Sample Lab Report: Limiting LED current in an Arduino Application

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I. BACKGROUND

Purpose The lab report should start with a purpose statement. Briefly provide the necessary background and explain what problem your are trying to solve/investigate.

Conclusions Don't be coy, cut to the point right away and state what you found. This should be breif.

Theory We never just measure stuff in Physics. There's always a theoretical idea behind the measurement we're making. Explain the ideas behind your work, starting at the level of a successful Physics 221/222 student.

Data Sketch out, in words and pictures, the apparatus you used to take data. Report the data, graphically, if possible, and state the uncertainties in your measurement. Don't provide pages of computer printout here. Data tables shouldn't be your first choice when it comes to communicating your measurements.[1]

Analysis With data presented, describe how the theory agrees/disagrees with the data you took. Normally this is accomplished with a fit line (or math model) that is interpreted.

Limitations and Recommendations Every measurement has limitations and it is only honest to report them to the reader. "Human Error" is a meaningless statement. After your analysis is complete, revisit the purpose statement. This is the place to more forcefully argue your conclusions.

Notes: Writing in the first person, eg "I" or "We," is fine.

II. EXAMPLE LAB REPORT:

III. PURPOSE

"Light Emitting Diodes" are common circuit elements which produce light at specific wavelengths. The operating voltage for these elements do not immediately match the voltages used by an Arduino micro-controller, and so I designed a simple circuit which can be used to limit the current going through the LED.

IV. CONCLUSIONS

I found that a green LED takes about 2.5 volts to begin to emit light, which agrees with a photon energy prediction of $2.2V$. With the 5.0 volt supply on a micro-controller like the Arduino, this means that a series resistor of $R = 500\Omega$ will produce a reasonable amount of light while not destroying the LED or overloading the micro-controller pin.

V. THEORY

When wired in series with a resistor, the LED can be analyzed via a Kirchhoff loop. If $V_{cc} = 5.0V$ is the voltage provided by the micro-controller, the loop equation wold be:

$$V_{cc} - V_{LED} - iR = 0. \tag{1}$$

The voltage necessary to light the LED, V_{LED} is dictated by the color (wavelength) of light emitted. Green has $\lambda \approx 560nm$, and with the following approximation from Modern Physics, I can estimate the energy necessary to produce a green photon:

$$E_{photon} = \frac{hc}{\lambda} \approx \frac{1234\ eV\ nm}{\lambda} \approx 2.2eV. \tag{2}$$

So, I expect that the voltage necessary to make the LED glow will be about $2.2V$. Accordingly, with a green LED and a $5.0V$ supply, I expect equation 1 to appear in the data as,

$$\begin{aligned} 5.0V - 2.2V - iR &= 0 \\ 2.8V &= iR \\ i &= (2.8\ volts)/R \end{aligned} \tag{3}$$

VI. DATA

The theory, equation 3, predicts that if the supply voltage is held constant, a resistor in series with an LED will produce an inverse relationship between current and resistance. To test this idea, I wired up a series circuit, as shown in figure 1. The multimeter was set to measure current in mA, and reported to the nearest $0.1mA$ The source voltage,

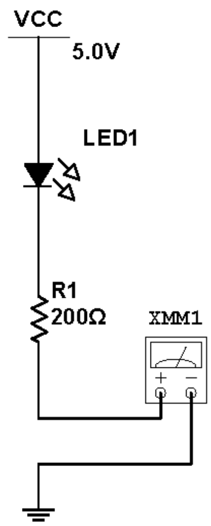

FIG. 1. This is the circuit used to take measurements. Image from NI Multisim.

$V_{cc} = 5.00V \pm 0.01V$. Resistor values were taken from color band and are assumed to be within 5% of listed value.

The data recorded is shown in figures 2 and 3. Note that these two figures show the same measurements, but the inverse scale in figure 3 agrees, at least in character, with the prediction, equation 3.

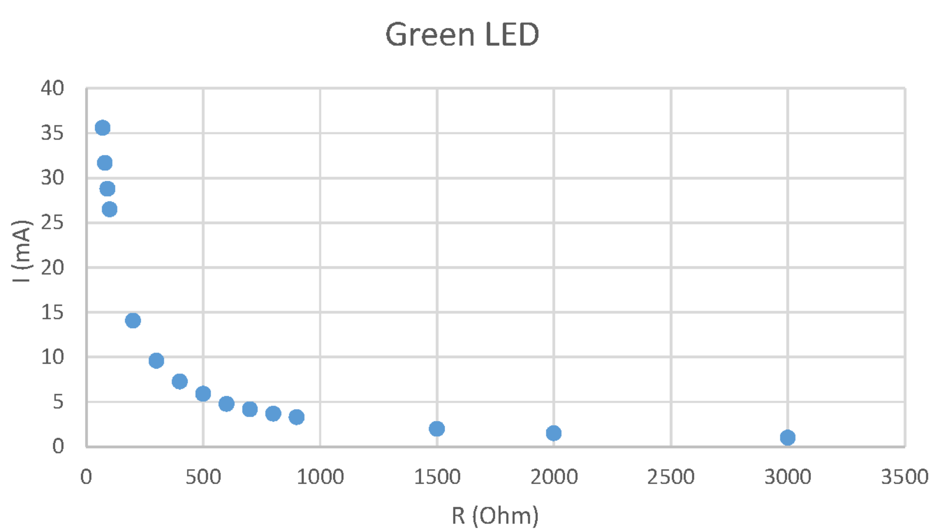

FIG. 2. Raw data from the lab. Error bars are smaller than the plot markers.

In each figure, error bars have been omitted. In terms of vertical scale the plot markers are larger than the multimeter (machine) uncertainty of $0.1mA$. The trendline in figure 3

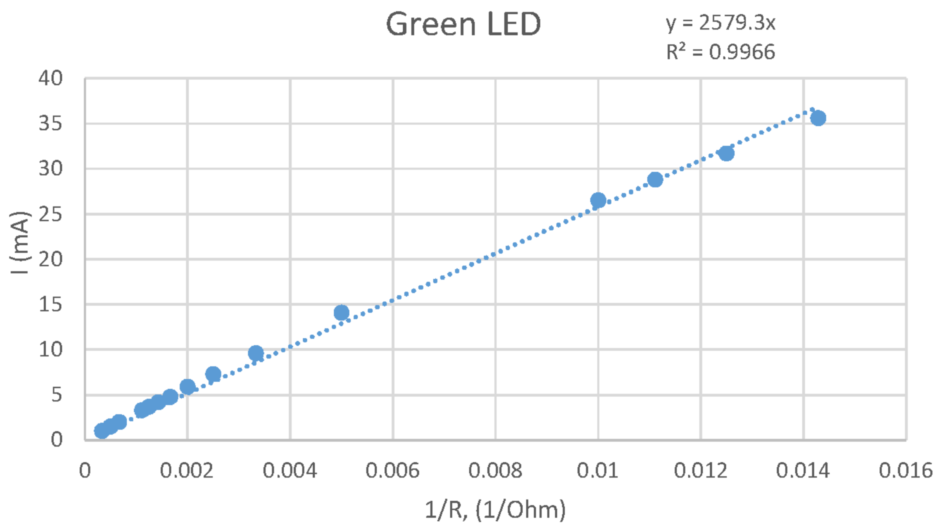

FIG. 3. Linearized $\frac{1}{R}$ scale on the horizontal axis allows the inverse relationship between current, i, and resistance, R, to be seen. The fit-line produced by Microsoft Excel was generated without measurement uncertainties.

can be written with units as,

$$i = (2579.3\ mA\ \Omega)\,\frac{1}{R} \tag{4}$$

$$i = (2.5793\ volt)\,\frac{1}{R} \tag{5}$$

VII. ANALYSIS

The slope of the trendline, equation 5, is within 8% of the predicted value, equation 3, and so this seems like a reasonable way to describe the behavior of the resistor and LED.

VIII. LIMITATIONS AND RECOMMENDATIONS

As mentioned, the resistor values were assumed from the color bands and are probably no better than 5% accuracy. A more thorough analysis would take estimates of uncertainty for resistance and current into account when generating the fit line and slope.

The general agreement between data and fit though makes it seem reasonable to take the voltage drop across the resistor to be $\approx 2.5V$. Assuming this, and noting from the Arduino documentation[2], that maximum pin current is $40mA$, we can use the resistor to limit current in the following way.

If we want current to be $5mA$, Ohm's law suggests that,

$$V_{resistor} = i\ R \tag{6}$$
$$R = \frac{2.5\ volts}{5\ mA} \approx 500\ \Omega. \tag{7}$$

A similar analysis for $i = 40mA$ gives $R = 62\Omega$, and I should note that while taking data, the LED burned out at $R = 60\Omega$.

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[1] See the perspectives on data communication at `<https://www.edwardtufte.com/tufte/books_vdqi>`.

[2] Arduino documentation, `<https://www.arduino.cc/en/Tutorial/DigitalPins>`, suggests maximum pin current of $40mA$.