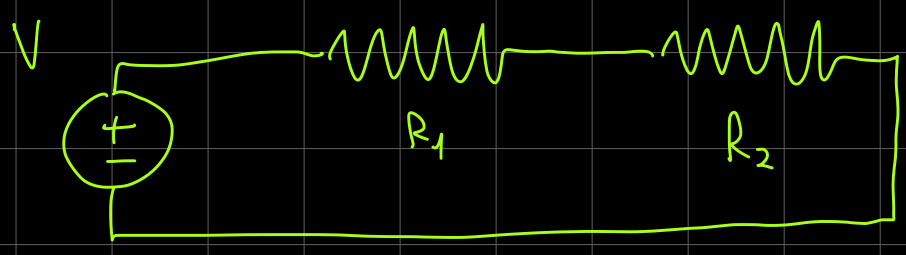
Skills section 1 09.10.2025

Objectives: become familiar with lab equipment, construct an EEE bug, learn how to use a multimeter, analyse voltage divider circuits and familiarise myself with arduino

Background: voltage divider action happens in series circuits according to the pattern below.



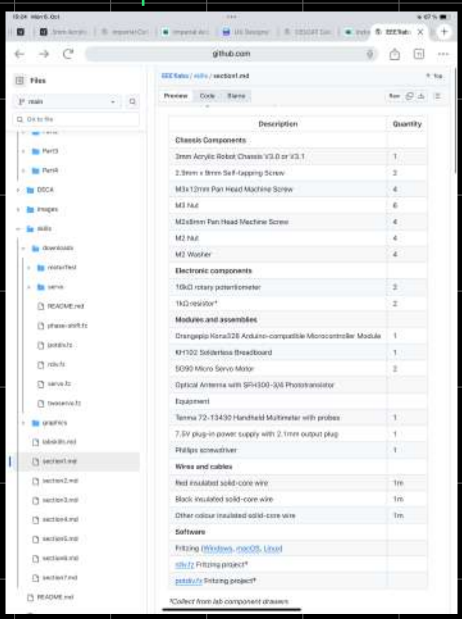
$$R = \frac{U}{I} \qquad I = \frac{V}{R_1 + R_2} \qquad V_2 = V \cdot \frac{R_2}{R_1 + R_2}$$

$$V_1 = V \cdot \frac{R_1}{R_1 + R_2}$$

So basically the voltage divides between resistors in dependence of their relative resistances. The bigger the resistance the greater percentage voltage will appear over it.

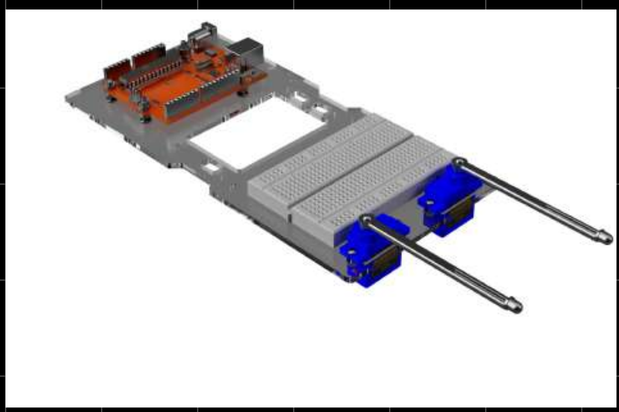
Materials and methods:

Elements required to assemble the EEE bug.



Description	Quantity
Chassis Components	
3mm Acrylic Robot Chassis V3.0 or V3.1	1
2.5mm x 8mm Self-tapping Screw	2
M3x12mm Pan Head Machine Screw	4
M3 Nut	6
M2x8mm Pan Head Machine Screw	4
M2 Nut	4
M2 Washer	4
Electronic components	
10kΩ rotary potentiometer	2
1kΩ resistor*	2
Modules and assemblies	
Orangepip Kona328 Arduino-compatible Microcontroller Module	1
KH102 Solderless Breadboard	1
SG90 Micro Servo Motor	2
Optical Antenna with SFH300-3/4 Phototransistor	
Equipment	
Tenma 72-13430 Handheld Multimeter with probes	1
7.5V plug-in power supply with 2.1mm output plug	1
Phillips screwdriver	1
Wires and cables	
Red insulated solid-core wire	1m
Black insulated solid-core wire	1m
Other colour insulated solid-core wire	1m
Software	
Fritzing (Windows, macOS, Linux)	
rdiv.fz Fritzing project*	
potdiv.fz Fritzing project*	

*Collect from lab component drawers



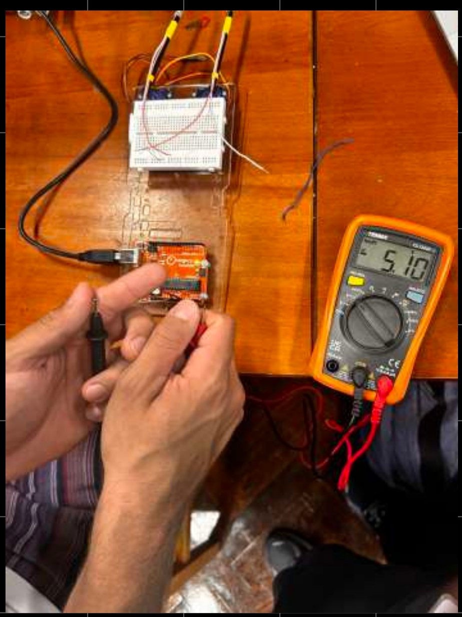
Desired look of the EEE bug

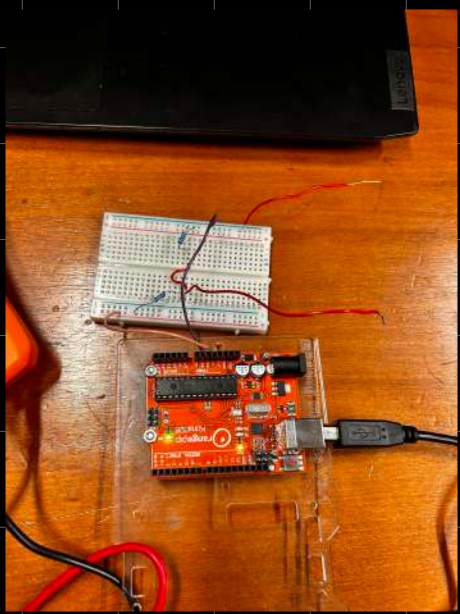
Using frizzing software as reference i will build a simple voltage divider circuit using an arduino, breadboard and two 1k resistors

Then i will measure the results using a multimeter to check if the voltage source(arduino) works properly and if `wpredicted results based on the voltage divider equation actually apply.

Analysis:

After measuring the voltage on the arduino power pin i got 5.1V. Then I measured the voltage of one of the 1k resistors and got 2.5V





The expected value for the power pin is 5V. I got 5.1V which shows a small deviation of 2% which is within the error uncertainty range because both the multimeter and the arduino power pin are not ideal which means that arduino can generate a voltage which is not exactly 5V and the multimeter doesn't have a infinite resistance so it draws some current and for this reason influences the measurement. As far as the second measurement goes i should get

$$V_1 = \frac{R_1}{R_1 + R_2} V = \frac{1}{2} V = 2{,}5V$$

The recorded value is exactly 2.5V which shows a high level of precision.

Discussion:

The measurement on the power pin was higher than expected due to the inaccuracy of the power pin itself and the non ideal nature of th multimeter

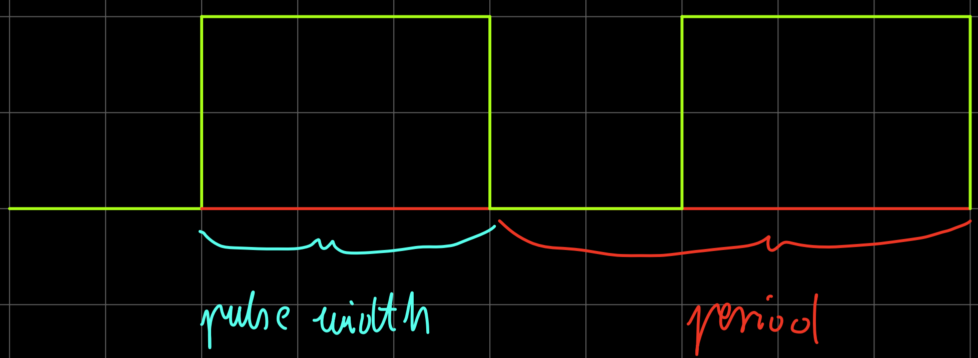
Conclusion:

Through this experiment I became familiar with the multimeter as well as with basic circuit elements such as resistors

Skill section 2 9.10.2025

Objectives: Become familiar with a potentiometer, operate the arduino software and become familiar with scripts, learn how to operate an oscilloscope, measure basic quantities characterising waveforms such as pulse width and period

Background: The potentiometer acts as a voltage divider and provides a varying voltage to the servo arm. Because of the C++ script the arduino moves the servo arm and the voltage is proportional to then angle which it makes with the starting position. An oscilloscope is a machine which allows for plotting voltage vs time graphs in real time. It has two pins which serve as input and ground loosely speaking.

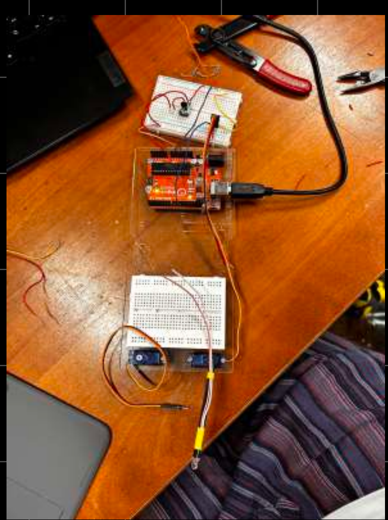


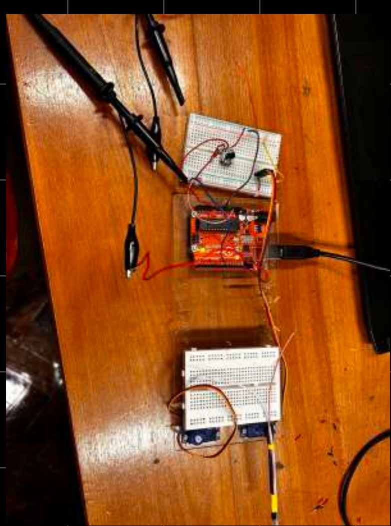
Pulse width is the time for which a single signal reaches a logical one. Period is the time after a waveform becomes repetitive.

Materials and methods:

Materials:

Description	Quantity
Modules and assemblies	
EEEBug Chassis Assembly	1
Equipment	
Oscilloscope	1
Electronic components	
3 way 2.54mm header	2
10kΩ rotary potentiometer	2
Wires and cables	
USB Cable	1
Software	
Arduino IDE	
Fritzing (Windows, macOS, Linux)	
Downloads	
servo.fz Fritzing project‡	
twoservo.fz Fritzing project‡	
servo.ino Arduino Sketch‡	





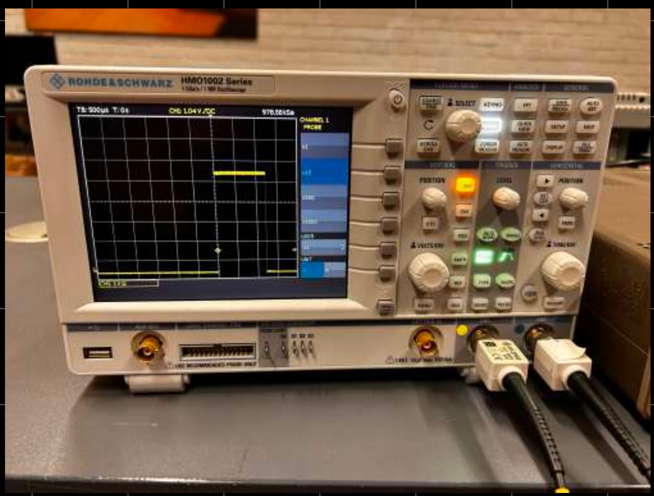
Methods: Firslty i uploaded a ready made arduino script to the IDE which allows to control the arm with a varying voltage.i unplugged the servo motor input (arduino analog pin number 9) and connected it to the oscilloscope as input. Then connected the second oscilloscope pin to a common ground to close the circuit. In this way i can analyse the input signal which is controlling the servo arm.

I assume that when the signal is high the program refreshes and the servo arm moves only in those periods.

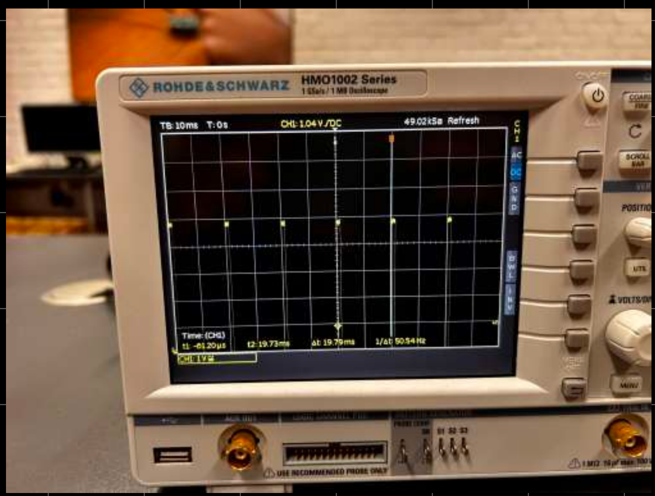
Then by using the oscilloscope and following options cursor measure/ voltage or time/ pressing the knob twice i carried out precise measurements of the pulse width period and high and low voltages

I'm going to measure the voltage across the potentiometer and the corresponding pulse width and check their dependence.

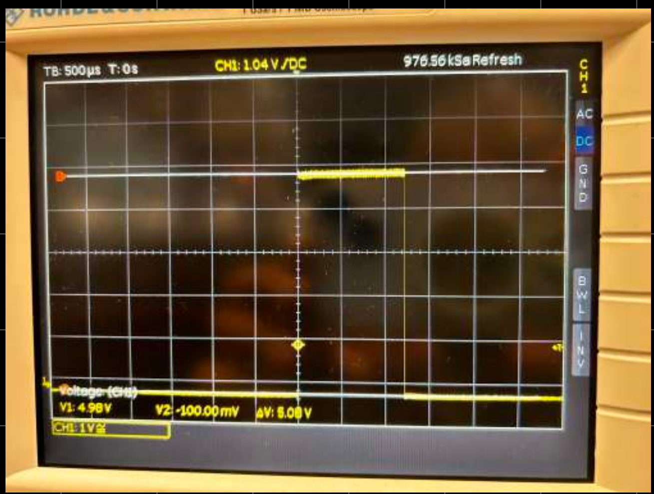
Results: The arm is moving based on the voltage input which varies since the potentiometer can take on different resistances. Additionally the greater the angle of rotation of the potentiometer knob the greater the rotation of the servo arm.



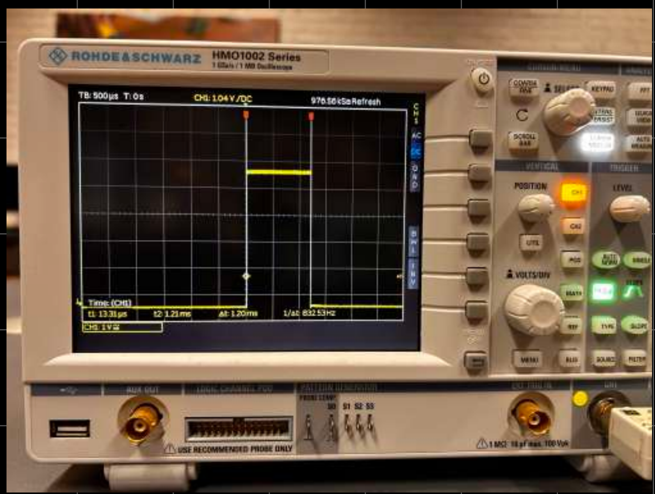
Pin 9 output signal (timescale 500us)



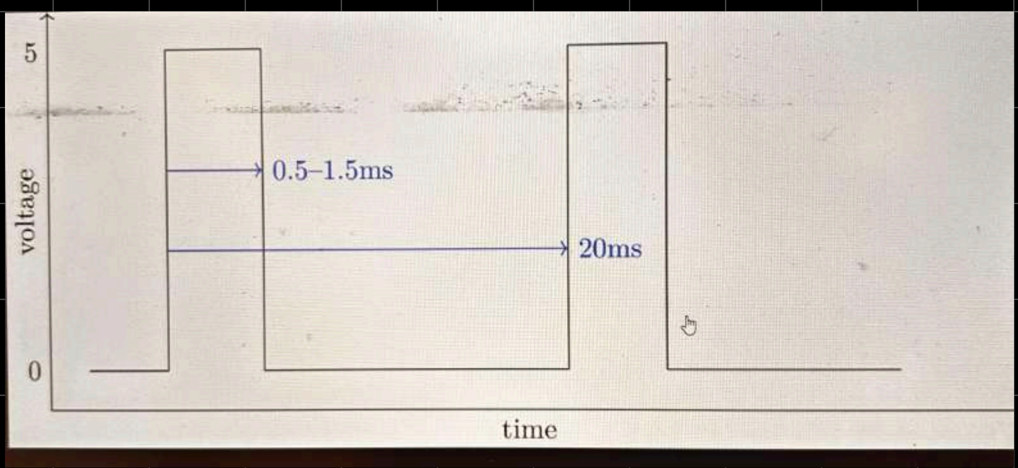
Period measurement



Voltage measurement



Pulse width measurement



After measuring the period turned out to be 19.79ms, the pulse width 1.2ms and high and low voltages respectively 4.98V and -100mV

Voltage -> pulse width tabel

Volts	Pulse width
0V	0.515 ms
1V	0.874 ms
1.99V	1.2 ms
3V	1.54 ms
4.01V	1.9 ms
4.99V	2.26 ms

Angle	Pulse width
0°	2.28 ms
30°	1.91 ms
60°	1.61 ms
90°	1.35 ms
120°	1.05 ms
150°	0.698 ms
170°	0.564 ms

Analysis:

Those are the expected values for measurments. Period length of 1979ms is very close to the expected one of 20ms. The error comes from slight inaccuracy in the measurement itself because the waveform was fuzzy and didn't have a unequivocal beginning and end. The pulse width of 1.2ms falls in the expected value range. When it comes to the measured voltage the higher boundary is achieved within desired accuracy. Again a small mistake of 0.02V comes from the fuzzy nature of the waveform. However the low voltage of -100mV doesn't exactly match the expected value of 0V. I think its due to the incorrect set up of the vertical position of the graph.

Discussion: Become more familiar with the oscilloscope and the options it offers.

Conclusion: The objective has been achieved the arm moves whenever the resistance of the potentiometer varies. The measurements carried out using the oscilloscope fall within expected ranges which shows the experiment has been conducted properly.

Challenge

Skill section 3 13.10.2025

Objectives: get to learn how a function generator works. See how an RC circuit introduces a phase shift between the input and output

Background: a function genrator uses the oscilloscope to create different periodic waveforms with adjustable parameters.

capacitor equation $C = \frac{Q}{V}$ $I = \frac{dv}{dt}$ $CV = I\,dt$ $V = \frac{1}{C} \cdot \int I\,dt$

Since the input is a sinusoid the output will be an integrated sin which is a cos divided by the frequency

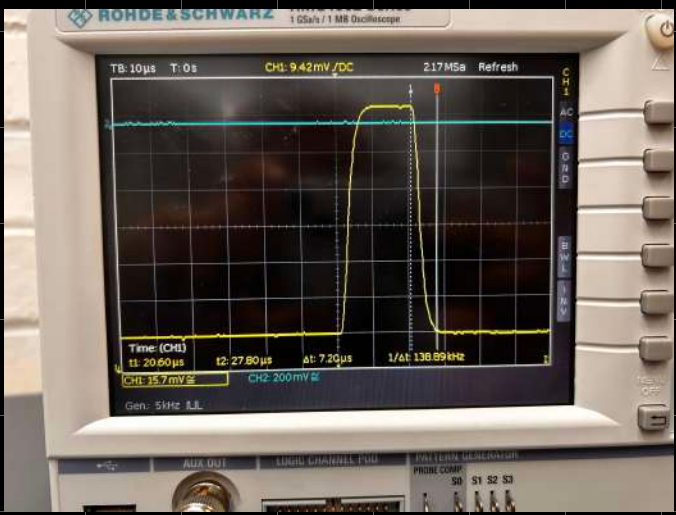
Materials and methods: To measure phase difference in radians i will use the oscilloscopes measure function

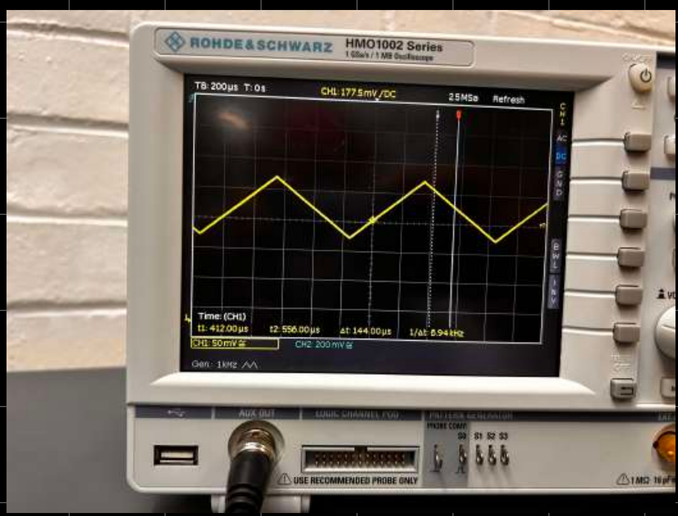
Description	Quantity
Modules and assemblies	
EEEBug Chassis Assembly	1
Equipment	
Oscilloscope	1
Electronic components	
3 way 2.54mm header	2
33kΩ resistor†	1
68kΩ resistor†	1
1µF ceramic capacitor†	1
Wires and cables	
USB Cable	1
Software	
Arduino IDE	
Fritzing (Windows, macOS, Linux)	
Downloads	
`phase-shift.fz` Fritzing project‡	
`twoservosin.fz` Fritzing project‡	
`servo.ino` Arduino Sketch‡	

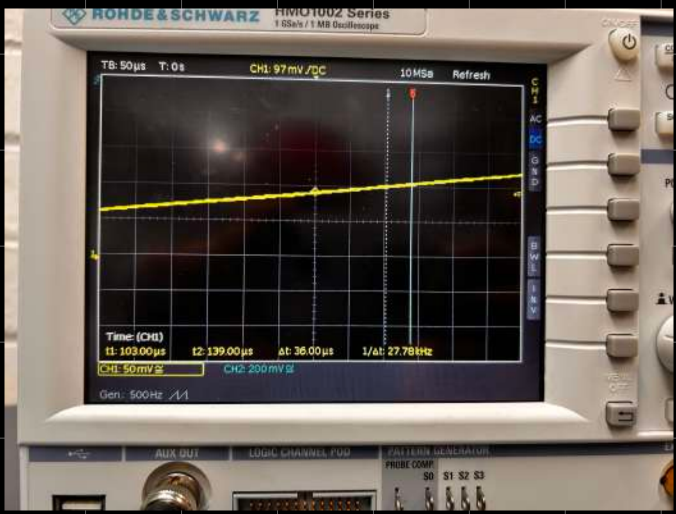
$\varphi = 2\pi t / T$ $t = 64.49\ ms$

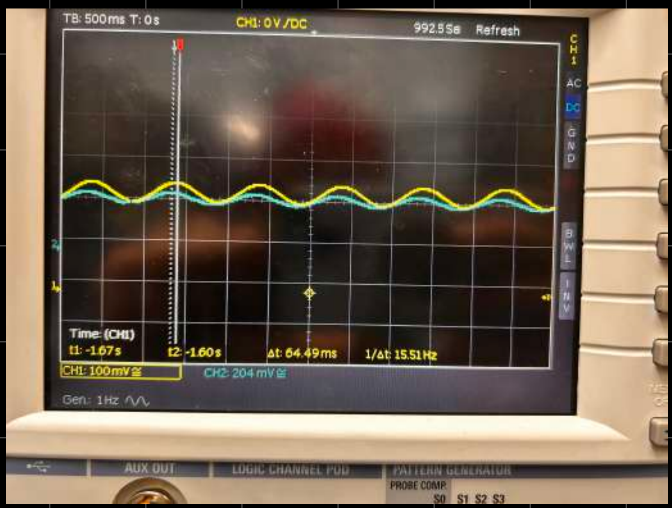
$T = \frac{1}{f} = 1s$ $\varphi = 0.405$

Results: The wave genartor produces the expected waveform. As suggested by theory the capacitor introduces a time shift to the circuit.









Questions;

1) rise time 8us and fall time 7.2 us so fall time is shorter than rise time

2)when in the AC mode the signal is connected in series with a capacitor which acts as a high pass filter and attenuates DC values so

$$y_{DC} = \sin x + C \rightarrow y_{AC} = \sin x$$

Which effectively shifts the waveform up or down

3) because the signal is produced digitally within finite time periods and when you zoom in so close (50us) you start seeing each small step

ADC part 1 impedance model
16.10.2025

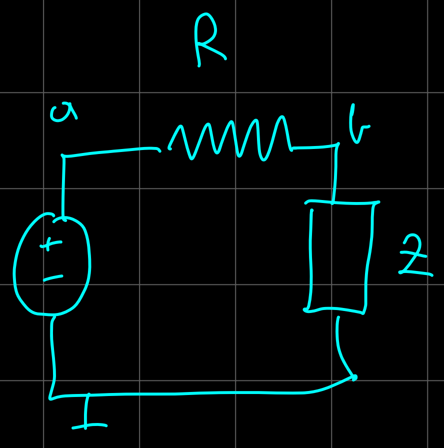
Objectives; Measure the impedance of different resistors

Background; The impedance model allows to extend the notion of resistance to all elements assuming they are operating in sinusoidal steady state. For different elements it has different forms

$$V_{in} = e^{st} \qquad s \in \mathbb{C} \qquad i = C \cdot \frac{dU}{dt} \qquad i = C \cdot s \cdot e^{st} \qquad \frac{e^{st}}{i} = \frac{1}{Cs} = \frac{1}{j\omega C}$$

$$R = \frac{U}{I} = \frac{U}{I} \qquad U = L \cdot \frac{di}{dt} \qquad i = \frac{1}{L}\int e^{st}\,dt = \frac{1}{Ls}e^{st} \qquad \frac{e^{st}}{i} = Ls = j\omega L$$

Since the oscilloscope measures the voltage relative to ground it’s impossible to directly measure voltage across R since it would be a-b and the oscilloscope can only measure voltage x relative to ground. For this reason I measure node a with reference to ground and then node b with reference to ground and them subtract them using the MATH function on the



$$R = \frac{U}{I} \qquad I = \frac{U_{ab}}{R}$$

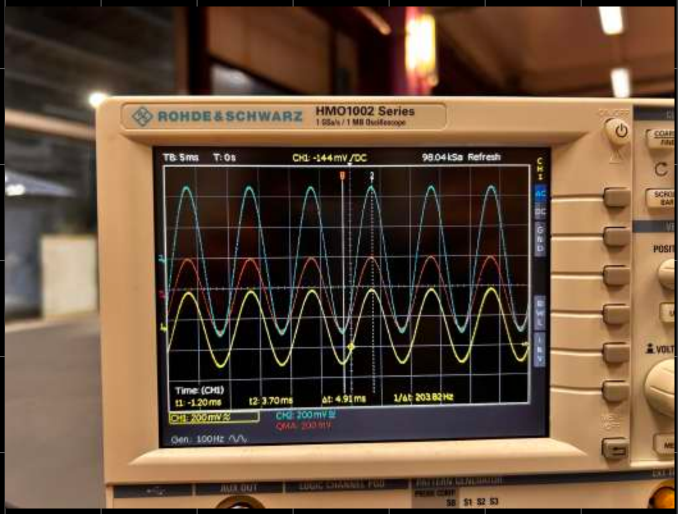
$$Z = \frac{U_b}{I} = \frac{U_b}{U_{ab}} \cdot R$$

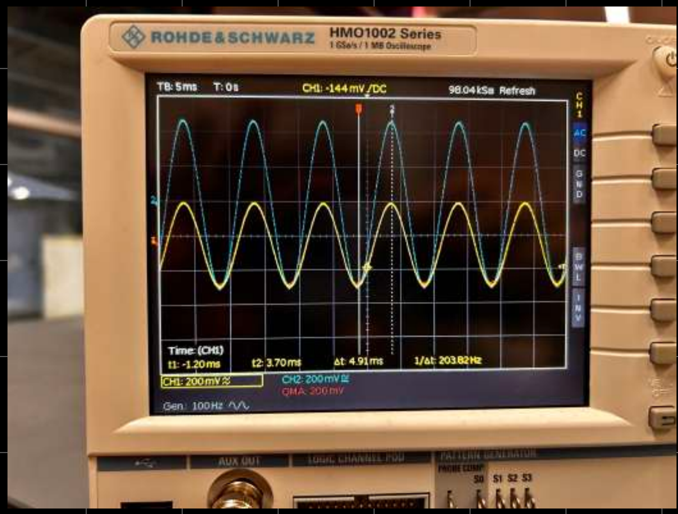
Additionally the oscilloscope can’t measure current so the way to find a current going through a element is to put a resistor (with a known resistance) in series with it and using ohms law find the current through it.

Materials;

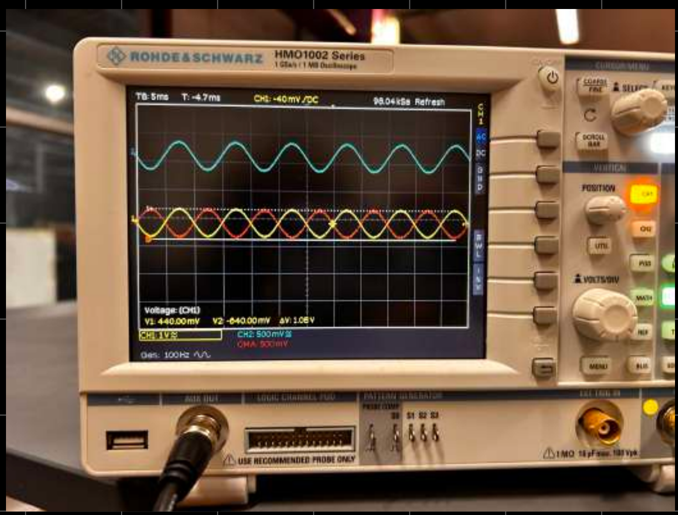
2x 1kOhm resistor, breadboard oscilloscope probes, oscilloscope function generator

Results;





On the oscilloscope there are three waveforms. Blue is the voltage across both resistors, yellow is the voltage across the impedance and red is their difference which should be equal to the voltage on the other resistor. By analysing the waveforms it is visible that they are in fact the same: they have the same frequency and amplitude.



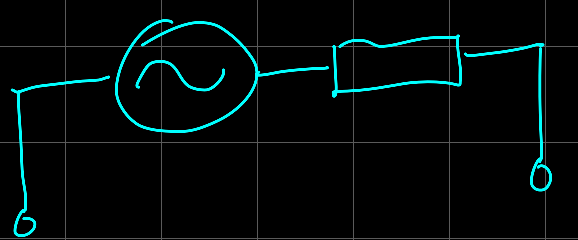
On two photos above I measure the voltage of the input signal using the oscilloscope and the multimeter to challenge its accuracy. The amplitude recorded by the oscilloscope is 1.0V and the one recorded by the multimeter is 1.043V which is within the desired level of accuracy and is satisfactory to confirm the reliability of the measurements provided by the oscilloscope.

Analysis;

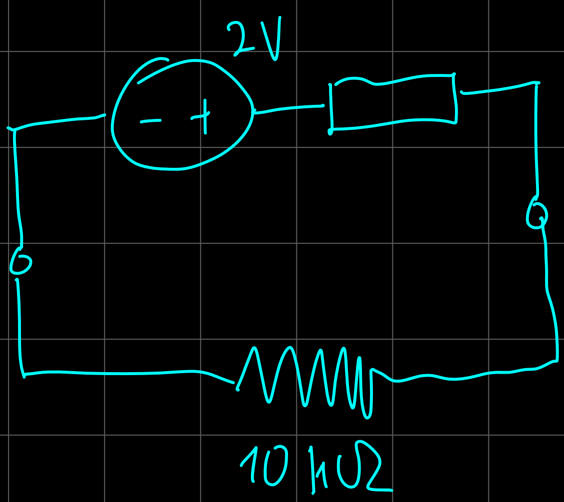
Small discrepancies of 1.08V (amplitude measured using the oscilloscope) and 1.043V (amplitude measurement using multimeter) arise from imprecise measurements with the oscilloscope, since the signal is fuzzy it is hard to exactly see where it begins and ends.

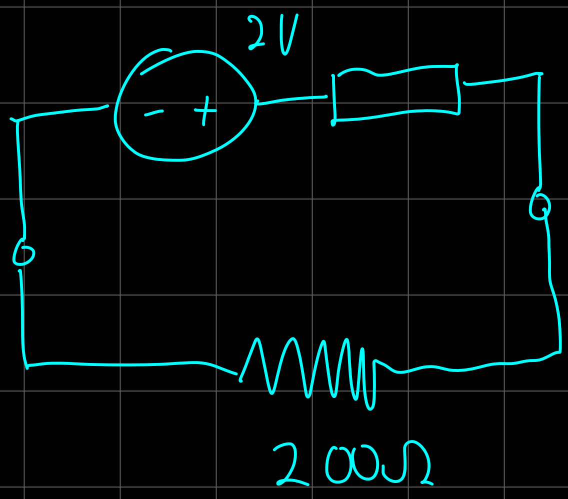
Challenge question; source impedance

In text it is suggested that the function generator provided within the oscilloscope also has some impedance. It can be measured by using a series connection with a resistor of a known resistance and a voltage source with a known value. Than it is sufficient to apply a simple voltage divider pattern to estimate the sources impedance .



Source model





$$1.949 = 2 \cdot \frac{10^4}{Z+10^4}$$

$$Z \approx 261{,}673\,\Omega$$

$$1.552 = 2 \cdot \frac{200}{Z+200} \Rightarrow Z = 57{,}73\,\Omega$$

$10\,\Omega$, $1\,mH$