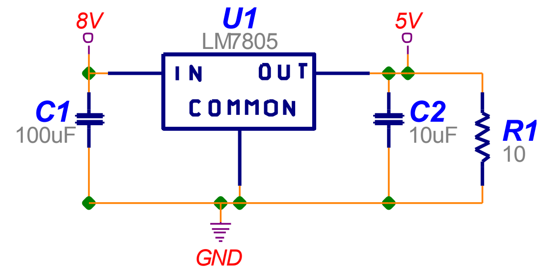
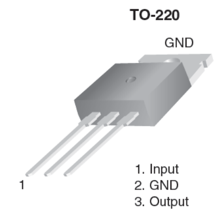
PHY 483/683 Midterm Oct. 18, 2018

Name ___________________________________

Show your work!



1) Given the voltage regulator circuit on the right:
a) (5 pts) How much power is dissipated in the 5V regulator?
Load current = 5V/10Ω = 0.5A
P = V*I = (8V-5V)0.5A = 1.5W



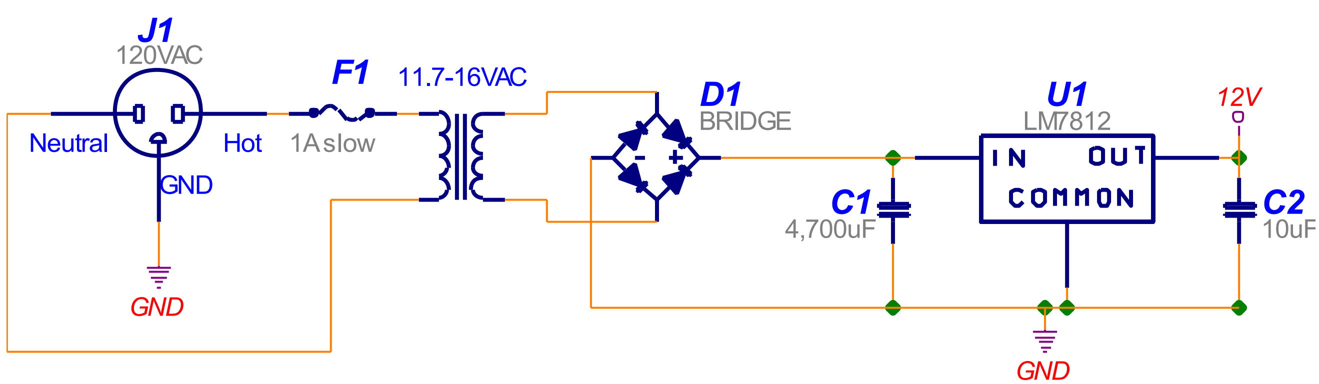
b) (5 pts) How far above ambient will the regulator junction be if no heatsink is used? The LM7805 has a thermal resistance of **6°C/W** junction to case & **54°C/W** case to ambient.

ΔT = Power * Thermal resistance = 1.5W(6°C/W + 54°C/W) = 90°C

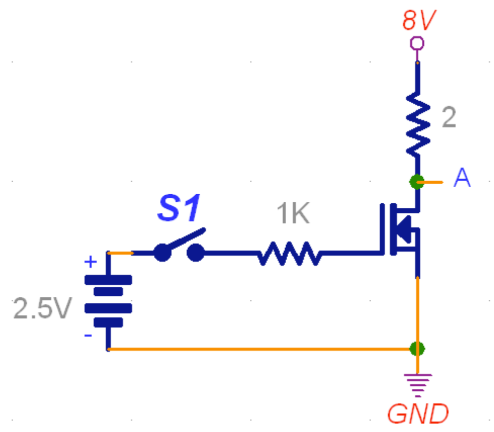
c) (5 pts) How hot will the regulator junction be if this heatsink is attached properly to the regulator? The thermal resistance of the heatsink is 3**0°C/W**. You can assume the ambient temperature is **25°C**.

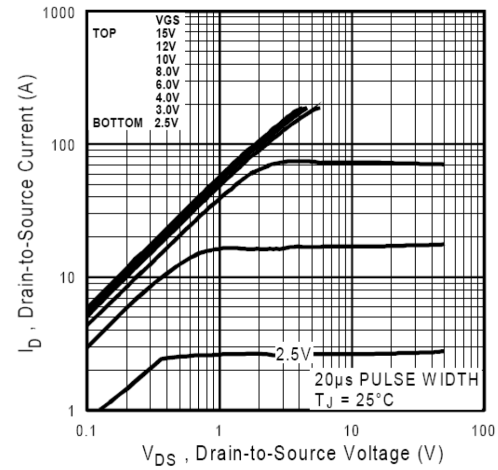
ΔT = Power * Thermal resistance = 1.5W(6°C/W + 30°C/W) = 54°C
T = 25°C + 54°C = 79C

2) (25 pts) Design a **12V** power supply that can provide up to **0.6A** of current (it isn't current limited, just guaranteed to work when you draw ≤0.5A). The input is **120VAC (60Hz wall power)**. You can assume each diode in the bridge rectifier drops **0.75V**. Limit the ripple on C1 to **0.8V**. You're told that the voltage regulator can't dissipate more than **4W** because of heatsink size constraints. **Draw a complete schematic.** Also calculate the maximum and minimum **transformer output voltage** that will work in your design. Show all calculations!



The ripple on C1 is 0.8V, C = (I*ΔT)/ ΔV = (0.6A*8.3ms)/0.8V = 6,200uF so round up to **6,800uF**
Min XFMR voltage, 12V + 2V regulator dropout + 0.8V ripple + 1.5V bridge= 16.3Vpeak = **11.5VAC**
With 11.5VAC transformer, Avg Vin to regulator is 14.4 (12V + 2V dropout + half the ripple voltage)
Power dissipated in regulator with 11.5VAC transformer = (14.4V-12V)0.6A = **1.44W** (<4W so OK)
4W in regulator would be 6.7V*0.6A so Vin Avg = 12V + 6.7V = 18.7V
18.7V + 0.4V (half the ripple voltage) + 1.5V bridge = 20.6V peak = **14.6VAC** Max XFMR for **4W**.





3) a) (5 pts) Given the Id vs. Vds graph above and the circuit shown, estimate the voltage at A about one second after S1 is closed (i.e. shorted).

The bottom trace on the graph shows with Vgs = 2.5V the maximum current is 2.5-3A.
At 2.5-3A the voltage drop across the two ohm resistor will be 5-6V making the voltage at A 2-3V.
If you wanted to be more accurate you could look at the graph with Vds 2-3V, Id ~ 2.7A. The voltage at A would be about 8V – (2.7A*2 ohms) = 2.6V. Anything around 2-3V is OK.

b) (5 pts) What is the voltage at A about one second after S1 is opened (i.e. no connection)?

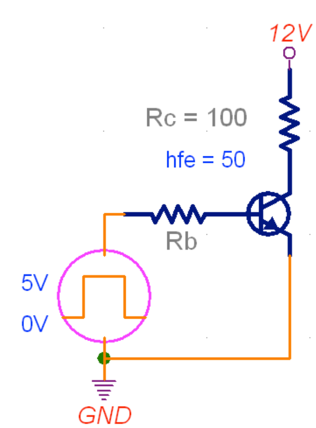
The voltage at A would still be about 2.6V. The gate capacitance is still charged and therefore the FET will still conduct as before until the charge on the gate slowly dissipates. This could take minutes or more for the FET used in class.

In both circuits the switches are first closed and the relays are energized.

4) (5 pts) Both switches are opened at the same time. In which circuit will the relay open first (A or B)?

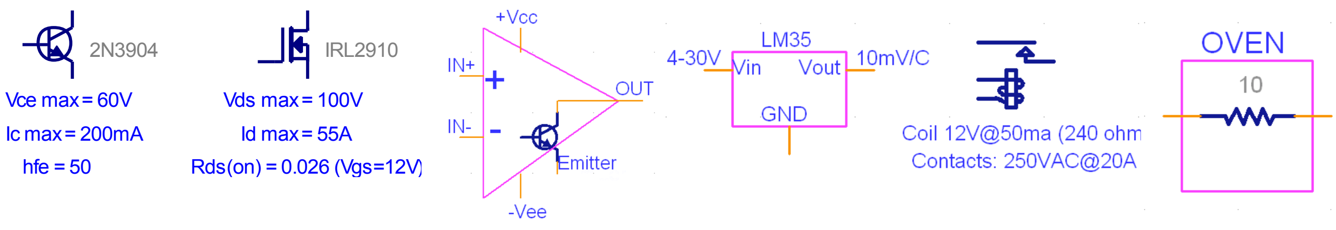
The relay in circuit B will open first. The diode in circuit A will allow the current to continue to circulate for a while after the switch is open.

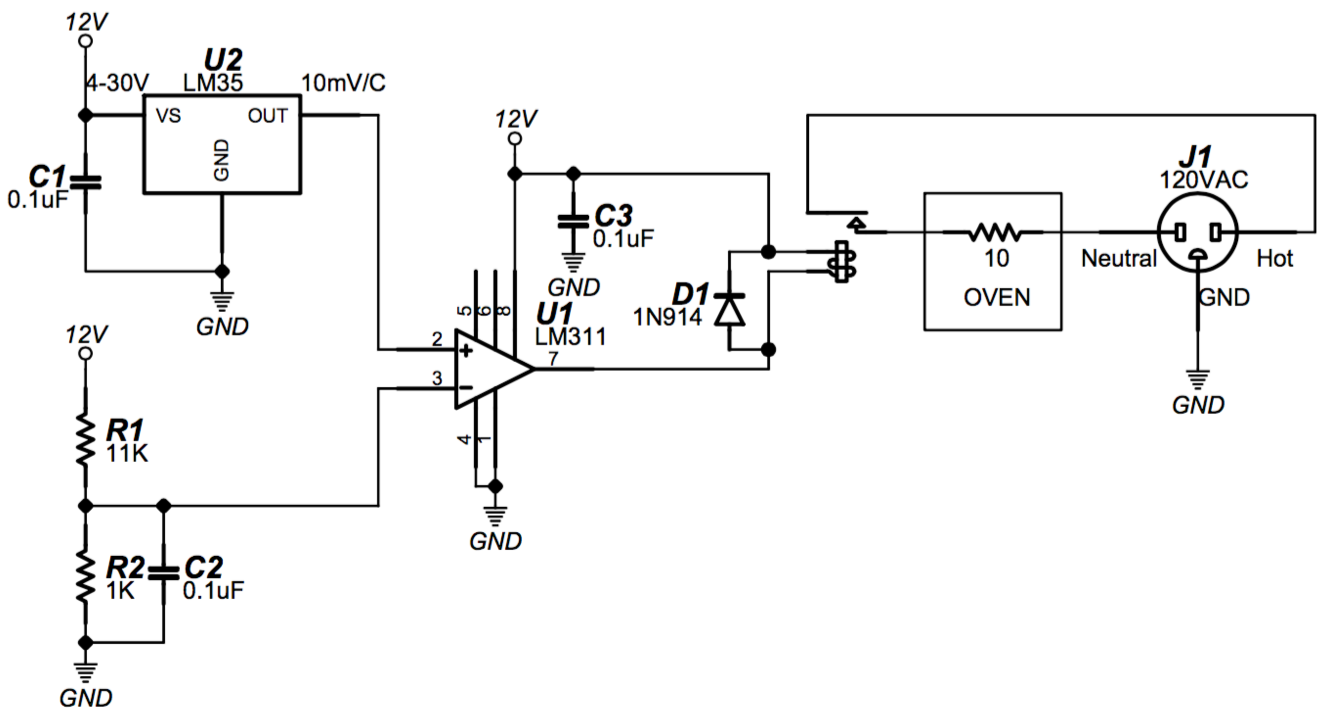
5) (5 pts) What is the minimum base current required to ensure the transistor turns on fully (i.e. is saturated) when the input is high (at 5V)?



When saturated Vce is about 0.2V,
Ic = (12 – 0.2V) / Rc,
Ic =12V/100 =120mA
Min Ib for saturation = Ic/hfe = 120mA/50 = 2.4mA

6) (35pts) Design a temperature controller for the oven using any of the items shown below (**and as many resistors, capacitors, and diodes as needed**). The oven should maintain **100C**. You have a **12VDC power supply** to use in your design. The 10Ω heating element should be powered from 120VAC wall power. Don't worry about adding hysteresis. **Draw a complete schematic** showing all power and ground connections and **use decoupling caps** where appropriate. Note: **The LM311 can sink a maximum of 100mA**. **Show all calculations!**



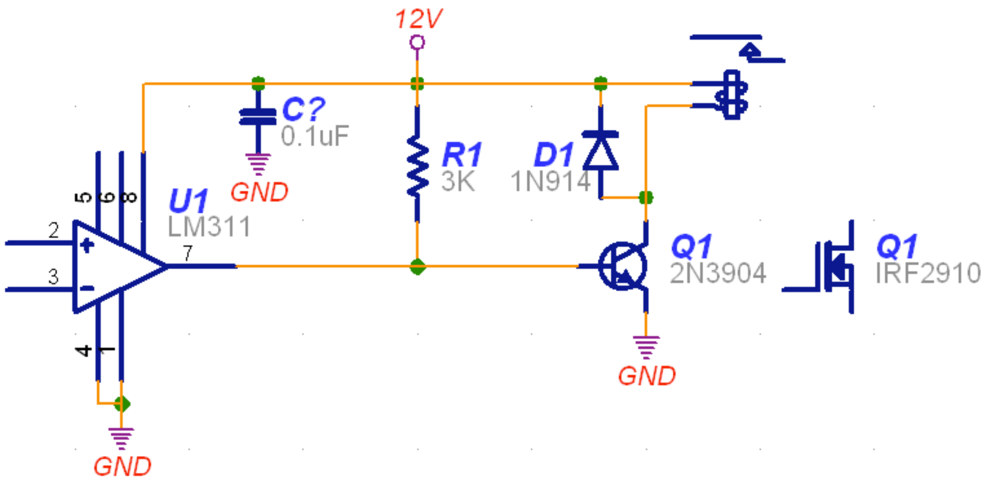


You're told the relay needs 50mA and the LM311 can sink 100mA so the easy way is to connect the relay to the output of the LM311. The relay will turn on when the output is low (i.e. when V- > V+). When the set point (V-) is greater than the current temp (V+) the heater will come on.

D1 protects the circuit from the high voltage spike the relay inductance will generate when current is abruptly switched off.

The oven should be kept at 100C. 10mV/C * 100C = 1V.
Vset = 12V * 1K/(11K + 1K) = 1V

C1 & C3 provide power supply decoupling (i.e. smooth out the 12V supply)
Similarly C2 limits the response time for the setpoint. This is a low pass filter, which shorts high frequency noise to ground.



Alternately you could use a pullup resistor on the output of the comparator to drive a transistor or FET. Now the relay will turn on the heater when the comparator output is high (i.e. when V+ > V-) so **the set point voltage should go to V+ and LM35 output to V-**.

Transistor:
The coil draws 50mA at 12V so IC would be 50mA. Ib min = IC/hfe = 50mA/50 = 1mA.
For safety we'll use 3mA as the base current.
R1 = (12V – 0.7V)/3mA = 3.8K ohms. I used 3K ohms above for even more safety margin.

FET:
The FET input is like a capacitor, not drawing any current when charged. R1 could be almost any value from 1K to 10M. Note: The larger R1 the longer it will take to turn on the FET (RC time constant where R is R1 and C is about 3nF for the FET used in class). When the comparator goes low it will discharge the gate capacitance quickly (current doesn't have to go through R1) turning the FET off quickly.