adafruit learning system

Li-Ion & LiPoly Batteries

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Guide Contents

Overview

If you want to take your project portable you'll need a battery pack! For beginners, we suggest alkaline batteries, such as the venerable AA or 9V cell, great for making into larger multi-battery packs, easy to find and carry plenty of charge. If you want to go rechargable to save money and avoid waste, NiMH batteries can often replace alkalines. Eventually, however you may want to upgrade to the shiniest new technology - rechargable lithium ion/polymer batteries.

Rechargeable Lithium Names

There are nearly a dozen different chemistries of rechargable lithium ion batteries but we will be specifically talking about Lithium Ion and Lithium Ion Polymer as a group.

On the left you can see two Lithium Ion Polymer cells. On the right, two packs made of cylindrical Lithium Ion batteries

Lithium Ion cells tend to be either rectangular or cylindrial. They are hard-shelled with a strong casing. They often weigh a little more and come in larger capacity but they are also more sturdy and are hard to puncture. They're often used for laptop batteries and other big packs. These are often called:

- Lithium Ion
- Li-Ion
- LiIon
- LiCo (lithium cobalt, the anode chemistry)

Lithium Ion Polymer cells tend to be thin rectangles in a silvery bag. They are soft-shelled and have an easy to damage casing. They often weigh a little less and come in smaller capacity. You can fit them into smaller devices such as tiny iPods. These are often called:

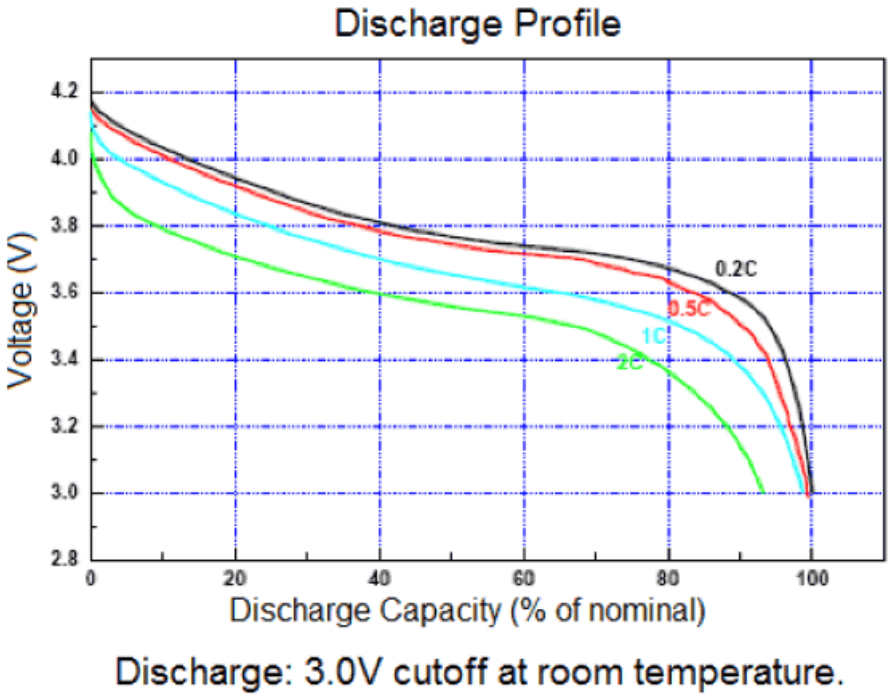
- Lithium Ion Polymer
- Li-Poly
- LiPoly
- LiPo

Despite the structural differences, you should treat them similarly and consider them two versions ('gentle and light' 'tough and strong') of the same kind of battery.

Voltages

Depending on the design and chemistry of your lithium cell, you may see them sold under different nominal "voltages". For example, almost all lithium polymer batteries are **3.7V** or **4.2V** batteries. What this means is that the **maximum** voltage of the cell is **4.2v** and that the "nominal" (average) voltage is **3.7V**. As the battery is used, the voltage will drop lower and lower until the minimum which is around 3.0V. You should see the number **3.7V** written on the battery itself somewhere.

For example, here is a profile of the voltage for a 'classic' **3.7V/4.2V** battery. The voltage starts at 4.2 maximum and quickly drops down to about 3.7V for the majority of the battery life. Once you hit 3.4V the battery is dead and at 3.0V the cutoff circuitry disconnects the battery (more on that later.



Discharge: 3.0V cutoff at room temperature.

You may also run across **4.1V/3.6V** batteries. These are older than 4.2V/3.7V - they use a slightly different chemistry and you'll see the 3.6V marking on the cell.

Nowadays you may also be able to purchase **4.35V** cells! These are the latest chemistry, they have a little more power as indicated by the voltage being higher than **4.2V**. They tend to be cylinder lithium ion's used for laptop batteries, and lights so its not terribly likely you'll just run into one unless you're looking for it.

Make sure when you're buying batteries and chargers to match them up! Overcharging a 3.6V battery by attaching it to a 4.2V battery charger can at the very least permanently damage your battery and at worst cause a fire!

Important Note! When charging batteries you must make sure that the charger voltage is less than or equal to the battery voltage. For the best battery performance/life you should have them matched. For example: 3.7/4.2V battery and 3.7/4.2V charger: OK - 3.7/4.2V battery and 3.6/4.1V charger: OK (but not ideal) - 3.6/4.1V battery and 3.6/4.1V charger: OK - 3.6/4.1V battery and 3.7/4.2V charger NOT OK!

Protection Circuitry

Lithium ion/polymer batteries are extremely power dense. This makes them great for reducing size and weight of projects. However, they are not 'safe' batteries and require extra care. Charging or using the batteries incorrectly can cause explosion or fire (as shown by this and many other youtube videos).

There are five main things to watch for when charging and using batteries:

- Do not charge them **above** their maximum safe voltage (say 4.2V) - usually taken care of by any on-cell protection circuit
- Do not discharge them **below** their minimum safe voltage (say 3.0V) - usually taken care of by any on-cell protection circuit
- Do not **draw more current** than the battery can provide (say about 1-2**C**) - usually taken care of by any on-cell protection circuit
- Do not **charge them with more current** than the battery can take (say about 1**C**) - usually taken care of by any on-cell protection circuit but also set with the charger by adjusting the charge rate
- Do not charge the batteries **above or below** certain temperatures (usually about 0-50 degrees C) - sometimes handled by the charger, but often not an issue as long as the charge rate is reasonable.

For specifics on each battery you must look at the datasheet to know what the safe voltages, currents and temperatures are - they can vary from cell to cell.

For the first 3 items, a circuit board attached to the battery can monitor the battery voltage and the current going out. These are often referred to simply as **protection circuits**. They are very common on standard batteries but **you must check the datasheet or product image** to verify that a protection circuit is attached

On the batteries we sell, the protection circuit is soldered onto the battery and then taped into the little cavity at the top of the battery. This is very common for lipoly cells.

If you don't see any taped circuit board, the cell may be 'raw' - these raw cells **are not** protected!

Important Note! We suggest that you should never use lithium ion/polymer batteries without protection cells. Without the protection, a slight mistake in their use could destroy the battery and they have a much higher risk of exploding or catching on fire.

"RC" Type Batteries

When purchasing batteries, its good to be aware there are two families of batteries: **Regular/Normal** and **RC** (radio control)

Regular/normal lithium ion batteries are what you find in your ipod, camcorder, phone etc. They are meant to last for over 500 charges, stay safe, and provide a **C** or two of current (For more details about **C** please read our basic battery tutorial (https://adafru.it/cl5))

RC lithium ion batteries are meant for radio controlled cars, planes, UAVs, quad copters, etc. They are meant to give a lot of power at once, up to 20C and are designed to never 'cut off' so that the battery will be damaged instead of having the plane fall out of the sky.

RC batteries are often raw cells, as seen here: There are two tabs coming out of the top and you see its labeled **20C** for high current output capacity. They are often less expensive because there is no protection circuitry.

Important Note! Unless you are specifically building an RC device like a quadcopter, we suggest that you should never use RC lithium ion batteries for DIY projects. They do not have protection circuitry and are designed to not be safe. They have a much higher risk of exploding or catching on fire. If you need more current capability, just go with a larger lithium ion/polymer battery

You may end up using camcorder or cell phone batteries. These are removable batteries in a hard case. They tend have protection cells inside the case. This battery for example, is an old project battery from before you could buy lipoly batteries easily.

Multi-battery Packs

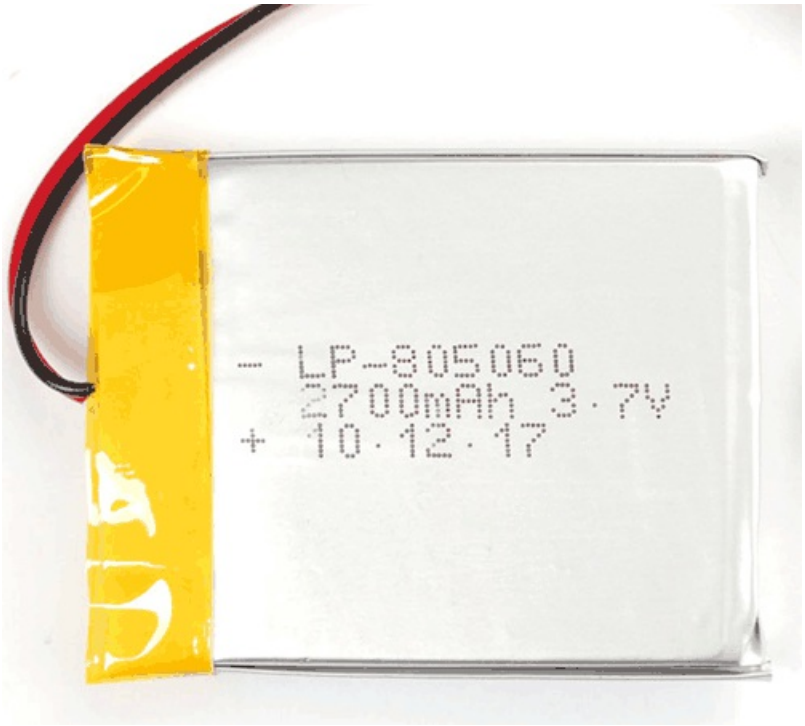
You may eventually find yourself needing a big battery, say because your project has twice as many LEDs or you want it to last twice as long. A lot of people think "well I know that if you parallel two batteries that doubles the capacity so I'll do that!"

For example, we could take two 1300mAh batteries, that are 3.7V nominal and connect them together in parallel...

However you should never ever do this!!

Not only should you not do this with alkaline batteries, but its especially dangerous with lithium batteries. One battery can discharge into another, damaging it or causing a fire!

If you ever need a larger battery, you should upgrade to a larger battery! Like this one which is twice the size and has twice the capacity.



You may be asking then, **How come adafruit sells battery packs that are paralleled?**

These two packs are clearly two and three batteries. Since they are 3.7V they must be in parallel. Isnt this unsafe?

The answer is that these batteries are assembled by a company that is experienced and certified to test and assemble battery packs. The individual batteries are tested and sorted by machine so that each pack has matching batteries with the same capacity and internal resistance. Individuals do not have this equipment, which is why you should not try to make your own packs.

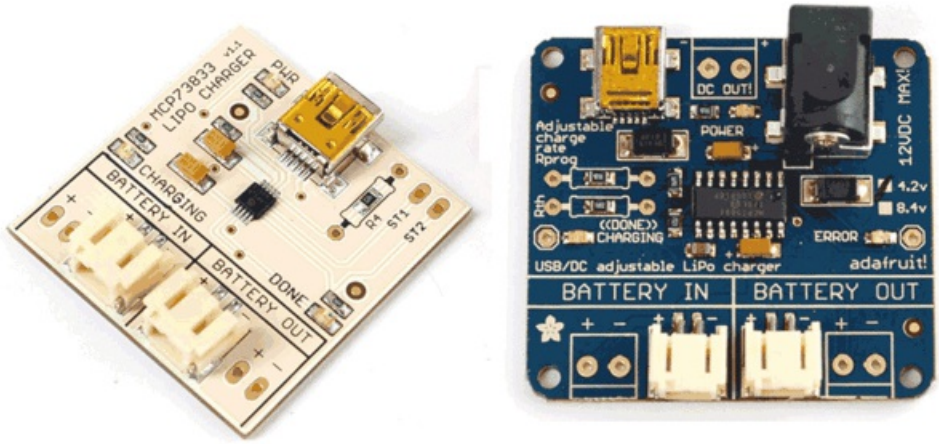
So the next question is whether you can connect batteries in series to get higher voltages?

This is also discouraged because the battery wont be able to be charged in a balanced manner. You should purchase a lithium ion pack that is preassembled.

Proper Charging

Now that you know how best to use your lithium ion/polymer battery, we'll finish up by making sure you know how to charge the battery. We'll have a longer tutorial for our chargers at some point but we want to get people started with how to best use our chargers!

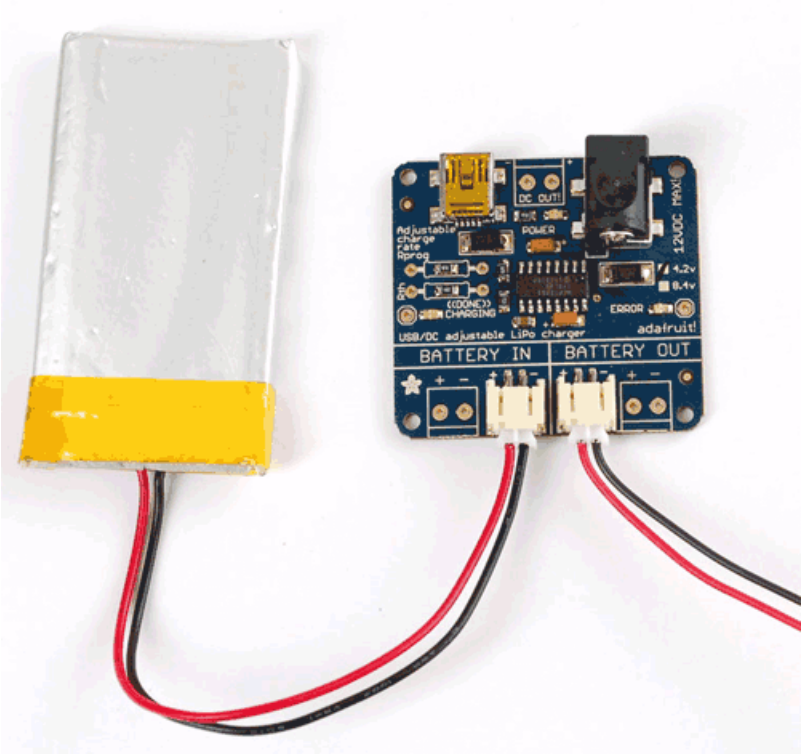
As we mentioned before, **you must use a proper lithium ion/polymer** battery charger. The good news is that nearly all batteries you will encounter are going to be 4.2V. And you can use a 4.2V charger for both lithium ion and lithium ion polymer. If you ever encounter a 4.35V battery, you can always use a 4.2V charger: it'll charge it up to 4.2V which is perfectly safe.



We carry two chargers in our store (at this time). A USB charger and a USB/DC charger. The USB charger is meant for charging single cells from a USB port that can provide 500mA or so. The USB/DC charger is meant for charging batteries from a USB port **or** a DC power supply up to 12V. The latter is more flexible, but more expensive because of the added circuitry.

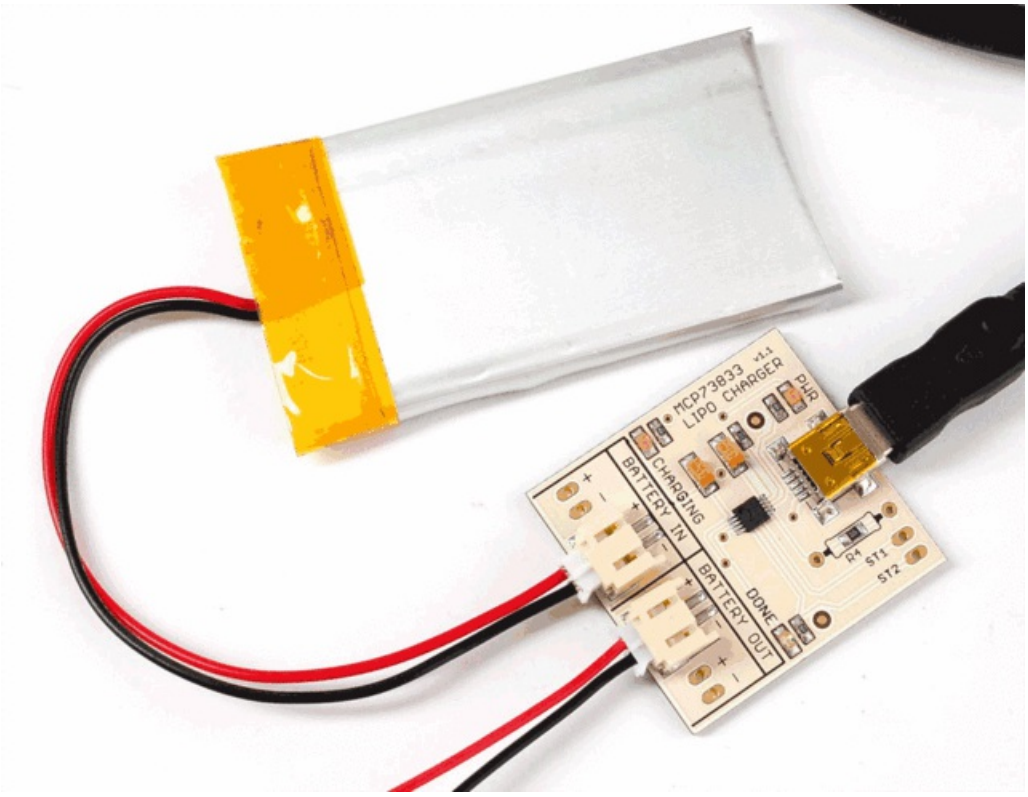
You'll note that both have battery ports on the bottom (Labeled Battery In and Out) and charging ports at the top (USB on the left and USB + DC on the right)

To connect the battery, simply plug it into the **BATTERY IN** slot.



If you want to use the battery while also having it connected to the charger (less plugging and unplugging that way) you can simply use the **BATTERY OUT** connecion on the right. The **IN** and **OUT** ports are connected together on the circuit board so it acts as a *pass-through*

To charge, connect a power supply to the top of the board.



The **PWR** red LED on either board will light up to let you know its powered properly. While charging, an LED will also be lit. For the USB only charger, a green done LED will light when the battery is full. For the USB/DC charger, the charging LED will blink slowly (once every few seconds).

You can change the charge rate of each charger by soldering a resistor into slot **R4** (for the USB charger) or **RPROG** (the USB/DC charger).

The max charge rate of the USB charger is about 1000 mA To acheive this charge rate, you can either solder a **2.0K** resistor on top of **R4** (default 2K) - this will make the total parallel restance 1.0K or you can remove **R4** by desoldering it or cutting the trace to it and solder a 1.0K resistor in its place.

The max charge rate of the USB/DC charger is about 1200 mA To acheive this charge rate, you should solder a wire (short) on top of **RPROG** (default 4.7K). You can also change the rate to a different value by either soldering a resistor on top of **RPROG** (and calculating the parallel resistance) or removing the resistor and soldering a different one in its place. See the schematic for what values result in what charge rates (https://adafru.it/aID).

For other values, use a parallel resistor calculator such as this one. (https://adafru.it/aIE) Put the desired resistance in **Rtotal** and the current resistance on the board into **R1** and then solder **R2** on top.

Important Note! Never charge a battery faster than 1C (so a 1300mAh battery should be charged at under 1300 mA) and we suggest staying at or below 0.5C Check the datasheet of the battery for more information about your cell

Conclusion

Lithium Ion and Lithium Ion Polymer batteries are a great power source for projects but they require care during use and charging. They can be easy to damage or misuse and can hurt you or your property! All the batteries we sell pass testing and certification but you should still be careful with them. Read the datasheet, follow our suggestions and those in the datasheet as well as common sense!

The manufacturer of our lithium ion batteries indicates the following warnings and cautions: (https://adafru.it/aIF)

- Do NOT immerse the battery in water or other liquids. Keep or store the battery in a cool and dry place/environment.
- Do NOT use or store the battery near any source of heat.
- Use a charger that is clearly specified to be compatible for charging the battery and has appropriate charging protection (voltage, current, temperature)
- Do NOT install the battery in reverse polarity.
- Do NOT connect the battery to an electrical outlet or other incompatible power source.
- Do NOT discard the battery in fire.
- Do NOT short circuit the battery. Do NOT connect the positive and negative terminals to each other with metallic object(s) or other conductive material(s).
- Do NOT transport or store the battery together with metal objects, such as hairpins, necklaces, or any other conductive object or material.
- Do NOT strike, crush, puncture, disassemble, or throw the battery.
- Do NOT directly solder the battery or battery terminals.
- Do NOT pierce the battery.
- Lithium batteries should be used only with proper voltage, current, and temperature protection circuitry and protection.
- Do NOT use or leave the battery in a high temperature environment (for example, under direct sunlight or in a vehicle in hot weather). Failure to take this precaution can lead to overheating of battery and/or fire or explosion. Also, performance of battery will degrade and lifetime will be reduced.
- Do NOT use battery in a location where there is high static-electricity or magnetic fields, otherwise safety devices may be damaged which cannot be visible.
- If the battery leaks and the electrolyte get into the eyes, do NOT rub eyes. Instead, rinse and wash eyes with clean water, and immediately seek medical attention.
- It the battery gives off an odor, generates heat, becomes discolored or deformed, or in any way appears abnormal during use, recharging, or storage, immediately remove it from the device or battery charger and stop using it.
- In case the battery terminals are dirty, clean the terminals with a dry cloth before use. Otherwise, poor performance may occur due to the poor connection with the instrument or device.
- Be aware that discarded batteries may cause fire or explosion. Therefore, apply a non-conductive tape to the battery terminals to insulate them before discarding.

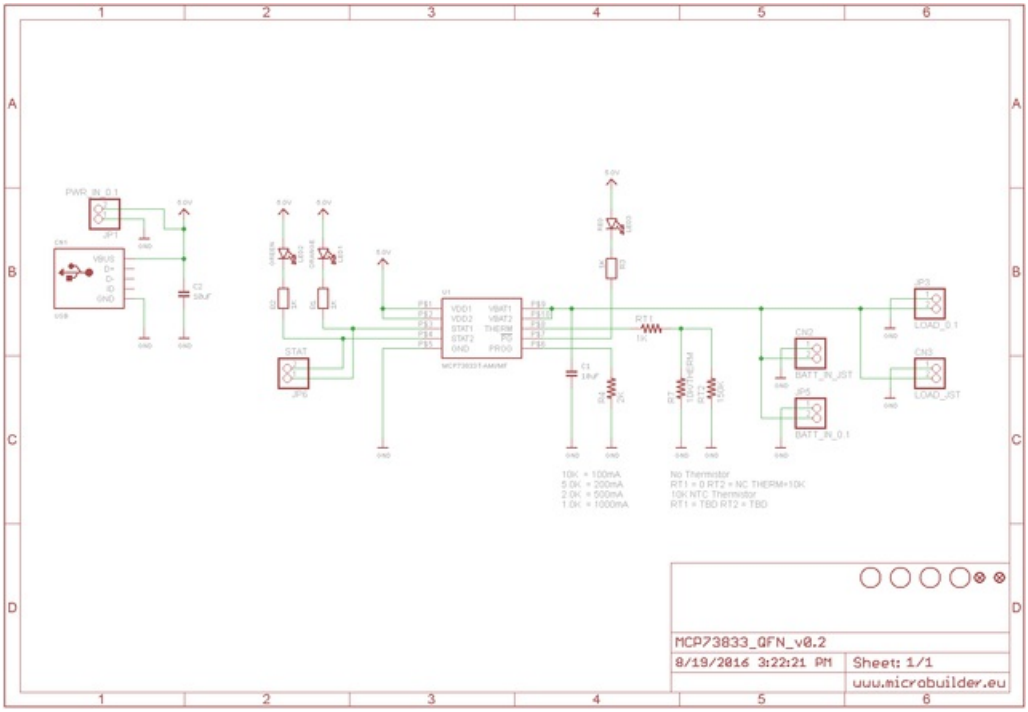
Temp sensor FAQ: Most DIY/hobbyist chargers don't come with temperature sensors built in because they are not always right next to your battery and they are intended to be used at low charge rates and indoors where the temperature is around 25 degrees C. If you want to charge your batteries at high rates (above 0.5**C**) or outdoors, you should get a temperature-based charging solution.

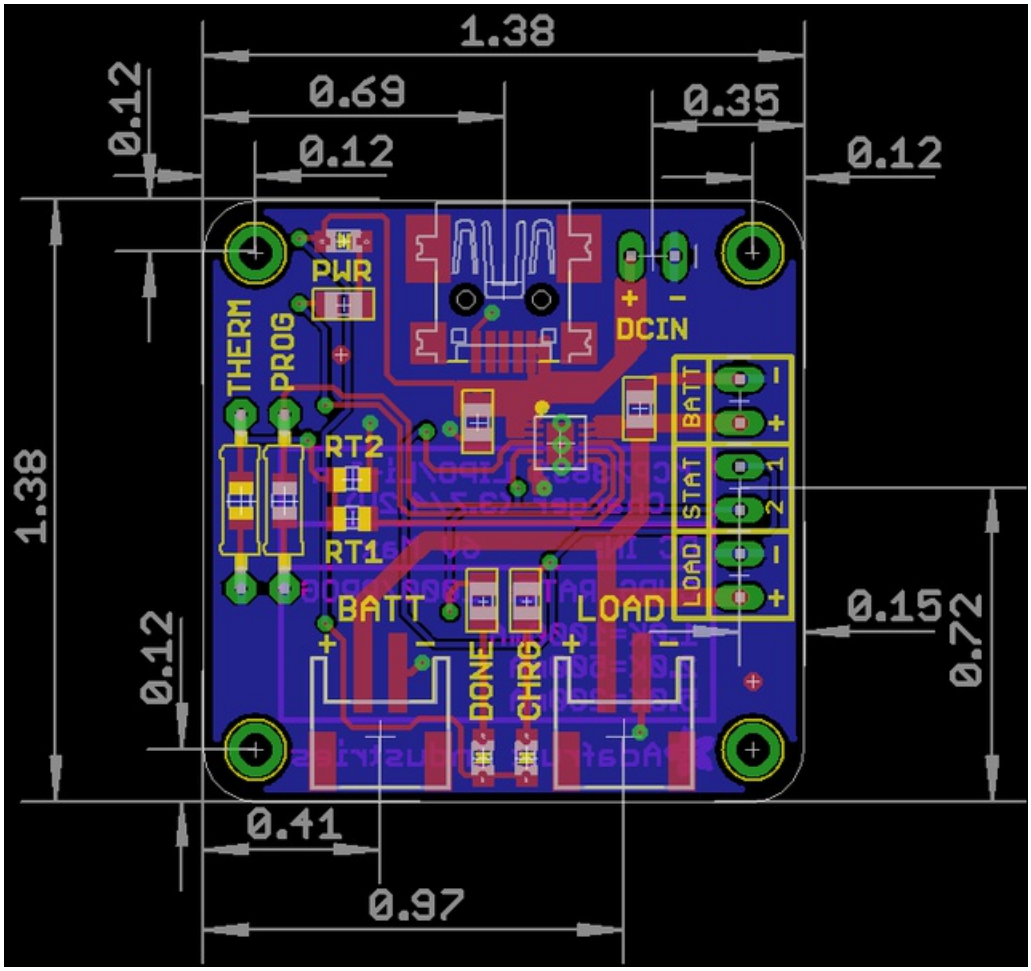
Downloads

Files

- MCP73833 Datasheet (https://adafru.it/qTC)
- EagleCAD PCB files on GitHub (https://adafru.it/qTD)
- Fritzing object in Adafruit Fritzing library (https://adafru.it/aP3)

Schematic & Fabrication Print

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