Lab 7: The effect of Negative Resistance on a Tungsten Filament

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Abstract

In this lab we connected the negative resistor from lab 6 in series with the tungsten filament light bulb from lab 5. When the bulb is in series with the negative resistor the voltage across the bulb does not change as it did in lab 5. By blowing on the filament of a broken bulb we saw how the negative resistor effects the voltage across the bulb.

1 The Circuit

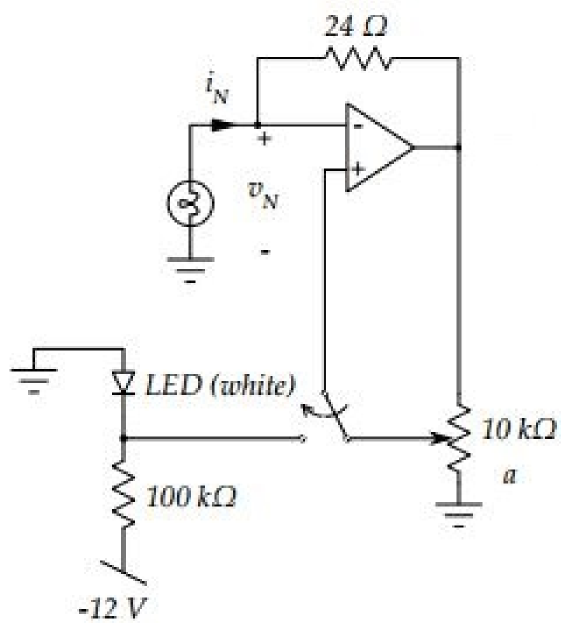

Figure 1: Circuit Diagram of negative resistor in series with light bulb. The op amps reference voltage V_+ can be switched between a voltage proportional to the output or a constant voltage when connected to the LED

1.1 quantitative analysis

Below is the Analysis of the op-amp for any value a of the potentiometer.

First we must write V_-, V_+, and V_o in terms of our variables:

$$V_o = Vn - R_f i_n \tag{1}$$
$$V_- = V_n \tag{2}$$
$$V_+ = aV_o = a\left(V_n - R_f i_n\right) \tag{3}$$
$$\tag{4}$$

For section I:

We assume...

$$V_+ = V_- \tag{5}$$
$$a\left(V_n - R_f i_n\right) = V_n \tag{6}$$
$$R_f i_n = \frac{aV_n - V_n}{a} \tag{7}$$
$$R_f i_n = V_n \frac{a-1}{a} \tag{8}$$
$$V_n = \frac{-a}{1-a} R_f i_n \tag{9}$$

...when

$$-V_s < V_o < V_s \tag{10}$$
$$-V_s < V_n - R_f i_n < V_s \tag{11}$$
$$-V_s + R_f i_n < V_n < V_s + R_f i_n \tag{12}$$
$$-V_s + R_f V_n * \frac{a-1}{aR_f} < V_n < V_s + R_f V_n \frac{a-1}{aR_f} \tag{13}$$
$$-V_s - \frac{1-a}{a} V_n < V_n < V_s - \frac{1-a}{a} V_n \tag{14}$$
$$-aV_s < V_n < aV_s \tag{15}$$
$$\tag{16}$$

For section II:

When...

$$V_o = V_s \tag{17}$$

$$V_s = V_n - R_f i_n \tag{18}$$

$$i_n = \frac{V_s - V_n}{R_f} \tag{19}$$

or solving for V_n, which will be useful later:

$$V_n = V_s + R_f i_n \tag{20}$$

...we assume

$$V_+ > V_- \tag{21}$$

$$a\left(V_n - i_n R_f\right) > V_n \tag{22}$$

$$V_n > \frac{-a}{1-a} R_f i_n \tag{23}$$

$$\text{but we know from line 22 } V_n = V_s + R_f i_n \tag{24}$$

$$V_s + R_f i_n > \frac{-a}{1-a} R_f i_n \tag{25}$$

$$\frac{1-a}{1-a} R_f i_n + \frac{a}{1-a} R_f i_n > -V_s \tag{26}$$

$$\frac{R_f i_n}{1-a} > -V_s \tag{27}$$

$$i_n > \frac{a-1}{R_f} V_s \tag{28}$$

$$\tag{29}$$

For section III:

We can just borrow from section II and flip the signs:

We assume...

$$V_+ < V_- \tag{30}$$

$$i_n < \frac{1-a}{R_f} V_s \tag{31}$$

...when

$$V_o = -V_s \tag{32}$$

$$i_n = \frac{V_n + V_s}{R_f} \tag{33}$$

or

$$V_n = R_f i_n - V_s \tag{34}$$

$$\tag{35}$$

1.2 Hi Emily!

I'm just including this because I want the next section to start on a new page and I can't figure out how.

2 Results

To get experimental data, a scope downloaded the voltage across the broken bulb as I blew on the filament. This was done for both configurations of the switch. The current across the bulb, i_n, was then found using the voltage drop across the 24Ω resistor, and the data was plotted. Two theoretical curves for the voltage across the bulb are ploted against the data. The results are in fig. 2 below.

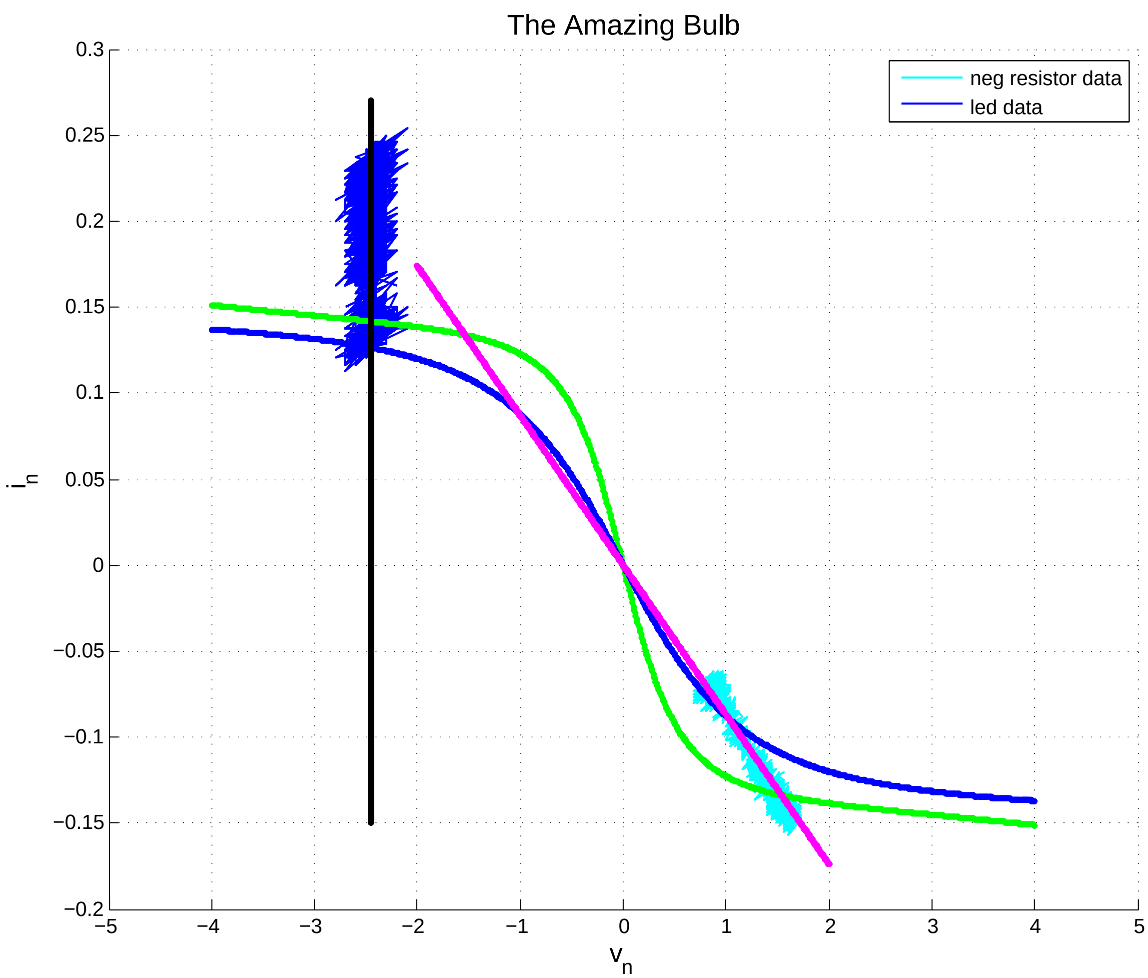

Figure 2: bulb resistance behavior

3 Qualitative Analysis

3.1 Changing Voltage (negative resistor)

The data taken with the switch connected to V_out follows a slope, seen as the magenta line in fig. 2. The data follows this line because as the filament cools, the theoretical curve shifts to intersect the magenta line at a new point. In reality this occurs continuously as the temperature of the filament changes, creating a series of points that form the magenta line.

3.2 Constant Voltage (LED connection)

The data taken when the switch is connected to the LED is very different in nature because the op-amp is no longer functioning as a negative resistor, and the voltage input into V_+ is constant. Because the voltage is constant and the current is changing, the resistanc eacross the bulb must be changing. This explains the verticle slop of the data and corresponding black line.