PHY405 Lab 1

Friday, January 24, 2024

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Collaborators for all questions: none. Partner (for Lab 1-10): Jacob Villasana.

R-1

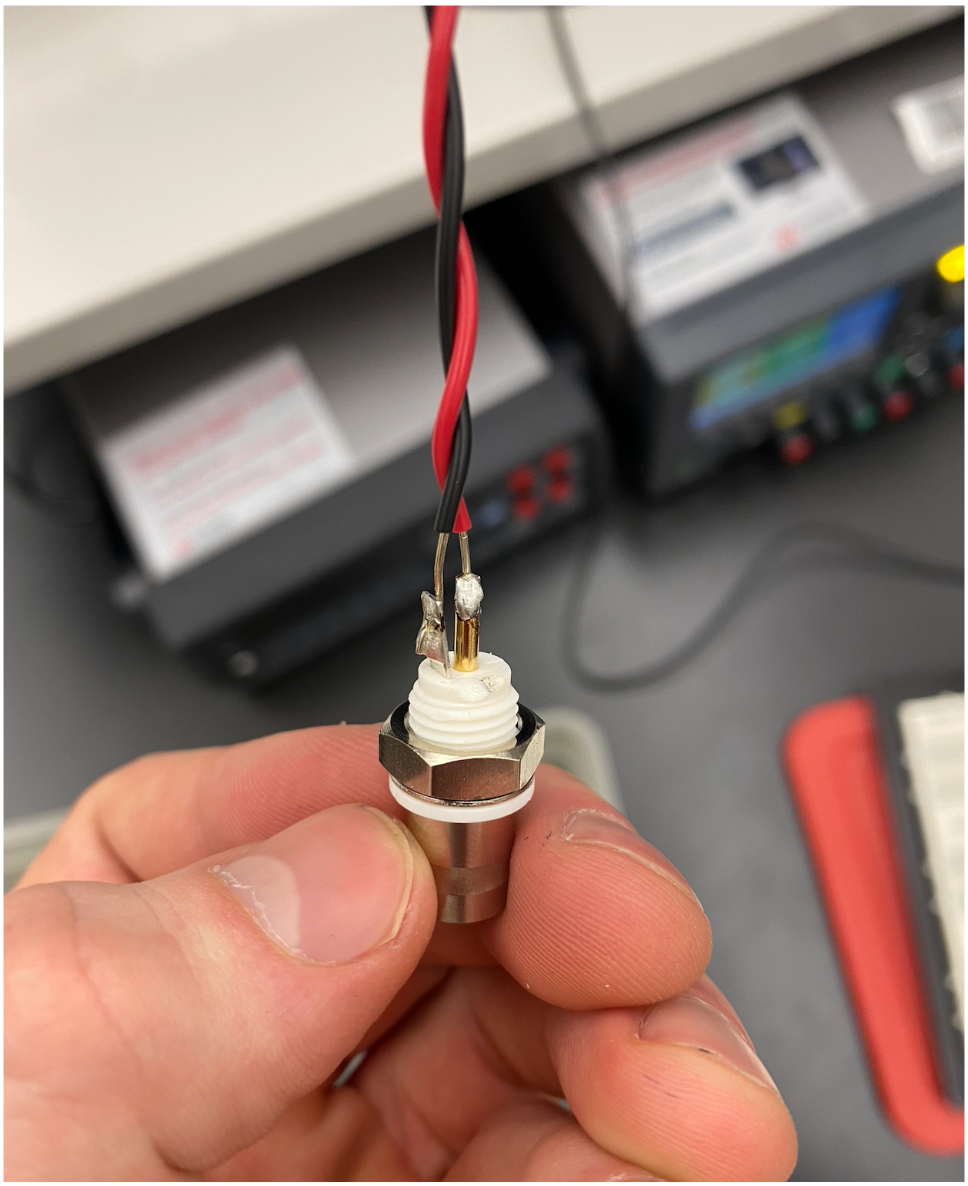

Figure 1: my mediocre soldering job (from an engineer's perspective). Though the wires won't fall loose, if I were to do this again I would wrap the ground (black) wire around the connection plate and solder it that way.

R-2

Methodology: On the oscilloscope, a sine wave was set in the wave generator with the frequency to be $f = 3.141020 \pm 0.000005$ kHz. The peak-to-peak voltage was set to 2.83 ± 0.01 V, which should correspond to approximately 1 V root-mean-square. Using the scope averaging, the 'type' was set to 'AC RMS' on source '1' with 'N Cycles' at 1298 samples.

On the scope, this was measured to be 1.00 ± 0.05 V_{rms} $(\pm 5\%)$. On the multimeter, connected to the scope via BNC-banana cables, the 'ACV' button was selected to measure the alternating current voltage. This was found to be 0.998 ± 0.001 V $(\pm 0.1\%)$.

True RMS AC voltage [2, 5, 6]					(MULTIMETER)
100 mV, 1 V, 10 V, 100 V, and 750 V ranges					
3 Hz to 5 Hz	1.00 + 0.02	1.00 + 0.03	1.00 + 0.03	1.00 + 0.03	0.100 + 0.003
5 Hz to 10 Hz	0.35 + 0.02	0.35 + 0.03	0.35 + 0.03	0.35 + 0.03	0.035 + 0.003
10 Hz to 20 kHz	0.04 + 0.02	$\boxed{0.05 + 0.03}$	0.06 + 0.03	0.07 + 0.03	0.005 + 0.003
20 kHz to 50 kHz	0.10 + 0.04	0.11 + 0.05	0.12 + 0.05	0.13 + 0.05	0.011 + 0.005
50 kHz to 100 kHz	0.55 + 0.08	0.60 + 0.08	0.60 + 0.08	0.60 + 0.08	0.060 + 0.008
100 kHz to 300 kHz	4.00 + 0.50	4.00 + 0.50	4.00 + 0.50	4.00 + 0.50	0.200 + 0.020

Figure 2: Keysight multimeter 34461A alternating current voltage data specifications for uncertainty.

	(OSCILLOSCOPE)
Probe attenuation factor	0.1X to 10,000X in 1-2-5 sequence; (–20 dB to +80 dB in 0.1 dB steps)
Hardware bandwidth limits	Approximately 20 MHz (selectable)
Vertical resolution	8 bits
Invert signal	Selectable
Maximum input voltage	150 Vrms, 200 Vpk
DC vertical accuracy	± [DC vertical gain accuracy + DC vertical offset accuracy + 0.25% full scale]
DC vertical gain accuracy [1]	+3% full scale (≥ 10 mV/div)
	+4% full scale (< 10 mV/div)
DC vertical offset accuracy	± 0.1 div ± 2 mV ± 1% of offset setting
Skew	Channel to channel: 1 ns (without deskew)

Figure 3: Keysight DSOX1204G Digital Storage Oscilloscope data specifications for vertical accuracy.

According to the scope/multimeter vertical accuracy specifications (shown above), the oscilloscope uncertainty is approximately $\pm 5.25\%$ on full-scale measurements, which is consistent with what was measured. Similarly, on the multimeter, the measured relative error for a 1 V AC input was around 1%, which is close to the $\pm 0.08\%$ range given within the specifications. *I'm still not sure of how to read these uncertainties, since it includes measurement uncertainty + range uncertainty. The footnotes of the manual say that it is over 20% over range on all ranges except a few values, and I don't know what this means either. My guess was the calculation* $0.05 \times 0.998V + 0.03 \times 1V = \pm 0.799$ *V since the meter range is up to 1V for this measurement.*

Sources:

- Keysight Multimeter 34461A data sheet: https://www.keysight.com/ca/en/assets/7018-03846/data-sheets/5991-1983.pdf, pp13.
- Keysight Oscilloscope DSOX1204G data sheet: https://www.keysight.com/ca/en/assets/7018-06411/data-sheets/5992-3484.pdf, pp12.

R-3

Methodology: Measurements of alternating current voltage (ACV) were taken from 1 Hz to 20 MHz, since my partner and I had trouble with generating a wave with frequency lower than 1 Hz (it wouldn't display on the screen). Table 1 include the measured data and reading uncertainties.

Oscilloscope Frequency f (Hz)	δf / $\pm\%$ (Hz)	Multimeter VAC (V)	δVAC / $\pm\%$
1.00	0.01 / 1%	0.8305	0.0001 / 0.01%
10.00	0.01 / 0.1%	0.9993	0.0001 / 0.01%
100	1 / 1%	0.9993	0.0001 / 0.01%
1000	1 / 0.1%	0.9993	0.0001 / 0.01%
10.00k	0.01k / 0.1%	0.9984	0.0001 / 0.01%
100.0k	0.5k / 0.5%	1.0036	0.0001 / 0.01%
350k	1k / 0.3%	0.6746	0.0001 / 0.02%
500k	1k / 0.2	16.3m	0.1m / 0.61%
1.00M	0.01M / 1%	0.43m	0.05m / 11.61%
20.0M	0.1M / 0.5%	0.55m	0.01 / 1.82%

Table 1: Oscilloscope frequency and multimeter alternating current voltage, including fractional uncertainties.

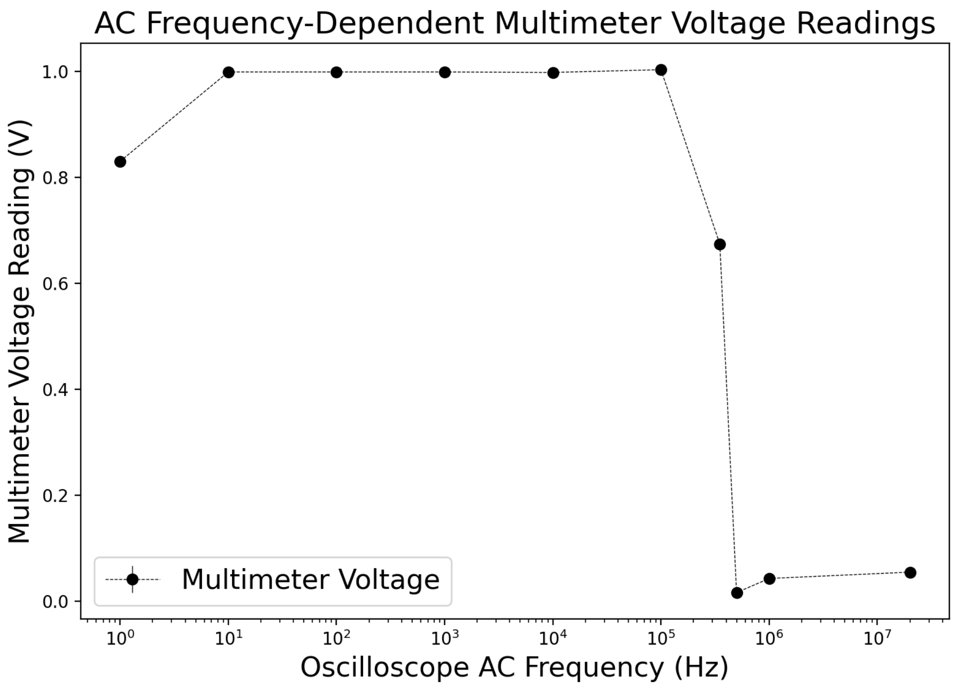

Figure 4: Data from Table 1 plotted on a log-scale axis to portray the relationships between AC frequency and AC voltage. Data was generated using a 1V RMS AC voltage in an oscilloscope.

At first, when performing the measurements of 1 and 10 Hz, we realized that the AC filter was set to $>$ 20 Hz on the multimeter, so this was adjusted to $>$ 3 Hz and the coresponding measurements were re-taken. We further note that the 1 Hz measurement in Table 1 / Figure 4 is reduced due to this filter. Observe a significant drop in voltage around the 10^5 Hz frequency. The errors were determined by carefully watching the multimeter reading uncertainties to examine the voltage fluctuations. Most of the time, these fluctuations were small compared to the read value, so I took

one decimcal place forward to account for any large jumps.
Comparing the Table 1 values with the specifications of the meter in Figure 2 (the whole column for 1 V range for each respective frequency):

- For 1Hz, the 0.01% error is not close to the multimeter 1.03% error.
- For 10Hz, the 0.01% error is close to the 0.38% multimeter error, but a little under.
- For 100Hz, 1kHz, 10kHz, 100kHz, and 350kHz, the same is true. The 0.01% error is significantly underestimated compared to the 0.08% 1 V specification.
- For the $>$500kHz measurements, the error should be approximately 4.5%. This is mildly consistent with what was determine via reading uncertainty, since all $>$500kHz measurements contain an increase in net uncertainty.

My assumptions for why these reading uncertainties are much less than the instrument data sheet specifications for the multimeter is either (A) I am reading the data sheet incorrectly, or (B) I just significantly underestimated the uncertainty of the multimeter. Regardless of uncertainty challenges, the grand result of this experiment was that the multimeter cannot be trusted for any measurement greater than approximately 10^5 Hz (100 kHz) since the voltage readings just drop off to the bottomless pit of McLennan.

R-4

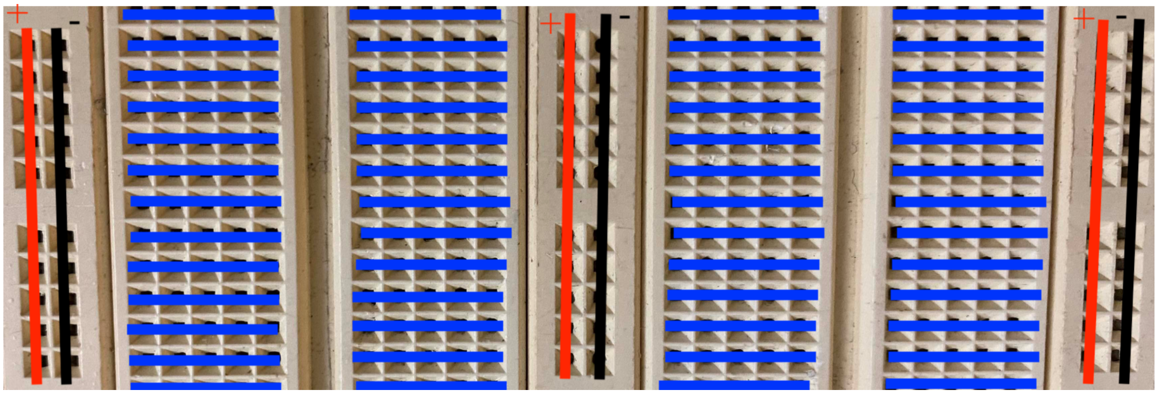

Figure 5: a breadboard map. Red vertical lines represent positive voltage terminals. Black vertical lines correspond to negative voltage terminals. Horizontal blue lines correspond to continuous connections located in rows. Where a line is broken, so is a connection of voltage.

R-5

Methology: The led circuit was assembled in the breadboard in resemblence to the schematic shown in Figure 6.

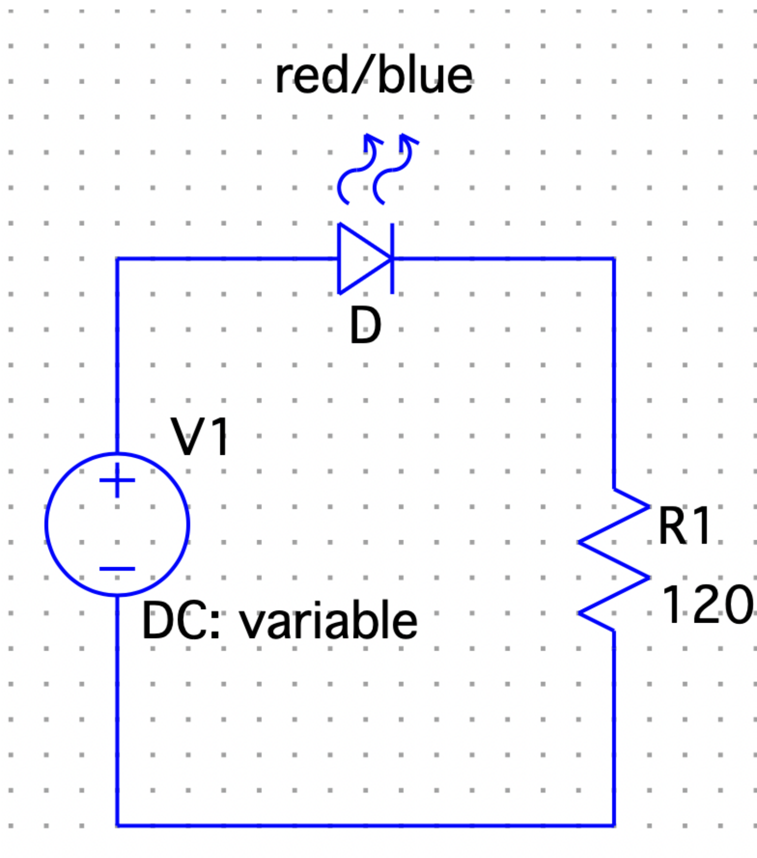

Figure 6: LTSpice schematic of an LED circuit, consisting of a DC voltage source and a 120Ω resistor.

Since we have no experience building circuits (yet), a 120Ω resistor was chosen arbitrarily so that we could initialize the circuit at a low voltage and gradually increase the power until the LED lit up so that it would not burn out. Once we knew the LED could light up, we proceeded by measuring the threshold voltage. This was done with both the red and blue LED's.

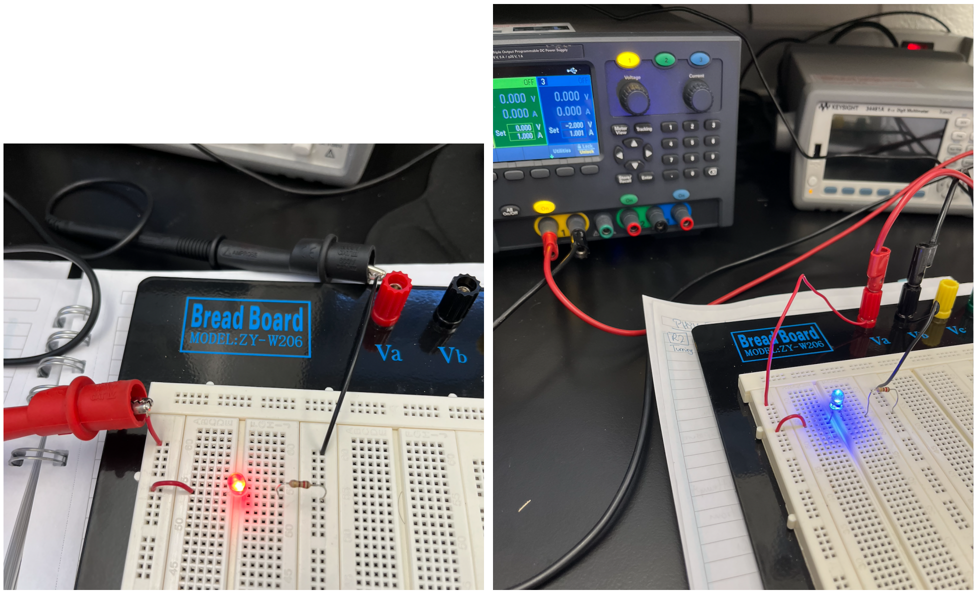

Figure 7: (left) breadboard circuit of the Figure ?? schematic, using the red LED. (Right) the equivalent using the blue LED.

At first, when assembling the circuit, BNC-clip cables were used and the wires were directly fed by the conduction of the clips. Eventually, we learned that the breadboard could be fed using the 'Va/Vb/Vc/Gnd' pins via BNC-banana cables so that the feeding breadboard wires wouldn't always need to be removed when changing the circuit.
To take out the measurements of threshold voltage for both LED's, the voltages were set near 1.000 ± 0.001 V on the DC power supply bank A with a constant current of 3.000 ± 0.001 A. Using the variable knob, the voltage was slowly increased until each of the LED's began emitted light. To know that the LED's began to slow, we placed a cupped hand over the LED so that a change in emission was more visible, though this is subject to human error and lack of eyesight.
For the red LED, the LED began emission around 1.60 ± 0.05 V (this is probably overestimating the uncertainty, but I want to account for human error as well in the measurement), and began completely visible after 1.8 V. For the blue LED, again initially increasing from 1 V, didn't begin emitting light until 2.40 ± 0.5 V as read on the DC power supply (again overestimating uncertainty).
Since LED's are semiconductors, the blue LED requires an increasing voltage because the bandgap of emission is greater than that of the red.

R-6

Methodology: Using the Falstad schematic developed in Lab S, shown in the schematic below, the circuit was constructed using two diodes and a 120Ω resistor to limit current (we don't want to short the LED's to short out). The LED placement of LED's was chosen arbitrarily, as long as either the short ends / long ends were pointing either together or away from each other.

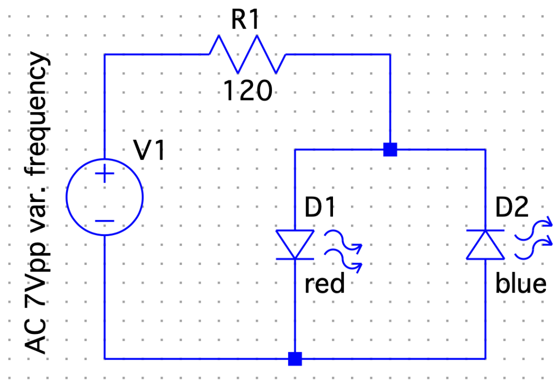

Figure 8: LTSpice schematic of the alternating diode circuit using a frequency-voltage-variable AC source, a resistor, and two diodes.

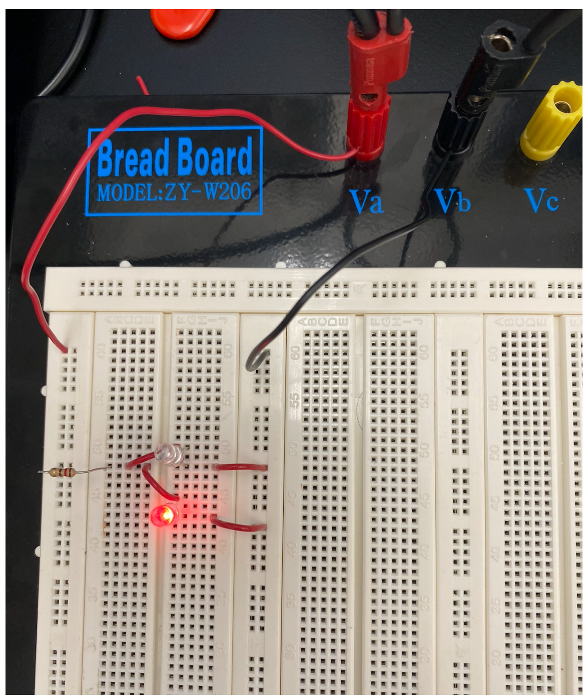

Figure 9: image of the breadboard circuit constructed from the Figure 8 schematic. The circuit include a blue (top) and red (bottom) LED in opposite polarities, a 120Ω resistor, and the AC voltage source.

At first, once the circuit was connected to the oscilloscope and the waveform generator was turned on, there was no emission of light. The first assumption was that the voltage was too low, so we increased the VPP. This seemed to work, and the LED's turned on and glowed brightly around

7.00 ± 0.05 VPP, and this is where we left the voltage. Furthermore, both LED's turned on together, which wasn't supposed to happen. Our first guess to fix this problem was to reduce the frequency of the AC, since it was initially around 100Hz. Once we began decreasing the AC frequency, both LED's began flashing independently (alternating) and this was visible around 40Hz. We finally chose to reduce the frequency to 3.0 ± 0.5 Hz so that the alternating blinking could be observed clearly.