Supercapacitor module for Illini-Robomaster robot

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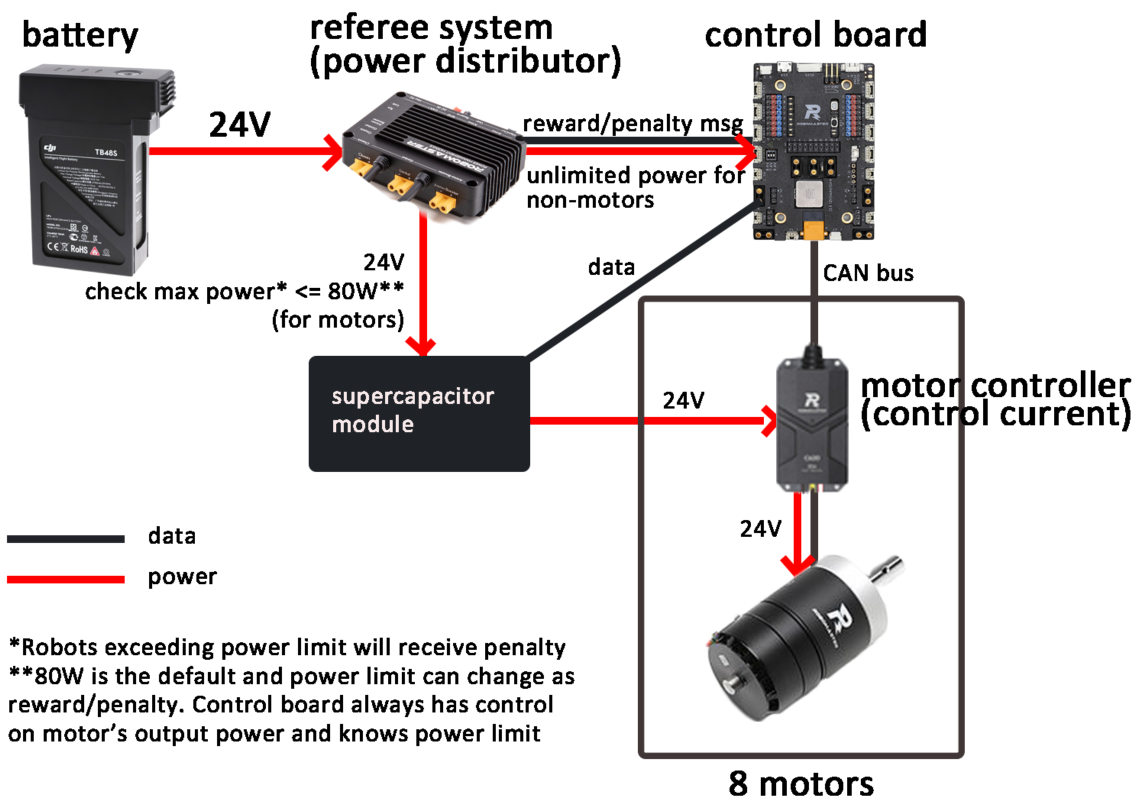
Problem: Illini-Robomaster (iRM) is an RSO at UIUC competing in the Robomaster robotics competition. During a match, robots will be penalized when motors exceed the power limit, but the monitoring system (referee system) is only checking the power output from the battery. To maximize available power for the motors and achieve greater mobility, we need a device to store and release energy. Existing solutions are either prohibited by the competition rules, too large to fit in our mobile robot, or sold at an unacceptable price by our competitor universities.



Visual aid. Note that the control board is the master control board on the robot, not on the module.

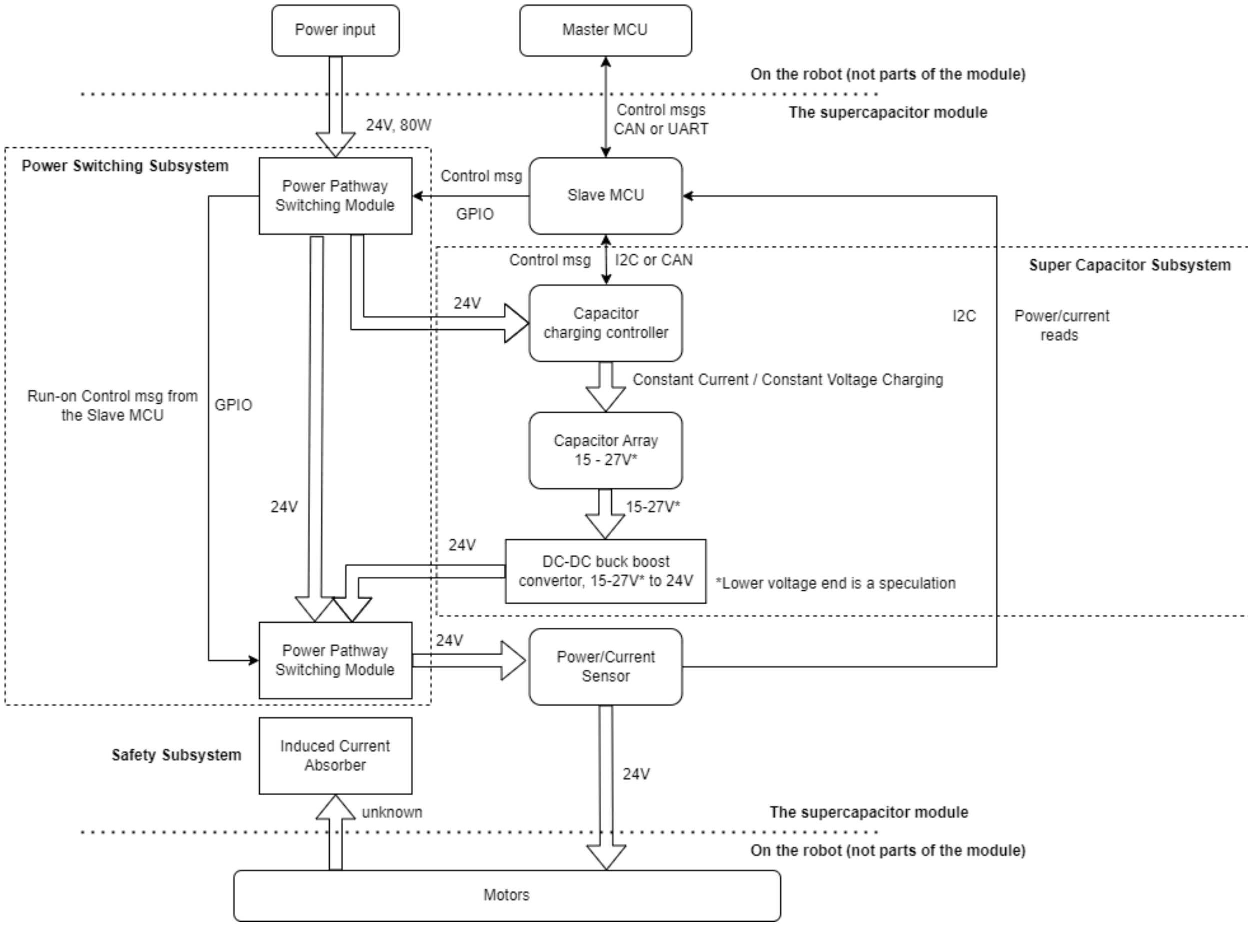
Solution: We propose a supercapacitor module to supply power in addition to the battery. It should be capable to store energy from the battery when the robot is running on low power and release energy when the robot needs it. Thus, we have more power available.

The supercapacitor module consists of a supercapacitor array and a control module. It should keep track of the current power stored and responds to requests from the master board by changing the power pathway of motors between by the battery or by the capacitors, and changing the behavior of the capacitor between charging and discharging.

High level requirements (Corresponding to 3 conditions of power requirement):

- When the energy required by the motors is less than power limit, the module should power the motors with the battery and use as much as the power left to charge the capacitor
- When the energy required by the motors is more than power limit and the capacitors have energy, the module should power the motors with the capacitor.
- When the energy required by the motors is more than power limit but the capacitors don’t have energy, the module should power the motors directly with the battery and make sure the capacitors are not charging to take up power.

Block diagram:



Block Diagram of the entire module

Legend:

Thick arrows: Power

Thin arrows: Data

Rounded Rectangles: Off-the-shelf products

Angled Rectangles: Customized circuits

Subsystem Overview:

Power Switching Subsystem:

Switching power pathway for the motors given the requests from the master MCU and current state.

The switching should be controlled by the slave MCU and unexpected ways of power pathway (for example, powering motors with battery and discharging capacitors together) should be prohibited. The subsystem should not decrease the voltage of its output by more than 2V or consume more than 1W

Super Capacitor Subsystem:

Store and release energy from the battery, controlled by the slave MCU and is coupling with the Power switching subsystem.

The DC-DC converter of the super capacitor subsystem should not raise the voltage over 27V in any condition, otherwise motors might be burnt.

Tolerance Analysis (Super Capacitor Subsystem):

The maximum energy allowed by the rules in the capacitors is 2000J (theoretically). We plan to use 10 2.7V 50F capacitors, which results in ½ CU^2 = 1822.5J at 27V. Average attacking window lasts for 5s and consumes 100W of power. So we want the capacitor module to release at least 500J of energy, and the ending voltage is 23V, which is higher than the minimum voltage our supercapacitor charging chip can support (2.1V for BQ24640).

Safety subsystem:
When motors stop, the induced current will flow back to the supercapacitor module. We need to make sure the induced current is safely handled. It's hard to define "safely" so we will use the following rule of thumb: everything should still work after the induced current is released and we don't smell anything burning. Also this subsystem should not force motors or the supercapacitor module to stop working to avoid the induced current.

Ethics and Safety:

As the use of supercapacitors is allowed and already regulated by rules in the competition, there are no known ethical concerns about using such a module on the robot. The safety concerns mostly revolve around storing large amounts of power in our module, as all the surrounding power sources are already determined safe and provided to us by Robomaster. We are limiting the capacitor voltage to reduce the danger present, and only charging the capacitor to a safe amount of energy stored, as ruled by Robomaster. Induced current from the motors can also damage our hardware, so we will have a subsystem dedicated to dealing with it.