SPARK MOTOR CONTROLLER

USER'S MANUAL

REV-11-1200-UM-00

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1 SPARK OVERVIEW

The REV Robotics SPARK Motor Controller is 12V 60A PWM-controlled brushed DC motor controller designed for *FIRST®* Robotics Competition robots.

The Spark features 60A continuous current with passive cooling, bi-directional limit switch inputs for smart mechanism control, an RGB LED status indicator, and a button-activated brake/coast mode.

Figure 1-1 SPARK Motor Controller

1.1 FEATURE SUMMARY

The SPARK Motor Controller provides the following features:

- RC servo style PWM control interface
- Passive Cooling
  - No fans required
- Synchronous rectification
  - Reduces heat generation
- Limit switch inputs
  - Stops forward and/or reverse motion automatically
  - No programming required
- Brake/Coast modes
- Calibration
  - Factory calibrated to 1ms - 2ms input signal
  - User calibratable
- Integrated cable retention for PWM port
- Clamping screw terminals
  - Better contact area and retention
  - Compatible with #6 and #8 "yellow" ring terminals
- RGB Status LED
  - Detailed mode and operation feedback

1.2 KIT CONTENTS

The following items are included with each SPARK Motor Controller:

- 1 - SPARK Motor Controller
- 1 - PWM Cable - 36" - 22 AWG
- 2 - Extra terminal screws - M3

1.3 SPECIFICATIONS

The following tables provide the operating and mechanical specifications for the SPARK motor controller.

CAUTION

DO NOT exceed the maximum supply voltage or maximum current rating. Doing so will cause permanent damage to the SPARK and will void the warranty.

Table 1-1 Electrical Specifications

Parameter	Min	Typ	Max	Units
Supply voltage range (V_{IN})	5.5	12	24	V
Supply voltage absolute maximum	-	-	30	V
Continuous output current	-	-	60[a]	A
Maximum output current - for 2 seconds	-	-	100	A
Output voltage range	- V_{IN}		+V_{IN}	V
Output frequency	-	15.625	-	kHz

a. Continuous operation at 60A may produce high temperatures on the heat sink. Caution should be taken when handling a SPARK if it has been running at higher current levels for an extended period of time.

Table 1-2 Servo-PWM Input Specifications

Parameter	Min	Typ	Max	Units
Default full-reverse input pulse[a]	-	1000	-	µs
Default neutral input pulse[b]	-	1500	-	µs
Default full-forward input pulse[c]	-	2000	-	µs
Input pulse width range	500	-	2500	µs
Input frequency	16	50	200	Hz
Input timeout[d]	-	65.5	-	ms
Input deadband[e]	-	40	-	µs
Digital high-level input current	7	-	25	mA

a. Full-reverse corresponds to negative output voltage (-V_{IN}).
b. Neutral corresponds to zero output voltage (0V) and is either braking or coasting depending on the current mode.
c. Full-forward corresponds to positive output voltage (+V_{IN}).
d. If a valid pulse isn't received within the timeout period, the SPARK will disable its output.
e. Input deadband is added to each side of the neutral pulse width. Within the deadband, output state is neutral.

Table 1-3 Limit Switch Input Specifications

Parameter	Min	Typ	Max	Units
Digital low-level input voltage[a]	-0.3	-	0.8	V
Digital high-level input voltage[b]	2.0	5.0	5.3	V
Pull-up resistor	16	35	200	kΩ
Response time	-	-	62.5	ms

a. Disables motion in corresponding direction.
b. Enables motion in corresponding direction.

Table 1-4 Mechanical Specifications

Parameter	Value
Dimensions	2.860" x 1.875" x 0.868"
Weight	74g / 2.61oz
Mounting hole size	#10 clearance / 0.200"
Terminal screw size	M3

2FEATURE DESCRIPTION

The REV Robotics SPARK Motor Controller includes a range of features designed specifically for use on *FIRST®* Robotics Competition robots. Each feature is described in detail throughout the following sections.

2.1 POWER AND MOTOR CONNECTIONS

The SPARK is designed to drive 12V brushed DC motors at currents up to 60A continuously. Power and motor connections are made through the two sets of screw terminals built into the SPARK. Figure 2-1 shows these connections in detail.

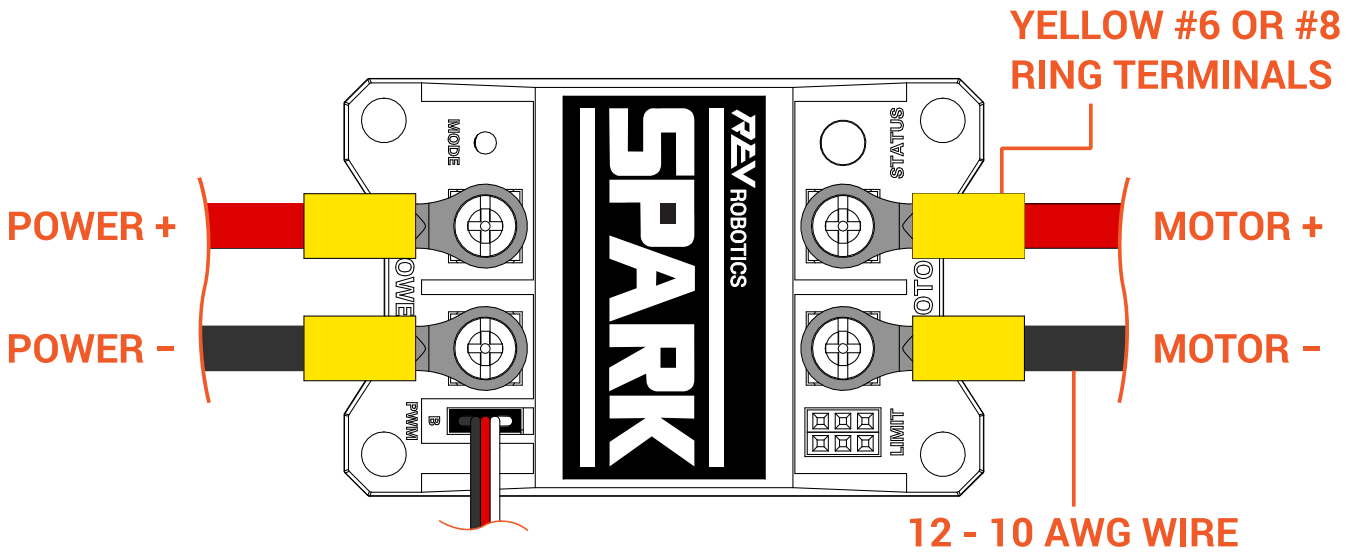


Figure 2-1 Power and Motor Connections

2.1.1 SCREW TERMINALS

The SPARK has four M3 sized screw terminals; two each for power and motor connections. Each screw has a clamping washer that improves the contact area and clamping force compared to plain screw heads. Table 2-1 lists the recommended crimp-terminal sizes and styles.

Table 2-1 Compatible Crimp-terminal Sizes

Terminal Screw/Stud Size	Standard Color	Ring	Fork
#6	Yellow	Compatible	Compatible
#8	Yellow	Compatible	Not Recommended
M3	Yellow	Compatible	Compatible

2.1.2 MOTOR OUTPUT

Motor output terminals are located above the SPARK logo and are marked with raised lettering. A raised "+" and "–" sign indicate the polarity of the motor terminals. See Figure 2-1 for more details.

It is recommended to follow a polarity convention when connecting motors to multiple SPARKs so that each motor responds in a predictable manner to the same input signals. When the SPARK is driving the output in the "forward" direction, the output polarity is positive from M+ to M–. When driving in "reverse" the output polarity is reversed.

2.1.3 POWER INPUT

Power input terminals are located below the SPARK logo and are marked with raised lettering. A raised "+" and "–" sign indicate the polarity of the power terminals.

The SPARK is intended to operate in a 12V DC robot system, however, it is compatible any DC power source between 5.5V and 24V.

CAUTION

DO NOT exceed the maximum supply voltage of 30V. Doing so will cause permanent damage to the SPARK and will void the warranty.

When using high current motors, it is recommended to use a power source that is capable of handling large surge currents, e.g. a 12V lead-acid battery. If the supply voltage drops below 5.5V the SPARK will brown out, resulting in a power loss to the motor. It is also recommended to incorporate a fuse or auto-resetting circuit breaker in series with the SPARK between it and the power source to prevent exceeding the maximum current rating.

CAUTION

DO NOT exceed the maximum current ratings of 60A or 100A for 2 seconds. Doing so will cause permanent damage to the SPARK and will void the warranty.

2.1.4 CONNECTING MOTOR AND POWER WIRES

Using an appropriate wire gauge for the expected current draw, tightly crimp either a ring or fork terminal on the wire. Insert the crimped terminal into the screw terminal and tighten the screw. Give the wire a tug to make sure it is secure. Figure 2-1 shows both motor and power wires connected to the SPARK.

CAUTION

DO NOT swap the motor and power connections. This can result in uncontrolled motor operation, can permanently damage the SPARK, and will void the warranty.

CAUTION

As with any electrical component, make all connections with power turned off. Connecting the SPARK to a powered system may result in unexpected behavior and may pose a safety risk.

2.2 SPEED AND DIRECTION CONTROL

A brushed DC motor's unloaded rotation speed is determined by voltage that is applied to it while the direction of rotation is determined by the polarity of that voltage. The magnitude and polarity of the SPARK output voltage is controlled by sending it a standard servo-style PWM signal. The following sections describe this interface in detail.

2.2.1 SERVO-PWM CONNECTION

The SPARK accepts a standard 3-wire servo/PWM cable in the port marked PWM in raised lettering. Please refer to the connection diagram in Figure 2-2 or the SPARK housing for polarity indicators. Align the ground/negative wire with the B marking on the case. This wire is usually black, but may be brown in some cases. The signal wire should be closest to the SPARK logo on the heat sink. This wire is usually white but may also be yellow or orange.

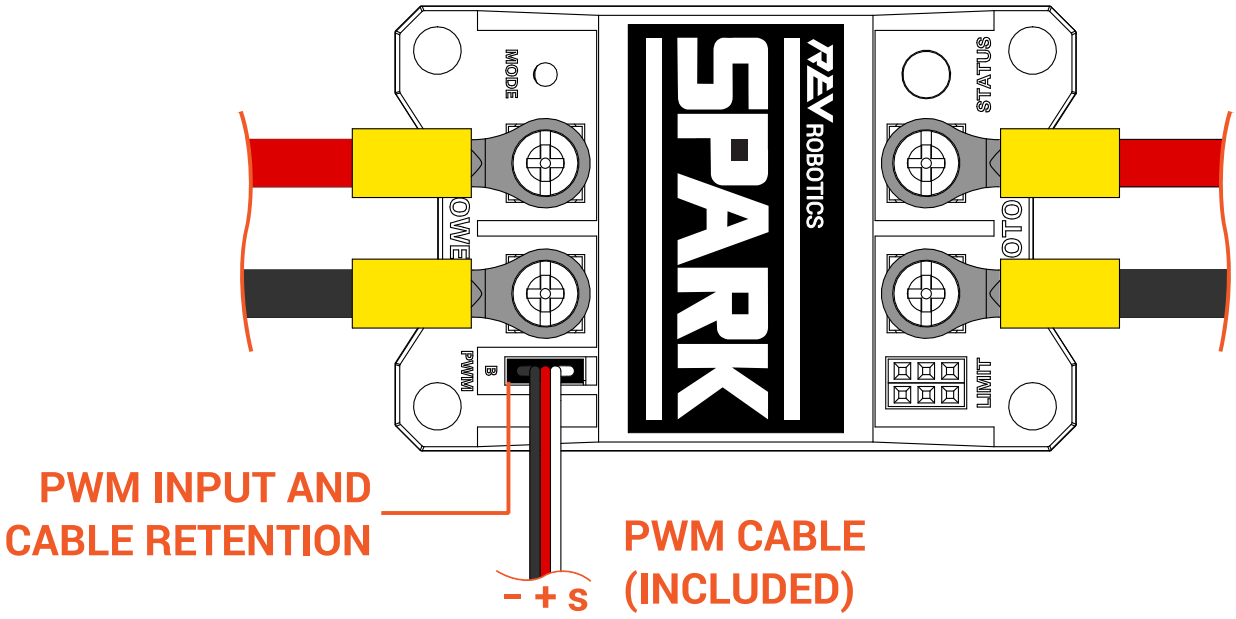


Figure 2-2 Servo-PWM Connection

The plastic surrounding the PWM port was designed provide cable retention by exerting pressure on the housing of a standard 3-wire cable housing. Retention effectiveness may vary depending on the cable being used.

2.2.2 CONTROLLING MOTOR SPEED AND DIRECTION

The SPARK responds to a factory default pulse range of 1000µs to 2000µs. These pulses correspond to full reverse and full forward rotation, respectively, with 1500µs (±40 µs deadband) as the neutral position, i.e., no rotation. The spark can be calibrated to respond to a different pulse range, see section 2.5.2 CALIBRATION. Table 2-2 describes how the pulse range maps to the output voltage, motor speed, and motor direction.

Table 2-2 Input Pulse Mapping

For input pulse p	Motor Speed and Direction				
	Full Reverse	**Prop. Reverse**	**Neutral**	**Prop. Forward**	**Full Forward**
Output voltage V_{OUT} (V)	$V_{OUT} = -V_{IN}$	$-V_{IN} < V_{OUT} < 0$	$V_{OUT} = 0$	$0 < V_{OUT} < +V_{IN}$	$V_{OUT} = +V_{IN}$
Default pulse width (µs)	$p \leq 1000$	$1000 < p < 1460$	$1460 \leq p \leq 1540$	$1540 < p < 2000$	$2000 \leq p$
Maximum pulse range (µs)	$500 \leq p \leq 2500$				

The output voltage seen by the motor is proportionally related to the input pulses. A change in pulse results in a proportional change in motor speed. The approximate output voltage is determined by the following equations:

P_{MAX} = Configured maximum pulse width in µs (default 2000)
$P_{NEUTRAL}$ = Configured neutral pulse width in µs (default 1500)
P_{MIN} = Configured minimum pulse width in µs (default 1000)
p = Input pulse width in µs
V_{OUT} = Approximate output voltage seen by the motor

$$Forward\ \%Duty = \frac{p - P_{NEUTRAL} + 40}{P_{MAX} - P_{NEUTRAL} + 40} \times 100$$

$$Reverse\ \%Duty = \frac{P_{NEUTRAL} - 40 - p}{P_{NEUTRAL} - 40 - P_{MIN}} \times 100$$

$$V_{OUT} = V_{IN} \times \%Duty$$

2.3 HEAT MANAGEMENT

The SPARK uses a method called synchronous rectification when switching the motor output in order to minimize the heat generated by its H-bridge. Some heating is unavoidable, so an aluminum heat sink passively dissipates heat into the surrounding atmosphere.

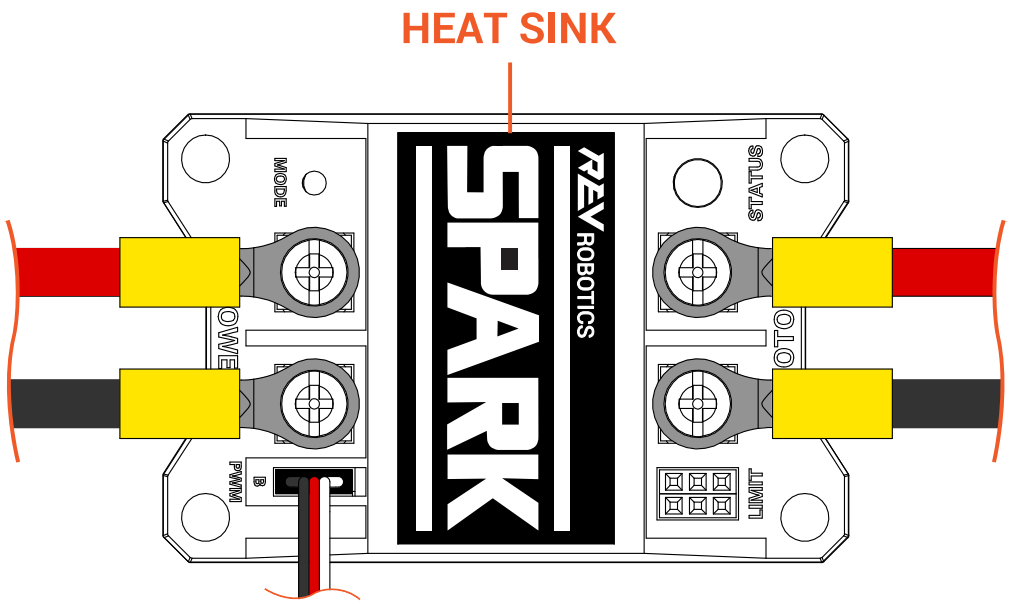


Figure 2-3 Heat Sink

As seen in Figure 2-3, the heat sink is located at the center of the SPARK. For most applications, a cooling fan isn't necessary, however, airflow should be kept in mind when using the SPARK in high-load applications. The heat sink is electrically isolated from the SPARK circuit board and components. APPENDIX B shows the temperature at various internal and external locations on the SPARK while it was under a 40A load for 300 seconds.

CAUTION

Under heavy loading conditions and prolonged periods of high current the SPARK heat sink may become hot. Use caution when handling a SPARK that has been used under heavy loading conditions.

2.4 LIMIT SWITCH INPUTS

The SPARK has two limit switch inputs that, when triggered, can independently prevent motion in both the forward and reverse directions.

2.4.1 LIMIT SWITCH OPERATION

When the signal (s) pin is shorted to the ground (-) pin, the SPARK will override an input command for the corresponding direction and force the SPARK to its neutral state. The STATUS LED will turn white and pulse the corresponding direction color when either of the two limits are triggered and overriding the input command. See section 2.6 STATUS LED for more information.

For example, if the Forward Limit Switch is triggered, a forward command from the PWM input is overridden and the output is forced into its neutral state. However, reverse commands are still accepted and sent to the output.

2.4.2 LIMIT SWITCH WIRING

The SPARK has two 3-pin connectors that can accept standard 3-wire sensor cables. The center pin is not used for the limit switch inputs. Figure 2-4 shows the locations of the Forward and Reverse ports and an example connection diagram. It is recommended to use a limit switch that is Normally Open (NO). When it is pressed, the switch closes and shorts the signal (s) and ground (-) pins.

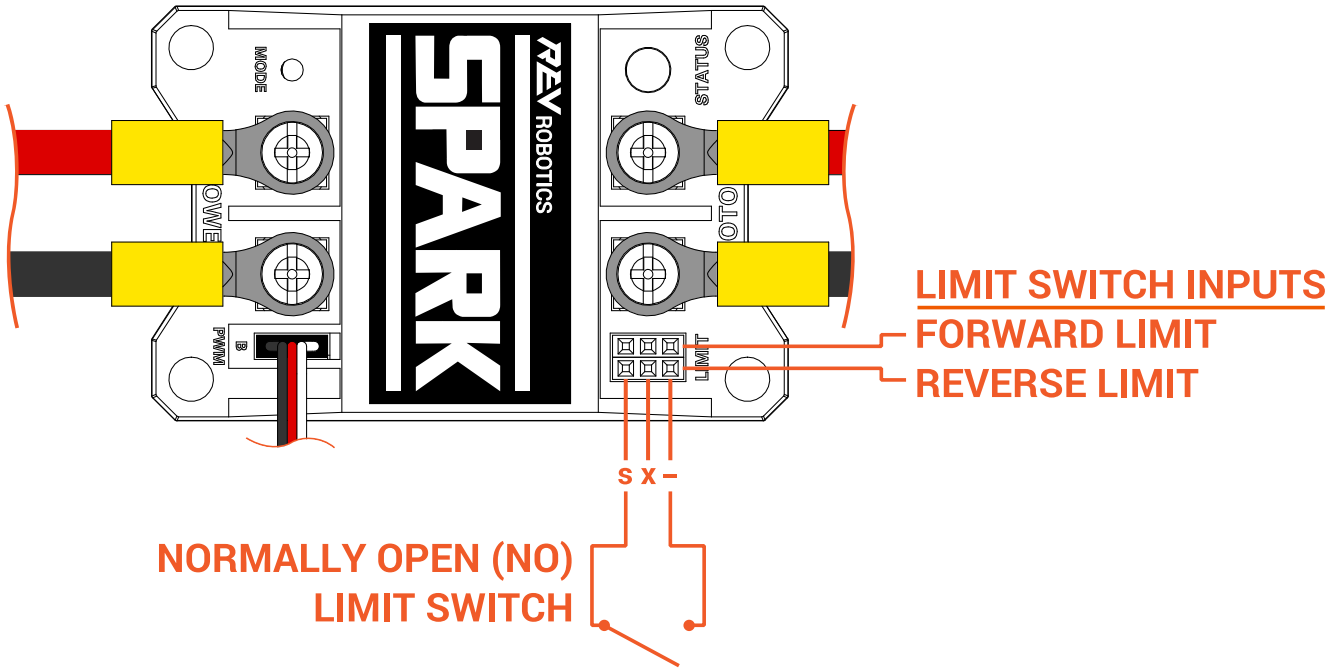


Figure 2-4 Limit Switch Inputs

2.5 OPERATING MODES

The SPARK has three operating modes consisting of Brake Mode, Coast Mode, and Calibration Mode. It can also be reset to the factory defaults.

The MODE button is used to switch between the three modes and to reset the SPARK to its factory defaults. It is located near the power input terminals and is labeled as MODE in raised lettering on the SPARK housing. See Figure 2-5.

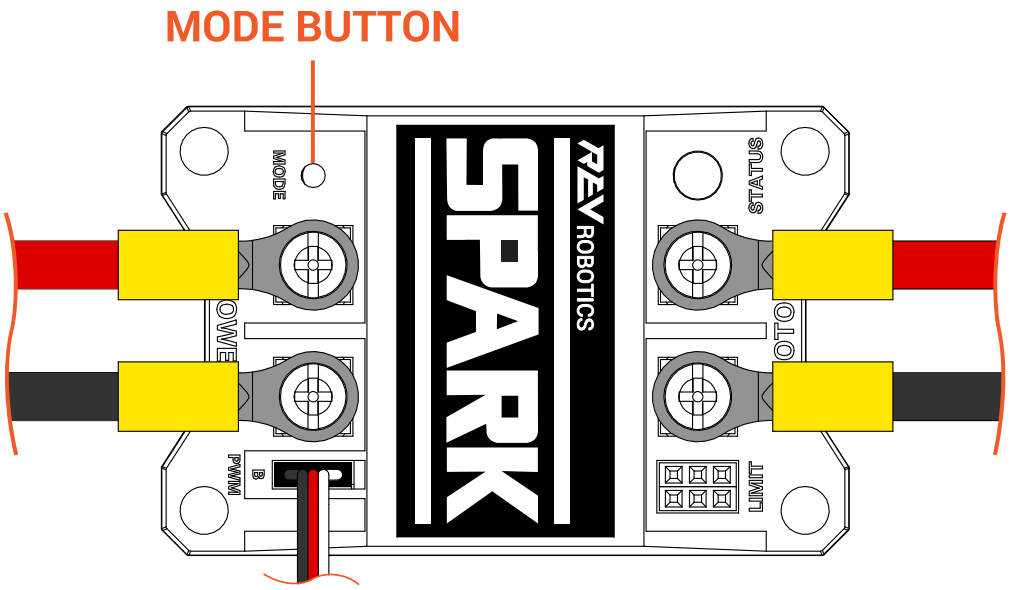


Figure 2-5 Mode Button

Use a straightened paper clip or other small implement to press the Mode Button.

The following sections describe each operating mode in detail.

2.5.1 BRAKE/COAST MODE

When not driving the motor, the SPARK will short the motor terminals to dissipate electrical energy, effectively braking the motor. Alternatively, the SPARK can be put in a Coast Mode which allows the motor to spin down at its own rate.

Press and release the MODE button to toggle between brake and coast mode. When in Brake Mode (default), the Status LED will display a solid or blinking blue color. When in Coast Mode, the Status LED will display a solid or blinking yellow color. See section 2.6 STATUS LED for more information.

This mode is saved in memory and persists through a power cycle.

2.5.2 CALIBRATION

The default input pulse width times should be compatible with most controllers. However, if a different mapping is desired, the SPARK can be calibrated as follows:

The SPARK must be receiving a signal to begin calibration. It is recommended that the motor be disconnected while calibrating to prevent unexpected movement.

1. Press and hold the MODE button for 3 seconds. The STATUS LED will start to blink white.
2. Sweep the input signal through the entire desired range.
3. Return the signal to the desired neutral value.
4. Release the MODE button.

If the calibration routine was successful, the status LED will blink white and green for several seconds while the SPARK immediately begins responding to the new signal range.

If the calibration routine was unsuccessful, the Status LED will blink white and red and the previous values are restored. Check that the signal didn't violate the timing constraints and/or the neutral value wasn't too close to the full forward or full reverse values. See section 2.6 STATUS LED for more information.

Calibration values are saved to memory and persist through a power cycle.

2.5.3 FACTORY RESET

The SPARK can be reset to its factory default settings with the following procedure:

1. Disconnect power to the SPARK
2. Press and hold the MODE button
3. Reconnect power while still holding the button
4. The Status LED will illuminate white
5. Release the button

The Status LED will blink white and green indicating that the factory defaults have been restored. See section 2.6 STATUS LED for more information.

2.6 STATUS LED

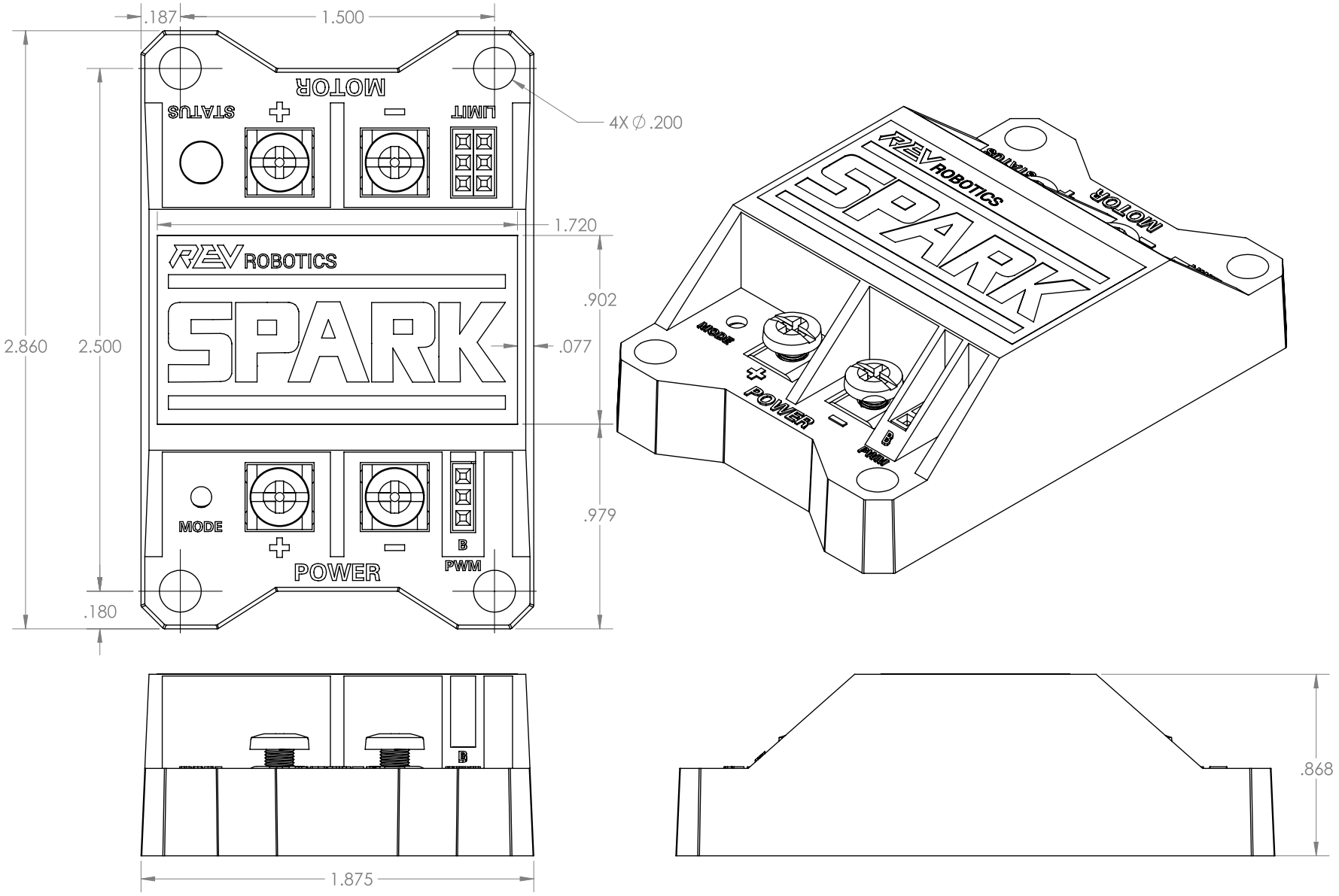
The SPARK can display information about its current mode of operation via its tri-colored STATUS LED. The STATUS LED is located next to the motor output terminals and is labeled as STATUS with raised lettering on the SPARK housing.

Figure 2-6 shows the status codes associated with each operating state of the SPARK.

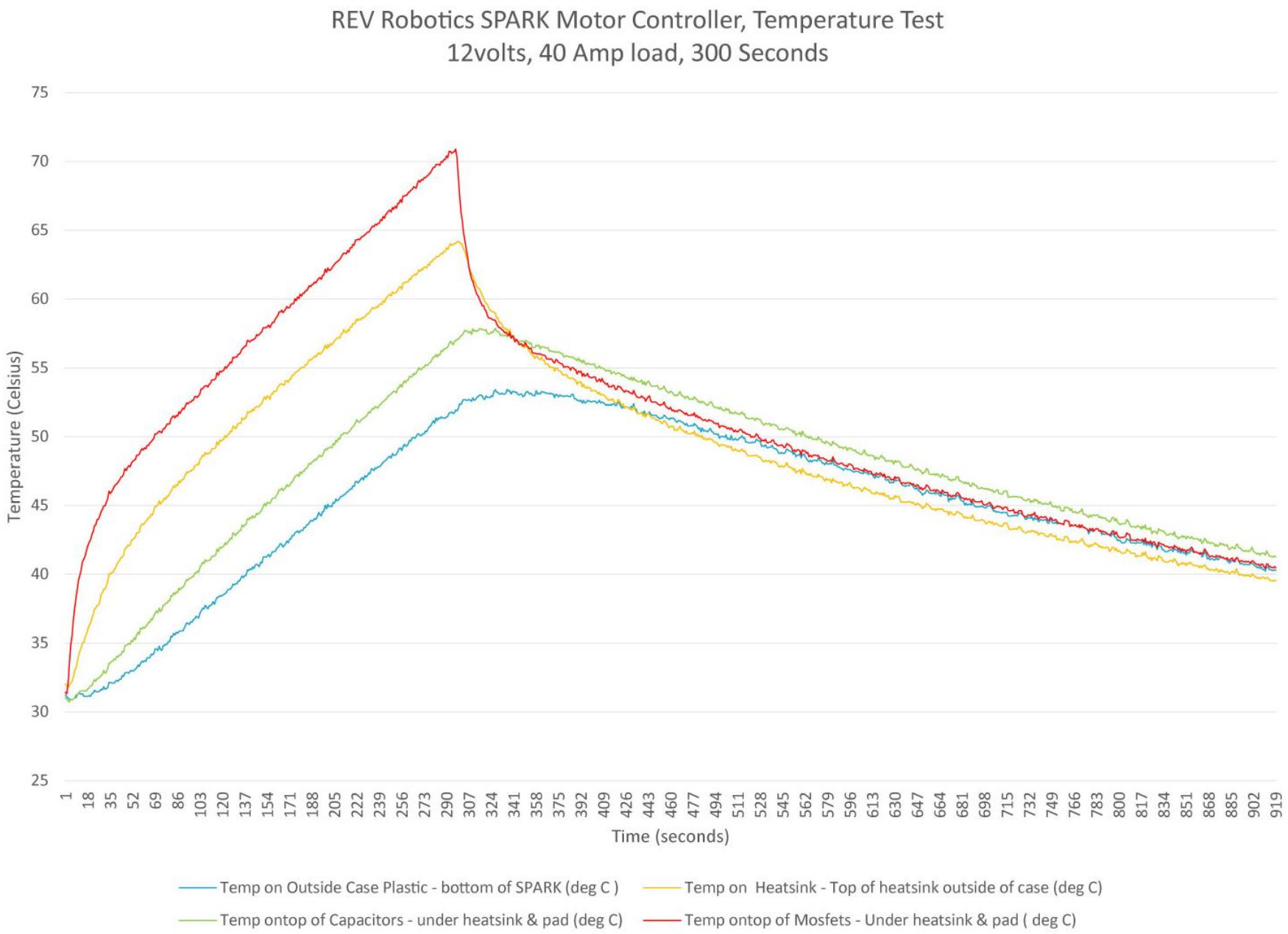
Figure 2-6 LED Status Codes

APPENDIX A DIMENSIONS

All dimensions are in inches.

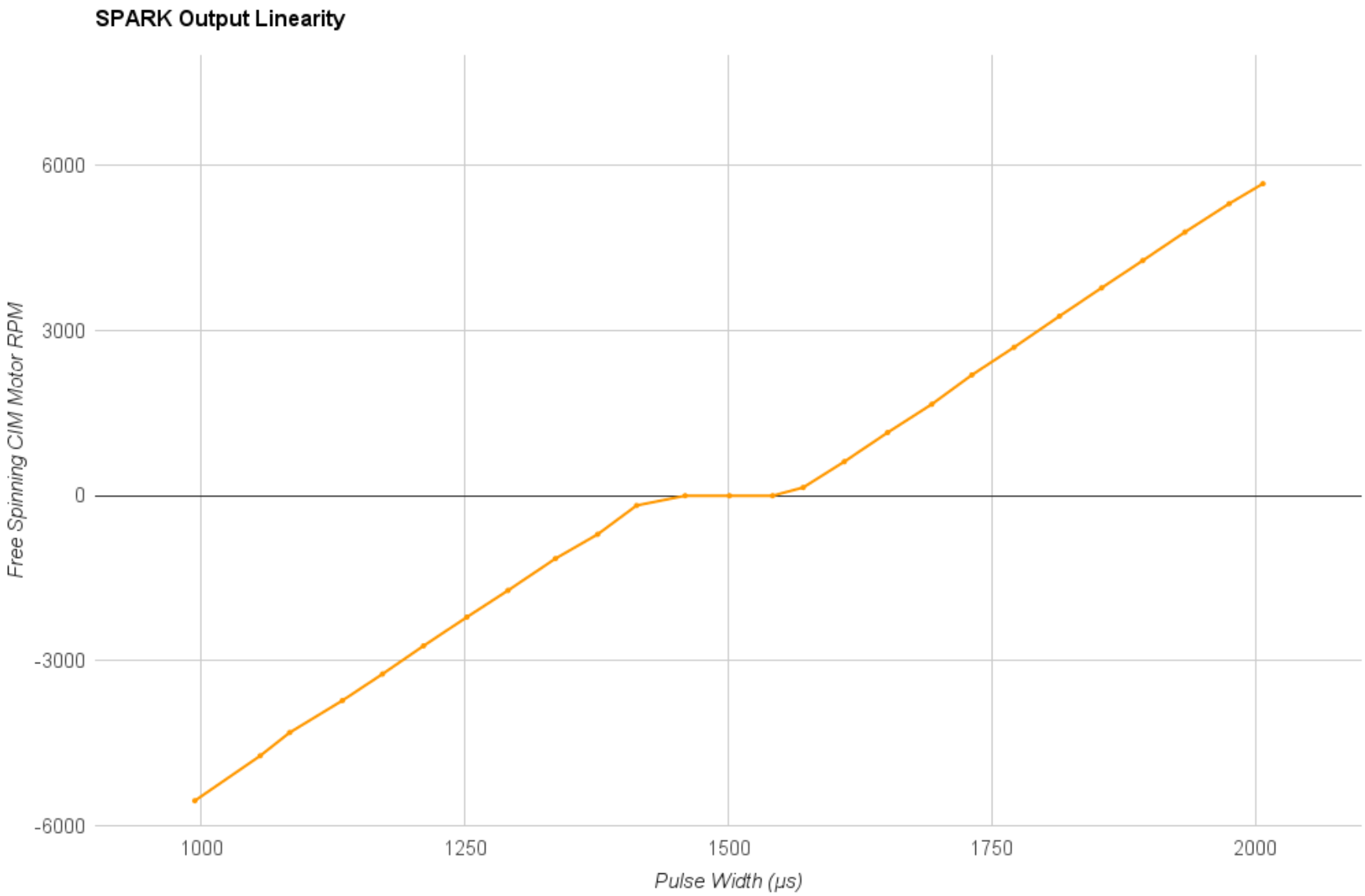


APPENDIX B THERMAL DATA



APPENDIX C LINEARITY DATA

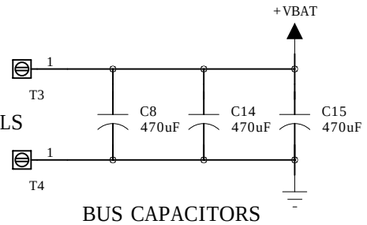
The following data was taken with a free spinning CIM motor and a 12V power source. The flat zone in the middle represents the 40µs input deadband on either side of the neutral pulse width.



APPENDIX D SCHEMATIC

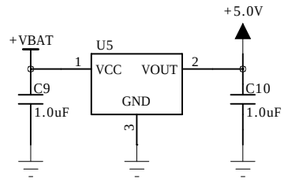
Appendix D shows the schematic for the REV Robotics SPARK Motor Controller.

POWER TERMINALS



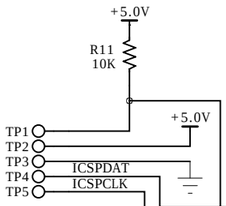
BUS CAPACITORS

5V REGULATOR

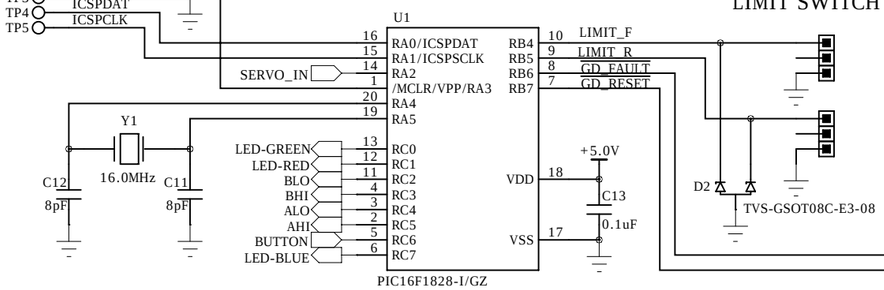


LDO-5V-TR9058-50GV

PROGRAMMING PADS



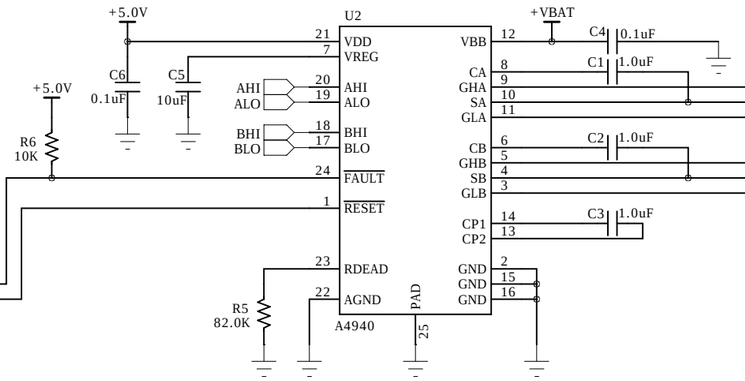
MICROCONTROLLER



PIC16F1828-I/GZ

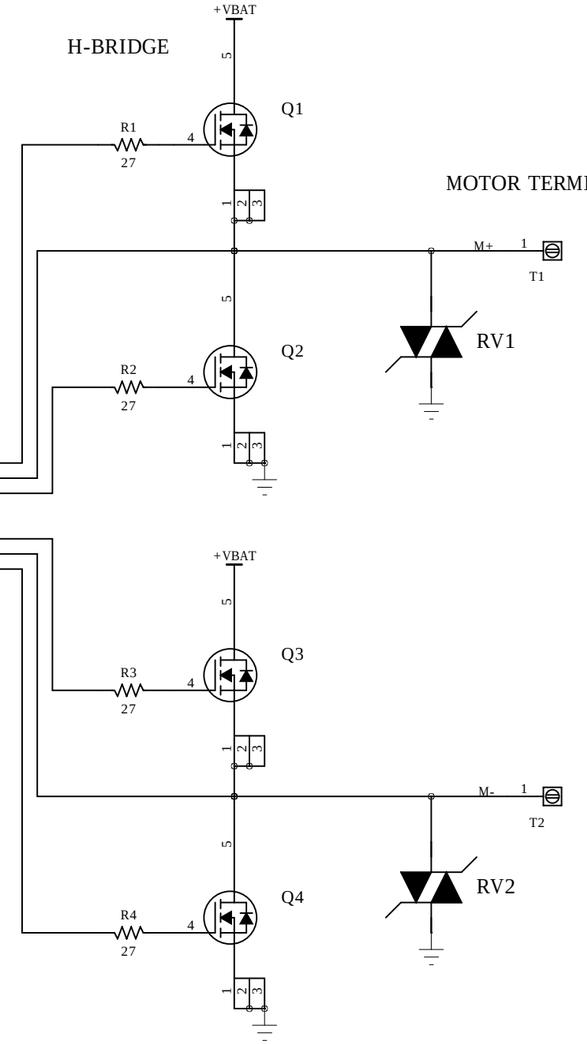
LIMIT SWITCH INPUTS

GATE DRIVER



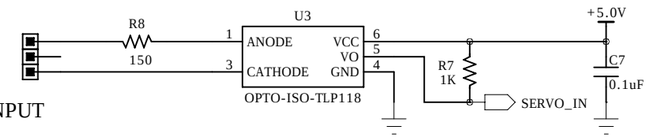
A4940

H-BRIDGE



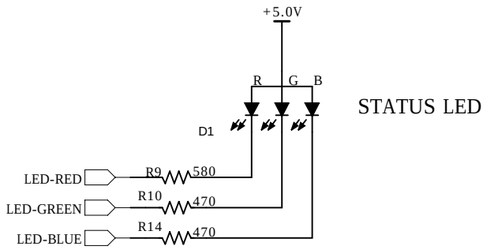
MOTOR TERMINALS

OPTICAL ISOLATOR

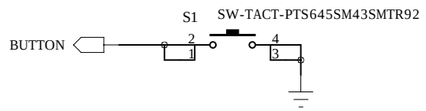


PWM INPUT

STATUS LED



MODE BUTTON



DESIGNER	REVISION	DATE
DAY	B	1/9/2016

PROJECT: SPARK Motor Controller

DESCRIPTION: Brushed DC Motor Controller
60A Continuous, 12V

FILENAME: RR-SPARK-BD-B.sch

REV ROBOTICS

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PART NO.	SHEET
REV-11-1200	1 OF 1