PHY 240: Basic Electronics
Homework Problem H4

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Aiden Rivera

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1. The Voltage Divider.

   (a) Draw the schematic for a voltage divider that uses your 5 V source and two resistors to achieve a 3 V output voltage. Indicate the resistances of your resistors clearly on your schematic, and indicate also where the output voltage, V_{out}, is to be taken.

   (b) We demand that our output voltage does not sag by more than 0.2 V when a load of 1 $k\Omega$ is attached across V_{out}. That is, with the load in place, V_{out} can not drop below 2.8 V. Check whether your circuit in part (a) satisfies this property. If it does not, redraw the circuit with new resistors in place that will satisfy this property and give the desired open circuit output voltage of 3 V. If your circuit from part (a) already satisfies this requirement, simply redraw it here

   (c) In addition to our first two requirements, we also demand that the voltage divider dissipate less than 100 mW when no load is attached. Draw the schematic for a voltage divider that satisfies all three of our requirements. As always, be sure that your resistor values are clearly indicated.

Solution:

(a)

$$V_{out} = V_{in} \times \frac{R_2}{R_1 + R_2}$$

$$V_{out}(R_1 + R_2) = V_{in}R_2$$

$$V_{out}R_1 + V_{out}R_2 = V_{in}R_2$$

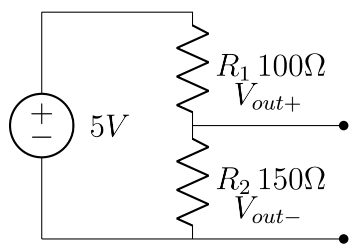
$$V_{out}R_1 = V_{in}R_2 - V_{out}R_2$$

$$V_{out}R_1 = (V_{in} - V_{out})R_2$$

$$\frac{V_{out}R_1}{(V_{in} - V_{out})} = R_2$$

$$\frac{3V \times R_1}{2V} = R_2$$

$$R_2 = \frac{3}{2}R_1$$



(b)

$$V_{out} = V_{in} \times \frac{R_T}{R_1 + R_T}$$

$$R_T = \frac{R_2 \times R_L}{R_2 + R_L}$$

$$R_2 = \frac{3}{2} R_1$$

$$V_{out} \geq 2.8V$$

$$\text{let } R_1 = 2R, R_2 = 3R$$

$$V_{out} = V_{in} \times \frac{R_T}{2R + R_T}$$

$$R_T = \frac{3R \times R_L}{3R + R_L}$$

$$V_{out} = V_{in} \times \frac{\frac{3R \times R_L}{3R + R_L}}{2R + \frac{3R \times R_L}{3R + R_L}}$$

$$V_{out} = V_{in} \times \frac{\frac{3R \times R_L}{3R + R_L}}{2R + \frac{3R \times R_L}{3R + R_L}}$$

After some hard math later...

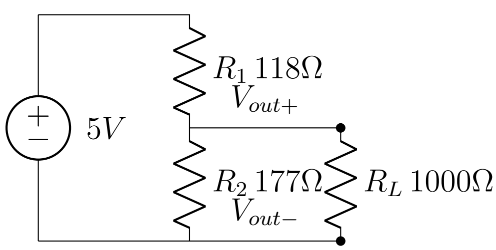
$$R = \frac{\frac{3R_L(V_{out} - V_{in})}{-2V_{out}} - R_L}{3}$$

$$R = \frac{\frac{3000\Omega(2.8V - 5V)}{-2(2.8V)} - 1000\Omega}{3}$$

$$R \approx 59\Omega$$

Finally...

$$R_1 = 118\Omega, R_2 = 177\Omega$$



(c) With $R = 59\Omega$

$$V = IR$$

$$P = IV$$

$$P = \frac{V^2}{R}$$

$$P = \frac{(5V)^2}{5R}$$

$$P = \frac{(5V)^2}{5R}$$

$$0.1\text{Watts} \geq \frac{25V}{295\Omega}$$

$$0.1\text{Watts} \gtrapprox 0.08\text{Watts}$$