

THE FOLLOWING WAS WRITTEN BY MAMU

With seeing quite a few questions and posts here and there about fuses thought I'd start a reference thread for modders to get help in understanding fuses as well as how to choose an appropriate fuse for the converter you've chosen to work with.

Why use a fuse?

A fuse is designed to protect in case of a current fault. In this day and age where we're pushing higher current loads at higher power as well as using batts with very high discharge ratings, wiring in a fuse during the build is the most basic safety device to protect you, the circuit, and the batt.

What is a PTC fuse and how does it work?

http://en.wikipedia.org/wiki/Resettable_fuse

<https://drive.google.com/file/d/0B-l3ksnipe8nV1N3am1zTUZIREk/view?usp=sharing>

http://unicarlos.com/_ARDUINO/Arduino%20MUY%20BUENO/Alimentacion-Paperduino_00/Docs/ResettableFusses.pdf

Fuse Specifications:

I_{hold} = Hold current: maximum current that the fuse will allow to pass without tripping.

V_{max} = Maximum voltage the fuse can withstand without damage at rated current (I_{max}).

R_{min} = Minimum resistance of the fuse in initial (un-soldered) state.

Time-to-trip: The time it takes for the fuse to trip at a given temperature.

I_{trip} = Trip current: minimum current at which the fuse will trip.

I_{max} = Maximum fault current the fuse can withstand without damage at rated voltage (V_{max}).

P_d = Power dissipated from the fuse when in the tripped state.

R_{1max} = Maximum resistance of device at 20°C measured one hour after tripping or reflow soldering of 260°C for 20 seconds.

How to choose an appropriate fuse for the converter you're working with:

A. The first step in choosing a fuse is to read the converter's datasheet and find the max input current. Choose a fuse with a hold current close to or equal to the converter's max input current.

You can choose a hold current slightly under or slightly over the max input current of the converter if you can't find a fuse that is equal to the max current and still have good protection as there is a current cushion between hold current and trip current. What is important is that you don't want to choose a hold current that is too low else you'll get annoying inadvertent tripping when running the converter at or near max output or from normal operating internal heat (plus each time a fuse trips, the resistance takes days to return to the initial state). For the most part, we are using fuses to protect us and the circuit from a batt fault or reverse polarity. Either of those situations will cause a huge current dump from the batt, so no matter if the hold current is a bit high the fuse will trip rather fast.

B. Next, look at the V_{max} rating of the fuse. V_{max} must be higher than the max input voltage for the converter. A boost converter's max input voltage is 4.2v, while a buck converter's max input voltage is 8.4v. For a boost converter a fuse's V_{max} rating of 6v is appropriate, but that V_{max} of 6v is not appropriate for a buck converter as higher than 6v input will damage and/or destroy the fuse when in the tripped state which then will result in loss of protection.

C. Next, look at the R_{min} rating of the fuse. The lower the resistance the least effect the fuse will have on the circuit - 10mOhms of resistance at 10A wastes 1W and causes an input voltage drop of 0.1v. So... to have the least effect with adding unwanted resistance to the circuit, we parallel fuses. Wiring 2x fuses in parallel cuts the fuse's internal resistance in half, BUT it also doubles the hold current and trip current. If you are going to use 2 fuses in parallel, you must then look for a fuse with a hold current half the max current of the converter. For example - if the converter's max current is 10A, you will need to choose a fuse with a 5A hold current ($2 \times 5A = 10A$).

D. Next, look at the fuse's trip time - the lower the trip time the faster the fuse will kick in at its trip current to protect the circuit. I try to choose fuses with less than a 5 second trip time.

E. Next, look at the fuse's I_{trip} - this should be less than or equal to $2 \times I_{hold}$. For example, if the I_{hold} is 5A, the I_{trip} should be around 10A. If I_{trip} is higher than $2 \times I_{hold}$, the fuse may not trip when you need it to.

F. Finally, you'll need to choose a fuse based on its type - leaded or smd. For some of us (me :laugh:) our mods are tightly packed and only an smd fuse will fit while some mods with larger enclosures don't have that space constraint, so a leaded fuse would be suitable. However, keep in mind that smd fuses usually have the lowest rated resistance and lower trip times and are therefore usually the better choice. But you may not find an smd fuse with the hold current you need. Lower I_{hold} fuses are readily available via smd, but higher I_{hold} fuses are not. After doing an intense search for the highest I_{hold} for an smd fuse I've finally found one from Littelfuse that is 7A, the next lower I_{hold} available via smd is 4.5A. AND these suckers are teeny tiny - so be prepared to use tweezers and a magnifying light lol.

Note: for series batts, a common fuse on the positive batt is appropriate. For dual parallel batts, a fuse for each batt is recommended. For dual parallel batts, a common fuse will NOT protect the batt that is put in backwards from a meltdown or protect a good batt from a bad batt that has internally shorted - each batt (when using dual parallel batts) needs its own fuse for full protection.

If working with parallel batts, the total combined hold current should be equal to or close to the max current of the converter. For example, if the max current of the converter is 10A, the total combined hold current of all fuses that you've added to the batts should be around 10A.

Various example configurations:

Buck converter with a 10A max input current:

Choose one 10A fuse and wire to the batt+ of the series batts or, more preferably to lower the fuse's resistance, choose two 5A fuses then solder the 2 fuses together in parallel and wire to the batt+ of the series batts.

Boost converter with 12A max input current:

For one batt mods - choose one 12A fuse and wire to the batt+ or, more preferably to lower the fuse's resistance, choose two 6A fuses then solder the 2 fuses together in parallel and wire to the batt+.

For dual parallel batts - choose two 6A fuses and wire one fuse to each batt+, then connect the free end of each fuse with a common wire. For me, I have a stash of 3A smd fuses lol and will be soldering two sets of 2x 3A fuses in parallel and putting one set on each batt for a total of 12A combined for the DNA30.

Some interesting facts about paralleling fuses:

- Derating is necessary because two fuses in close proximity radiate heat less effectively than single fuses. As a general rule, a minimum reduction in rated current of 10% for 2 fuses in parallel (20% for 3 or 4 fuses in parallel). Because of the derating factor, you don't want to put more than 2x fuses in parallel.

- The voltage rating of 2 fuses in parallel can be less than the voltage rating of a single fuse. The derating factor can be 15%. Again because of the derating factor, you don't want to use more than 2x fuses in parallel.

- Fuses for parallel connection must be of identical type and rating.

- For a given prospective short circuit current, the duty on parallel fuses is eased, as the current in each fuse is inversely proportional to the number in parallel.

-An ideal parallel arrangement will give equal current sharing, but even if completely balanced paths are not achieved, a small degree of self compensation will occur.

Final note:

When applying solder to a fuse, make it quick and short - heat will increase the fuse's internal resistance and that resistance may take days to lower back to its initial state.

The most basic safety device for a battery is a fuse...

http://batteryuniversity.com/learn/article/safety_circuits_for_modern_batteries