EE419/519 Homework Assignment #1

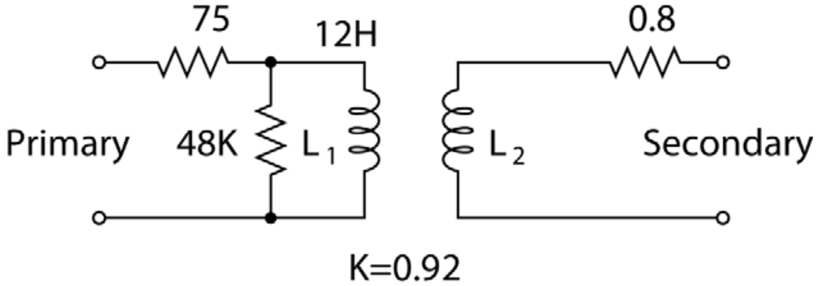
Due September 26, 2024

Write the following statement in the first line of your solution sheet:

"I completed this homework assignment independently."

We need a high-efficiency DC power supply that can deliver a variable voltage between +3.3 to +5 V with a maximum current of 0.5A. The pp output ripple should be less than 25 mV. We would like to use an adjustable linear regulator (since we do not yet know how to design a switching regulator). With most adjustable regulators, you can change the output voltage by changing a single resistor. Go to the website of Analog Devices and choose a suitable adjustable positive linear regulator. Check that the regulator you choose has an LTSpice model.

The DC input to the regulator is to be obtained from the secondary of a transformer. The model of an available transformer is given below. The turns-ratio of the transformer can be adjusted by choosing a value for L_2. Note that you can generate a transformer in LTSpice with two coupled inductors, L_1 and L_2. Specify L_1=12 H and $L_2 \approx (1/n)^2 L_1$ and insert the coupling coefficient spice directive: K L1 L2 0.92. The coupling coefficient specifies the amount of leakage inductor. With a perfect coupling of K=1, there will be no leakage inductance.



The 50 Hz AC line voltage is assumed to fluctuate between the limits $230V_{rms}$±15% (between $195.5V_{rms}$ to $264.5V_{rms}$). Note that LTSpice voltage sources specify the peak value rather than the rms value. You need to full-wave rectify and filter the secondary AC voltage using a large capacitor to generate a DC voltage possibly with some ripple. The regulator will get rid of most of the ripple. Make sure that the minimum voltage requirement of the linear regulator is satisfied. Use the rectifier or Schottky diodes available in LTSpice library with a suitable current and voltage rating. Note that Schottky diodes have a smaller voltage drop, so they dissipate less power. Make sure that the reverse voltage rating of the diode satisfies the maximum reverse voltage across the diode.
All capacitors used for filtering should have an equivalent series resistance (ESR) to be realistic. ESR is a spurious and undesirable element, but it is unavoidable. Insert 1.6Ω resistors in series with capacitors larger than 100µF and insert 0.2Ω resistors in series with capacitors smaller than 10µF. (Smaller ESR capacitors are available at a higher price.) As a result, there will be power dissipation in capacitors.
To plot the instantaneous power dissipated or delivered by a component: ALT-Left Click on the component. Use the "Time to start saving data" option to plot the instantaneous power for exactly one full cycle after the circuit reaches the steady state (approximately after one second, or at least five-time constants: The time constant of the transformer input is approximately L/R=12/75=0.16s. In the steady state, the input current should have zero average value.). You can find the *average* power by CTRL-Left by clicking on the

instantaneous power waveform's title in the waveform window. This way you can find the input power and the output power to calculate the efficiency.
The worst-case condition is when the input AC voltage is at its minimum (195.5V_{rms}),the output voltage is at its maximum (5V), and with full-load current. The transformer turns ratio (the value of L_2) should be adjusted to a minimum value to maximize the efficiency of the voltage regulator.

Your report should contain (2.5pts each)

a. A schematic of your design (specifying L_2 of the transformer, rectifier diodes, filter capacitor, and the chosen linear regulator with associated components.)
b. A plot showing the output voltage (with a ripple less than 25mV_{pp}) and the instantaneous input source power while the AC input voltage is at its minimum, 195.5 V_{rms}, and the output voltage is 5 V with a 10Ω load. Give the calculated efficiency under this condition.
c. A plot showing the output voltage and instantaneous input power while the AC input voltage is at its maximum, 264.5 V_{rms}, and the output voltage is 3.3 V with a 6.6 Ω load. Give the efficiency under this condition.
d. A plot showing the output voltage and instantaneous input power while the AC input voltage is 230 V_{rms}, and the output voltage is 3.3 V with no load connected. Give the *average* input power under this no-load condition.