Homework #5 Solution (Power Supply)  Due Mon, 10/8/07

Design a linear power supply that will provide 5V at up to 0.75A from a 120VAC input (wall power). Use a **LM7805 (TO-220 package)** voltage regulator in your design. Label capacitor values and provide Digikey part #s for the transformer and bridge rectifier. Calculate the ripple voltage on the filter cap and show there is sufficient headroom for the voltage regulator to operate. Don't forget about the full wave rectifier voltage drop (the current flows through two diodes so double the individual diode drop).

Calculate the power dissipated in the voltage regulator when at full load (i.e. 0.75A). Calculate the temperature of the voltage regulator die if the ambient temp is 25°C. Page four of the datasheet lists the thermal resistance of the TO-220 package (T) is typically **5°C/W junction to case and 65°C/W case to ambient**.

Do you need a heatsink to keep the voltage regulator die temperature below its maximum value? Note: Page three of the datasheet lists the maximum Junction Temperature of the T Package as 125°C.

How large of a heatsink would be needed to keep the die temperature below 50°C (assume an ambient temperature of 25°C)?

**Solution:**

The regulator needs 2V of headroom so you need a minimum of 7V at the input to the regulator. Assume there will be about 1V of ripple on the caps so you need a minimum of 8V on the filter cap (so the minimum voltage doesn't fall below 7V). The bridge rectifier will drop about 1.5V (two diodes at about 0.75V each). Therefore the input to the bridge rectifier needs to be greater than 8V + 1.5V = 9.5V peak. Lets say we need greater than 10V peak at the input to the bridge so we have a little safety margin. 10V peak = 7.1VAC (rms).

The transformer needs to be rated at >7.1VAC@>0.75A (should have a safety margin on the current as well).

I found the following transformer from digikey: **595-1008 (14A-10R-16)**
The secondaries are: 16V@0.62A in series & **8V@1.25A** in parallel.
I picked a standard 4 pin dip bridge: **DF01M**. It's rated at 100V reverse voltage and 1.5A forward current. It drops about **0.9V** across each diode at 0.75A (a bit more than the 1.5V assumed so we lost about 0.3V of safety margin).

http://www.signaltransformer.com/sites/all/pdf/14A.pdf
https://www.fairchildsemi.com/datasheets/DF/DF005M.pdf

To keep the ripple to less than one volt at 0.75A means the capacitor has to be **C = 0.75A(8.33ms)/1V = 6,250uF**. I'll use a **10,000uF** cap to be safe. Note: The ripple should be well below 1V so we'll get back the 0.3V of safety margin lost on the rectifier. The final circuit is shown below:

Note: The primary windings are wired in parallel since we're using 120VAC and not the European 240VAC. The secondary windings are wired in parallel for more current at a lower voltage (8VAC@1.25A instead of 16VAC@0.62A). The parts used have a safety margin for both voltage and current.
Voltage calculations: $8\text{VAC(rms)} = 11.3\text{V peak} - 1.8\text{V diode} - 0.625\text{V ripple} = 8.9\text{V}$ (well above the 7V needed for the regulator to operate). I'll assume the average value of the input voltage to the regulator is in the middle of the ripple (i.e. $V_{\text{in}} = 8.9\text{V} + 0.31\text{V} = 9.21\text{V}$).

Power dissipated in the regulator is: $(V_{\text{in}} - V_{\text{out}}) \times I = (9.21\text{V} - 5\text{V}) \times 0.75\text{A} = 3.15\text{W}$.

Without a heatsink the temperature rise would be $(5^\circ\text{C/W} + 65^\circ\text{C/W}) \times 3.15\text{W} = 220^\circ\text{C}$

Since the maximum junction temperature is $125^\circ\text{C}$ this regulator would need a heatsink to work.

With an ambient temperature of $25^\circ\text{C}$ and a desired junction temperature of $50^\circ\text{C}$ there can only be a $25^\circ\text{C}$ rise due to the $3.15\text{W}$ being dissipated in the regulator.

$25^\circ\text{C} = (5^\circ\text{C/W} + \text{heatsink}^\circ\text{C/W}) \times 3.15\text{W}$

therefore the heatsink would need to be about $2.93^\circ\text{C/W}$ to limit the temperature rise to $25^\circ\text{C}$.

I ended up choosing this heatsink (HS380-ND). It has TO-220 mounting and is rated at $2.6^\circ\text{C/W}$.


When dissipating $3\text{W}$ it lists the temperature rise at about $14^\circ\text{C}$ (about a $29^\circ\text{C}$ rise at $3.15\text{W}$ including the $5^\circ\text{C/W}$ to the die. The datasheet lists it's thermal impedance at $1.6^\circ\text{C/W}@400\text{LFM}$(linear feet per minute, air flow). If a fan were added to provide $400\text{LFM}$ of air flow then the junction temp would be about:

$(5^\circ\text{C/W} + 1.6^\circ\text{C/W}) \times 3.15\text{W} = 21^\circ\text{C}$ above ambient (about where we wanted).

There was no reason to require such a low temperature ($50^\circ\text{C}$). This regulator will operate at much higher temperatures. The lifetime of the part goes up as the temperature goes down. The lifetime of the part doubles for every $10^\circ\text{C}$ drop in temperature.

Note: Newer, high power transistors & FETs, are much better at getting the heat out. Some have thermal resistances (junction to case) less than $1^\circ\text{C/W}$ (as compared to the $5^\circ\text{C/W}$ for the old LM7805).