Lawrence Technological University
MRE 6183 – Mechatronic Systems II
Spring 2023

Lab 1: Electronic Systems and Testing

Ahmed Khan Mohammed Zia
Shanawaz Hussain Mohammed

"I pledge that on all academic work that I submit, I will neither give nor receive unauthorized aid, nor will I present another person's work as my own."

Lab Summary

Lab 1 was an introduction to the electronic test equipment present in the Mechatronics lab. This was done by focusing on building and testing the given two electronic systems:

1. Passive Low-Pass Filter circuit
2. Force-sensing circuit

Prelab

We went over the lecture notes from Mechatronics Systems 1: Electronic Systems [1]. Important points noted:

1. Capacitor and resistor identification
2. Circuit Analysis rules:
    a. Ohm's Law
    b. Kirchhoff's Voltage Law
    c. Kirchhoff's Current Law

Datasheets for the test equipment were reviewed from the blackboard [2].
Equipment datasheets reviewed:

1. Keysight (Agilent) DSO-X 2012A or MSO-X 2014A Oscilloscopes
2. Keysight (Agilent) E3631A Triple Power Supply

Components utilized for the Lab work:

1. Digital Multimeter
2. Keysight (Agilent) DSO-X 2012A or MSO-X 2014A Oscilloscopes (Built-in function generator)
3. RC Circuit components

Table 1: RC Circuit components

Item	**UoM**	**Value**	**Qty**
Solderless Breadboard	Pcs	N/A	1
Resistor	KΩ	1	1
Capacitor	uF	0.1	1
Jumpers (M-M)	Pcs	N/A	4

4. Force-sensing circuit:

Table 2: Force-Sensing circuit Components

Item	**UoM**	**Value**	**Qty**
Solderless Breadboard	Pcs	N/A	1
Resistor	KΩ	10	1
OpAmp (UA741CP)	Pcs	N/A	1
FSR 402	Pcs	N/A	1
Jumpers (M-M)	Pcs	N/A	8

1. RC Circuit

3a. Build RC Circuit:

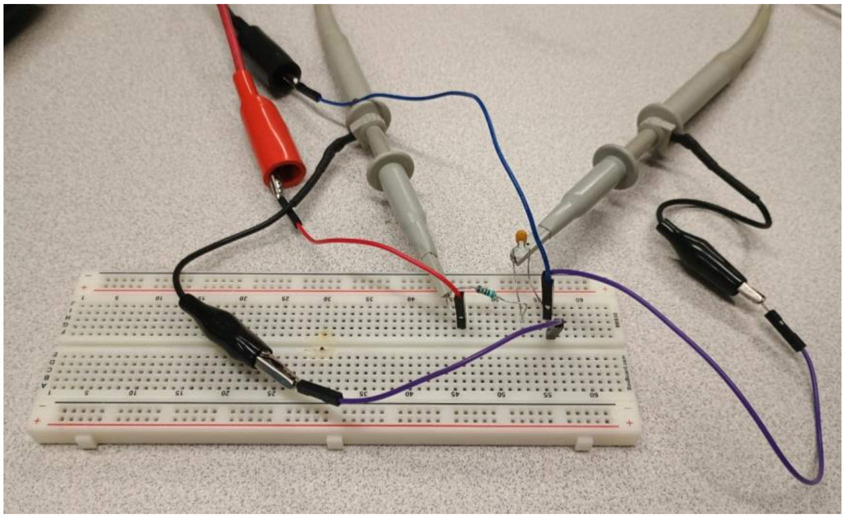


Figure 1: Built RC Circuit

3a. Schematic:

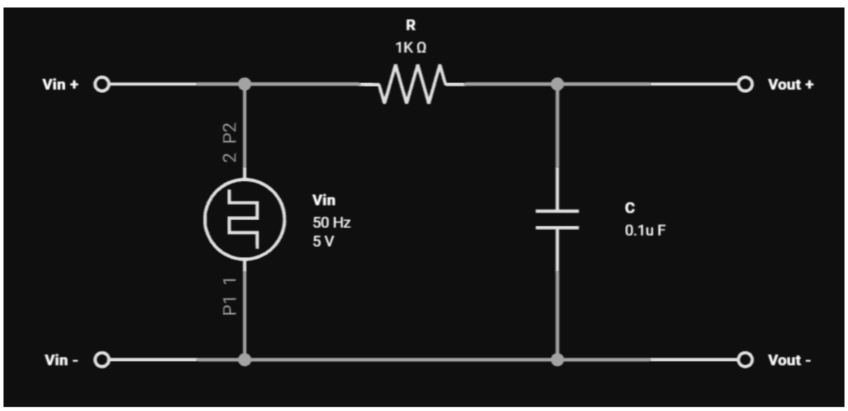


Figure 2: RC Circuit Schematic

3b. Nominal resistance = 1 kΩ
Tolerance = ±1% (brown)
Measured value = 996 Ω
Yes, the resistor was within the expected range (±1%).

3c. Nominal capacitance = 0.1uF
Tolerance = ±20% (No indicator, assumed)
Measured value = 0.116uF
Yes, the capacitor was within the expected range (±20%).

3d. Derivation of ODE for RC Circuit:

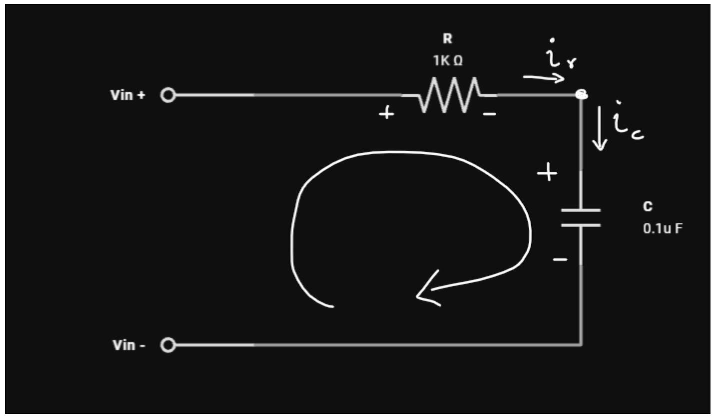


Figure 3: KVL on RC loop

As per KVL:

$$\sum_i V_i = 0$$

$$-V_s + V_r + V_c = 0$$

$$\Rightarrow V_r = V_s - V_c \qquad \text{...(1)}$$

From Ohm's Law and Eq (1):

$$\Rightarrow V_r = i_r R$$

$$\Rightarrow i_r = \frac{V_s - V_c}{R} \qquad \text{...(2)}$$

Also for a capacitor:

$$i_c = C\frac{dV_c}{dt} \qquad \text{...(3)}$$

As per KCL:

$$\sum_i i_{IN} = 0$$

$$i_r - i_c = 0$$

$$i_r = i_c \qquad \text{...(4)}$$

From Eq(2) and Eq(3):

$$\Rightarrow \frac{V_s - V_c}{R} = C\frac{dV_c}{dt}$$

$$\Rightarrow V_s - V_c = RC\frac{dV_c}{dt}$$

$$\Rightarrow RC \cdot V'_c + V_c = V_s \qquad \text{...(5)}$$

Here,

$$V_s = V_{in} \qquad \text{...(6)}$$

$$V_c = V_{out} \qquad \text{...(7)}$$

From Eq(5) and Eq(6):

$$\Rightarrow RC \cdot V'_{out} + V_{out} = V_{in} \qquad \text{...(8)}$$

Eq(8) is the derived First-Order ODE relating V_{in} to V_{out}.

3e. Standard form of Fist-Order ODE:

$$\tau y' + y = Ku \qquad \text{...(9)}$$

Where τ is the time constant and K is the static gain. Relating Eq(9) with Eq(8) we get:

...(10)

τ relates to break frequency (ω_b) as:

$$\omega_b = \frac{1}{\tau} = \frac{1}{RC} \qquad \text{...(11)}$$

To represent in Hertz:

$$f_b = \frac{\omega_b}{2\pi\tau} = \frac{1}{2\pi RC} \qquad \text{...(12)}$$

Thus, for the values of R and C, using Eq(10) and Eq(11), the value of time constant τ and break frequency ω_b are:

$$\tau = RC = 996 * 0.116 * 10^{-6} = 1.15536 * 10^{-4}\ s$$

$$\omega_b = \frac{1}{\tau} = \frac{1}{1.15536 * 10^{-4}}$$

$$\omega_b = 8655.31\ \frac{rad}{s} \qquad \text{...(13)}$$

$$f_b = \frac{8655.31}{2\pi\tau} = 1377.535514\ Hz \qquad \text{...(14)}$$

3f. 5% settling time of a first order ODE is approximately

$$t_{s(5\%)} = 3\tau$$

Experimental findings for $t_{s(5\%)}$:

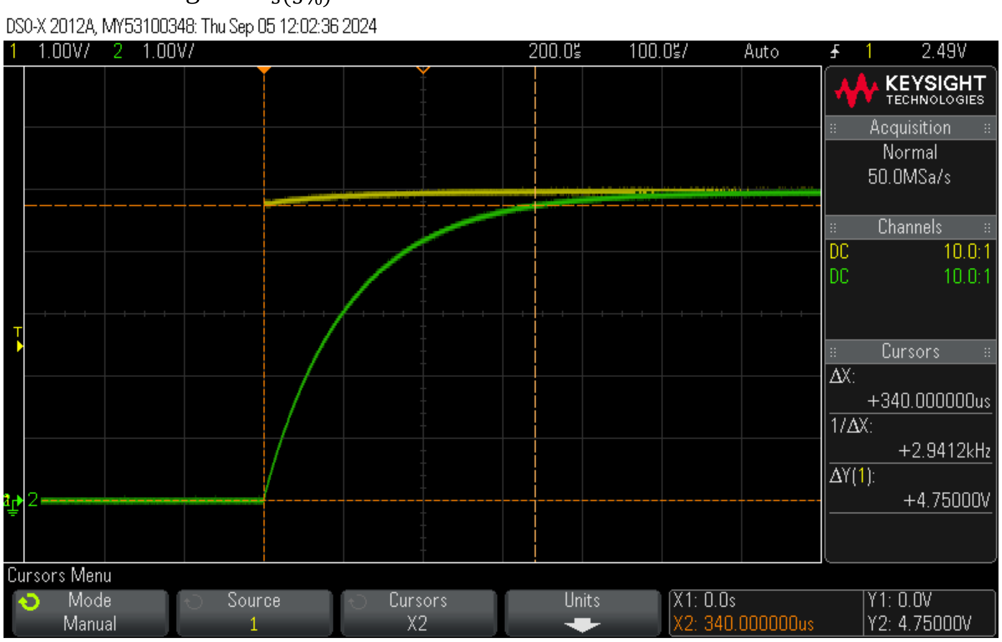


Figure 4: Settling time for given Low-Pass Filter

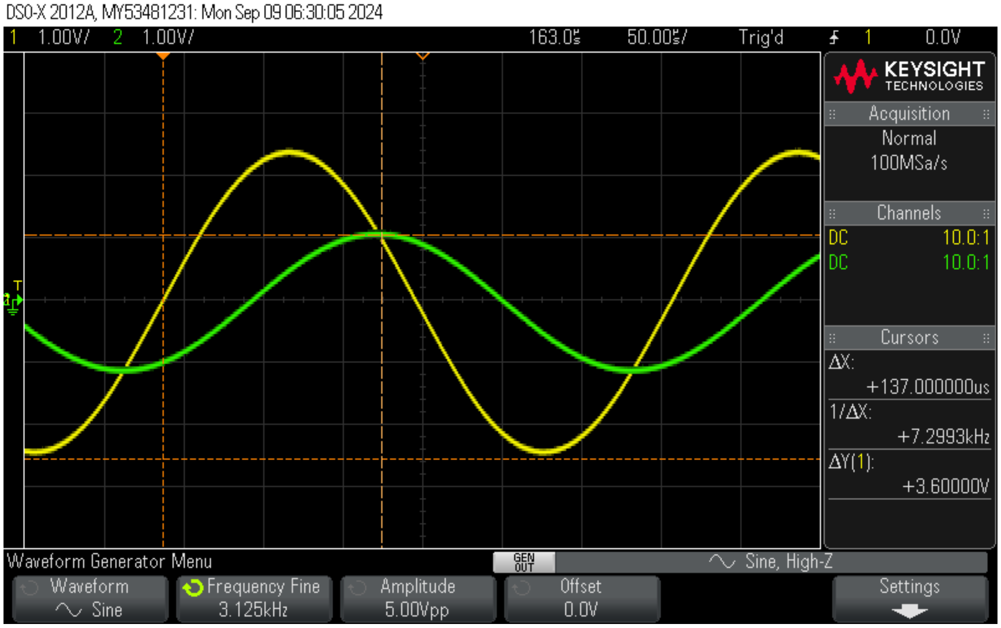
Input signal used: Square wave signal 5V 100Hz
Measured settling time = 340 us
Time constant = 340/3 = 113.3 us = 1.113*10^{-4} seconds
The percentage error is 3.6%.

3g. f_b or ω_b corresponds to the point where $\frac{V_{out}}{V_{in}} = 0.707$.

$$V_{out} = 0.707 * 5 = 3.535v$$

After setting the cursors we got the Time constant as 137 us, which is at -17.3% error. We weren't sure what we were doing wrong here.

DSO-X 2012A, MY53481231: Mon Sep 09 06:30:05 2024



2. Force sensing circuit:

4a. Build FSR Circuit:

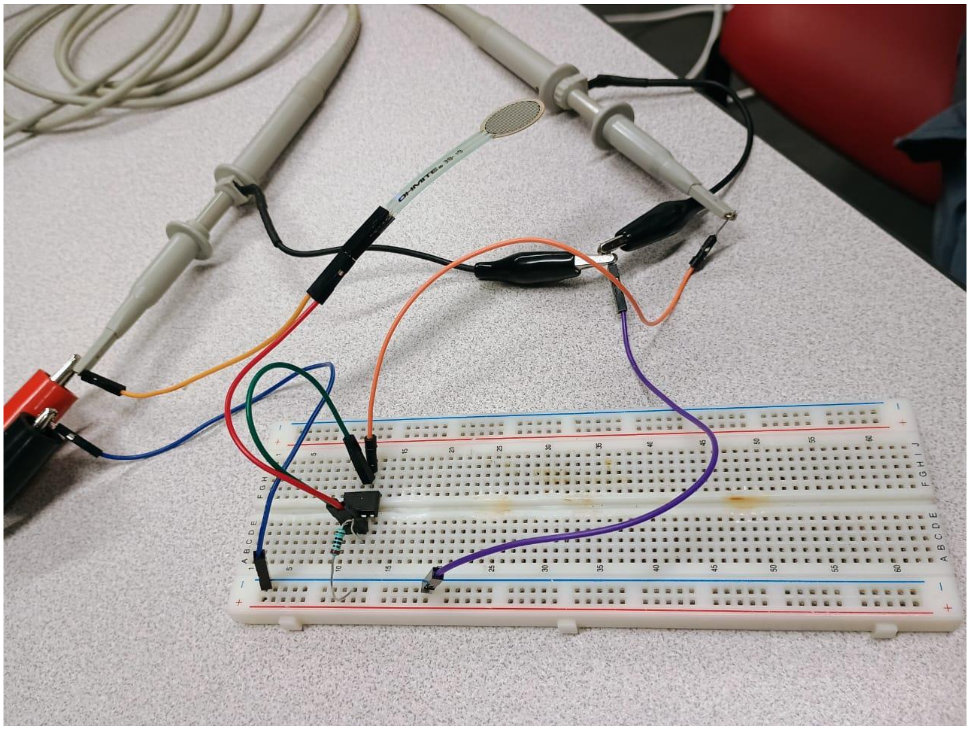


Figure 5: Built Force-Sensing circuit

4a. FSR Circuit Diagram

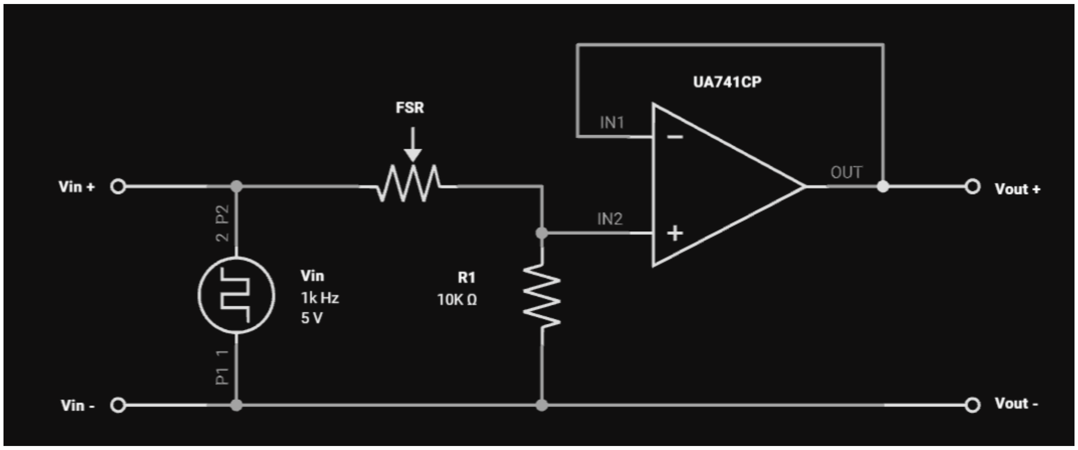


Figure 6: Force-Sensing Circuit Schematic

4b. Nominal resistance = 10 KΩ
Tolerance = ±1% (brown)

4c. Measured value = 9.93 KΩ
Yes, the resistor was within the acceptable range (±1%).

4d. FSR 402 was selected.
No-Load Resistance (R_{FSR}) = 320KΩ

4e. Application of KVL and Ohm's Law to determine voltage at A.

- At input side:

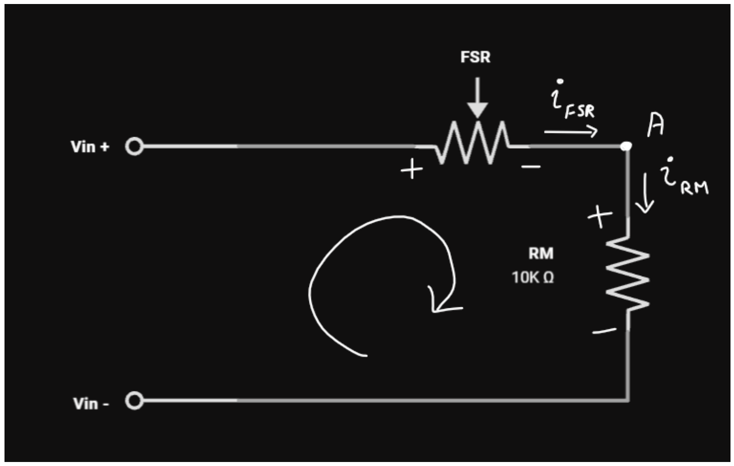


Figure 7: Applying KVL at input side

As per KVL, input voltage:

$$\sum_i V_i = 0$$
$$-V_{in} + V_{FSR} + V_{RM} = 0$$
$$\Rightarrow V_{in} = V_{R_M} + V_{FSR}$$
$$\Rightarrow V_{in} = i_{R_M} R_M + i_{FSR} R_{FSR} \qquad ...(15)$$

As per KCL, since R_M and FSR are in series:

$$\sum_i i_{IN} = 0$$
$$i_{FSR} - i_{R_M} = 0$$
$$i_{FSR} = i_{R_M} \qquad ...(16)$$

Using Eq(16) in Eq(15):

$$V_{in} = i_{R_M}(R_M + R_{FSR}) \qquad ...(17)$$

- At output side:

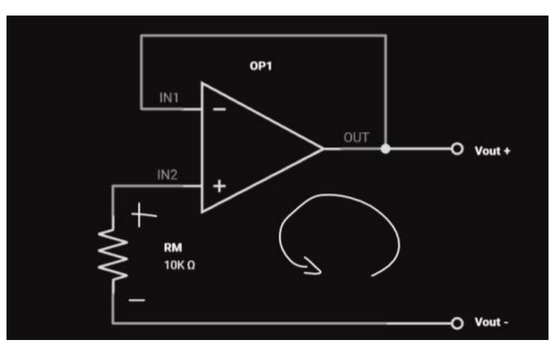


Figure 8: Applying KVL at output side

Applying KVL and Ohm's law:

$$\Rightarrow V_{R_M} - V_{out} = 0$$
$$\Rightarrow V_{out} = i_{R_M} R_M$$
$$\Rightarrow i_{R_M} = V_{out}/R_M \qquad ...(18)$$

Using of Eq(18) in Eq(17):

$$V_{in} = \frac{V_{out} \cdot (R_M + R_{FSR})}{R_M}$$
$$\Rightarrow V_{out} = \frac{R_M \cdot V_{in}}{(R_M + R_{FSR})} \qquad ...(19)$$

Thus, Eq(18) gives the voltage across R_M (Output voltage or voltage at point A).

4f. Output of the circuit with no load on FSR:

$$V_{out} = \frac{R_M \cdot V_{in}}{(R_M + R_{FSR})} = \frac{9.93 \cdot 5}{9.93 + 320}$$
$$V_{out} = 150.48\, mV \qquad ...(20)$$

Experimental results:

- Square Wave signal at 5V and 1KHz
- Output voltage: 162.5 mV

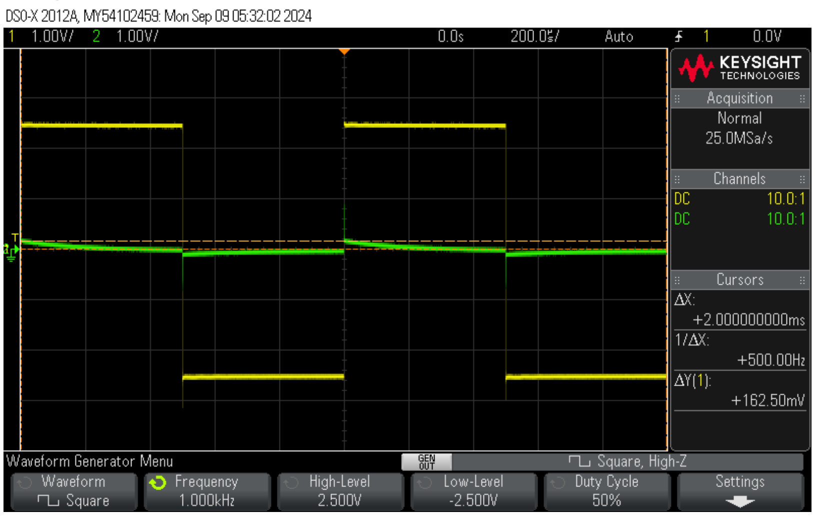


Figure 9: Output voltage with no load on FSR

The calculated value differs from experimental value by just -7.39%, it seems acceptable.

4g. Output of the circuit with loaded FSR:

$$V_{out} = \frac{R_M \cdot V_{in}}{(R_M + R_{FSR})} = \frac{9.93 \cdot 5}{9.93 + 50}$$
$$V_{out} = 828.46\, mV \qquad ...(20)$$

- Square Wave signal at 5V and 1KHz
- Output Voltage: 887.5 mV

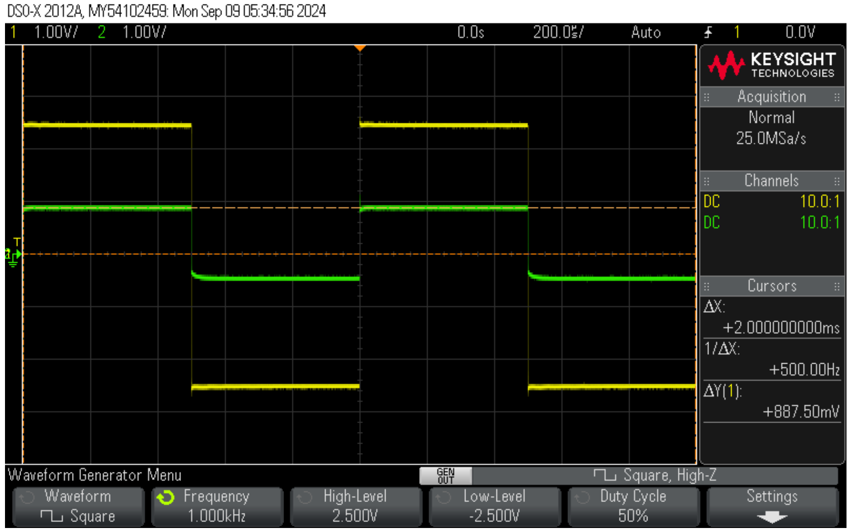


Figure 10: Output voltage at Loaded FSR

The calculated value differs from experimental value by just -6.675%, it seems acceptable.

4h. Op-Amp follower reduced voltage drop across FSR as noted in the otherwise absence of the op-amp. The FSR Voltage divider became more accurate when used with Op-Amp Follower.

Conclusion

In Lab 1, we focused on getting familiar with the test equipment and practiced building electronic circuits, Low-Pass filter and FSR Voltage follower. We learned to use Oscilloscope, function generator and multimeter while analyzing those circuits. Differences between theoretical and experimental values had us recheck our experimental approach, emphasizing meticulous measurement and calculation. Extensive practice in report writing was also received.

Citations

[1] J. A. Mynderse, "Electronic Systems: 1359_1734-Mechatronic Systems," Lawrence Technological University, [Online]. Available: https://lawrencetech.instructure.com/courses/17830/pages/electronic-systems.

[2] J. A. Mynderse, "Lab Components: 1359_1734-Mechatronic systems," Lawrence Technological University, [Online]. Available: https://lawrencetech.instructure.com/courses/17830/pages/lab-components.