sensors to sequence power on the motor's three windings in order to generate smooth continuous rotation. The controller also uses the Hall sensor or encoder input information to compute speed and measure traveled distance inside a 32-bit counter. The motor may be operated in open or closed loop speed mode. Using low-cost position sensors, they may also be set to operate as heavy-duty position servos.

The SBL13xx accepts commands received from an RC radio, Analog Joystick, wireless modem, or microcomputer. Using CAN bus, up to 127 controllers can be networked on a single twisted pair cable. 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

- Electric Bikes
- Machine Control
- Terrestrial and Underwater Robotic Vehicles
- Automatic Guided Vehicles
- Police and Military Robots
- Hazardous Material Handling Robots
- Telepresence Systems
- Animatronics
- Industrial Controls
- Hydraulic Pumps control

Key Features

- RS232, 0-5V Analog, or Pulse (RC radio) command modes
- Available in version with CAN bus up to 1 Mbit/s
- Auto switch between RS232, Analog, or Pulse based on user-defined priority
- Built-in 3-phase high-power drivers for one brushless DC motor at up to 30A
- Support for 10 KOhm NTC temperature sensors through analog inputs (requires an external 10 KOhm pull-up resistor)
- Trapezoidal switching based on Hall Sensor position information
- Smooth and quiet three Phase sinusoidal mode (A-version)
- Support for absolute angle encoder, Sin/Cos analog (A version)
- Field Oriented Control in Sinusoidal modes
- Full forward & reverse motor control. Four quadrant operation. Supports regeneration
- Operates from a single power source
- Programmable current limit up to 30A for protecting controller, motor, wiring and battery.
- Connector for Hall Sensors
- Accurate speed and Odometry measurement using Hall Sensor or encoder data
- Quadrature encoder input with 32-bit counter
- Up to six 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 six Digital Inputs for use as Deadman Switch, Limit Switch, Emergency stop or user inputs
- Two general purpose 40V, 1.5A output for brake release or accessories
- Custom scripting in Basic language. Execution speed 50000 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, Encoder or Hall counter capture are outside user selectable range (soft limit switches)
- Open loop or closed loop speed control operation
- Closed loop position control with encoder, analog or pulse/frequency feedback
- Torque mode
- PID control loop
- 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 RC radio, RF Modem or microcomputer
- Separate Programmable acceleration and deceleration for each motor
- Support for two simplified CAN protocols
- Efficient 10 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
- Watchdog for automatic motor shutdown in case of command loss
- Overtemperature protection
- Diagnostic LED indicators
- Efficient heat sinking using conduction bottom plate. Operates without a fan in most applications
- Power wiring via screw terminals
- 70mm x 70mm x 27mm
- -40° to +85° C operating environment
- Easy configuration, tuning and monitor using provided PC utility
- Field upgradeable software for installing latest features via the Internet

Orderable Product References

Reference	Number of Channels	Amps/Channel	Volts	CAN	USB	FOC
SBL1360	1	30	60	Yes	Yes	No
SBL1360A	1	30	60	Yes	Yes	Yes

Warning

A dangerous uncontrolled motor runaway condition can occur due to various reasons, including, but not limited to: command or feedback wiring failure, configuration errors, faulty firmware, errors in user scripts or programs, or controller hardware failure.

Users must be aware that such failures can occur and must ensure the safety of their system under all conditions. Roboteq will not be held liable for any damage or injury resulting from product misuse or failure.

Important Note

All products are not serviceable. If damage is suspected, the item must be replaced rather than repaired.

Attempting to service or repair the product voids any existing warranty and may pose safety risks.

Consult customer support for more information on replacements.

Power Wires Identifications and Connection

Power connections are made via screw terminals.

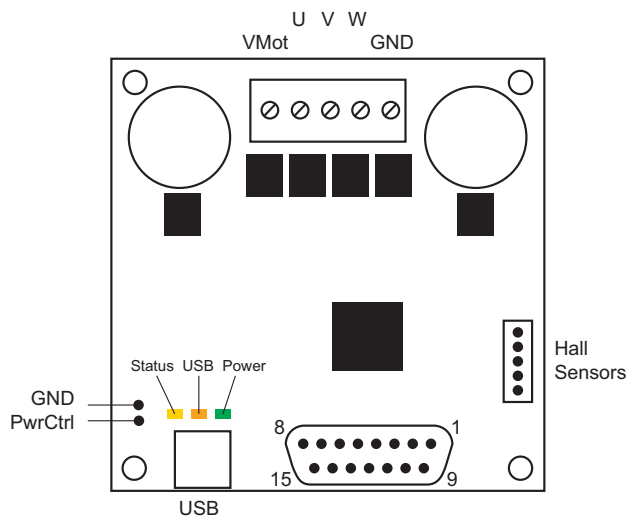

FIGURE 1. Controller Layout

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

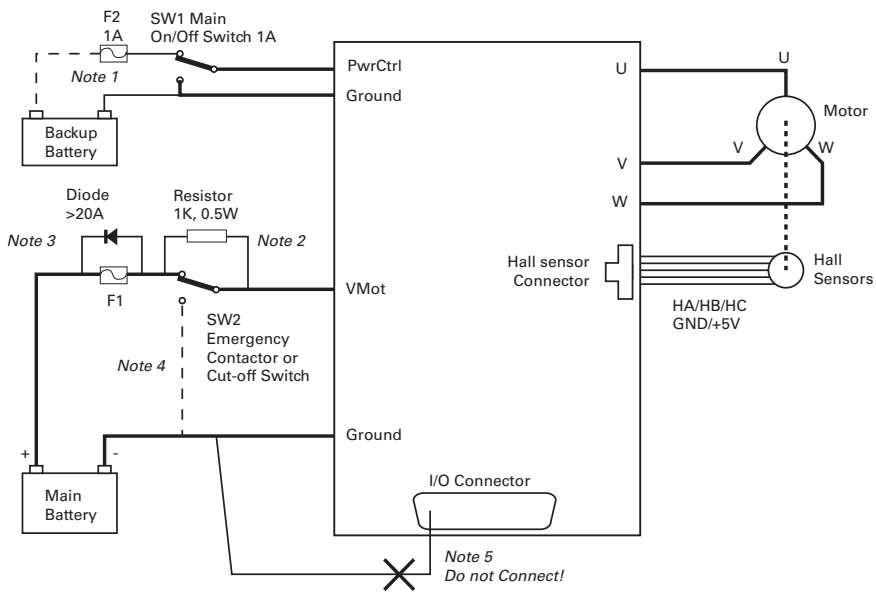

FIGURE 2. Powering the Controller. Thick lines identify **MANDATORY** connections

Caution

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 line are mandatory. The controller must be powered On/Off using switch SW1on the Power Control tab. 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 VMot tab 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 input 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 (SBL1360).
Note 5: 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.

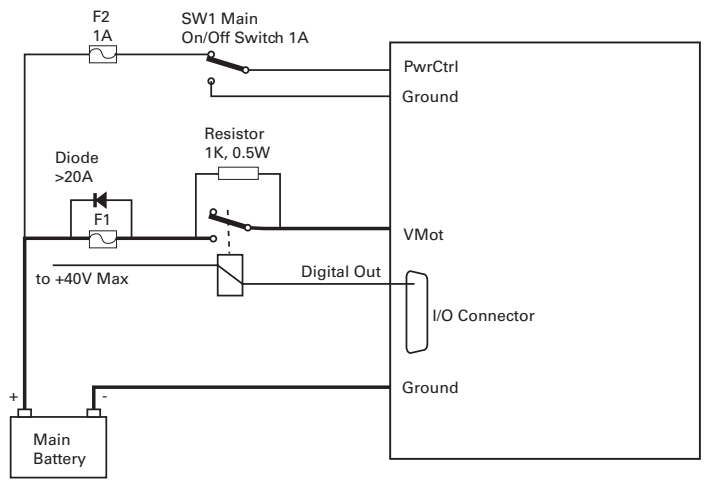

FIGURE 3. Contactor Wiring Diagram

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 "Warning" on Page 3.

Measured and Calculated Amps

SBL13xx 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.

SBL13xxA 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.

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. Mount the controller so that the bottom plate makes contact with a metallic surface (chassis, cabinet) to conduct the heat.

Hall Sensors Connection

Connection to the Hall Sensors is done using a special connector on the right side of the controller. The Hall sensor connector is a 5-pin JST PH, model PHR-5. Pin assignments are in Table 1, below.

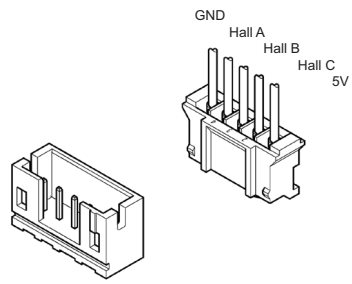

FIGURE 4. Connector Wiring Diagram

TABLE 1.

Pin Number	1	2	3	4	5
Signal	5V	Hall C	Hall B	Hall 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 the figure below.

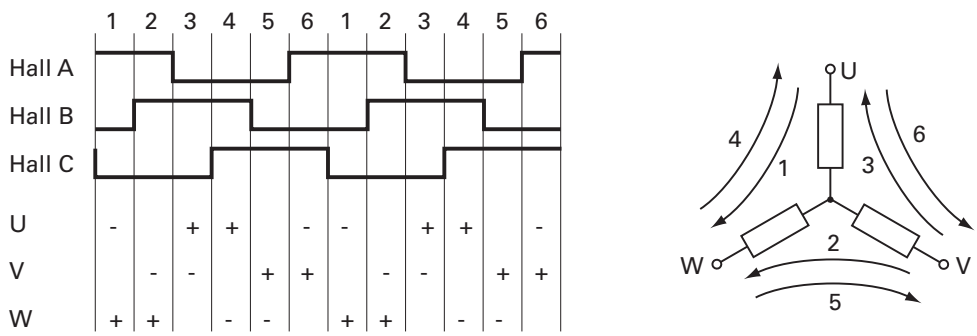

FIGURE 5. Hall Sensors Sequence

Connection to Analog Sin/Cos Absolute Encoder (A-version)

The SBL13xxA have two high-speed analog inputs that can be used to capture absolute angle position from angular sensors with sin/cos voltage outputs. The signal must be 0-5V max with the 0 at 2.500V.

The table below shows the signals assignment on the 15-pin connector.

TABLE 2.

Signal	Pin Number	Pin Name
Sin	10	ANA5/ASIN
Cos	15	ANA6/ACOS

Commands and I/O Connections

Connection to RC Radio, Microcomputer, Joystick and other low current sensors and actuators is done via the 15-pin connector located in front of the controller. The functions of many pins vary depending on controller model and user configuration. Pin assignments are found in the Table 3, below.

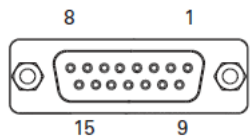

FIGURE 6. Connector Pin Locations

TABLE 3.

Connector Pin	Power	Dout	Com	RC	Ana	Dinput	Enc	Default Config
1		DOUT1						Brake
9		DOUT2						
2			TxOut					RS232Tx
10				PIN5(5)	ANA5/ASIN(1)	DIN5		
3			RxIn					RS232Rx
11				PIN4	ANA4	DIN4		AnaCmd (3)
4				PIN1	ANA1	DIN1	ENCA (2)	RCRadio1
12				PIN3	ANA3	DIN3		Unused
5	GND							
13	GND							
6			CANL					CAN Low
14	5VOut							
7			CANH					CAN High
15				PIN6(5)	ANA6/ACOS(1)	DIN6		
8				PIN2	ANA2	DIN2	ENCB (2)	Unused

Note 1: ASIN and ACOS are only available on SBL13xxA

Note 2: Encoder input requires Pulse inputs 1 and 2 to be disabled. Pulse inputs are enabled in factory default.

Note 3: Analog command is disabled in factory default configuration.

Default I/O Configuration

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 an analog potentiometer, an RC radio, the RS232 port, and the Digital output to a motor brake solenoid. 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.

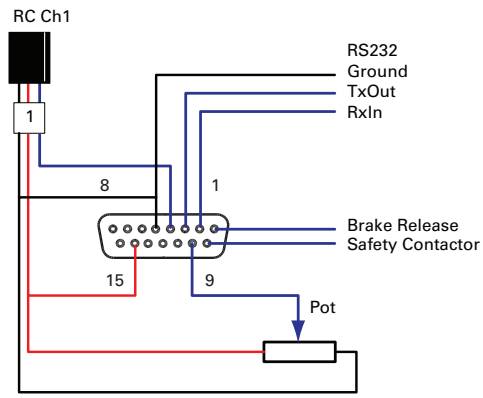

FIGURE 7. Factory Default Pin Assignment

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. Use the PC utility to enable and assign analog inputs.

Connecting Thermistors

10 KOhm NTC temperature sensors can be connected to the controller's analog inputs. This enables reading of motor temperature through the controller's runtime variables and allows for active temperature protection. This connection can be achieved by using a 10 KOhm pull-up resistor between the analog input and the controller's 5V output. For more information about motor temperature readings and controller parameterization, please refer to the Roboteq Controller's User Manual.

CAN Bus Operation

The controller can interface to a standard CAN Bus network, using 4 possible protocols: Standard CANOpen, and three proprietary schemes (MiniCAN, RawCAN and RoboCAN). Please refer to the User Manual for details. USB and CAN can operate at the same time only on the SBL1xxxA. On the SBL1xxx, 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 two seconds interval. The flashing pattern and color provides operating or exception status information. Note that model SBL13xxA had bicolor Red/Green LED and SBL13xx has monochrome Red LED.

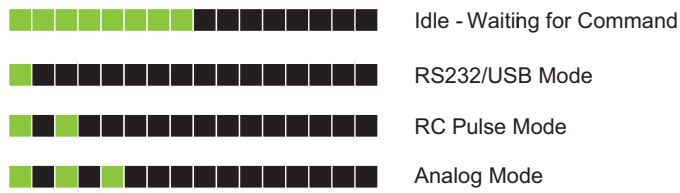

FIGURE 8. Normal Operation Flashing Patterns

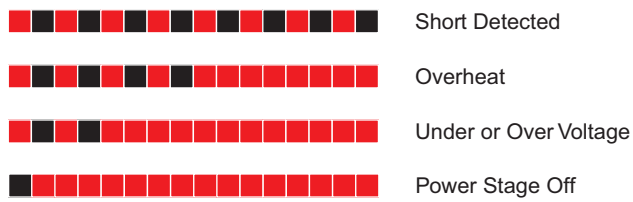

FIGURE 9. Exception or Fault Flashing Patterns

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

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

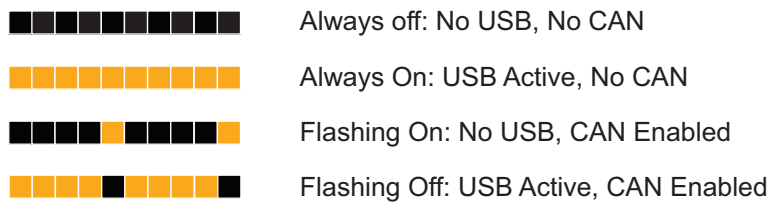

FIGURE 10. Com LED

Electrical Specifications

Absolute Maximum Values

The values in Table 4, below, should never be exceeded. Permanent damage to the controller can occur.

TABLE 4.

Parameter	Measure point	Min	Typical	Max	Units
Battery Leads Voltage	Ground to VMot			60	Volts
Reverse Voltage on Battery Leads	Ground to VMot	-1			Volts
Power Control Voltage	Ground to Pwr Control wire			65	Volts
Motor Leads Voltage	Ground to U, V, W wires			60 (1)	Volts
Digital Output Voltage	Ground to Output pins			40	Volts
Analog and Digital Inputs Voltage	Ground to any signal pin on 15-pin & Hall inputs			30	Volts
RS232 I/O pins Voltage	External voltage applied to Rx/Tx pins			30(2)	Volts
Case Temperature	Case	-40		85	°C
Humidity	Case			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 5.

Parameter	Measure point	Min	Typical	Max	Units
Battery Leads Voltage	Ground to VMot	0 (1)		60	Volts
Motor Leads Voltage	Ground to U, V, W wires	0 (1)		60 (2)	Volts
Power Control Voltage	Ground to Power Control wire	0 (1)		65	Volts
Minimum Operating Voltage	VMot or Pwr Ctrl wires	9 (3)			Volts
Over Voltage protection range	Ground to VMot	5	55 (4)	60	Volts
Under Voltage protection range	Ground to VMot	0	5 (4)	60	Volts
Idle Current Consumption	VMot or Pwr Ctrl wires	50	100 (5)	150	mA
ON Resistance (Excluding wire resistance)	VMot to U, V or W. Ground to U, V or W		10		mOhm
Max Current for 30s	Motor current			30	Amps
Continuous Max Curren t per channel	Motor current			20 (7)	Amps
Current Limit range	Motor current	5	20 (8)	30	Amps
Stall Detection Amps range	Motor current	5	30 (8)	30	Amps
Stall Detection timeout range	Motor current	1	65000 (9)	65000	milliseconds

TABLE 5.

Parameter	Measure point	Min	Typical	Max	Units
Short Circuit Detection threshold (10)	Between Motor wires or Between Motor wires and Ground	100 (11)		200 (11)	Amps
Short Circuit Detection threshold	Between Motor wires and VMot	No Protection. Permanent damage will result			
Motor Acceleration/ Deceleration range	Motor Output	100	500 (12)	65000	milliseconds

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 heat sink 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: Sensitivity selectable by software

Note 11: 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 pin on DSub15	4.7	4.9	5.1	Volts
5V Output Current	5V pin on DSub15			100	mA
Digital Output Voltage	Ground to Output pins			40	Volts
Digital Output Current	Output pins, sink current			1	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		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

Command, I/O and Sensor Signals Specifications

TABLE 6.

Parameter	Measure point	Min	Typical	Max	Units
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			200	KHz
Note1: Encoders are disabled in factory default.					

Operating & Timing Specifications

TABLE 7.

Parameter	Measure Point	Min	Typical	Max	Units
Command Latency	Command to output change	0	0.5	1	ms
PWM Frequency	Motor outputs	10	16 (1)	20	kHz
Closed Loop update rate	Internal		1000		Hz
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 8.

Parameter	Measure Point	Min	Typical	Max	Units
Scripting Flash Memory	Internal		8000 32000(1)		Bytes
Max Basic Language programs	Internal	1000		3000	Lines
Integer Variables	Internal			1024 4096(1)	Words (2)
Boolean Variables	Internal			8192	Symbols
Execution Speed	Internal	50 000	100 000		Lines/s
Note 1: Available on SBL13xxA Version, only Note 2: 32-bit words					

Thermal Specifications

TABLE 9.

Parameter	Measure Point	Min	Typical	Max	Units
Board Temperature	PCB	-40		85 (1)	°C
Thermal Protection range	PCB	70		80 (2)	°C
Thermal resistance	Power MOSFETs to heats sink			2	°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					

The SBL13xx uses a conduction plate at the bottom of the board for heat extraction. For best results, attach firmly with thermal compound paste against a metallic chassis so that heat transfers to the conduction plate to the chassis. If no metallic surface is available, mount the controller on spacers so that forced or natural air flow can go over the plate surface to remove heat.

Mechanical Specifications

TABLE 10.

Parameter	Measure Point	Min	Typical	Max	Units
Weight	Board		96 (.21)		g (lbs)
Power Wire Gauge	Screw Terminals			12	AWG
Torque	D-sub standard connector		0.4 (3.54)		Nm (in-lbs)
Torque	Terminal block		0.8 (7.10)		Nm (in-lbs)
Torque	Mounting screws (4/M2.5)		0.36 (3.2)		Nm (in-lbs)

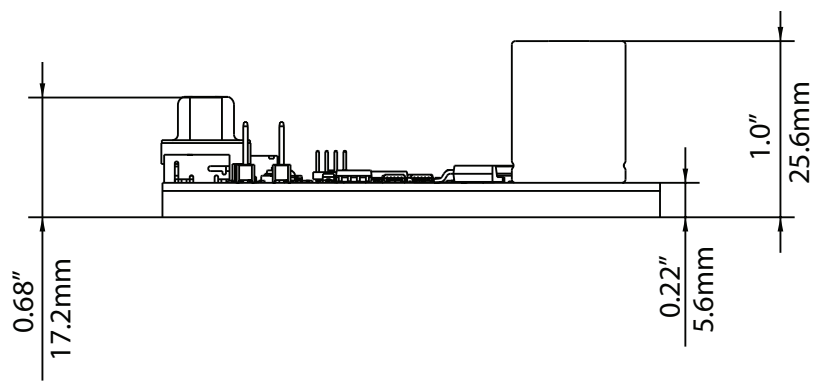

FIGURE 11. SBL13xx Front View and Dimensions

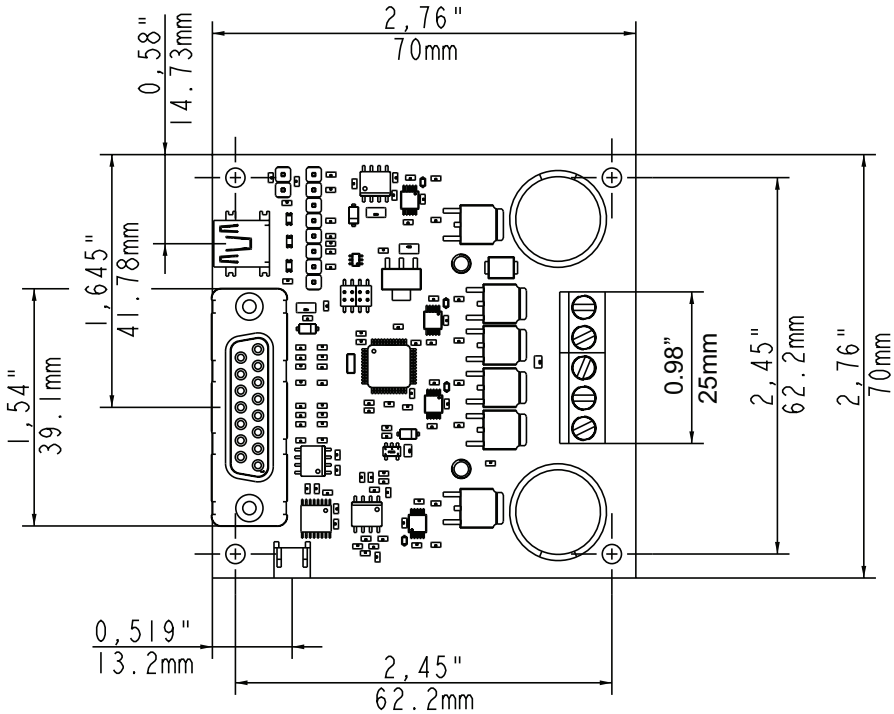

FIGURE 12. SBL13xx Top View and Dimensions