Lab 5: Thermal Systems

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Abstract

In this lab we built a hysteretic oscillator followed by a buffer, a resistor, and a tungsten light bulb, as seen in figure 1. The idea was to observe the effect of temperature on the resistance of the tungsten filament over time by sweeping a voltage over the bulb.

1 The Circuit

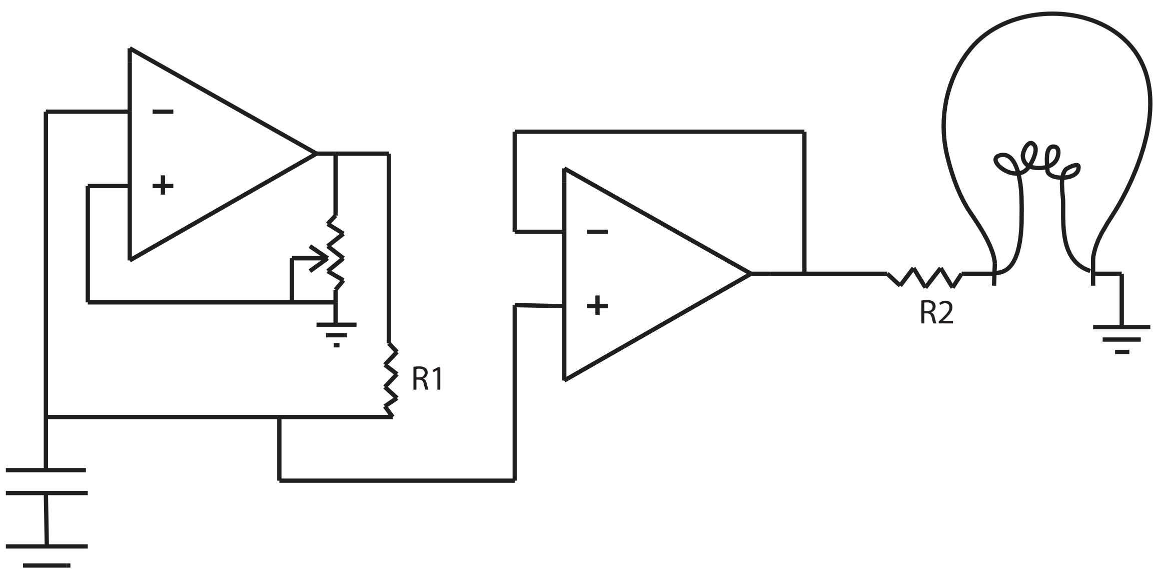

Figure 1: Circuit Diagram of lab 5

1.1 qualitative analysis

So basically what's happening in the circuit is a triangle-ish wave of some frequency f causes an AC to pass through the bulb, causing the temperature of the filament to rise and fall at the same frequency f. As the magnitude of the voltage across the bulb increases, so does the temperature across the bulb. By graphing voltage across the bulb against current through he bulb we can see how temperature effects the resistance of the filament, because the slope of the graph at a given point is $\frac{1}{R_{bulb}}$. This effect will be discussed further in the following section.

2 Explaining the Graphs

So what do these funny shapes mean? Are they caterpillars? Nope, just some funny looking graphs. In figure one we can see that the slope is changing a lot. The reason the slope is changing so much in this graph is that the frequency is slow enough (about .05Hz) that the filament has time to cool off and heat up as the voltage changes. The second graph, seen in figure 3, was taken at about .25Hz. As you can see, the slope doesn't change all that much because the filament doesn't have much time to heat up and cool off. An interesting thing to note here is that the average slopes of the two graphs are equal, plus or minus experimental errors. But why does temperature effect resistance in the first place? There are lots of electrons in the tungsten filament – some are obediently orbiting their atoms, but the majority are "free" electrons. Under cool temperatures and in the presence of an electric field, these electrons travel slowly towards the positive end with some number of collisions amongst themselves due to random kinetic energy. These collisions are what create resistance. So as temperature increases, the kinetic energy of the atoms and electrons increase, causing more collisions to occur and more resistance as a result.

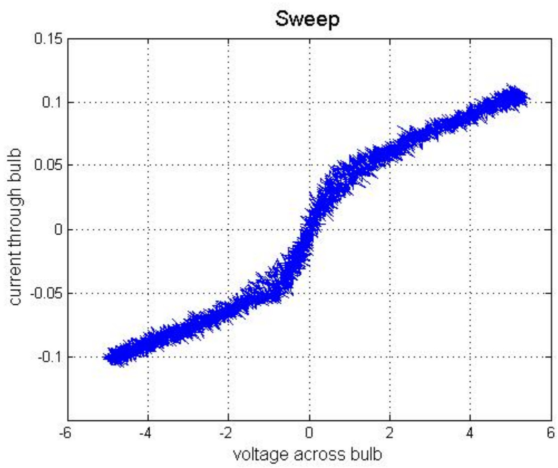

Figure 2: Sweep of the bulb at .05Hz

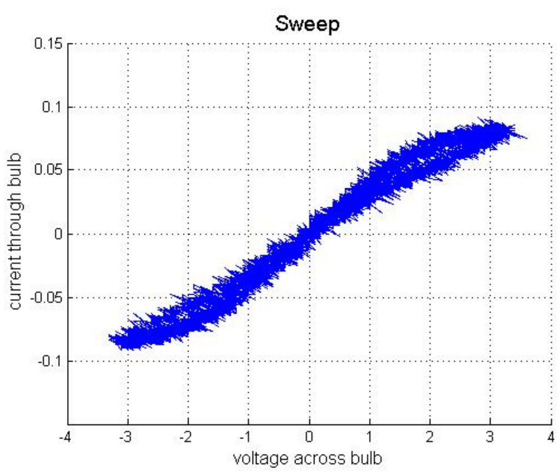

Figure 3: Sweep of the bulb at .25Hz

3 Black Body capabilities of Tungsten

So it might be interesting to look at tungstens black body rating, to understand how well it absorbs and radiates heat. An ideal black body absorbs all electromagnetic wavelengths and radiates them all back out again. So is tungsten a good black body? It doesn't look like it. Figures 2 in particular shows that at high frequency sweeps, the tungsten does a terrible job radiating the heat it's taken in. One possible way of looking at this is noticing that the average resistance calculated from this graph (about 31Ω) is significantly higher than the resistance at room temperature (only 7.4Ω) , indicating that the tungsten does a pretty bad job getting rid of heat. But we should also look at the actual change in temperature of the tungsten, using the equation below. Also, it has been suggested (dictated) in the lab that I use the resistance R where $V = 4$ from the graph in figure 1.

To find ΔT:

$$R = R_0 \left(1 + \alpha \left(\Delta T\right)\right) \tag{1}$$

$$\frac{R}{R_0} - 1 = \alpha \Delta T \tag{2}$$

$$\alpha \Delta T = \frac{R}{R_0} - \frac{R_0}{R_0} \tag{3}$$

$$\Delta T = \frac{R - R_0}{\alpha R_0} \tag{4}$$

We know that $\alpha = .0044$ and $R_0 = 7.4\Omega$, but we need to calculate R

$$R = \frac{1}{\text{slope}} \tag{5}$$

$$R = 80 \tag{6}$$

Now we plug in our values

$$\Delta T = \frac{80\Omega - 7.4\Omega}{.0044 * 7.4\Omega} \tag{7}$$

$$\Delta T = 2229.7 \text{ Kelvins} \tag{8}$$

$$\tag{9}$$

That's 3553.8 degrees Fahrenheit! Yikes!