

# **ECE 214 – Electrical Circuits Lab**

## **Lecture 8**

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# Announcements

- Remember, I am out of town on Tuesday. Lecture will be at 8am on Thursday.



# Lab #8 – Boost Converters



# Final Lab Sequence

- Lab#8 through Lab#10 are part of a sequence that will end with a circuit that can convert 9V to 45V DC.
- You will write up these three labs into a final report. The content will be covered in both ECE214 and ECP214.
- The final report will be due on May 1st 2015.

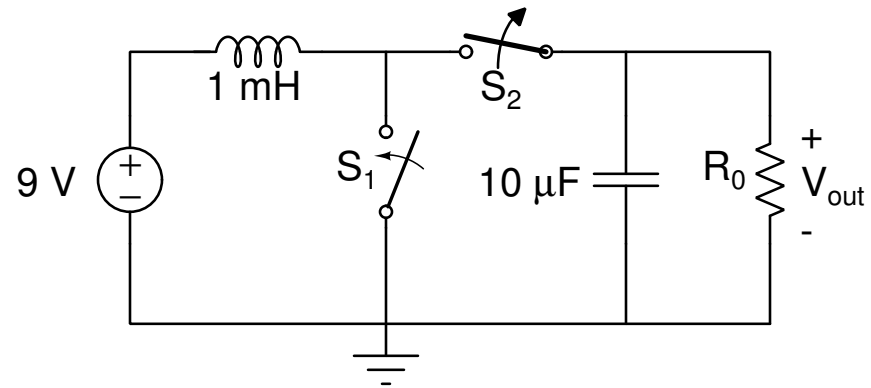


# Boost Converter Uses

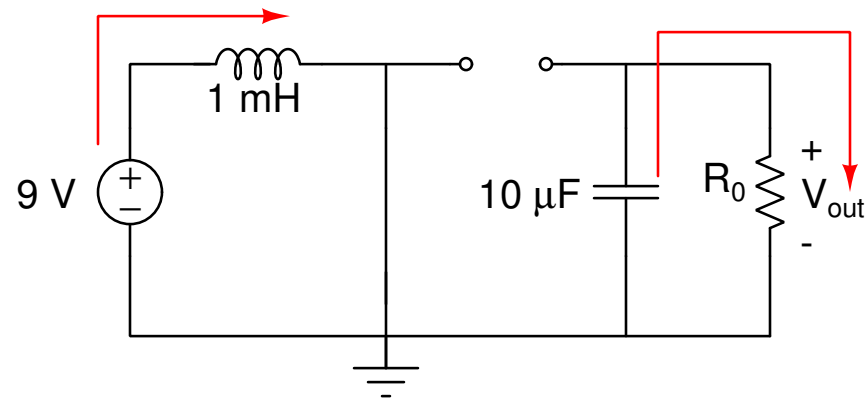
- High voltage supplies for things like electric cars (that need 500V DC for motors)
- LEDs often need at least 3V or so, but you might want to use a single 1.5V AA battery to light it.
- Old-style CFL laptop backlights needed high DC voltage
- “Joule Thief” – get last bit of energy from batteries that have discharged to low voltages



# Switch Boost Circuit



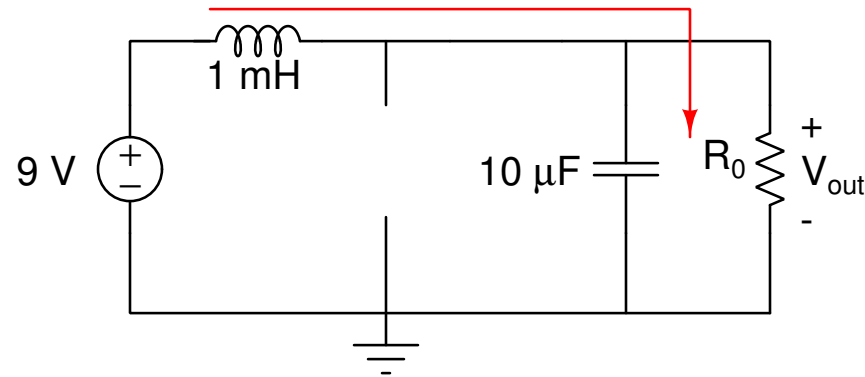
# Switch Boost Circuit – S1 closed/S2 open



- Inductor charges
- Capacitor discharges through resistor



# Switch Boost Circuit – S1 open/S2 closed

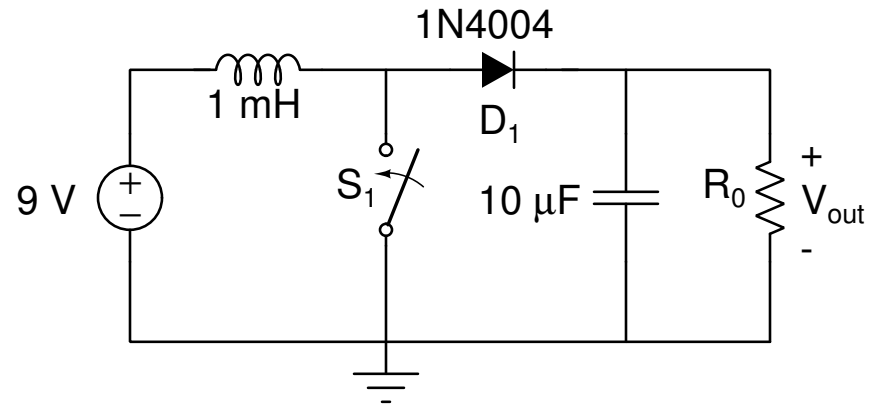


- Inductor tries to maintain current through higher impedance, voltage in series with source, charges the capacitor.





# Diode Boost Circuit



- Diode is one-way, can replace one of the switches.



# Pre-Lab

The pre-lab is extensive, you probably want to start early.

1. Calculate energy in the capacitor when drops from 20V to 19.9V

$$\text{Potential energy } U_C = \frac{1}{2}CV^2.$$

2. Calculate  $t_1$ , the time it takes the inductor to absorb the energy from last step

$$\text{Energy across inductor } E = \frac{1}{2}L(i(t))^2$$

$$\text{where } i(t) = \frac{V}{R}(1 - e^{-\frac{R}{L}t}).$$



3. What is the maximum current through the inductor before switch S1 opens?

It likely happens at  $t_1$

$$i(t) = I_{final}(1 - e^{-\frac{R}{L}t}).$$

Plug in the values.  $I_{final}$  can be calculated by Ohms law ( $I = \frac{V}{R}$ ).

4. What value of  $R_0$  is required so the capacitor drops from 20V to 19.9V in  $t_1$ ?

Decay in an RC circuit

$$V(t) = V_0 e^{-\frac{t}{RC}}$$



5. How much energy is lost in  $R_0$  when switch  $S_1$  is closed?
6. Approximate  $t_2$ , the time it takes for current to stop flowing from inductor after  $S_1$  is open.

Remember the voltage drop across diode.

There are various ways to calculate this. Note that it's very similar to the RLC circuit from last lab.

Time constants can also be used.

$$\text{At end of on, } I = \frac{1}{L} \int_0^{t_1} V_i dt = \frac{t_1}{L} V_i$$

If we assume capacitor voltage doesn't drop and ignore voltage drop of diode:

$$\text{At end of off, } I = \int_{t_1}^T \frac{(V_i - V_o) dt}{L} = \frac{(V_i - V_o)(T - t_1)}{L}$$



Put this with energy equation, and the duty cycle can be estimated as:  $D = 1 - \frac{V_i}{V_o}$

7. The period of the square wave  $T$  ( $t_1+t_2$ )

8. Using  $T$ ,  $V$ , and  $R_0$ , how much current can the boost-circuit deliver?

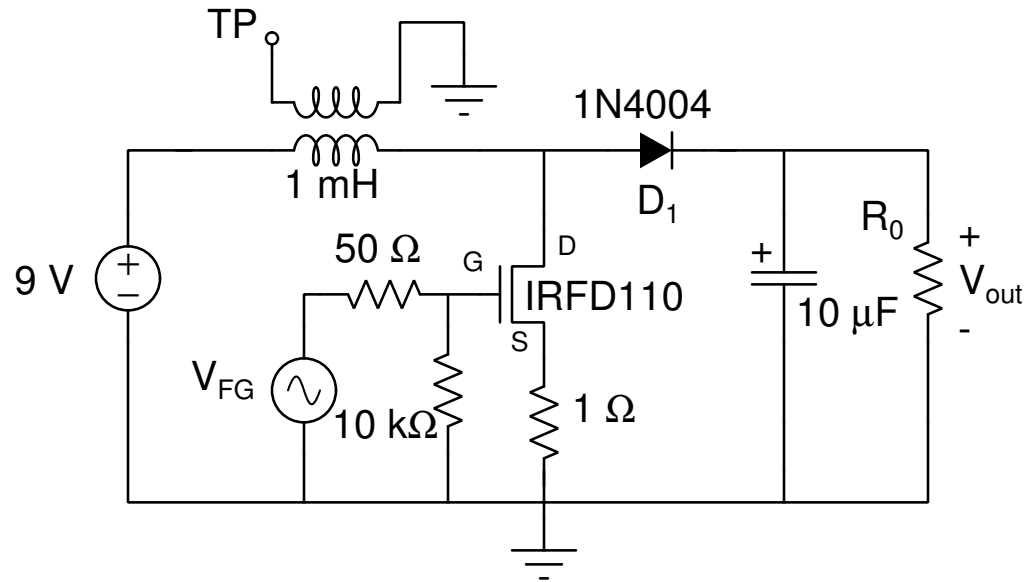
Ohms law

9. How much power must the resistor bank absorb?

$$P = i^2 R$$



# Boost Circuit to Build



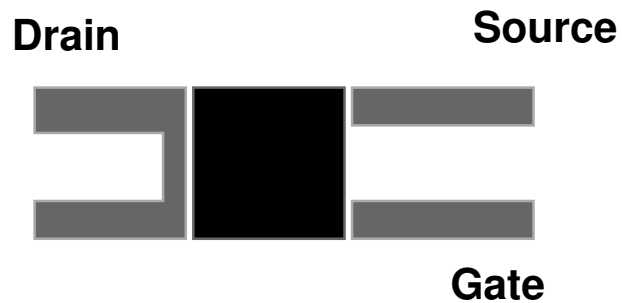
- No need for you and lab partner to be frantically pushing switches.
- MOSFET acts as the switch, driven by a square wave.



# Lab Notes

- Leave room on your breadboard (and do not disassemble at the end of lab) as Lab#9 and Lab#10 will build on this one.
- 10uF electrolytic capacitor. These are polarized! The stripe (and short lead) indicate the negative terminal.
- MOSFET pinout. Not your typical transistor. Data sheet is on the course website on the references page.





- Creating non-symmetric square waves:  
Find the frequency for the overall period  $T$ .  
Then calculate the duty cycle (how long it is high)  $\frac{t_1}{T}$   
Then press Shift - %Duty to set the duty cycle in percent.
- Resistor bank. The resistors in the lab are 1/4 Watt resistors, so if the power you are absorbing is more than that then you will need to put resistors in parallel.





Remember that  $\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_N}$

- You don't want the current across the MOSFET to get too high. Why? MOSFET and Inductor reasons. How can you measure current on the scope? Use Ohm's law. The voltage across a  $1\Omega$  resistor is the same as the current.
- Your signal might be noisy. Look at average voltage on the signals. You can (probably) ignore the spikes.
- Winding some magnet wire around the inductor to turn



it into a transformer. Measure the signal across.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

Where s is secondary and p is primary and N is the number of turns.



# Post-Lab

- None, but for Lab#10 you will have to chain a second boost circuit with this one to get 45V output so you can look into those calculations if you have time.

