MEAM 5100: Design of Mechatronic Systems Fall 2024

**Lab 0 Solutions**

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# 1 Multimeters

1. 1. - We measure only current with the probe in 10A and COM slot. Typically, we measure current only above 400mA (DMM specific).
      - We can measure voltage (both AC and DC), resistance, temperature (in both °C and °F), frequency, current below 400mA (through the mA and $\mu$ A ports). We can also perform the connectivity test using these two ports.
      - If we incorrectly measure something that does not correspond to the correct probe then first of all, we will get a wrong reading. The DMM will most likely show a 0 for the reading. Second, if used for longer, it might also damage the multimeter and blow the fuse.
   2. The multimeter I used was EXTECH Instruments EX330. It can measure voltage (both AC and DC), resistance, temperature (in both °C and °F), frequency, current (through the 10A, mA and $\mu$A ports). We can also perform the connectivity test to check if things are connected properly. The multimeter's datasheet mentions that it can also measure capacitance and duty cycle.
   3. - I chose a battery with a rating of 1.5V. Upon measuring with the DMM, it gave a voltage of 1.599V between the terminals of the battery.
      - The measured voltage comes out to be higher than the rated voltage of the battery possibly because it was a new battery. Over time, as the battery is used, the voltage between its two terminals drops.
   4. I tried the connectivity test on two things - a belt buckle and a jumper wire. I connected one probe to one end of the jumper wire and the other probe to the other end of the jumper wire. Since the jumper wires are supposed to be shorted, the multimeter starts beeping. Similarly, the belt buckle also passes the connectivity test.

# 2 Variable Power Supply

2. 1. - As we turn the voltage knob, the current display does not change. It always shows 0. This is due to the voltage supply not being connected to anything, hence the circuit is an open circuit with no current flowing through the power supply terminals.

- When no load is connected, the power supply stays on CV mode, i.e. the CV light is always on. The CC light is always off, but whenever we change the voltage, the CC light flashes on and then switches off again. But that most likely does not signify anything. When load is connected, for example, a resistor is connected across the power supply terminals using a breadboard, current is flowing in the circuit and the current display shows some non-zero value. Now if we set the current limit to a value less than the current given by Ohm's Law (I = V/R where I is the current, V is the voltage supplied, R is the resistance), the power supply switches to CC mode, thus limiting the current and changing the set voltage to V = I(limit) * R. If we set the current limit to a value more than the current given by Ohm's Law, then the power supply switches to CV mode, maintaining the voltage limit set by us and displaying the current according to Ohm's Law.
- If we change the current knob all the way to zero when no load is connected, it does not matter because current is anyways zero. The voltage display still shows whatever value we had set it at before. The CV light still stays on. If we set current to 0 when a load/resistor is connected across the power supply, then the voltage display also shows 0 and the CC light switches on.

2.
- The DMM measures the voltage from the voltage supply pretty accurately. I set the voltage to 5V, and the DMM measured 5.02V. So there is some error, but pretty accurate.
- The current display does not show any current. It just shows 0 throughout. This again would be due to no load connected to the power supply.
- The voltage difference between the ground and positive terminals comes out to be a really small value close to zero. Between the ground and negative terminals the potential difference is not zero. In most circuits, the negative and ground terminals are connected but not in this lab. The ground is simply a reference point that we can use to define an electrical ground in our experiments. It is a sink where we can dump excess current. Whereas the negative terminal is for getting voltage from the power supply. Hence, they are not related in any way and since they are not connected to each other, the potential difference is non-zero (opposite to conventional thought).

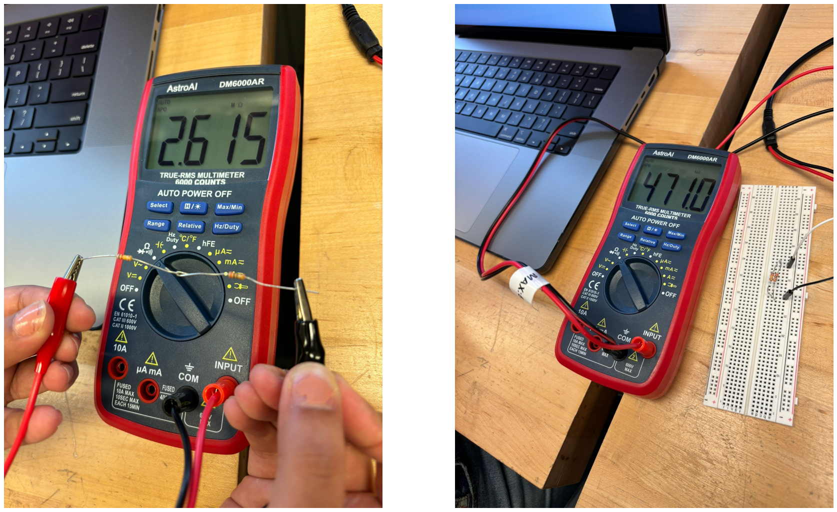
# 3 Resistors

3. 1.
- The following are the values for the rated and measured resistances and the error in the measurement:-

| Resistor Rating | Measured Resistance | Error in Measurement (%) |
|---|---|---|
| 2.2kΩ | 2.18kΩ | 0.91 |
| 10kΩ | 9.93kΩ | 0.7 |
| 150kΩ | 146.1kΩ | 2.6 |
| 620kΩ | 615kΩ | 0.81 |
| 2MΩ | 2.001MΩ | 0.05 |

- I combined the 620kΩ and 2MΩ resistors to form series and parallel connections:-

| Connection | Calculated Resistance | Measured Resistance | Error (%) |
|---|---|---|---|
| Series | 2.62MΩ | 2.615kΩ | 0.15 |
| Parallel | 473.28kΩ | 471kΩ | 0.48 |




((a)) Series connection ((b)) Parallel connection

Figure 1: Resistor connections to form new resistances

- All resistors had a golden band, which means that the tolerance rating is 5% for all of them. Thus, we can see that the error in measurement for all of them is less than 5% and hence all the readings are within tolerances.
- During these measurements, I was not touching the resistors or the probes with my fingers. But once I touched the resistors with my fingers, the measured resistance reduced significantly. For example, the 620kΩ resistor gave a reading of 170kΩ when held on both ends. The interesting thing to note is that the measured resistance varies with the position of the finger on the resistor or probes. The measured resistance decreases when you touch the resistor because our body is a really good conductor of electricity with a low resistance. Hence the entire connection becomes like a parallel circuit and the equivalent resistance measured by the multimeter reduces.

2. - All these experiments are done with a 5V supply.

| Resistance (Ω) | Expected Current (A) | Measured Current (A) | Error (%) |
|---|---|---|---|
| 33 | 0.152 | 0.15 | 1.32 |
| 149.4 | 0.033 | 0.031 | 6.06 |
| 218.3 | 0.023 | 0.021 | 8.7 |

   - The values more or less match, with some error in the expected vs measured currents. This might be because of wire connection issues, or error in the resistance of the resistor, or error in the power supply.

3. - I set the current limit on the voltage supply to 0.2A and the voltage limit to 3V, and connected it across a 10Ω resistor. The power supply showed a current

reading of 0.198A and a voltage reading of 2.08V. The digital multimeter on the other hand, measured the voltage drop across the resistor as 1.984V. This does not match the power supply voltage because after all, it is a non-ideal case and the multimeter does not have infinite resistance. Thus, some of the current flowing from the power supply goes to the resistor and some to the multimeter, hence causing a drop in the measured voltage.

- We see that the voltage measured by the multimeter is much closer to the voltage predicted by Ohm's Law. But overall, Ohm's Law is satisfied.

# 4 Oscilloscope

4\. 1.
- Yes, the results are different. When the probe and scope are set to 1X, the voltage seen on the oscilloscope is 5V only (the power supply is set to 5V), but when the probe and scope are set to 10X, the voltage on the scope is 500mV.
- This feature is included so that the oscilloscope is not damaged in case of high voltages or high currents, and also it becomes easier to view very large signals on the oscilloscope. The 10X probe increases the scope impedance by a factor of 10, which results in less circuit loading, thus protecting the circuit and oscilloscope from very high voltages.

# 5 Function Generator

5\. 1. I tried all three wave functions - square, triangular and sinusoid. The duty cycle affects only the square wave, but not the triangular and sine waves. That is because duty cycle is defined as the ratio of the active/on time of the wave to the total time period of the wave. For triangular and sine waves, the positive and negative portions of the wave with respect to the mean value are always for the same duration of time, and there is no concept such as off time of the wave because both the positive and negative portions contribute equally. On the other hand, for a square wave, there is a well-defined active/on time, and hence the duty cycle is well-defined too.

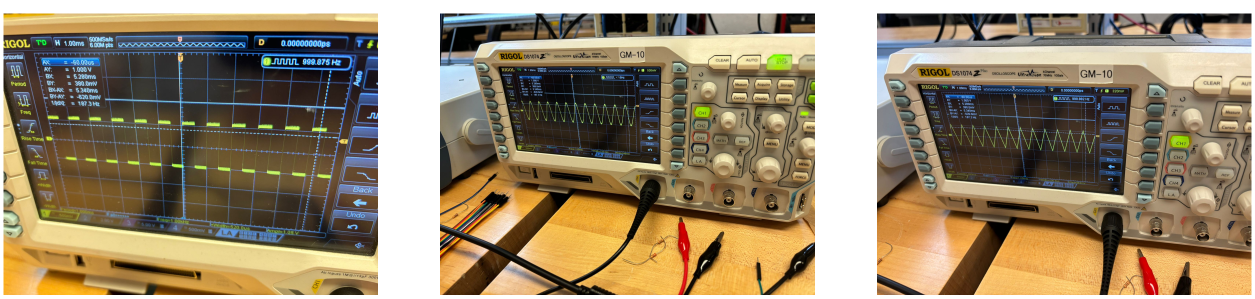



Figure 2: Square, Sine and Triangular Waves

2. I kept the offset of the square wave as 1.525V, and the amplitude as 160mV. This ensures that the wave is always positive. Now, when we increase the amplitude by a

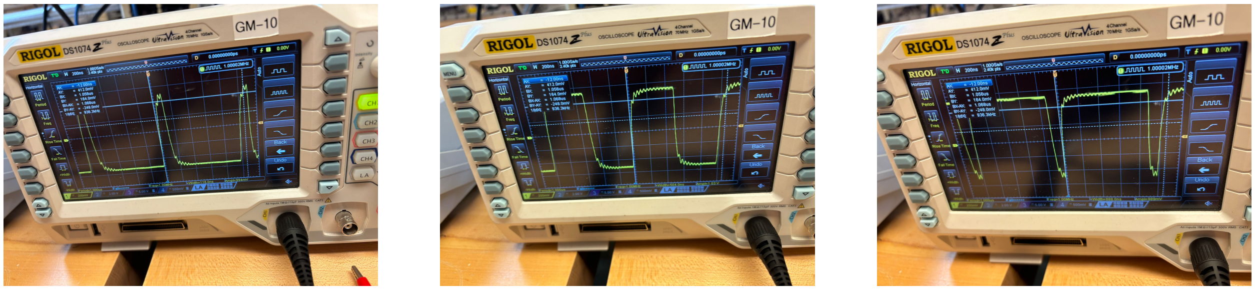



Figure 3: Duty cycles of 10%, 50% and 80% from left to right

factor of 15, i.e. make it 2.4V, we observe a few things. First, the wave stretches in the vertical direction; second, the wave goes below the 0 line, which means that it does not remain always positive like it was before.

3. - If the trigger is beyond the bounds/limits of the wave, the wave just keeps traveling, i.e. the oscilloscope shows the real-time data it captures. As we bring the trigger within the limits of the wave, the wave is 'fixed into position'. Thus, the trigger helps us capture the wave at a particular instant of time. As we move the trigger up and down on a falling edge, we see the sine wave shifts to maintain the intersection of the wave's falling edge and the trigger line on the y-axis (this is similar to capturing the wave at a particular instant of time). This feature is also useful for capturing the phase of the sine wave. Thus, as we move the trigger up and down, the sine wave shifts forward and backward showing us real-time data.
   - On the other hand, for a square wave, the vertical edge is just a straight line (ideally). Therefore, as we move the trigger up and down, the wave does not shift but stays in the same position. But if we zoom into the wave, we can see that the vertical edge is not exactly vertical, and then the square wave shifts a tiny bit when we move the trigger up and down.

# 6 References


1. Latex template from the course CIS 5190 taught this fall.
2. Google generative AI.
3. Referred to Oscilloscope probes for Q4.
4. EXTECH Instruments Multimeter datasheet.
5. I performed some of the experiments in the lab with other people but have written my own report.