Fourth Generation Single Channels 30A/60V Brushless DC Motor Controller

CANopen

Roboteq's SBLG13xx is a compact, full digital, high-performance and high-efficiency controller for Brushless DC motors. It is a direct replacement for the company's popular SBLG13xx, using a 4th generation processor and implementing many performance, algorithmic, and other qualitative enhancements. The controller supports a large selection of rotor position sensor types in order to generate smooth continuous rotation. The controller can be commanded via serial, USB, Analog or Pulse signals. Multiple controllers can be networked over a low-cost, twisted pair CANbus networks.

The SBLMG13xx uses the latest motion control technology, such as field-oriented control (FOC), acceleration/velocity feed forward, and fast loop frequency to deliver quick and precise motion control in speed, torque or postilion modes. Numerous safety features, including Safe Torque Off (STO) are incorporated into the controller to ensure reliable and safe operation.

The controller's operation can be extensively automated and customized using its built-in scripting language. 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

- Personal Mobility
- Machine Control
- Terrestrial and Underwater Robotic Vehicles
- Automatic Guided Vehicles
- Factory Automation
- Robotic Arms
- Animatronics
- Hydraulic Pumps control

Key Features

- USB, Serial, 0-5V Analog, or Pulse (RC radio) command modes
- One RS232 serial ports
- MODBUS ASCII & RTU Support over RS232
- CAN bus up to 1 Mbit/s. Multi-Protocol support
  - CANOpen DS402
  - RoboCAN Meshed Network
  - RawCAN Customizable to Any Protocol
- Auto switch between Serial, USB, CAN, Analog, or Pulse based on user-defined priority
- Built-in 3-phase high-power drivers for one brushless DC motor
- 40A Max, 20A continuous Current with I2T protection algorithm
- Programmable current limit up to 30A for protecting controller, motor, wiring and battery.
- 97% or better typical Efficiency
- Supports Surface Permanent Magnet (SPM) motors or Internal Permanent Magnet (IPM) motors
- Multiple Motor Operating mode
  - Trapezoidal with Hall Sensors
  - Sinusoidal with Hall+Encoder
  - Sinusoidal with Encoders
  - Sinusoidal with Hall Sensors
  - Sinusoidal with sin/cos Sensors
- Field Oriented Control in Sinusoidal modes
- Automatic Field Weakening for maximizing motor speed and torque
- Operates from a single 10V-60V power source
- STO - Safe Torque Off (Certification Pending)
- Separate connector for Hall Sensors
- Accurate speed and Odometry measurement using Hall Sensor or encoder data

- 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 Dead-man Switch, Limit Switch, Emergency stop or user inputs
- Two general purpose 35V, 1.5A output for accessories
- Custom scripting in Basic language. Execution speed up to 100000 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 speed control operation
- Closed loop speed, position and/or torque control
- Closed loop position control with encoder, hall sensors, analog or pulse/frequency feedback
- Cascaded Speed, Position, Torque PID loops
- High-Performance 16kHz Current Control loop
- Automatic Tuning of Torque, Speed and Position loops
- Automatic Field Weakening for maximum Speed & Torque
- Automatic Motor Characterization
- Advanced performance optimization algorithms (Anti-cogging, notch filter, ...)
- Configurable Data Logging of operating parameters on Serial Outputs for telemetry or analysis
- Separate Programmable acceleration and deceleration
- Built-in Battery Voltage and Temperature sensors
- Connector for external Motor Windings Temperature sensor
- Optional 12-24V 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-100mA output for powering sensors, RF Modem or microcomputer
- Stall detection and selectable triggered action if Amps is outside user-selected range
- Ultra-efficient 4.2 mOhm ON resistance MOSFETs
- Short circuit protection with selectable sensitivity levels
- Over voltage and Under voltage protection
- Watchdog for automatic motor shutdown in case of command loss
- Over temperature protection
- Power and Diagnostic LED indicators
- Efficient heat sinking using conduction bottom plate. Operates without a fan in most applications
- IP40 case protection rating
- Power wiring via High-Current carrying Faston Terminals
- 70mm x 70mm x 27mm
- -40° to +85° C operating environment
- Easy configuration, tuning and monitor using provided PC utility
- Easy configuration, tuning and monitoring using provided PC utility
- Field upgradeable software for installing latest features via the Internet

Orderable Product References

Reference	Amps Max/Cont	Volts	CAN	STO
SBLG13xxT	40/20	60	Yes	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 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 via screw terminals.

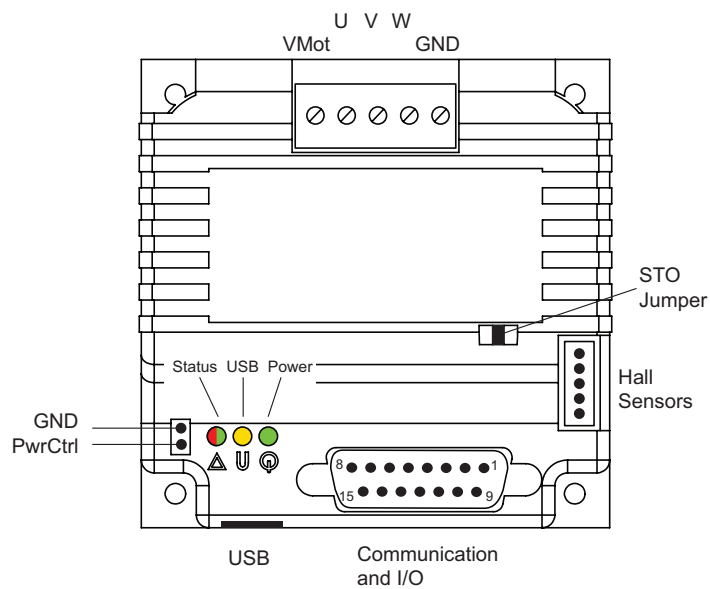


FIGURE 1. Controller Layout

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

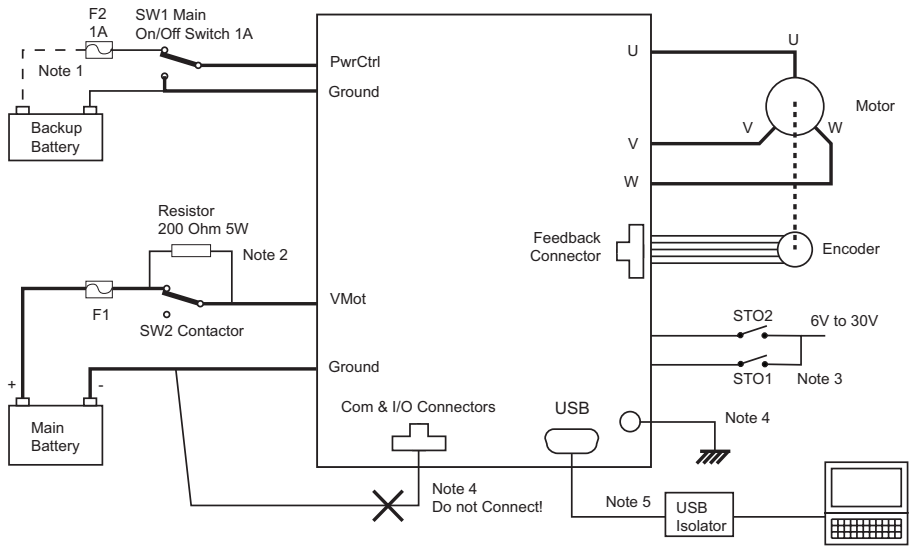


FIGURE 2. Powering the Controller. Thick lines identify **MANDATORY** connections

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 line are mandatory.

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. Use a suitable high-current fuse F1 as a safety measure to prevent damage to the wiring in case of major controller malfunction.

Power On/Off Switch

The **controller must be powered On/Off using switch SW1** on the Power Control pin.

Note 1: To ensure motor operation with weak or discharged batteries, connect a second battery to the Power Control pin via the SW1 switch. This will keep the controller alive and responding even if no voltage is present on the Vmot terminal.

Precharge Resistor

The controller has internal capacitance which will cause a short duration but important current inrush the moment power is applied.

Note 2: If there is a concern that this current can overload the power supply or the contactor, insert a precharge resistors as shown in the figure. For precharging to take place, the controller must be turned off by grounding the Power Control pin.

Enable Safe Torque Off

Note 3: On versions of the controller with STO support, the Motor will be prevented from running until its STO inputs are both connected to a voltage of 6V or higher. If one or both STO lines are floated or grounded, the drive will be ON and able to communicate but the motor will not be driven. See details further down in this datasheet and in the User Manual.

Connection to Chassis

Note 4: For improved EMI immunity and reduce emissions, it is recommended to connect the controller's bottom plate to the system's chassis. Note that the integrated controller's ground is not DC electrically connected the plate. There is, however, a capacitor between the controller's ground and the bottom plate, and therefore AC conductivity.

Avoid Alternate Ground Paths

Note 5: Beware not to create a path from the ground pins on the I/O connector and the battery minus terminal. It is highly recommended to avoid this connection as current could circulate in the signals ground, which could create noise on the low power signals. If the main ground power terminal is loose or disconnected, very high current may circulate in the signals ground wire and damage it.

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.

Precautions When Connecting PC via USB

Note 6: Always use an USB isolator to protect the drive and the PC against possible electrical damage. When using a portable PC, operate it from battery to avoid accidental return ground path via the charger.

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.

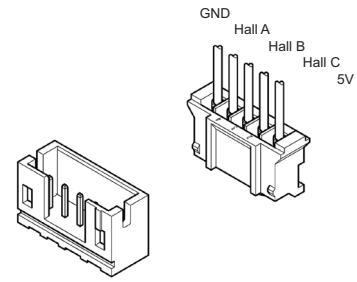


FIGURE 3. Connector Wiring Diagram

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.

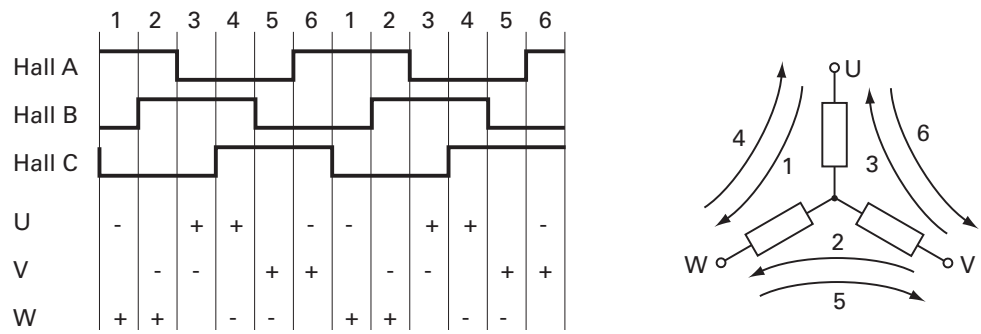


FIGURE 4. Hall Sensors Sequence

Connection to Analog Sin/Cos Absolute Encoder

The SBLG13xx 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.

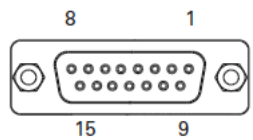


FIGURE 5. Connector Pin Locations

TABLE 3.

Connector Pin	Power	Dout	Com	Pulse	Ana	Dinput	STO	Enc
1		DOUT1						
9		DOUT2						
2			TxOut					
10				PIN5	ANA5/ASIN	DIN5		
3			RxIn					
11				PIN4	ANA4	DIN4	STO2 (1)	
4				PIN1	ANA1	DIN1		ENCA
12				PIN3	ANA3	DIN3	STO1 (1)	
5	GND							
13	GND							
6			CANL					
14	5VOut							
7			CANH					
15				PIN6	ANA6/ACOS	DIN6		
8				PIN2	ANA2	DIN2		ENCB
Note 1: STO jumper must be removed for STO signals to be active								

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. 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.

Important Warning

Always use an USB isolator to protect the drive and the PC against possible electrical damage. When using a portable PC, operate it from battery to avoid accidental return ground path via the charger.

CAN Communication

CAN is the SBLG13xx's primary and recommended communication interface. Up to 127 drives can be networked on a low cost twisted pair network up to 1000m long and at speeds up to 1Mbit/s. Roboteq support four CAN protocols:

- CANOpen for interoperability with other vendor's DS301 and DS402 compliant devices
- RoboCAN, a simple and effective peer to peer meshed network protocol
- MiniCAN, a simplified subset of CANOpen PDOs
- Raw CAN, a low-level system used with scripting for constructing and parsing CAN frames to handle any protocols

TABLE 4. CANOpen Communications Specification

Feature	Value
Motion Network type	CAN, CANOpen
CANOpen Standards Support	DS301, DS402
Operating Modes	cyclic sync torque, cyclic sync velocity, cyclic sync position, profile position, profile velocity, profile torque modes, homing
Process Data Objects (PDO)	Cyclic sync and free run modes. Cyclic messages can be set for 20 objects on 4 maps

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 SBLG13xxA had bicolor Red/Green LED and SBLG13xx has monochrome Red LED.

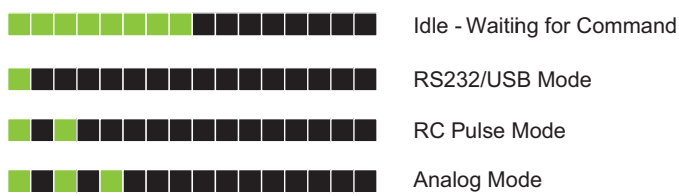


FIGURE 6. Normal Operation Flashing Patterns

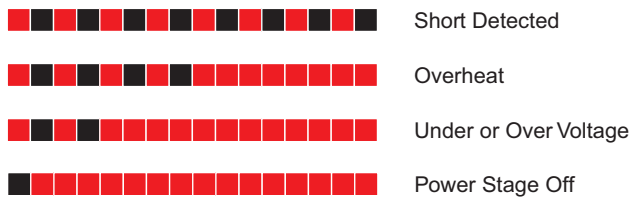


FIGURE 7. Exception or Fault Flashing Patterns

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.

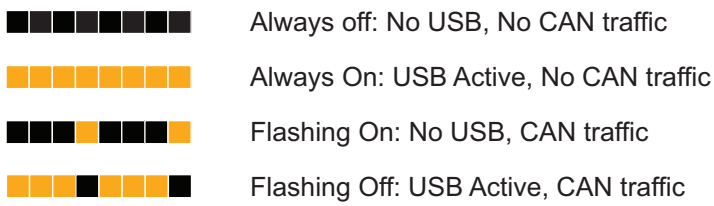
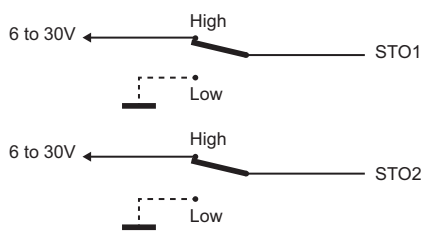


FIGURE 8. Com LED

Safe Torque Off - STO (Certification Pending)

Safe Torque Off is a safe method for switching controller in a state where no torque is generated, regardless whether the controller is operating normally or is faulty. When STO is enabled, two digital inputs, DIN1 and DIN2 are remapped as STO1 and STO2. The inputs are redundant and both must have a 6V to 30V signal present at the same time in order for the Power MOSFETs to be energized. The controller will perform a self-check of the STO circuit at every power on and every time the STO inputs go from any state to both high. Once the STO hardware is verified to work, the controller will safely allow the motors to be energized. If either input is below 1V, the controller's outputs will be disabled. The STO circuit is verified and validated and can therefore be trusted instead of external relays. See the STO Manual for more information and maintenance instructions.

By factory default STO functionality is disabled. It must be enabled by removing the jumper located on the top of the controller's case.



STO1	STO2	Motors Output
Low	Low	Disabled
High	Low	Disabled/Fault
Low	High	Disabled/Fault
High	High	Enabled

FIGURE 9. STO input levels effects on controller output

The STO function is compliant to:

- IEC 61800-5-2:2017, SIL 3
- IEC 61508:2010, SIL 3
- IEC 62061:2015, SIL 3
- ISO 13849-1:2015, Category 3 Performance Level e

Important Warning

Activating STO causes the motor to float and stop generating torque. The motor will not be actively stopped and will slow down only through the system's friction. In Mobile Robot applications, the robot may keep moving for several meters. To be safe, additional braking should be provided by applying a mechanical brake, or braking electrically by shorting the motor's winding using Roboteq's SBSxxxx series Safety Electric Brake Switches

Electrical Specifications

Absolute Maximum Values

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

TABLE 5.

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 6.

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
Input Capacitance	Ground to VMot		940		uF
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 Current 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
Short Circuit Detection threshold (10)	Between Motor wires or Between Motor wires and Ground			78 (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: Controller will stop until idle command given in case of short circuit detection

Note 11: Approximate value

Note 12: Factory default value. Time in ms for power to go from 0 to 100%

Command, I/O and Sensor Signals Specifications

TABLE 7.

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	3.8		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
Minimum Pulse on or Pulse off duration	Pulse inputs	25			us
Frequency Capture	Pulse inputs	100		2000	Hz
Encoder count	Internal	-2.147		2.147	10^9 Counts
Encoder frequency	Encoder input pins			500(1)	kHz
Note1: Encoders are disabled in factory default.					

Operating & Timing Specifications

TABLE 8.

Parameter	Measure Point	Min	Typical	Max	Units
Command Latency	Command to output change	0	0.5	1	ms
Maximum PWM duty cycle	Motor outputs			90.8	%
Closed Loop update rate	Internal		1000		Hz
RS232 baud rate	Rx & Tx pins		115200 (1)		Bits/s
RS232 Watchdog timeout	Rx pin	1 (2)		65000	ms
Note 1: 115200, 8-bit, no parity, 1 stop bit, no flow control Note 2: 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 τ=L/R and the maximum operating electric speed.

TABLE 9.

Parameter	Input DC Voltage (V)	Value	Units
Minimum load phase inductance (1)	12	25	uH
	24	40	uH
	48	60	uH
	60	80	uH
Minimum load inductance/resistance ratio (1)	0 - 60	1	msec
Maximum operating electric speed (2)	0 - 60	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 10.

Parameter	Measure Point	Min	Typical	Max	Units
Scripting Flash Memory	Internal		8000 32000(1)		Bytes
Integer Variables	Internal			1024 4096(1)	Words (2)
Boolean Variables	Internal			8192	Symbols
Execution Speed (3)	Internal	30,000		70,000	Lines/s
Note 1: Available on SBLG13xxA Version, only Note 2: 32-bit words Note 3: Execution Speed was calculated based on low communication load with the controller. In high communication workload, minimum time might be reduced drastically.					

STO Specifications

TABLE 11.

Parameter	Measure Point	Min	Typ	Max	Units
STO Input High Level	Ground to STO input pin	6		30 (1)	Volts
STO Input Low Level	Ground to STO input pin	0		1	Volts
STO Response Time	Input to output change			5	msec
STO Operating temperature		-20		55	°C
STO Storage temperature		-20		70	°C
Humidity		5		95	%
IP degree				IP40	
Operating Altitude				2000	m
Cable Length				2	m
EMC Immunity	According to IEC 61800-3 and IEC 61800-5-2 Annex E				
CE Declaration	Available at www.roboteq.com				

Thermal Specifications

TABLE 12.

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 SBLG13xx 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 13.

Parameter	Measure Point	Min	Typical	Max	Units
Weight	Board		96 (.21)		g (lbs)
Power Wire Gauge	Screw Terminals			12	AWG

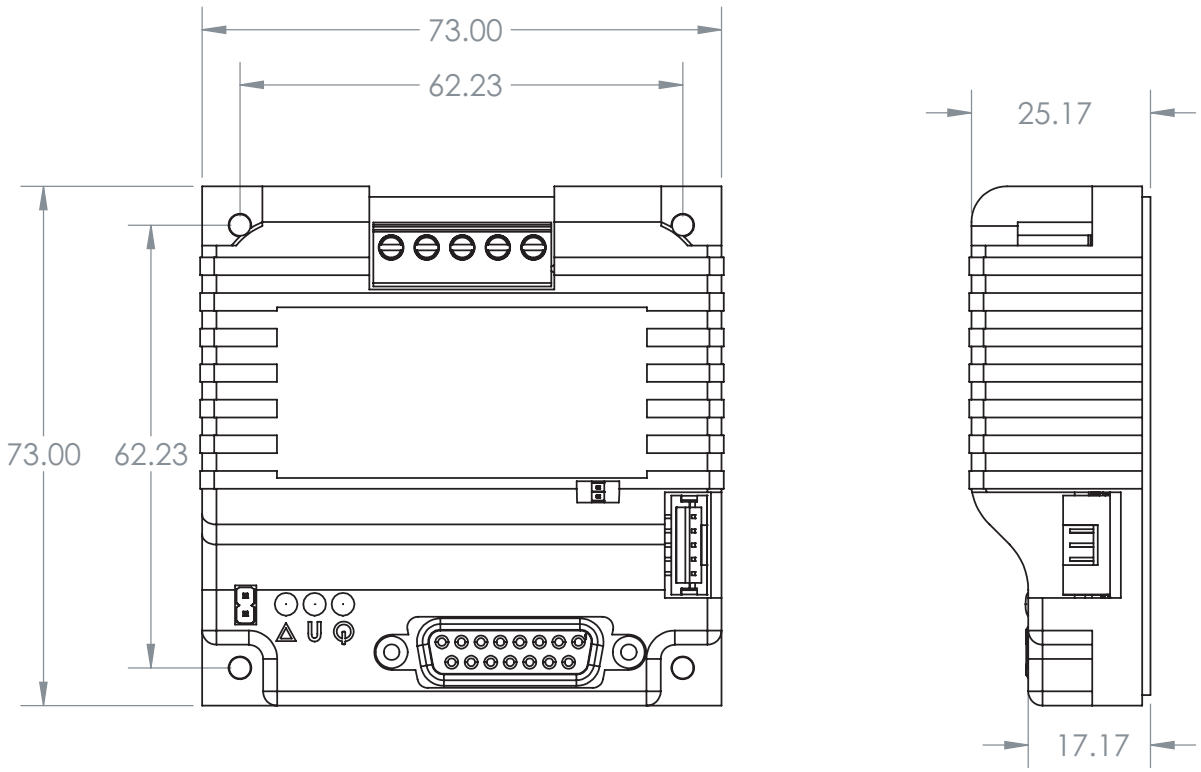


FIGURE 10. SBLG13xx Top View and Dimensions

Revision history

Revision	Date	Additions/Changes
1.0	September 6, 2022	First Release