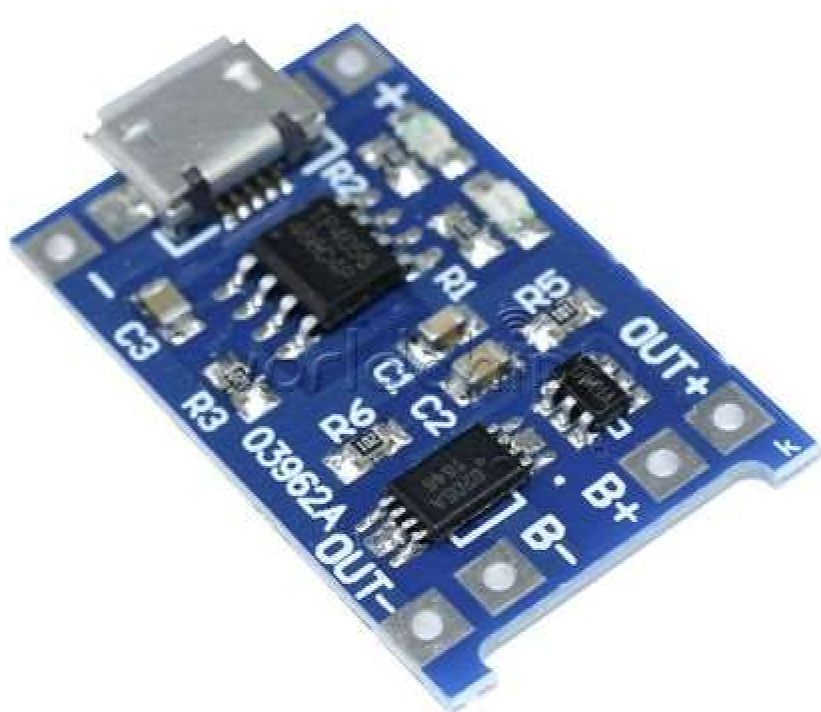
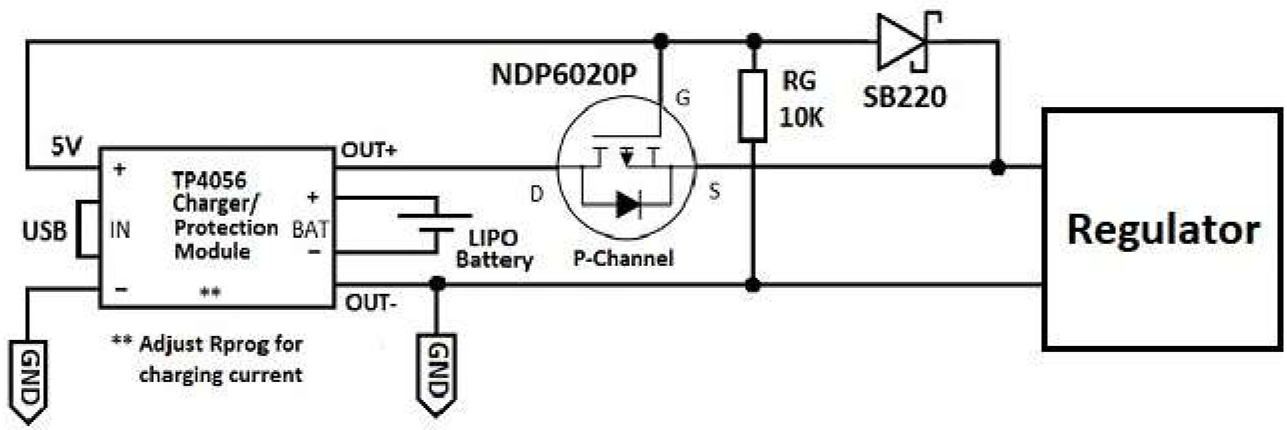
Solar Charger Load Sharing

There are many inexpensive 5V-powered charger modules available for single-cell lithium batteries. Here's an example which also includes battery protection circuits. It uses the TP4056 charger IC:



However, if such a module is used in a battery backup system which powers a project load, it needs to have a "load sharing" (also called "power path") circuit added so that power for the load will be directly provided by the 5V supply when it is plugged in, rather than by the charger. The load sharing circuit consists of a P-channel mosfet, a Schottky diode, and a resistor. Here's an example circuit:

LIPO Charger with Load Sharing



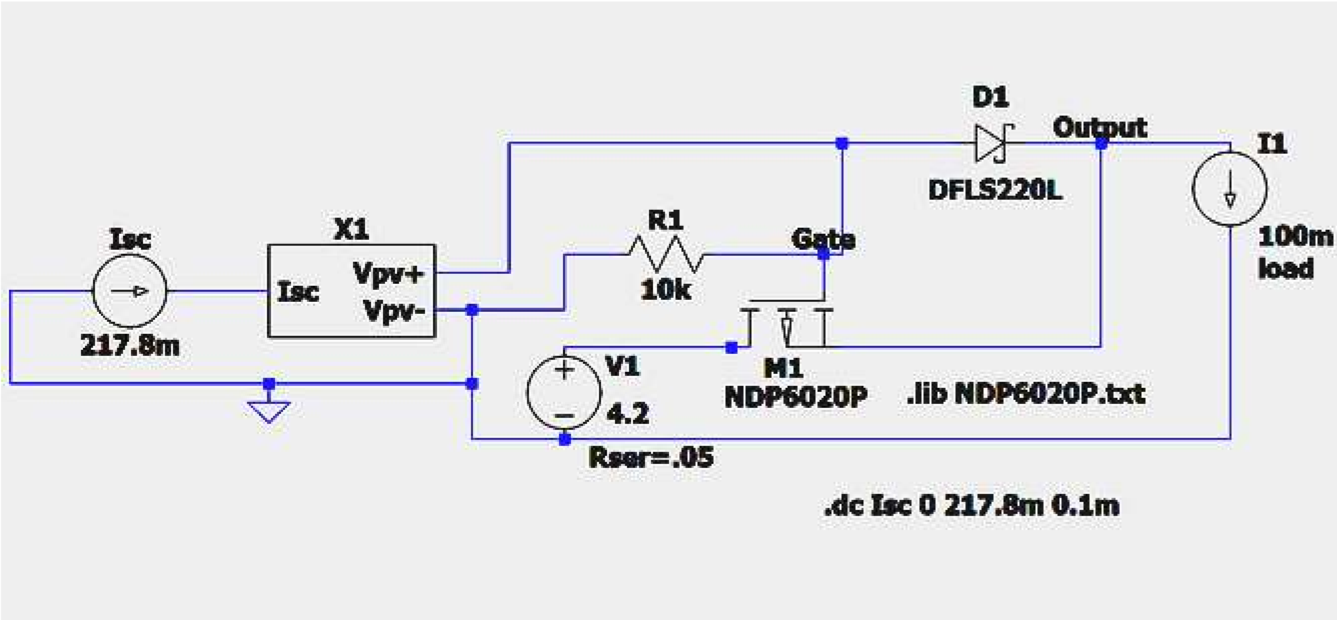
The mosfet takes the place of what would be a second diode in the battery path, and has almost no voltage drop. All of this is explained in a video I contributed to my local Open Source Hardware Group:

https://www.youtube.com/watch?v=T70mBHeIOZA

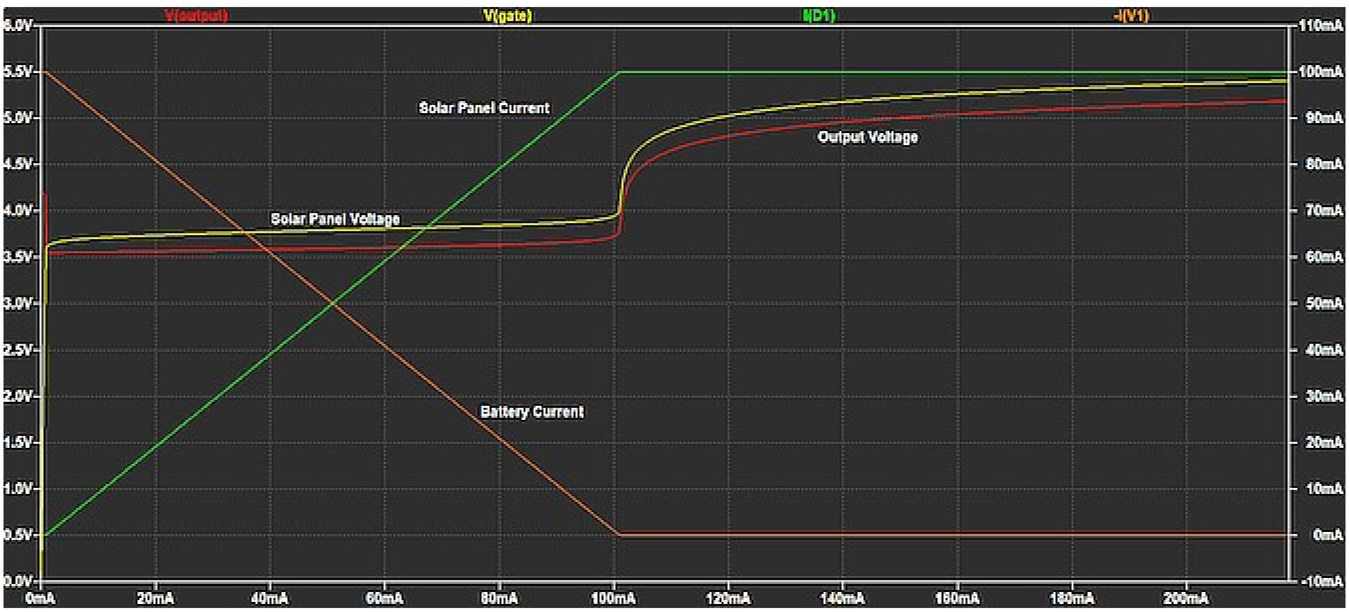
The load sharing circuit works with a standard 5V power input (USB or equivalent) because that power is either connected and supplying 5V with enough current to charge the battery and power the load, or it is completely absent. There's no in-between. The mosfet is either on or off, and no charging current is ever used to power the load.

In the video I suggested that this circuit should not be used with solar power because the input power could wander, and it was unclear what would happen with the mosfet at intermediate supply voltage and current levels. What's presented here is an LTspice simulation of the load sharing portion of the circuit when powered by a 5V solar panel. It shows what happens when the input current, which is proportional to solar illumination, is swept from zero to the panel's short circuit current in full sunlight. The model for the solar panel ("X1" in the schematic) was obtained from a Youtube video, with adjustments made to match a specific panel available from Digikey. All the LTspice files are included in the relevant folder above.

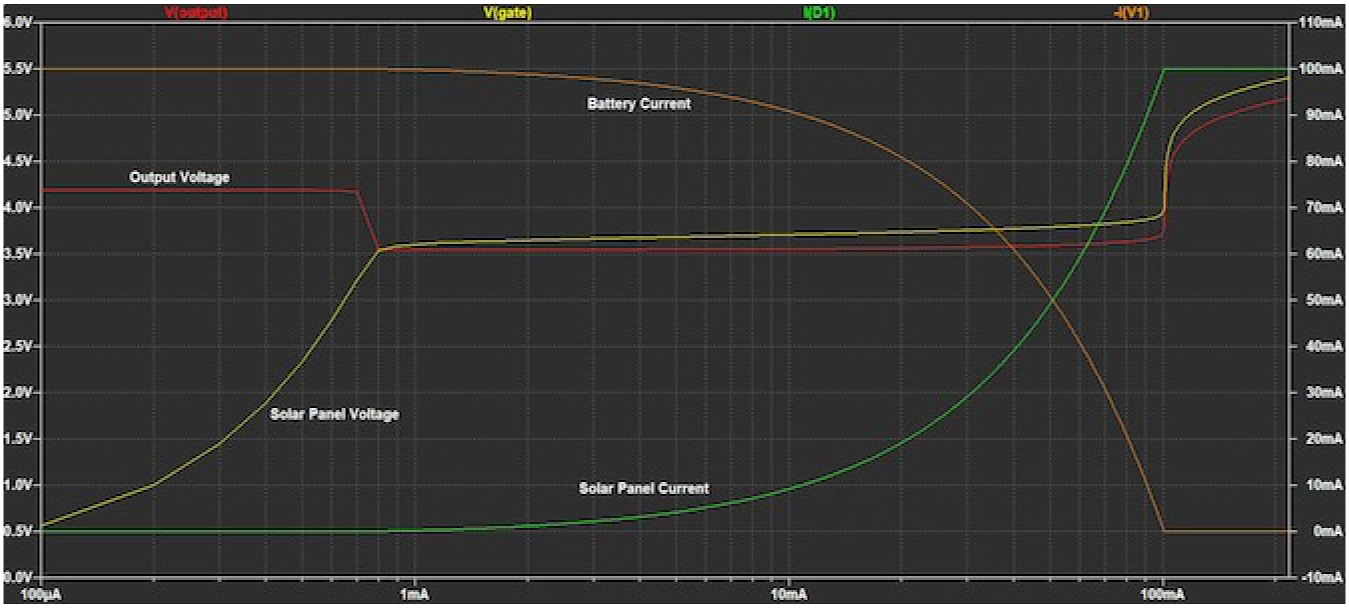
This is the schematic used. The charger is not included because I don't have a simulation available for the TP4056 charger. The battery is assumed to be fully charged at 4.2V, and the load current is fixed at roughly half the maximum short-circuit current of the panel.



And this is the DC sweep simulation with the illumination current on the X axis, and plots of the output voltage, solar panel voltage, battery current, and solar panel current:



Overall, the simulation shows that with increasing illumination the solar panel supplies more and more of the load current, and the battery supplies correspondingly less current. At the very far left, when illumination is near zero, the output voltage is 4.2V, which is the battery voltage with the mosfet fully turned on. The entire load current is provided by the battery. But as the solar panel even begins to supply current, the output voltage drops to about 3.5V. That happens because the mosfet switches off, and all of the battery current now passes through the mosfet's body diode. Looking at a logarithmic display of this same simulation, we can see more clearly what happens on the far left:



Remember that the solar panel voltage is also the mosfet's gate voltage, and the circuit output voltage is also the mosfet's source voltage. The 10K gate pulldown resistor current briefly delays the rise of the solar panel voltage. But when it gets closer to the output voltage, the Vgs threshold voltage (about 1V) is no longer met, and the mosfet shuts down. Battery current then passes through the body diode, which accounts for the 0.7V drop in output voltage.

This means that when the solar panel is providing any amount of current to the output, the mosfet will be turned off, and any current supplied by the battery will flow through the body diode. We know that must be true because if current is flowing from the panel through the Schottky diode, the diode's anode voltage must be 0.3V higher than its cathode voltage, and that means the mosfets gate voltage must be 0.3V higher than its source voltage, so the mosfet is forcefully turned off.

The bottom line is that for solar power this circuit is the same as a two-diode model - except at night. In total darkness, the mosfet turns on, and the diode voltage drop is prevented. But in daylight, it's just the Schottky and the body diode carrying the current. It would be up to the designer to decide whether the avoidance of the diode Vf drop at night is worth using the mosfet. It is unlikely to affect battery life because the biggest challenge to the battery would be in the morning when the battery voltage is at its lowest and partial illumination reimposes the Vf drop before it's bright enough to begin charging. The 0.7V drop would be a major challenge to battery life if a regulated 3.3V is ultimately needed.

A Small Modification

If avoiding the night time Vf drop is felt to be important, one should at least make the two-diode operation at all other times as efficient as possible. That can be done by installing another Schottky diode across the mosfet in parallel with the body diode. That effectively replaces the body diode with one which has a much lower Vf, so that the output voltage under partial illumination would be almost 1/2 volt higher. Shown below are the schematic and simulation of this version. The only difference is the lower voltage drop in partial illumination. Also, remember that the charger is not included here. One would need to make sure the TP4056 charger works properly with this circuit.