# Homework #5 Solution (Power Supply)

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).

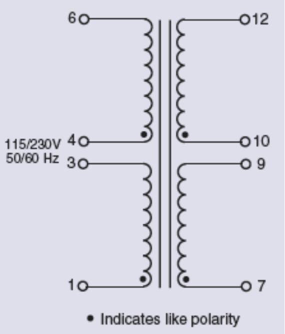
Calculate the power dissipated in the voltage regulator when at full load (i.e. 0.75A). Calculate the temperature of the voltage regulator die if the ambient temp is 25C. Page one of the datasheet lists the thermal resistance of the TO-220 package (T) is typically **5°C/W junction to case and 65°C/W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

Do you need a heatsink to keep the voltage regulator die temperature below its maximum value? Note: Page one of the datasheet lists the **maximum Junction Temperature of the T Package as 150°C**.

How large of a heatsink would be needed to keep the die temperature below 60C (assume an ambient temperature of 25C)?

## 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).

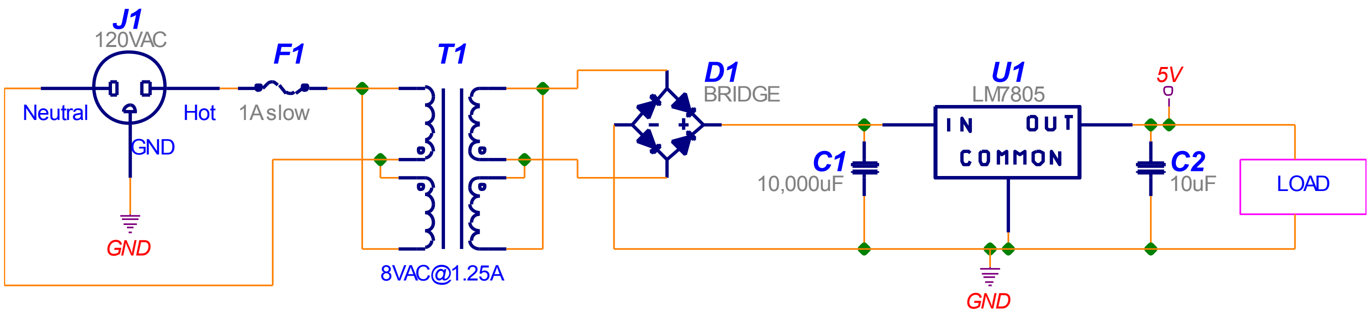


The transformer needs to be rated at >7.1VAC@>0.75A (should have a safety margin on the current as well).

I found the following transformer from digikey: 595-1008 (**14A-10R-16**)
The secondary's 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).
https://belfuse.com/resources/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 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: **8VAC(rms) = 11.3V peak – 1.8V diode – 0.625V ripple = 8.9V** (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. Vin = 8.9V + 0.31V = 9.21V).

Power dissipated in the regulator is: (Vin – Vout)* I = (9.21V-5V)*0.75A = **3.15W**.

Without a heatsink the temperature rise would be (5°C/W + 65°C/W) * 3.15W = 220°C
Since the maximum junction temperature is 150°C this regulator would need a heatsink to work.

With an ambient temperature of 25°C and a desired junction temperature of 60C there can only be a 35°C rise in the die temp due to the 3.15W being dissipated in the regulator.
35°C = (5°C/W + heatsink°C/W) * 3.15W
therefore the heatsink would need to be about < **6.1°C/W** to limit the temperature rise to 35C.

I ended up choosing this heatsink (6400BG). It has TO-220 mounting and at 3.15W the graph shows about an 18°C temperature rise (about 5.7°C/W).
https://www.boydcorp.com/aavid-datasheets/Board-Level-Cooling-High-Power-Extruded-6390.pdf
The die temp is then 25°C + (5.7°C + 5°C/W)*3.15W = 25°C + 33.7°C =58.7°C. That's not much of a safety margin when aiming for 60°C and assuming a 25C amibient.

Note: At 300LFM the thermal resistance of the heatsink drops to about 2.2°C/W which would lower the die temp by (5.7°C/W -2.2°C/W)*3.15W = 11°C (if you want to add a fan).

There was no reason to require such a low temperature (60C). 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 will roughly double for every 10°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) of 1-2°C/W (as compared to the 5°C/W for the old LM7805).