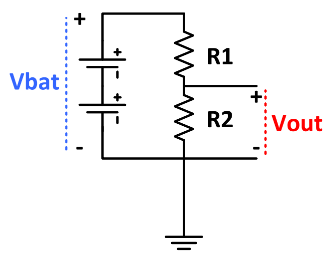
# Homework 3: Voltage, Current, and Circuits

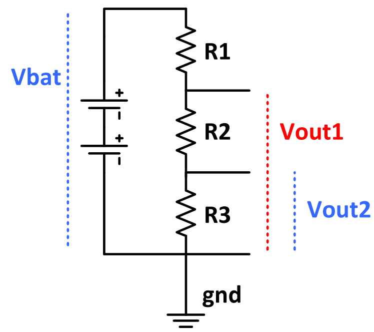
**Due: September 18, 2014**

Note: for the resistor values below, $k\Omega = 1 \times 10^3\Omega$ and $meg\Omega = 1 \times 10^6\Omega$. So $10k\Omega = 10 \times (1 \times 10^3)\Omega = 10^4\Omega$.

## 1 Voltage Dividers (8pts)

Assume $v_{bat} = 3.3v$. Compute all $v_{out}$ and $i_{R2}$ for the following values of $R1$, $R2$, and $R3$.

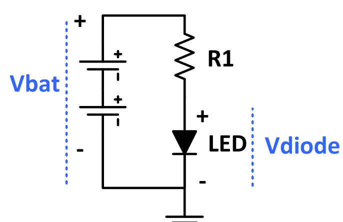



a. $R1 = 10k\Omega$, $R2 = 10k\Omega$
b. $R1 = 10k\Omega$, $R2 = 100\Omega$
c. $R1 = 10k\Omega$, $R2 = 10meg\Omega(1 \times 10^7\Omega)$

d. $R1 = 10k\Omega$, $R2 = 10k\Omega$, $R3 = 10k\Omega$

## 2 Electrical Power (8pts)




In the lecture on non-linear circuit elements, we talked about light-emitting diodes (LEDs), and noted how resistors are used to simplify the mathematics. When the LED is on, the voltage drop across it is 0.8 volts. We can summarize the LED model with the following three equations:

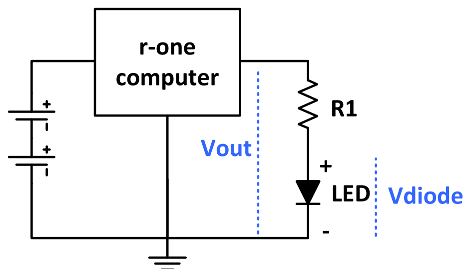
$$v_{\text{diode}} = 0.8v \quad v_{bat} = v_{R1} + v_{\text{diode}} \quad i_{R1} = i_{\text{diode}}$$

Assume $v_{bat} = 3.3v$. Remember that electrical current flows *through* electrical elements, and that voltage is measured *across* elements. Power in any electrical element is the (voltage across it) $\times$ (the current though it): $p = vi$. Compute the current flowing through the LED and the electrical power in the LED for the following values of $R1$:

a. $R1 = 10k\Omega$ b. $R1 = 1k\Omega$ c. $R1 = 100\Omega$

## 3 Controlling Electrical Power(8pts)

Controlling the LED power by setting a resistor does not let you change the brightness without building a new circuit. But we know that we can adjust LED brightness from a computer – lots of things have variable-brightness LEDs. In fact, the r-one robot has 15 LEDs, each with an individual brightness control. How does this work?




The trick is to use the r-one computer to turn the LED on and off quickly, too quickly for us to see. The flicker fusion rate for human vision is 60hz [1]. This means that anything that happens faster than 60 times a second appears as continuous, smooth motion to us. This is how movies and TV work, and we will use this fact to adjust the brightness of our LED.

For the following questions, assume that $v_{out}$ from the r-one computer is a *binary* output, *i.e.* it can only be in one of two output states: 3.3v or 0v, but no voltage in between. However, it is under computer control, so we can write software to change its value quickly, hundreds or thousands of times a second if we want to. So, we will turn it on and off quickly to change its perceived brightness. This technique is called *pulse width modulation*.

1. If we do not want to perceive the flashing of the LED, how many times a second do we need to turn it on and off? What is the period of this frequency?
2. If we want to run the LED at 25% power, *how long* should we turn it on for during each period? Give your answer in milliseconds.
3. Draw a sketch of $v_{out}$ for 25% power over three periods. In other words, if we looked at the output of $v_{out}$ over time, what would it look like?
4. The *duty cycle* is the ratio of on time to the total period. What is the duty cycle of $v_{out}$ for 25% power? For 50% power? For 100% power?

[1] This is the nominal value across the entire population, measured at the center of the retina (the fovea). However, many people can perceive flickering at this rate, and the fusion rate is higher in peripheral vision. When I was your age, I used to run my monitors at 85hz to prevent seeing flickering, 75hz was not fast enough.