February 4, 2022

OpAmp Version Revisited

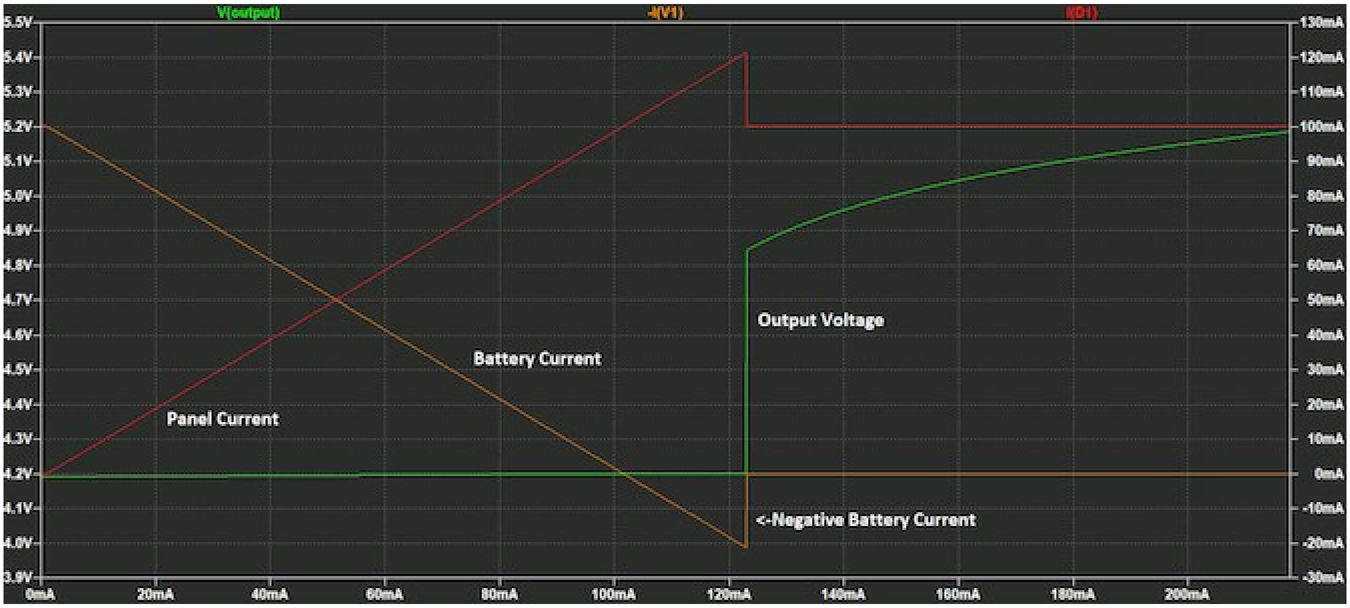
The original analysis of the opamp version was done without regard to the input offset voltage of the opamp. The input offset voltage may not make any difference if it is very small, or if it is negative. But if it is positive, and large enough, then there may be an issue.

A positive input offset voltage means that with the two inputs connected together, the output of the opamp is low. A positive voltage would have to be applied to the non-inverting input to get the output up to the midpoint of Vcc and Vss. Any individual copy of an opamp can have positive or negative input offset voltage, the maximum size of which is shown in the datasheet.

If the output of the opamp is low when the inputs are equal, then as illumination increases and the solar panel voltage begins to rise above the battery voltage, the opamp output will remain low, and the mosfet will still be turned on even though solar voltage is slightly higher than battery voltage.   As a result, reverse current will pass from the solar panel back through the mosfet to the battery, which is something generally to be avoided, particularly if the battery is already fully charged. As solar illumination increases further, the solar panel will supply increasing current to the battery at the same voltage until the mosfet's Rds(on) resistance causes enough voltage drop to overcome the input offset voltage, and the opamp output will snap high, turning off the mosfet.

This effect is shown in the simulation on the following page. With increasing illumination, the solar panel provides an increasing percentage of the load current. It should switch over completely when the battery current reaches zero. But instead the panel provides additional current over and above the load current, and that extra current flows back through the mosfet into the battery. The battery current is negative. Then as the reverse current continues to rise, Rds(on) eventually causes enough voltage drop across the mosfet that the input offset voltage is overcome, and everything snaps back to where it should be - the mosfet turns off, and the battery is isolated.

This glitch will not occur if the opamp has a negative input offsset voltage (the opamp output is high if the inputs are equal). It only occurs just at the point when the panel starts providing all of the load current, and the load voltage just begins to rise above the battery voltage. So this will not happen in low light or full sunlight, but rather at some intermediate illumination level which is not likely to be fixed for any significant period of time. The physical test circuit had this problem because the input offset voltage of the selected opamp was 0.8mV, but was not even noticed until specifically tested for. However, the MCP6041 can have input offset voltage as high as 3mV, and in the worst case of a 3mV positive input offset voltage on any individual copy of that part, reverse current could be substantial. So it is necessary to change the circuit to mitigate the problem.



One solution is to add some negative feedback into the circuit by adding two resistors. This solved the problem in the physical test circuit using the opamp with +0.8mV input offset voltage, and in simulation it works for +/-3mV input offset voltage.