MPPT Summary

The maximum power point tracker (MPPT) is NOT a DC-DC converter; it is actually a very special kind of charge controller. It compares 50% of the thermoelectric generator (TEG) open circuit voltage to the actual TEG voltage. These are then fed into a comparator and the result is used to switch the switching FET in a boost converter. This boost converter is NOT being used as a boost converter in the traditional sense but rather as an electronic load. The purpose is to apply the optimum load to the TEG and thus draw out the maximum power. The stability of the system is completely reliant on the output stage. In this circuit it is a buck converter, which steps down the output voltage from the boost converter to that required to charge the battery.

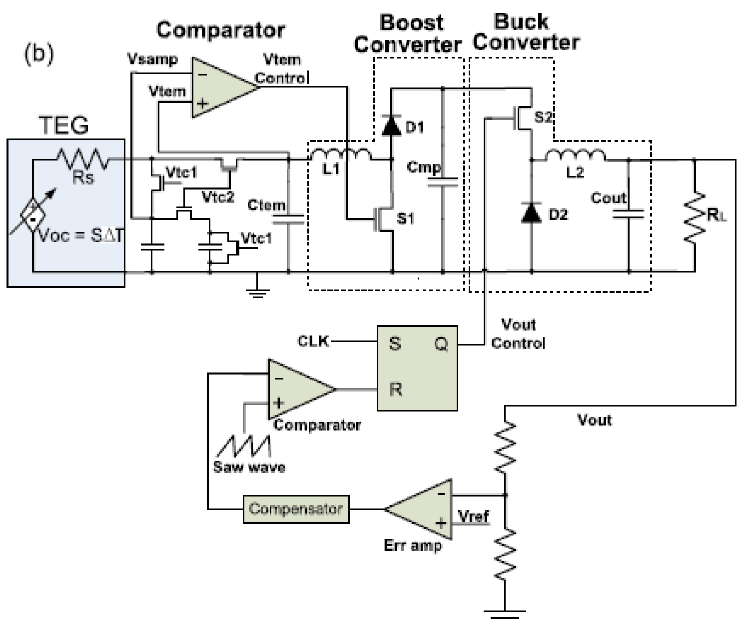

Figure 1: The schematic used by the design in the paper.

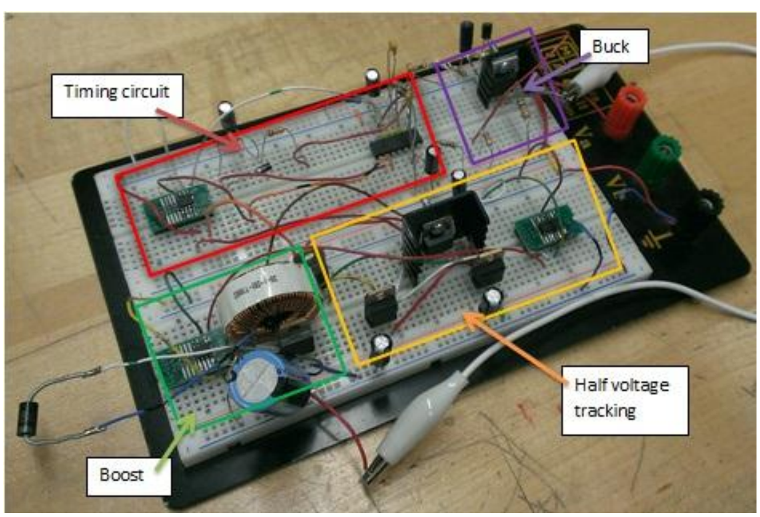

Figure 2: MPPT prototype

While we never got the whole MPPT system operating over the required input range, we did experience some success with the circuit for a limited range of loads/input voltages. The network of FETs in the front end work perfect as designed. The entire mppt prototype should be available to test/analyze (Probably stored in Dr. Stevens Lab). The main purpose of the FET network is to divide the open circuit TEG voltage by half and then compare it to the current TEG voltage. The open circuit voltage is the key for maximum power transfer to occur; the TEG should operate at exactly half its open circuit voltage. The ½ voltage is tracked by the two caps at the bottom of the circuit. When one of the time pulses fires, it charges up the first cap to full open circuit voltage. Then with the next time pulse, that voltage is divided by two to the other cap. Make sure that all of the caps in this circuit are the same value or this will not work at all. Also make sure there is a small dead time between signal pulses. If both pulses are high at the same time the TEG is will be shorted to ground.

For the timing circuits, V_{TC1} and V_{TC2}, I use a 555 timer with a clock around 1.5Hz, and around an 8% duty cycle. There should be a spreadsheet called "mppt timer.xlxs" which shows the required resistor values needed to achieve these values. This then goes into a delay network to create the "dead" time so the FETs are not switching at the same time, and thus create a short circuit situation. This is the schematic for the delay portion:

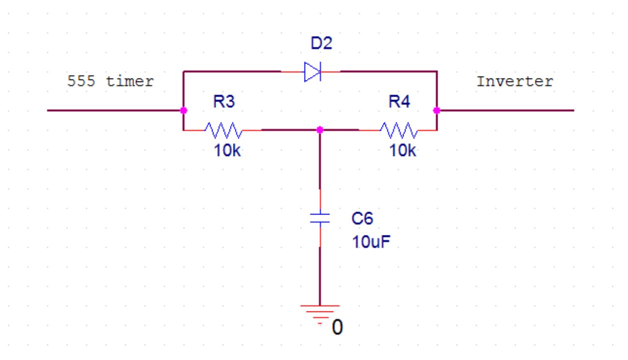

Figure 3: The delay network to create dead time.

You can adjust the dead time easily by altering the R and C values. From this delay circuit, we go into another 555 timer, set to monostable mode, to generate V_{TC2}. Both of these lines, the output from the 555 timer(V_{TC1}) and the output from the CMOS inverter (V_{TC2}) feed into the correct FETs above. Gate drivers were required in order to boost the signal voltage high enough to switch the FETS. Alternatively P-channel FETS could be used so they could just be pulled down to ground. Note that on the mppt prototype both of these 555 timer circuits come from the 556 dual package. The resulting timing signals are shown in Figure 4.

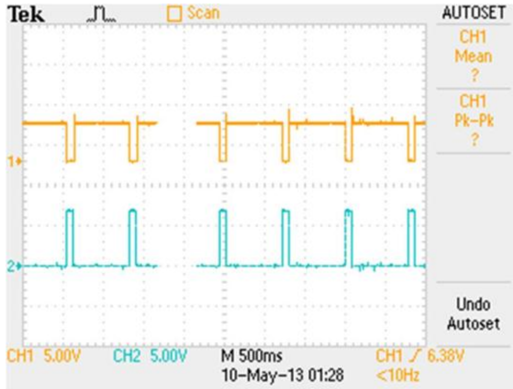

Figure 4: Vtc2 (Top), Vtc1(bottom)

Now we come to the tricky part of this system which gave us the most trouble: the comparator and boost converter. Our first approach to this problem stemmed from a deep misunderstanding of how the MPPT works with the comparator. Our first approach was to ditch the comparator all together and just stick a premade TI boost converter after the FET circuit. Sadly, this doesn't work. For the MPPT to actually function, the boost converter needs to fire based on the output form the comparator. When the actual TEG voltage is above the ½ open voltage, the comparator fires and allows for more current to be drawn, thus lowering the TEG voltage.

You should speak with Dr. Hoople when it comes to boost converter design; he is the power electronics expert. This design will prove more complicated due to the variable input voltage (from the TEG) as well as the varying switching frequency (from the comparator). These result in a constantly varying output voltage from the boost converter. The best you can hope to do is design the inductor and load resistor to boost above the required final battery charge voltage over the entire range of input conditions. We found the best method to accomplish this was through trial and error. A 1mH inductor (rated for high current ~2A) was chosen and it saw boost output of 27-32V given a 6 V TEG input voltage.

The final portion of the mppt circuit is the buck converter. Its purpose is simply to step down the boosted voltage to a constant value that can be used to power the load. We used an LM 317 because it is able to step down voltages from up to 45 V. By attaching a heat sink to the device we can push this limit even a little bit further. The advantage of using a store bough buck converter over designing your own is you don't need to worry about the feedback system required t control the bucks switching frequency.

So in short:

1. Read the Analog MPPT design paper!
2. Understand this paper, we're basically copying the design and adjusting the specification to meet was is required for our specific TEG device
3. The FET network/timing circuit works great as is, play with it to get a further understanding

4. MAKE SURE YOU UNDERSTAND HOW THIS CIRCUIT ACTUALLY WORKS!!! (this was my biggest killer, I waited way too long to do this)
5. Focus on the comparator/boost converter. Make sure it operates over a wide input range.
6. Read the final technical paper. We further summarize the expected and actually mppt operation as well as provide suggestions for future improvements and different directions you may wish to take.

Good Luck!