Battery Regulators Design Documentation:

Zybo Board Battery Regulator/Indicator:

Voltage Range: 3.0 V – 4.2 V per battery (2-Cell Input)

Assuming:
 -Full battery status = 8.2 V
  -Low battery status = 6.7 V

       A regulator needs to be built such that the system will take a voltage input range of 6.0 V to 8.4 V, and give out what is required by the Zybo board, which is a constant output of 5 V & 2.5 A. To expedite the design process, the online tool TI Webench was utilized. (www.ti.com/Webench).
To use this tool, one needs to enter the expected input voltage as well as the desired output voltage and current. A list of design solutions is then generated. One needs to use caution to make sure the components in the chosen design are practical to solder and are in stock.

Creating the Schematic in EAGLE:

       When a circuit has been chosen, you will need to create its schematic using a PCB design program. For this purpose, EAGLE will be used, and can be downloaded using this link:
http://www.cadsoftusa.com/download-eagle/

       Once the program has been successfully installed, you can see that there is a toolbar on the left with various buttons. These will allow you to create your circuit using the parts library provided by EAGLE. To do this, click on the "ADD" button, which will bring up a window allowing you to search for the parts you need to place. An example is shown below which demonstrates finding a p-channel MOSFET. On the right hand side, the packaging information is given along with a to-scale drawing.
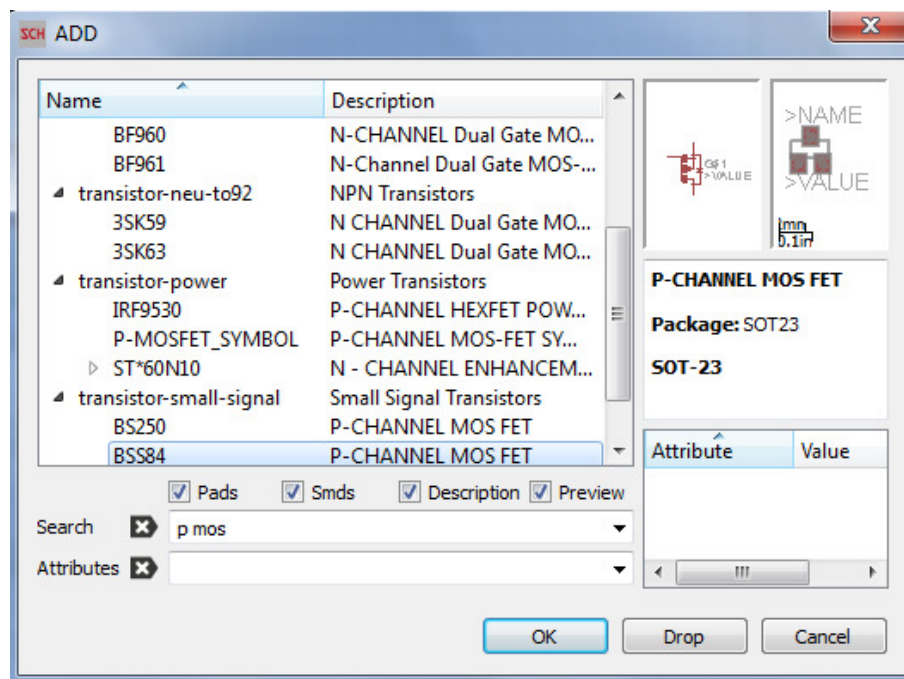
Once you've found the right part, double click on it, and place it on the grid. Use the "wire" tool to connect all of the components together. To double check your schematic for any errors, hit the Electrical Rule Check (ERC) icon in the left toolbar. This will indicate any errors that need to be addressed before creating your board.

Creating the Board from the Schematic:

To create a printed circuit board (PCB) from the schematic, click on the "Generate/switch to board" button.
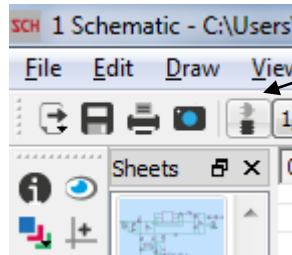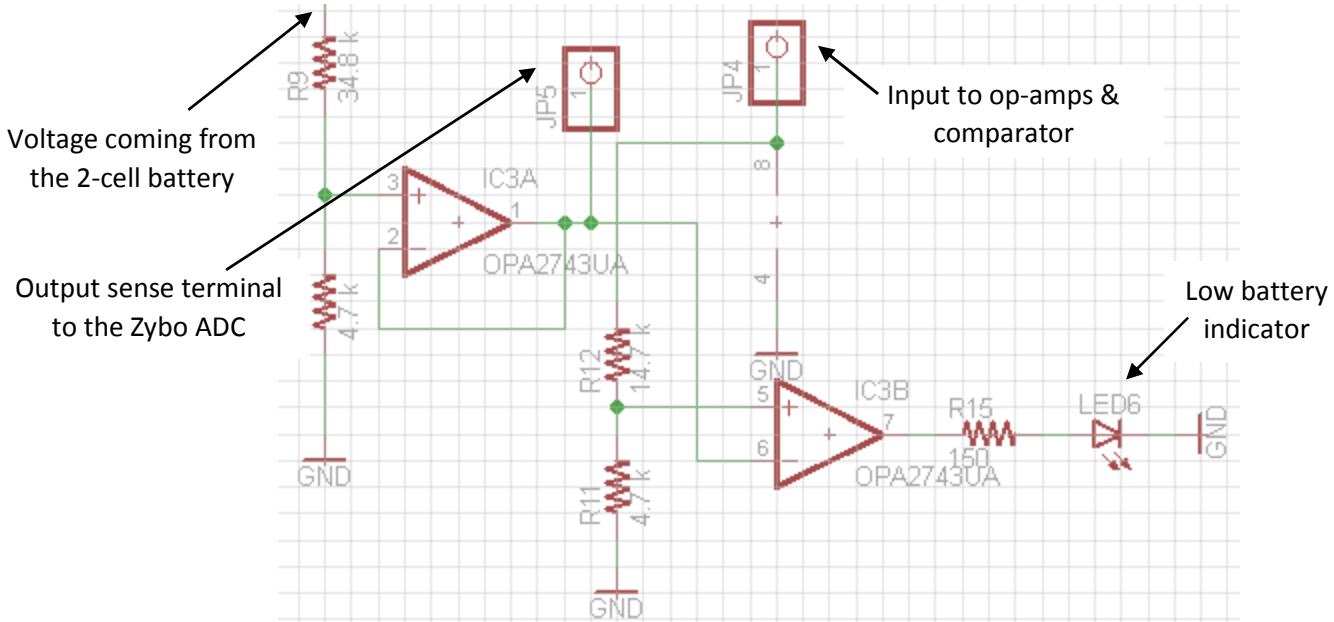

From there, the board still needs to be routed. For simple boards such as the ones being created here, the "Autorouter" tool can be utilized. This will generate several solutions where the vias and routings are automatically placed. To make sure all wires have been properly connected, click on the Ratsnest icon. If everything has been connected properly, the message "Ratsnest: Nothing to do!" will appear. Then, to double check for any other errors, hit the Design Rule Check (DRC) icon in the left toolbar. This will indicate any errors that need to be addressed. Once all the design requirements have been satisfied, the next step is to create the Gerber files which will be sent to the manufacturer. To do this, go to the following website, https://learn.sparkfun.com/tutorials/using-eagle-board-layout, and download the SparkFun's CAM file, and save it to your working directory. Then click on the "CAM Processor" icon in the upper toolbar. From there, navigate from File → Open → Job, and select the CAM file you just downloaded. Then, make any changes to the file tabs if desired, and then hit "Process Job." At this point, the Gerber files have been generated, and should appear in your working directory. To order your boards, you can save your files in a zip folder, and send them to the manufacturer of your choice. MicroCART has chosen to use OSH Park for this purpose, who can print 3 copies of the board for $5 per square inch.
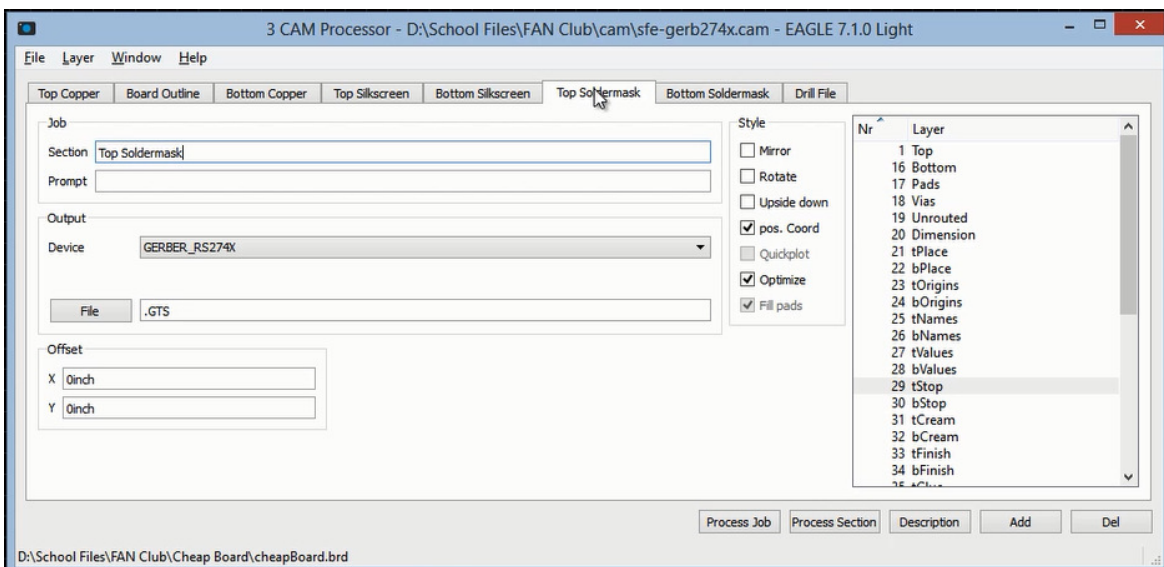
<u>Reading from the Zybo ADC pin:</u>

Firstly, a voltage divider is needed to set the full battery value near 1 V, since 1 V is the maximum value the ADC on the Zybo can read.

$$\frac{4.7\ k\Omega}{4.7\ k\Omega + 34.8\ k\Omega} * 8.4\ V = 0.999494\ V\ (Full\ Battery\ Status)$$

Voltage coming from the 2-cell battery

Input to op-amps & comparator

Output sense terminal to the Zybo ADC
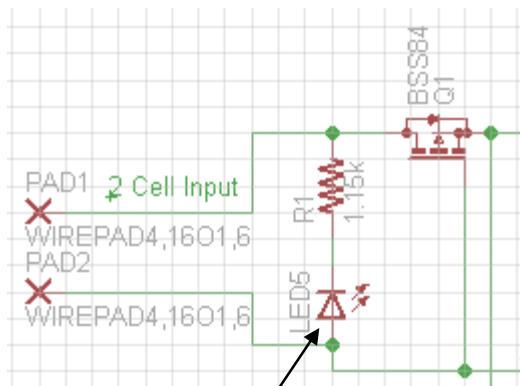
Low battery indicator

<u>Comparator Design:</u>

Since the Zybo board outputs 3.3 V, resistor values need to be determined that will give the same low battery status output when 6.7 V is the output, as when 3.3 V is given as the input to the comparator network (and the op amp power supplies).

$$\frac{4.7\ k\Omega}{4.7\ k\Omega + 34.8\ k\Omega} * 6.7\ V = 0.797215\ V\ (Low\ Battery\ Status)$$

$$\frac{4.7\ k\Omega}{4.7\ k\Omega + 14.7\ k\Omega} * 3.3\ V = 0.799485\ V\ (Low\ Battery\ Status)$$

If the voltage read by the ADC reaches 0.799 V, this means the battery is low, and the comparator will trigger, thus lighting the low voltage LED.

Reverse Polarity Protection:

A mechanism needs to be implemented such that if the battery is plugged in incorrectly, the system will automatically prevent backwards circuit flow, eliminating risk to safety. For this purpose, a p-channel MOSFET was chosen. If the battery is plugged in backwards, current will flow through the MOSFET in a forward biased manner, causing the LED to light, thus indicating a reverse polarity situation. A shunt resistor of 1.15 kΩ was chosen.

Reverse polarity
indicator

Motors Battery Regulator/Indicator:

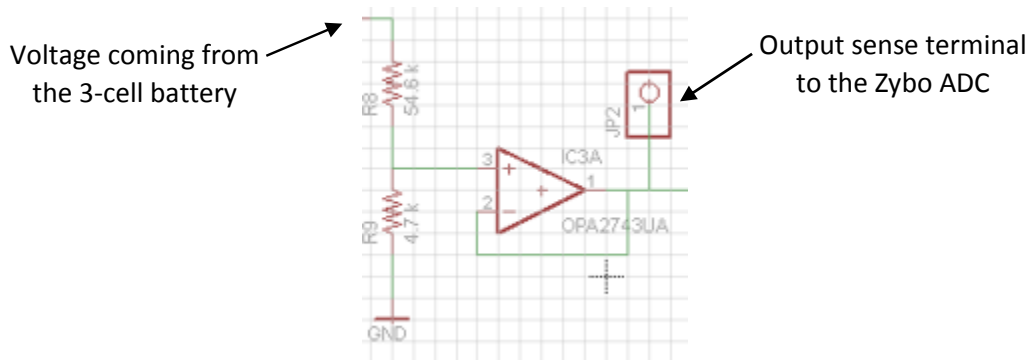Voltage Range: 3.0 V – 4.2 V per battery **(3-Cell Input)**

Assuming:
   -Full battery status = 12.6 V
   -Low battery status = 9.8 V
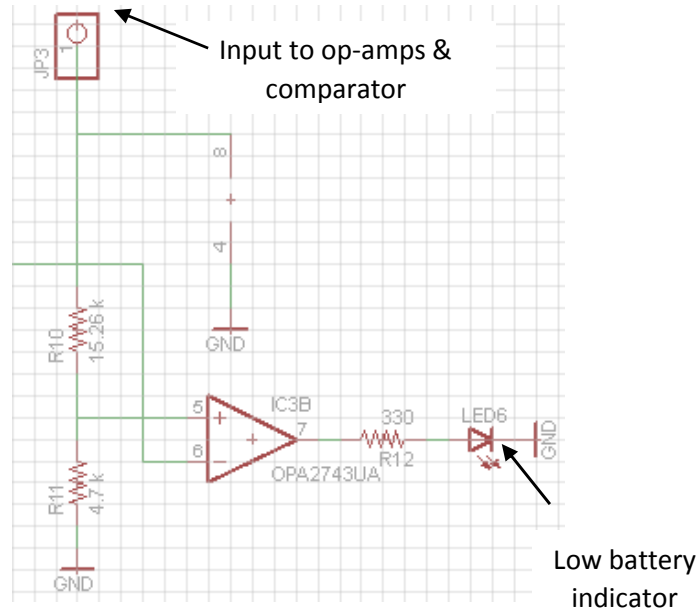
Reading from the Zybo ADC pin:

Firstly, a voltage divider is needed to set the full battery value near 1 V, since 1 V is the maximum value the ADC on the Zybo can read.

$$\frac{4.7 \ k\Omega}{4.7 \ k\Omega + 54.6 \ k\Omega} * 12.6 \ V = 0.998651 \ V \ (Full \ Battery \ Status)$$

Voltage coming from
the 3-cell battery

Output sense terminal
to the Zybo ADC

Comparator Design:

Since Zybo board outputs 3.3 V, resistor values need to be determined that will give the same low battery status output when 9.8 V is the output, as when 3.3 V is given as the input to the comparator network.

Input to op-amps & comparator

Low battery indicator

$$\frac{4.7 \ k\Omega}{4.7 \ k\Omega + 54.6 \ k\Omega} * 9.8 \ V = 0.776728 \ V \ (Low \ Battery \ Status)$$

$$\frac{4.7 \ k\Omega}{4.7 \ k\Omega + 15.26 \ k\Omega} * 3.3 \ V = 0.777054 \ V \ (Low \ Battery \ Status)$$

If the voltage read by the ADC reaches 0.777 V, this means the battery is low, and the comparator will trigger, thus lighting the low voltage LED.

Motors Battery Regulator/Indicator:

Voltage Range: 3.0 V – 4.2 V per battery **(4-Cell Input)**

Assuming:
 -Full battery status = 16.8 V
 -Low battery status = 13.1 V

Reading from the Zybo ADC pin:

Firstly, a voltage divider is needed to set the full battery value near 1 V, since 1 V is the maximum value the ADC on the Zybo can read.

$$\frac{4.7 \ k\Omega}{4.7 \ k\Omega + 75 \ k\Omega} * 16.8 \ V = 0.990715 \ V \ (Full \ Battery \ Status)$$

Comparator Design:

Since Zybo board outputs 3.3 V, resistor values need to be determined that will give the same low battery status output when 13.1 V is the output, as when 3.3 V is given as the input to the comparator network.

$$\frac{4.7 \ k\Omega}{4.7 \ k\Omega + 75 \ k\Omega} * 13.1 \ V = 0.772522 \ V \ (Low \ Battery \ Status)$$

$$\frac{4.7 \ k\Omega}{4.7 \ k\Omega + 15 \ k\Omega} * 3.3 \ V = 0.78731 \ V \ (Low \ Battery \ Status)$$

If the voltage read by the ADC reaches 0.78731 V, this means the battery is low, and the comparator will trigger, thus lighting the low voltage LED.

Reverse Polarity Protection:

A mechanism needs to be implemented such that if the battery is plugged in incorrectly, the system will automatically prevent backwards circuit flow, eliminating risk to safety. For this purpose, a p-channel MOSFET was chosen. If the battery is plugged in backwards, current will flow through the MOSFET in a forward biased manner, causing the LED to light, thus indicating a reverse polarity situation. A shunt resistor of 1.15 kΩ was chosen.