DC Voltage Conversion

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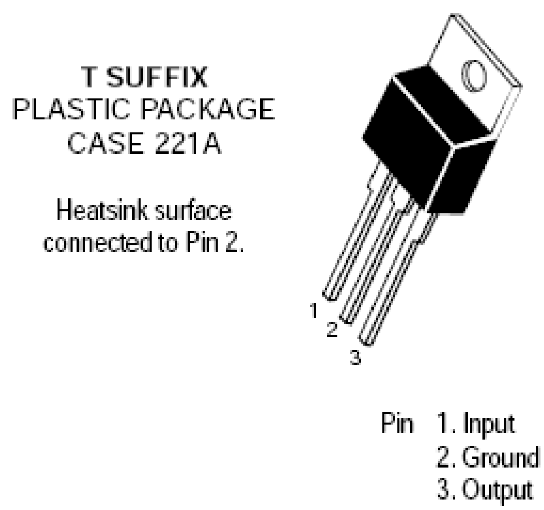
One of the most electrical common needs of an astronomer in the field these days is some way of creating numerous small DC voltages from one big one. The most frequently used source being a 12V marine or automotive battery. The smaller voltages could be anything from 5 to 9 volts and are used to power a hub, a camera etc.. Fortunately, there is a family of step-down voltage regulators that are very inexpensive and easy to work with that can provide what you need. These are the 7800 series 3-lead positive voltage regulators.

The 7800 series come in 5, 6, 8, 9 and 12 volt flavours and all need around 2.5 volts of overhead in order to work. So, the 5v needs an input of 7.5v, the 9v needs 11.5v etc. All are protected for over-current and over-temperature and also have short-circuit protection. The general layout of the parts is as below:



As you can see, the part has three legs which are labeled input, output and ground. The tab (which screws to a heatsink if needed) is also connected to the centre leg, or ground. The input leg is connected to the positive wire from your source, the output leg is connected to the positive wire of your device and the two share the ground lead.

The 7800 series regulators need very few external components to function. If you read the datasheet (every electronic component has a datasheet) you'll see that really, all it wants is a small capacitor connected between the input leg and ground. Other components can be added for additional functionality and stability and we'll discuss those a bit later.

The package shown above is called a TO-220 package and has standard dimensions within a small range. They are approximately 29mm long from the end of the tab to the end of the legs, approximately 10mm across and approximately 4.75mm thick. They don't take up a lot of space. The black part containing the internal electronics is generally comprised of a high-temperature plastic and the tab (the part with the hole) of an aluminum alloy that will move a lot of heat away from the internal parts.

There is a smaller cousin to the TO-220 regulators called a 78Lxx (the L being for 'low power'). These come in a package called TO-92 which is a small flattened cylinder. These are only for use in powering small logic chips and are limited in the current that they can source. We'll stick to the big fella'; the TO-220.

The 7800 series parts can take an input voltage up to 24v depending on the output voltage. The table below explains:

DEVICE TYPE/NOMINAL OUTPUT VOLTAGE

MC7805AC	5.0 V	MC7812C	12 V
LM340AT–5		LM340T–12	
MC7805C		MC7815AC	15 V
LM340T–5		LM340AT–15	
MC7806AC	6.0 V	MC7815C	
MC7806C		LM340T–15	
MC7808AC	8.0 V	MC7818AC	18 V
MC7808C		MC7818C	
MC7809C	9.0 V	MC7824AC	24 V
MC7812AC	12 V	MC7824C	
LM340AT–12			

I mentioned heat sinks. There has to be some method of moving heat away from the internal circuitry of the regulator. They can only handle a junction (internal) temperature of 150C, and as we will see, that can come fairly quickly.

If you want to know how much power is being dissipated there is a simple calculation you can do.

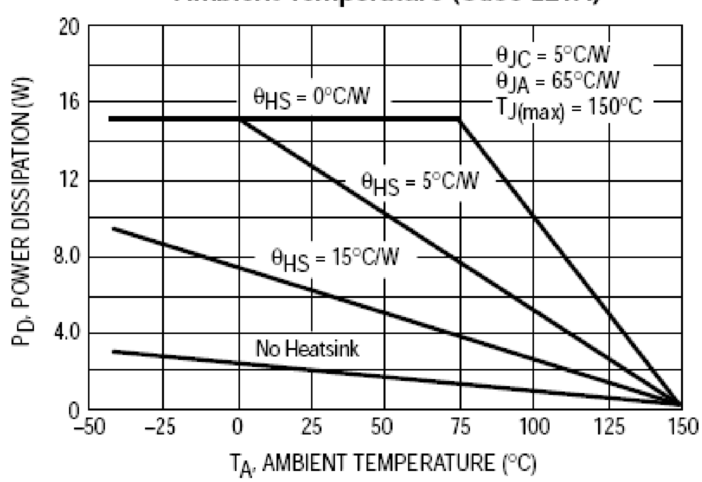
Power dissipated = drop in voltage x current draw

Let's look at a 7805 powering a USB Hub from a 12v battery. The 7805 is a 5v part so the drop in voltage would be 12-5 (actually 13.6-5 as automotive batteries generally put out more than 12v). So we have 7 volts dropped. Now we need to know what all of the stuff plugged into the hub will draw AND what the hub draws just sitting there. Let's say we have 600mA of current (.6A). So we have 7v * .6A or 4.2W.

Now, the power has to do something; it just can't disappear. What it does is heat things up. So, the more power is dissipated by the regulator the more heat is generated. Fortunately, we don't need to have to figure too much out. All we need to know are two of the specifications of a part that are on the datasheet: Thermal resistance junction to case and/or thermal resistance junction to ambient. This sounds a bit odd but look at it this way. Thermal resistance is the amount of heat left behind when the power is dissipated away into the air.

So when do we know when too much heat is created inside the part? Most datasheets provide at least a chart and that for the 7800 series regulators is one. I've included it here so that you can see how it's used.

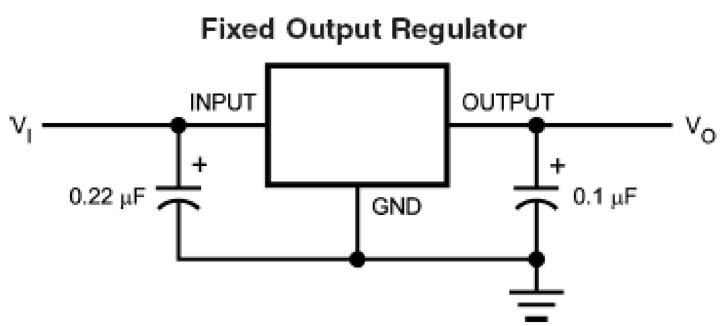
Figure 11. Worst Case Power Dissipation versus Ambient Temperature (Case 221A)



If we have no heatsink on the regulator then we use the 'No Heatsink' line and look up the ambient temperature that the part will be used in. As you can see, with no heatsink at 25C ambient the regulator will be able to safely dissipate about 2W, well below the 4.2 that we have to handle in our example. So some form of heatsink is required here. This can be a simple piece of bent aluminum, a 25 cent purpose-built part or something large and complex . Here are a couple of simple examples:

Both of these are screwed onto the tab of the TO-220 part with a bit of thermal grease between them to help the connection. The one on the left is a 20C/W part and the one on the right is a 10C/W part. The bare regulator's thermal resistance from junction to case is 5C/W. From case to ambient would be 60C/W. With a heatsink this value becomes the value of the heatsink. So if we use a 20C/W heatsink the 5C/W junction to case is added to the 20C/W case (with heatsink) to air for a total of 25C/W. With 4.2W this gives us 105C plus the ambient temperature of say 25C for a total of 130C. The part will be hot but it won't burn up... the 10C/W or even a more efficient heatsink would be much better..

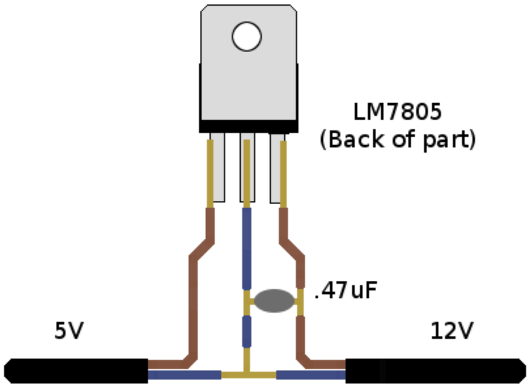
So, how are 7800 series regulators used? As I mentioned previously, the input leg connects to the 12v positive, the output leg connects to 5v positive (for a 5v part) and the negative (ground) of each are tied together and connected to the ground leg. The datasheet wants a capacitor between input and ground to smooth out any transients in the input voltage. Optionally, another capacitor can be connected between the output leg and ground, especially if the device that it's powering is a long way away. Here is a schematic:



The input voltage is on the left. The datasheet that this diagram was take from calls for a .22uf capacitor on the input, others call for a .33uf. Anything around that value would be fine. Most datasheets have the .1uf capacitor on the output listed as 'optional'. If you're picky put one in. Both capacitors go between their voltage lead and ground. Try to keep them as close to the 7800 part as possible.

There are times when you might want a large capacitor (100-220uf) on the output leg to handle any voltage drops caused by instantaneous loads such as a shutter opening. In that case you'll have to protect the regulator from a sudden drop of the input voltage such as turning off the power which would lead to the output voltage being well over the input voltage. To add this protection a reverse biased diode such as a 1N4001 from output before the capacitor to input would keep things alive.

We've talked about 'fixed' regulators so far but there is another option; the variable regulator. These look the same as the 7800 series parts we are discussing but can generate any voltage within set limits. These regulators are known by the part number LM317 if you wish to look them up. But for now, we'll keep on with our discussion of the 7800s.



Here's a real-life example of a simple 12v to 5v converter that I designed to power a USB hub that I keep on my telescope mount. The hub is 4-port device and with 500mA allowed per port that could be a 2A+ draw on the regulator. A lot of current. I don't draw that much, but 1A could be realistic.

One ampere of current through a 7805 with a 13.6v source will (from our equation above) means I'll be dissipating 8.6W of power. There will be a LOT of heat generated so I will need a LOT of heatsink. I happened to have an old 486 or Pentium (can't remember) heatsink lying around so it was pressed into use. A hole was drilled and tapped so that the regulator could be screwed tightly to the battom.

My heatsink had to stand off the floor of the project box I had for it to allow the 7805 to clear. Three layers of plastic were hot-glued together to form the standoffs which were then hotglued to the project box. The heatsink was glued to the standoffs with epoxy (which won't melt as quick if heated).

The regulator was screwed into position and then was just air-wired together with no circuit board. A .47uf bypass capacitor was soldered in place on the input leg (I didn't have either a .22 or .33).

The project box's top was opened up to let the heatsink 'see' some daylight and notches were cut in the side to let the wires through; one for the 12v coming in with an RCA plug and the other with the DC plug that fit the USB hub.

Thats about it. I haven't stress tested it with a full amp of current yet but at 400mA the heatsink stays cool. The project took me about 30 minutes to slap together (and a few hours for epoxy to cure).

Clear Skies
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