UROV Physical Kill-Switch Options (Fall 2019)

Some Background Info:

As mentioned in the 2018 RobotX Rules and Regulations [1], all competing vehicles must have both an onboard emergency stop capable of being actuated by personnel from a support craft, and a wireless remote emergency stop, located off-board, operating on its unique frequency and link. While a wireless remote emergency stop will be included in the future, the current design plan is to install a physical kill switch system capable of cutting battery power from all six thrusters within one second of switch activation. The wireless kill system should be capable of being integrated with the components of the physical switch.

The UROV (BlueROV2):

The physical kill switch system will be installed on the BlueROV2 purchased from BlueRobotics [2]. The BlueROV2 is equipped with six T200 thrusters [3] and two enclosures (top and bottom) that hold all hardware components of the BlueROV2. The top enclosure contains pre-existing hardware with limited space for any additional components toward a kill switch system. The bottom enclosure comes empty and is used to hold the battery [4].

BlueROV2 and T200 thruster, images from bluerobotics.org

Thrusters (T200):

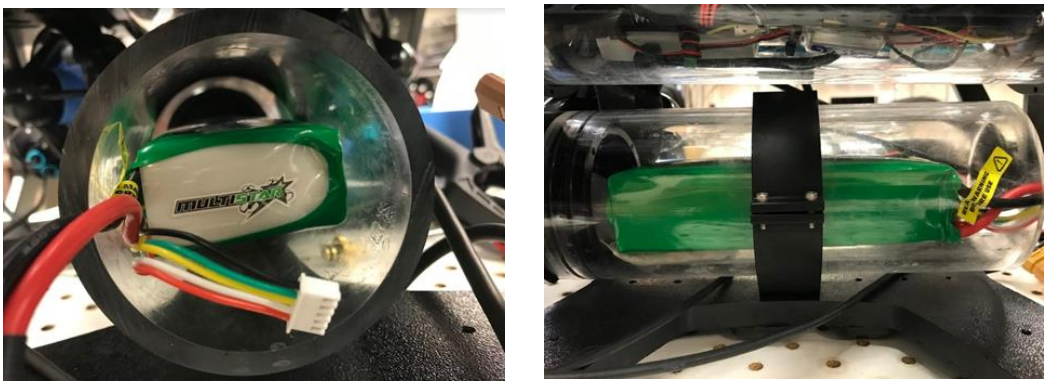
Each T200 thruster is capable of drawing approximately 20 amps of current at an operating voltage of about 15 volts at full thrust forward and backward. With six thrusters at full thrust a maximum of about 120 amps is drawn from the battery, excluding the other hardware which passively draws about 0.7 amps to operate, creating a total maximum current draw of 121 Amps. Power consumption for each thruster can also be calculated via *Power = Voltage * Current* for a value of 300W per thruster, and a total of 1800W. The maximum current draw and power consumption will vary on the battery voltage with specific details listed on bluerobotics.org [3].

Enclosures:

The top enclosure holds all hardware necessary to operate the UROV, resulting in no space for additional hardware except toward the butt end of the enclosure, where a space of $11in^2$ x 1.5in is available.

Top enclosure, image from bluerobotics.org

The bottom enclosure comes completely empty, which currently only holds the battery necessary to power the UROV's hardware and thrusters. The most available space is above the battery. with a maximum height between the enclosure perimeter and battery to be about 0.7 inches.



Bottom enclosure with battery inside

Battery:

The battery inside the lower enclosure is the Multistar 10,000 mAh 4S LiPo battery [4], with a nominal voltage of 14.8 volts and a maximum current output of 100 amps. The battery dimensions are about 1.5" x 2.5" x 5.75".

Quantitative Requirement:

Select or design a system to cut power from all six thrusters of the BlueROV2 within one second of activation. Switch should be capable of handling up to 120 amps of current, and fit within the space permitted by enclosures.

Explored Solutions:

1. Reed Switch (magnetic switch)

A reed switch is a magnetically operated switch capable of opening and closing a circuit via a magnetic field [5]; when a magnet is near the switch, it will stay closed until the pulled away, opening the circuit. Reed switches are rather small and can be soldered into a circuit but can only withstand current up to 5 amps, which removes them from being an option to be connecting thrusters directly to power. Instead however reed switches can be used to pass or restrict the signal to the motor controlling circuit but would no longer fall within the rules and requirements established in the 2018 RobotX competition [1].

Reed switch, image from sparkfiun.com

Other complications that arise include setting up the external magnet (placement and stability underwater), controlling six reed switches.

2. Solid-state Relay

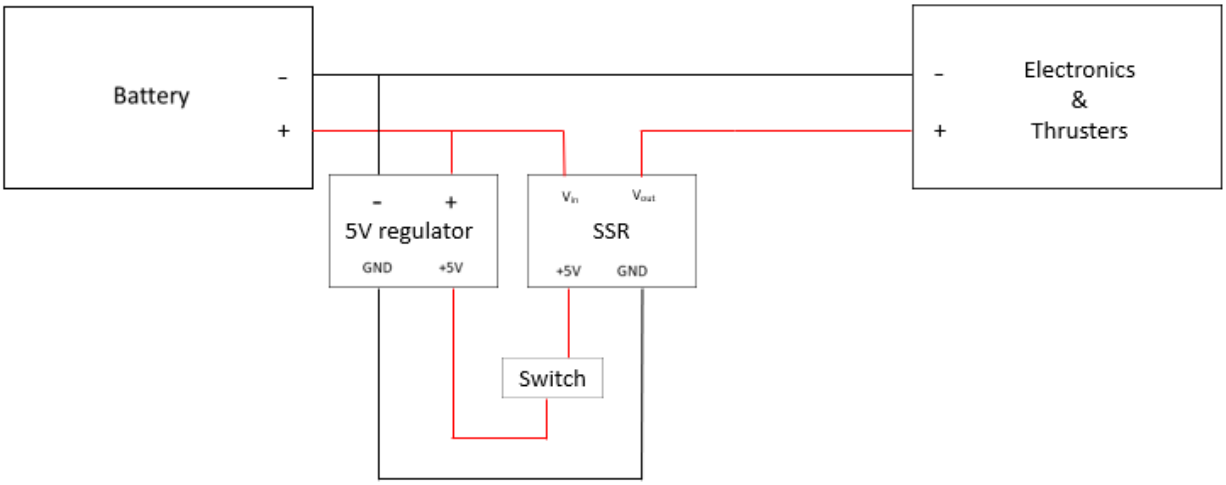
The solid-state relay (SSR) requires a low DC voltage signal to switch "ON" or "OFF" and pass large DC currents. Specifically, by applying a low voltage drop (specifically between 3 and 32 volts) across two terminals of the solid-state relay, currents as high as 100 amps can flow across the other two terminals, effectively creating a switch to control large amounts of current. At the same time, the switch must be capable of toggling from outside the UROV. A prime candidate for this switch being the one provided by bluerobotics.org [7], rated to handle up to 5 amps (shown below). Unfortunately, because no switch capable of handling the current required for the thrusters can fit within either enclosure, this solution requires a regulator. 5-volt regulators within the lab are enough for dropping the current below 5 amps and fit in the enclosures. This signal can be controlled manually via the switch provided by blue robotics compatible with the butt ends of the BlueROV2's top and bottom enclosures. The dimensions of the SSR are 2.6" x 1.8" x 0.9", barely able to fit the top enclosure. The regulator can also fit in the upper region of the top enclosure.

100-amp solid-state relay, image from amazon.com

Switch, image from bluerobotics.org

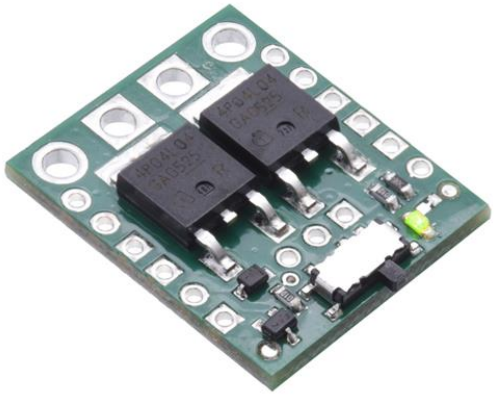
5v buck converter, image from banggood.com

The switch can handle up to 5 amps of current. If the battery is used to generate the 5 volts using a voltage regulator, an additional 3 amps of current will result in the regulator's conversion. A circuit diagram for the solid-state relay is shown below:

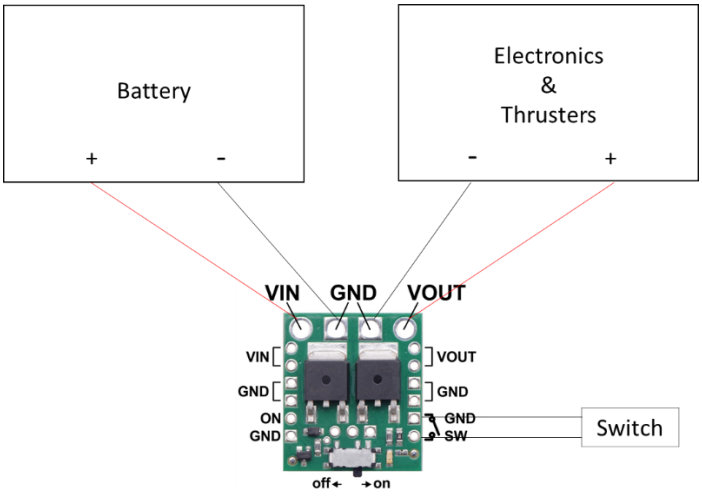


3. MOSFET circuit board

The MOSFET solution is like the solid-state relay; a circuit component restricts the flow of current via a switch. The same switch mentioned in the solid-state relay will be used as the human interface. The MOSFET circuit board [8] is only capable of withstanding 90 amps of current but requires the least amount of space compared to all other solutions. The battery connects directly to the two large pins on the top left of the board, while the outgoing voltage uses the top two right pins. A manual switch can be soldered to the right of the included slide switch by leaving the slide switch in the "OFF" position. The dimensions of the circuit board is 0.8" x 1.0" x 0.16", able to fit in top enclosure.



MOSFET integrated circuit chip, image provided by pololu.com



Circuit diagram, circuit provided by polulu.com

4. Electromechanical Relay

The electromechanical relay is the safest option [9]. Capable of withstanding up to 200 amps, a 12V signal can either restrict or grant current flow, similar to the MOSFET and solid-state relay solutions. An electromechanical relay is a normally open, with the 12v signal This would also be wired identically to the solid-state relay circuit schematic, only swapping the solid-state relay for the electromechanical relay. One problem for this solution is the lack of space. This component will not fit anywhere in either UROV enclosure due to its 1.77” x 1.77” x 1.77” size requirement a 12v buck converter will also be necessary to step down our battery voltage.

Electromechanical relay, image provided by amazon

Selected Solution:

Among the four solutions, the solid-state relay is the current best option for a kill switch system. All parts fit in the enclosures, and the amperage isn't too likely to exceed the rated 100 amps for long enough of a time to damage the relay. Technically, the current battery will not exceed 100 amps, but safer is better. The electromechanical relay would be ideal, but just doesn't fit the size constraints. This solution will be implemented within a week after necessary parts are acquired (switch, relay, regulator).

References:

[1] 2018 RobotX Rules & Regulations: https://robonation.org/app/uploads/sites/2/2019/09/RobotX-2018-Rules-FINAL_v4.0.pdf

[2] BlueROV2: https://bluerobotics.com/store/rov/bluerov2/

[3] T200 Thruster: https://bluerobotics.com/store/thrusters/t100-t200-thrusters/t200-thruster/

[4] Multistar 4S 10000mAh LiPo Battery: https://hobbyking.com/en_us/multistar-high-capacity-10000mah-4s-12c-multi-rotor-lipo-pack-w-xt90.html

[5] Reed Switch: https://www.sparkfun.com/products/10601

[6] Solid-state Relay (100 amps, DC DC): https://www.amazon.com/SSR-100DD-Solid-State-RelayModule/dp/B07PFDJQLV/ref=sr_1_2?keywords=100+amp+dc+dc+relay&qid=1576308501&sr=8-2

[7] Bluerobotics switch: https://bluerobotics.com/store/comm-control-power/switch/switch-10-5a-r1/

[8] 90 Amp MOSFET: https://www.pololu.com/product/2815

[9] 12V 200 amp relay: https://www.amazon.com/Starter-Charge-Footprint-Terminal-Automotive/dp/B07FL3TYCT/ref=sr_1_4?crid=ADEFOSZYSU06&keywords=200+amp+relay+12v&qid=1576323075&sprefix=200+amp+%2Caps%2C287&sr=8-4