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Power Supply Design Using Environmental Scavenged Energy

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Problem

Thermoelectric devices (commonly known as Peltier devices) can be used to generate electricity through a temperature differential. At their optimum efficiency, the output voltage from a thermoelectric generator (depending upon its geometry and temperature gradient though it) is usually too low for microprocessors and other electronics to operate on directly.

Design Restraints

- Design a boost circuit to reach an output Voltage of 3.3 Volts to be used by a microcontroller system.
- Utilize the max efficiency of the Thermoelectric at 1V with 10mA output, and maintain a 90% dc to dc conversion efficiency.
- Circuit Loads vary and at times draw 10's of mA from the output of the power supply.

Solutions

Boost Converter

The boost converter in Fig. 1 is a 2 cycle converter. The first cycle grounds the inductor causing a current to flow through it. In the second cycle the path to ground is opened causing the current stored in the inductor to flow to output capacitor. This allows the output capacitor to reach voltages higher than the supply.

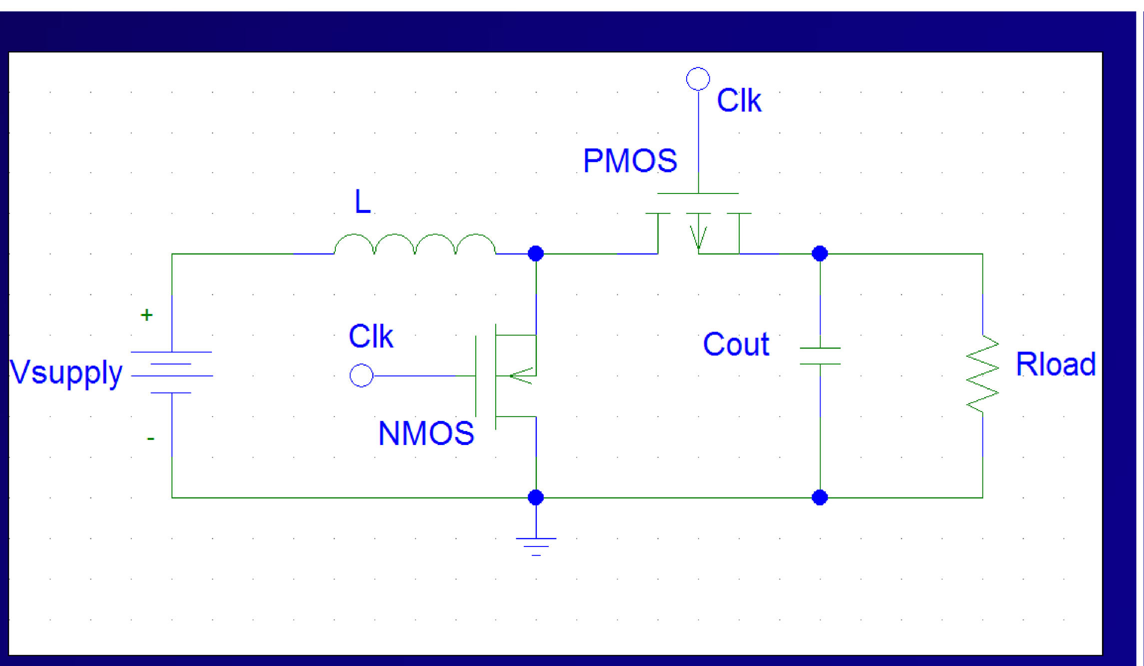

Fig. 1: Simple Boost Converter Circuit

Pros

- By adjusting duty cycle, can optimize to the peak efficiency of the Thermoelectric device.
- Low Part count.

Cons

- Using the duty cycle to draw 10mA of current for the thermoelectric, isn't necessarily the most efficient duty cycle for the boost circuit.
- Requires some feedback for over voltage protection on the output.

Charge Pump

The charge pump in Fig. 2 is also a 2 cycle converter. The first cycle stores a charge equal to Vsupply on the storage capacitor. In the second cycle it stacks the storage capacitor on top of the supply, which leave you with a voltage of Vsupply*2 across Cout.

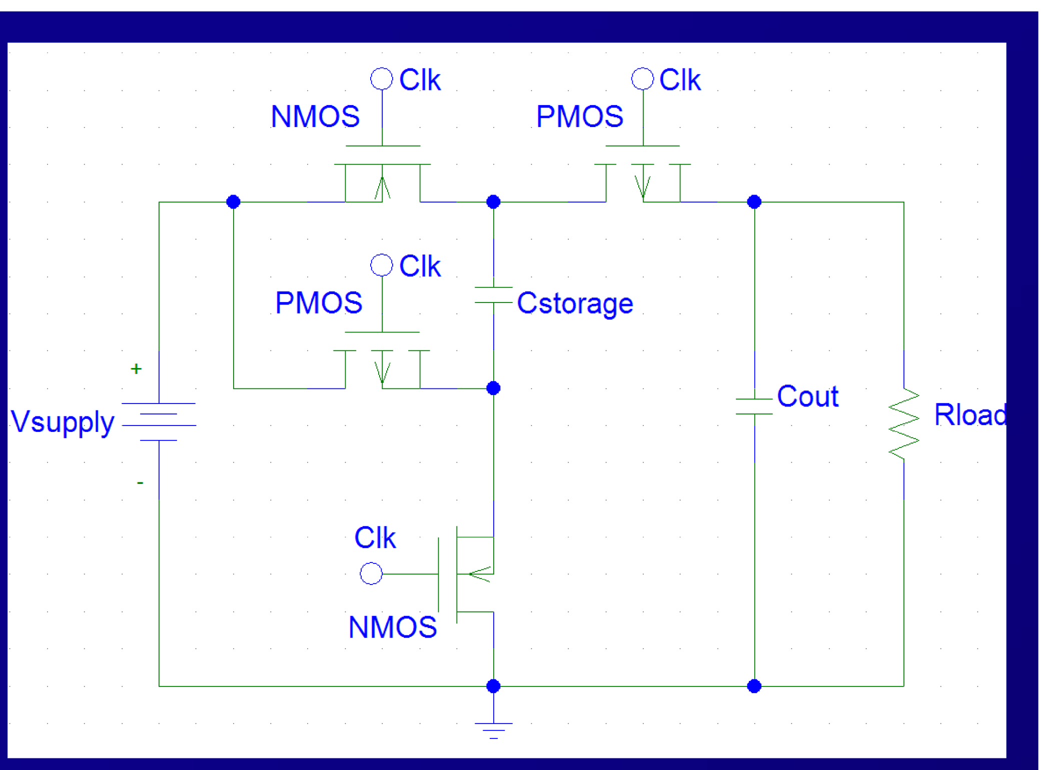

Fig. 2: Basic Charge Pump Circuit

Pros

- Low clock frequency can be used to minimize switching loses.
- No over voltage protection required since output will always be a predictable multiple of Vsupply.

Cons

- The current the capacitors draw vary based on the load and output voltage. Under light loads, as all the capacitors reach their highest potential, their current draw falls below the peak efficiency of the Thermoelectric generator.
- To reach voltages higher than Vsupply*2, more stages are required, which means a higher part count, and more losses in switching.

Simulation and Design

Orcad's Capture program was used for the design and simulations. Capture is a great program for doing simulations that prove that circuits work, but we were having trouble getting accurate efficiency readings from the program. The main issue was that the models being used didn't reflect the real life properties of the parts that were being used in our test circuits. We came to the conclusion that it would be easier to build the designs and test them for ourselves. This is faster and more accurate than having to test the parts and enter the information to into the computer model. The outputs we obtained are in Figure 3, they show that our designs are functional.

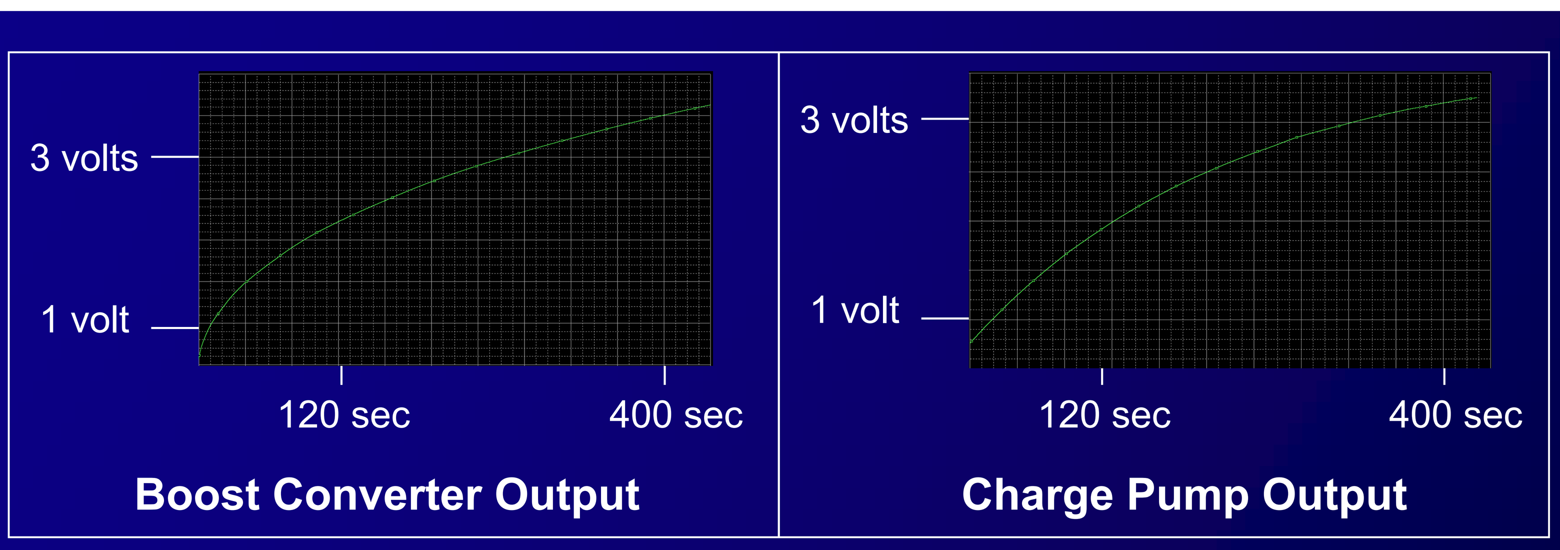

Fig. 3: These are the simulated output voltages two designs. The wave-forms are similar but the efficiency characteristics differ.

Hardware and Future

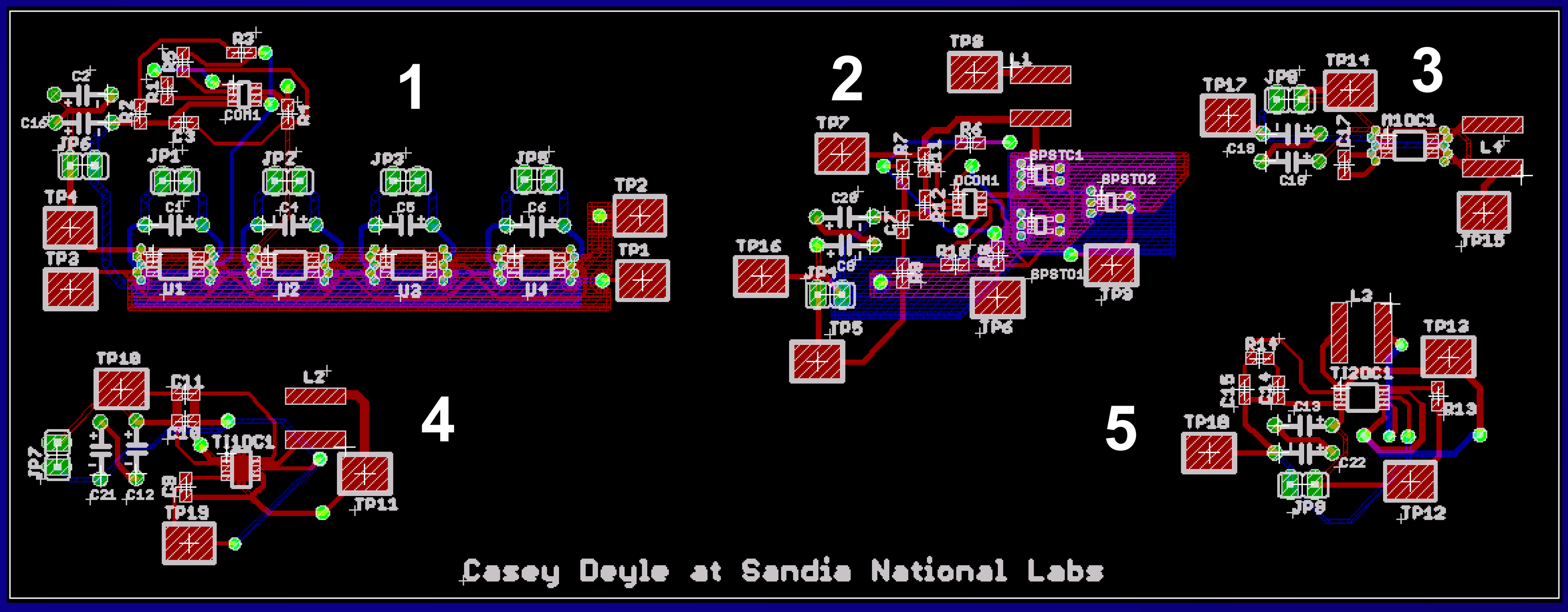

Fig. 4: The layout of the PCB design made in Eagle.

The layout of the printed circuit board (PCB) was done in a program called Eagle (free version available at http://www.cadsoftusa.com/). There is a total of 5 independent circuit printed on the board (Fig.4 to left): circuit 1 is the charge pump design, circuit 2 is the boost converter design, and 3-5 are the chip solutions made by Texas Instruments and Maxim IC.

Once the PCBs are received they will be loaded and the efficiencies of the designs and standalone chips can be tested. The most promising design will need a new board made so the values can be adjusted to better suit the load of microcontroller system that it will be powering.

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