Embedded Electronics Lab Report

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LAB 1

1.1

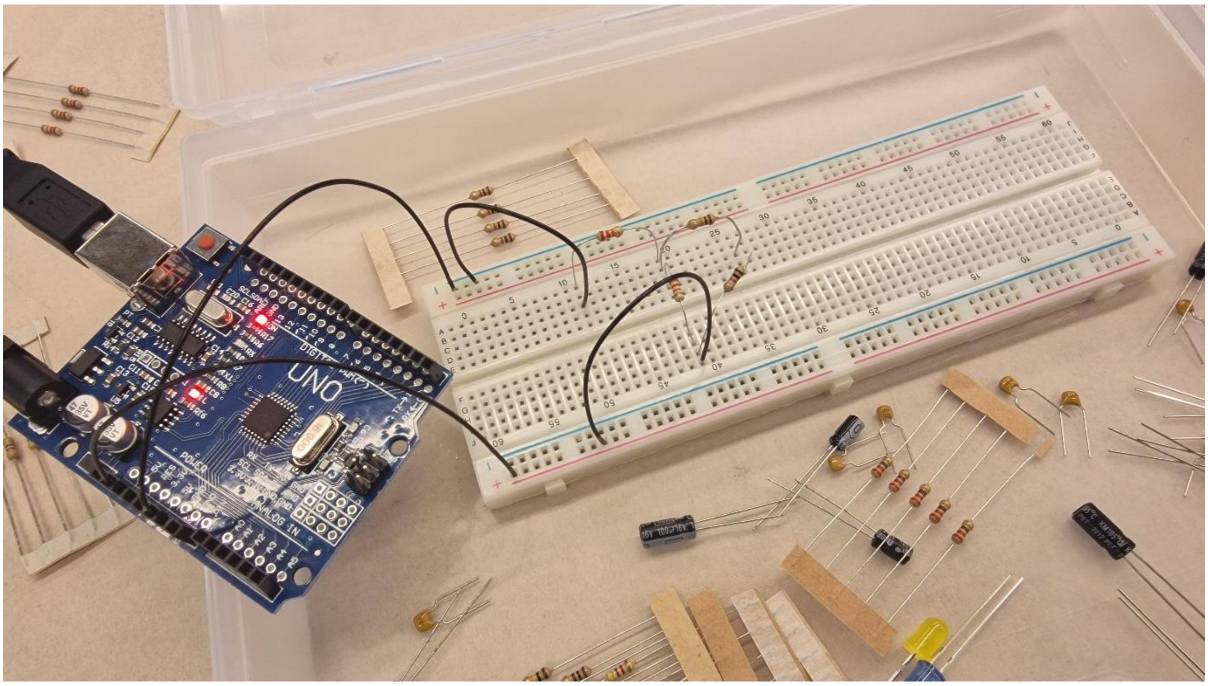


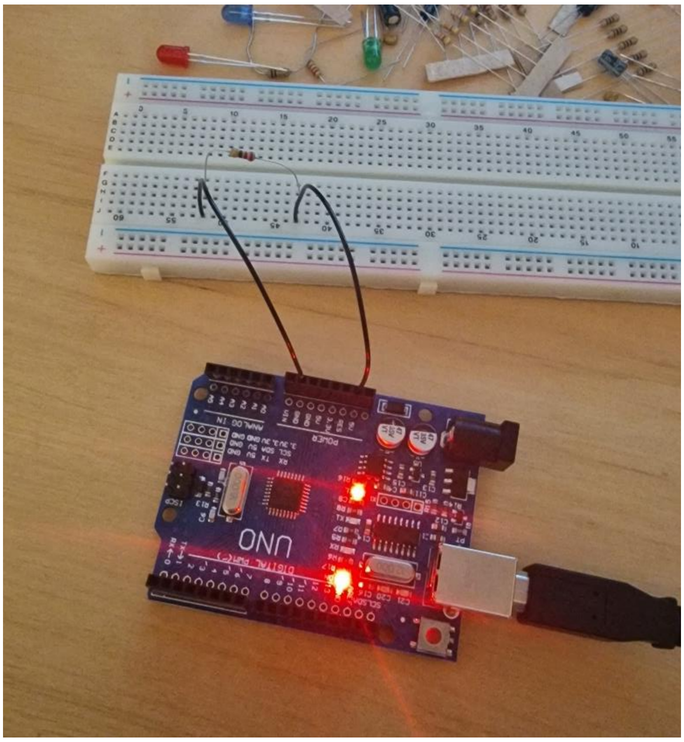
Figure 1: Lab 1.1 Circuit

Comp	Meas R Multimeter [kOhm]	Meas V Multimeter [V]	Meas I Multimeter [mA]	Calc R=V/I [Ohm]	Calc P=VI [mW]	Simulated V QUCS [V]	Simulated I QUCS [mA]	Simulated P QUCS [mW]
R1	21.4	4.33	0.202	0.202	0.874	4.62	0.215	0.996
R2	2.15	0.377	0.175	0.175	0.0660	0.382	0.178	0.067
R3	9.88	0.342	0.0346	0.0346	3.38	0.378	0.038	0.014
R4	0.996	0.034	0.0341	0.0341	0.00116	0.00381	0.038	0.145
Arduino 5V	Not applicable	4.92	0.200	Not applicable	-0.984	5	0.215	-1.08

The simulated and measured values are mostly the same within the measurement/simulation accuracy. There are a couple exceptions. Notably, the measured Voltage over R4 was 0.034V, whereas the simulated voltage was 0.00381V. This seems like it could just be a conversion error, but I checked the values over and over to ensure they were correct.

1.2.

1.2.1.



V_TH = 5.01 V

V_L = 4.98 V

R_L = 216 Ohms

R_TH = (V_TH – V_L) / (V_L / R_L)

R_TH = (5.01 – 4.98) / (4.98 / 216)

R_TH = 1.30 Ohms

1.2.2.

V_TH = 4.99 V

V_L = 4.32 V

R_L = 216 Ohms

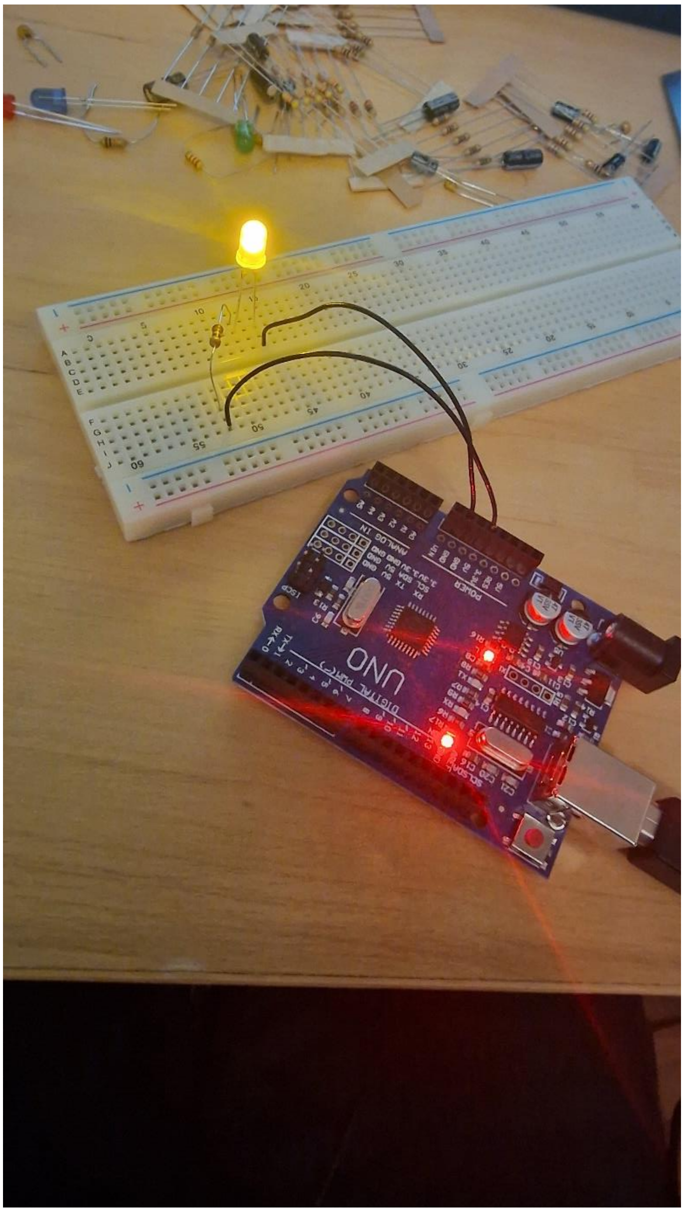
R_TH = (V_TH – V_L) / (V_L / R_L)

R_TH = (4.99 – 4.32) / (4.32 / 216)

R_TH = 33.5 Ohms

1.3

1.3.1



Yes the LED shines

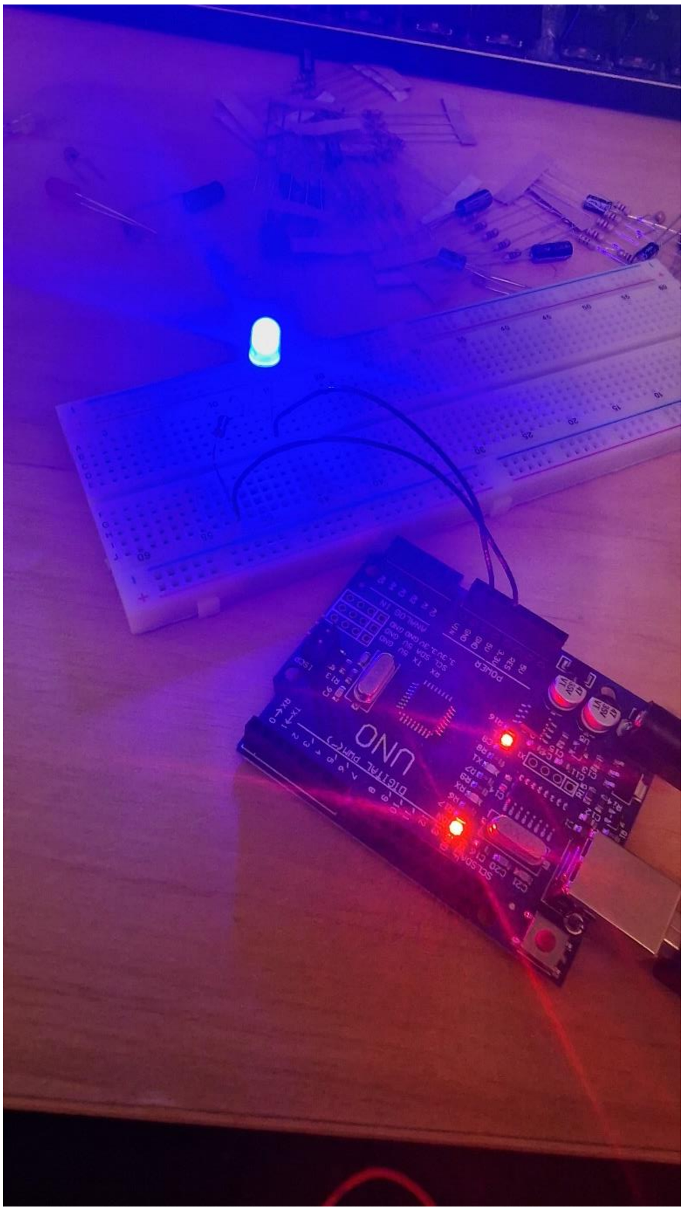
V_R = 3.01 V

V_LED = 1.98 V

I_LED = I_R = V_R / R = 3.01 V / 216 Ohms = 0.0139 A

P_LED = V_LED * I_LED = 1.98 V * 0.0139 A = 0.0275 W

1.3.2



Yes the LED shines

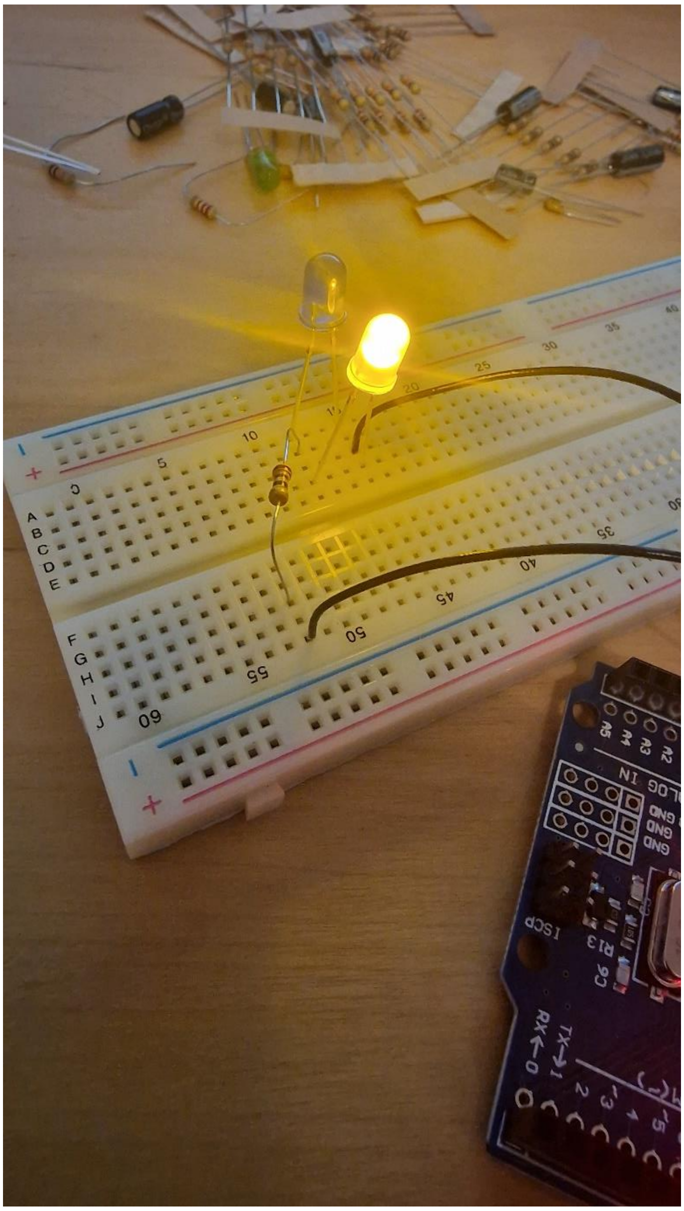
V_R = 2.29 V

V_LED = 2.69 V

I_LED = 2.29 V / 216 Ohms = 0.0106 A

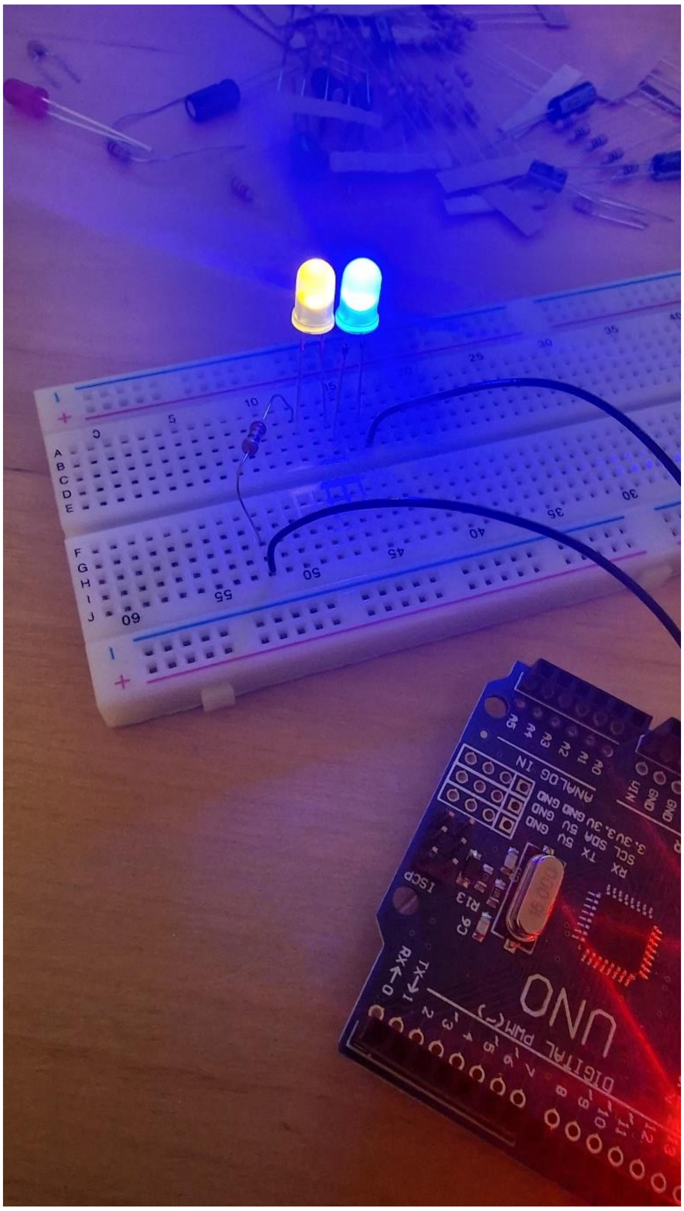
P_LED = 2.69 V * 0.0106 A = 0.0285 W

1.3.3.



It seems like the yellow LED only shines, but the blue one is in reality shining very softly, since it still has some current flowing through it.

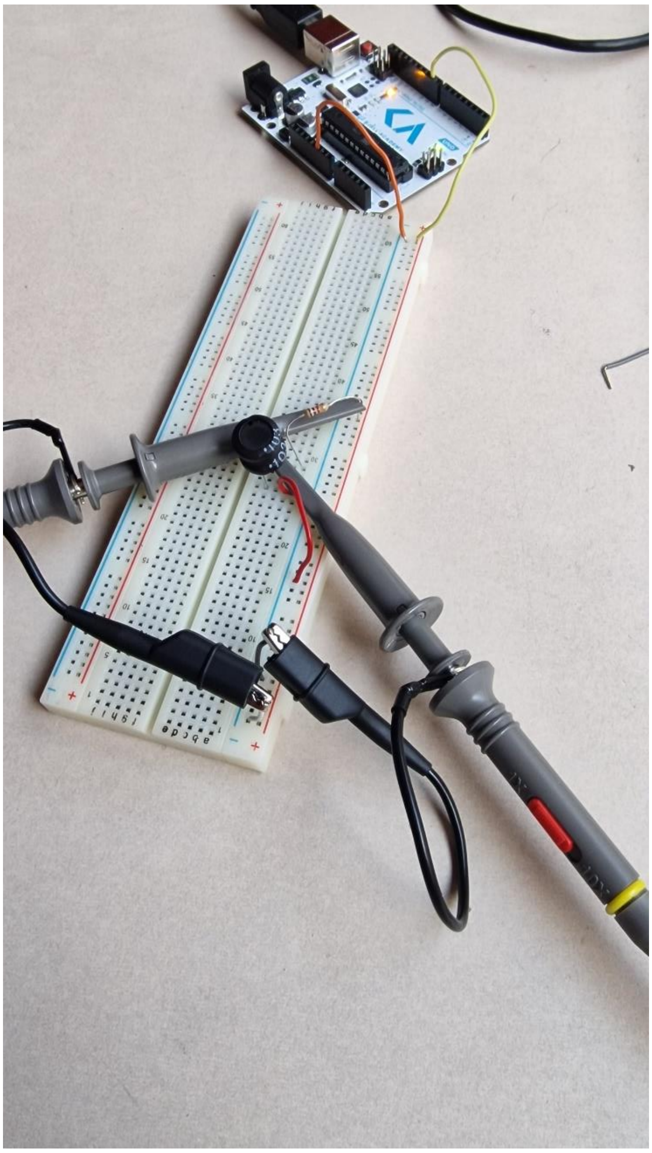
1.3.4.



Both LEDs shine. This is because the amount of current going through them is equal since they are in series. This is according to KCL, since there is no other node at which the current can go.

LAB 2

2.1.

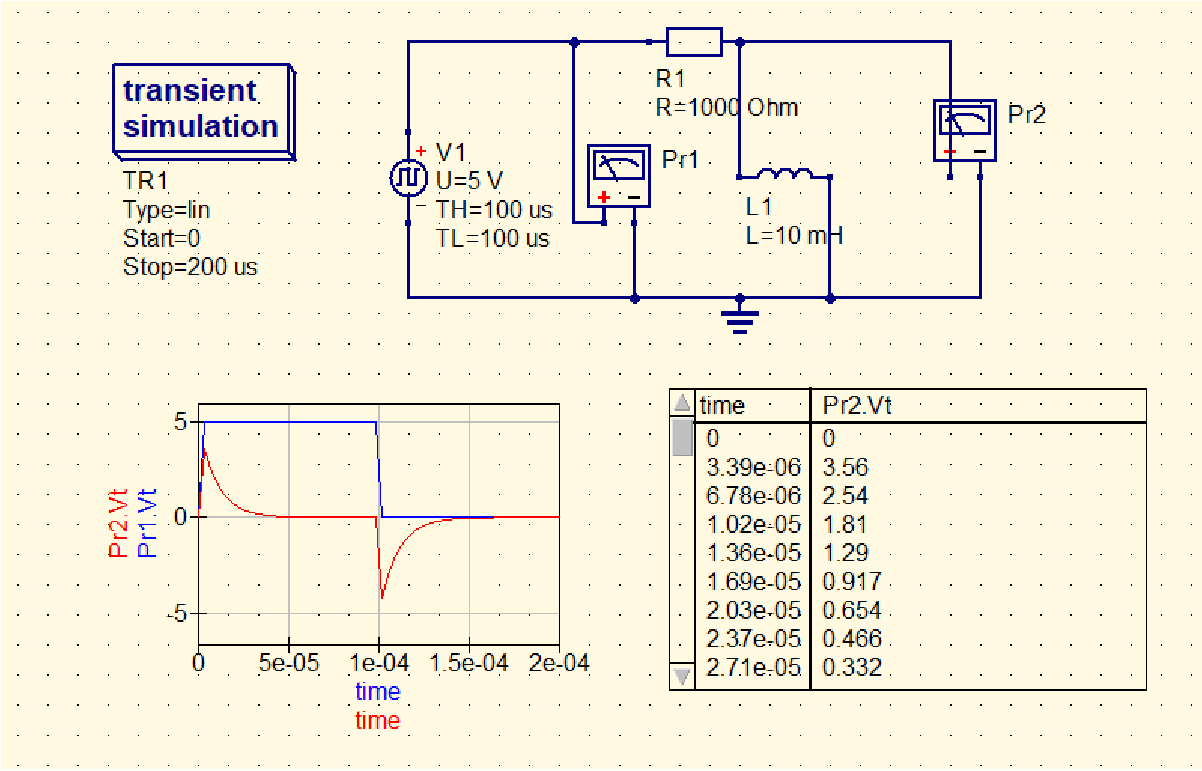


Calculated:

Tau = T

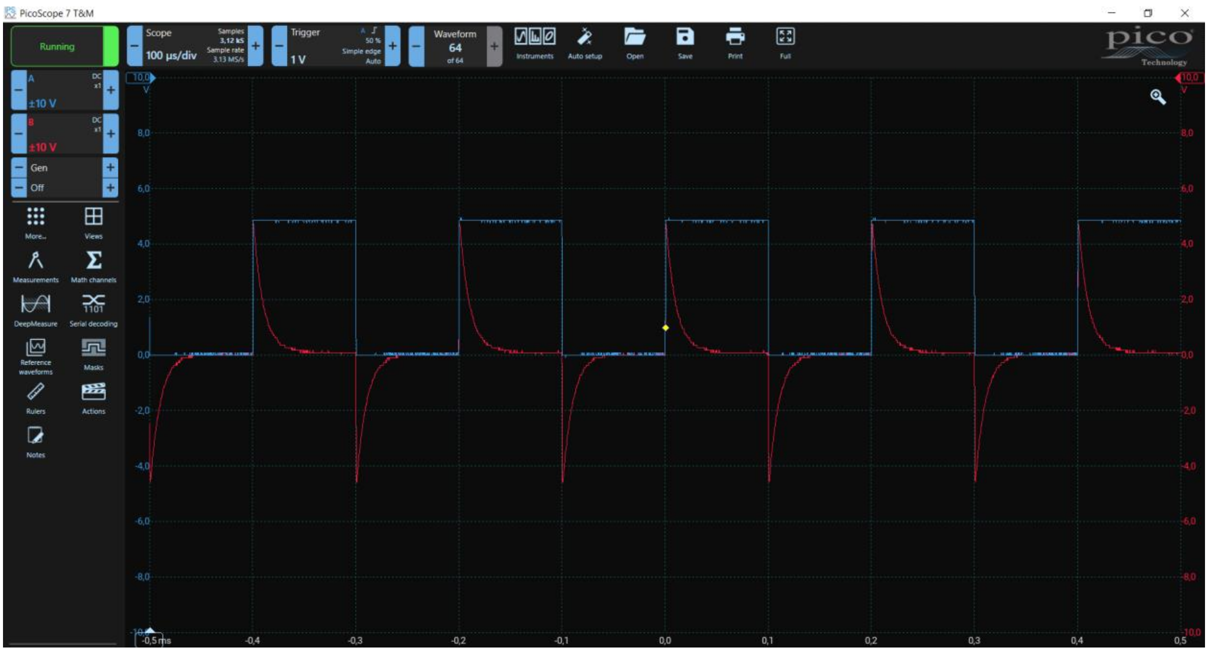
T = L/R

T = 10mH / 1kOhms = 10 microseconds



Simulated:

The time constant is when we are at approximately 37% of max voltage, in this case being 1.85V. We reach 1.81V at 1.02e-05 seconds, which is 10 us. This is consistent with our calculated time constant.



The QUCS simulation and the measured voltages have a very similar graph. This graph forms this shape because the voltage is slowly dropping as the inductor gets charged. The more the inductor gets charged the closer it acts to a short, and it does this logarithmically.

Therefore, the curve tends to 0, and then spikes when the input voltage suddenly changes, as the inductor is once again resisting the current change.

Measured:

V = V_0 * e^-(t/RC)

V = V_0 * e^(-t/T)

1 = 2.33 * e^-(8 / T)

1 / 2.33 = e^-(8 / T)

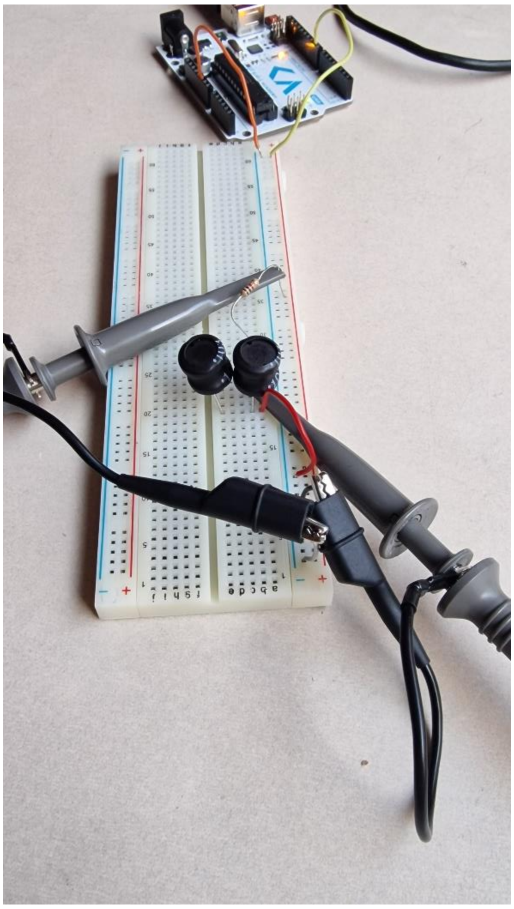
ln(1 / 2.33) = -(8 / T) * ln(e)

-0.845 = -(8 / T) * 1

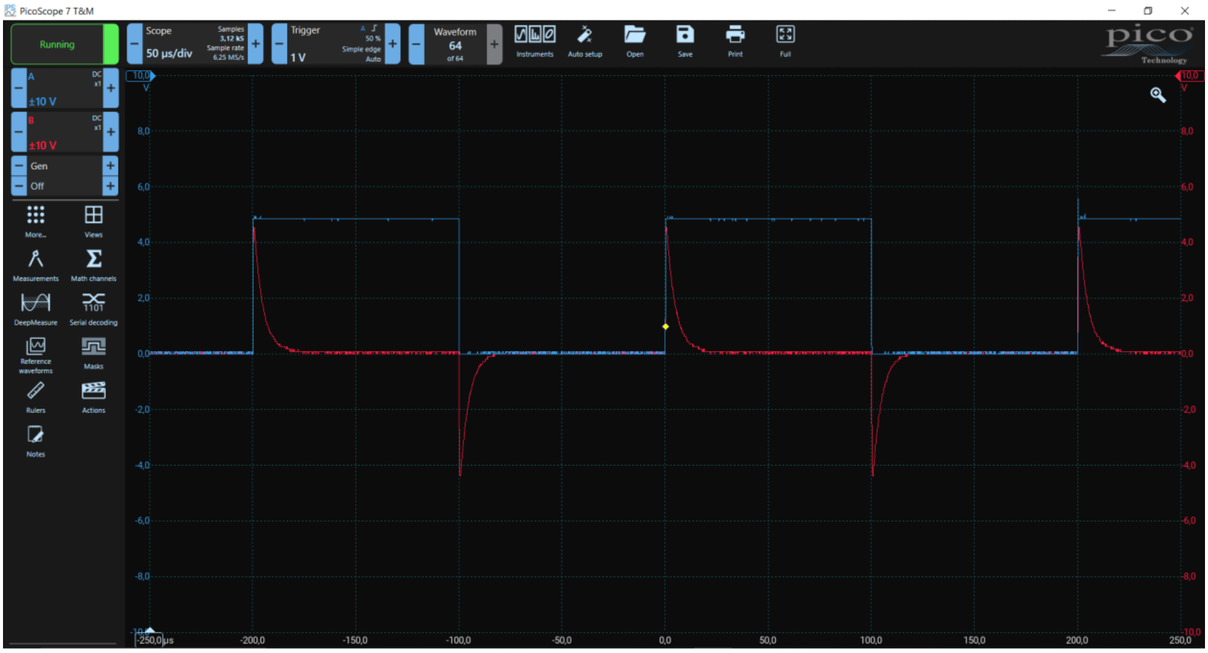
-0.845 T = -8

T = 9.4 microseconds

If we add an inductor in parallel like so,

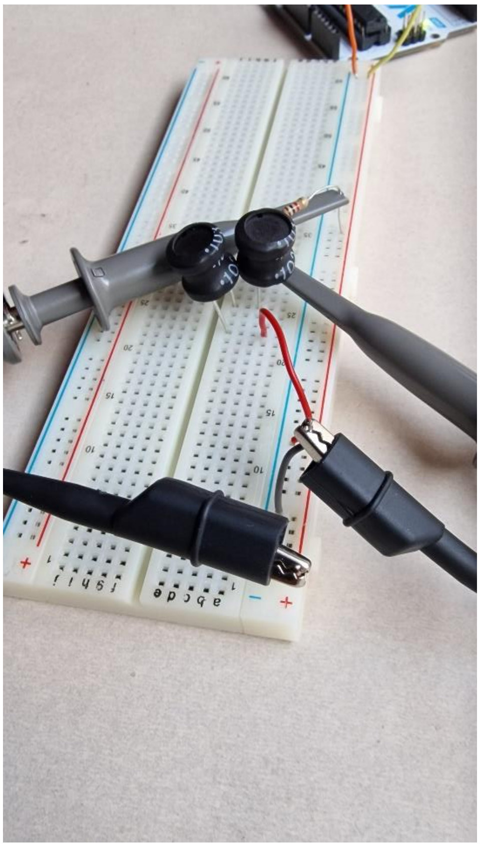


we get the following graph:

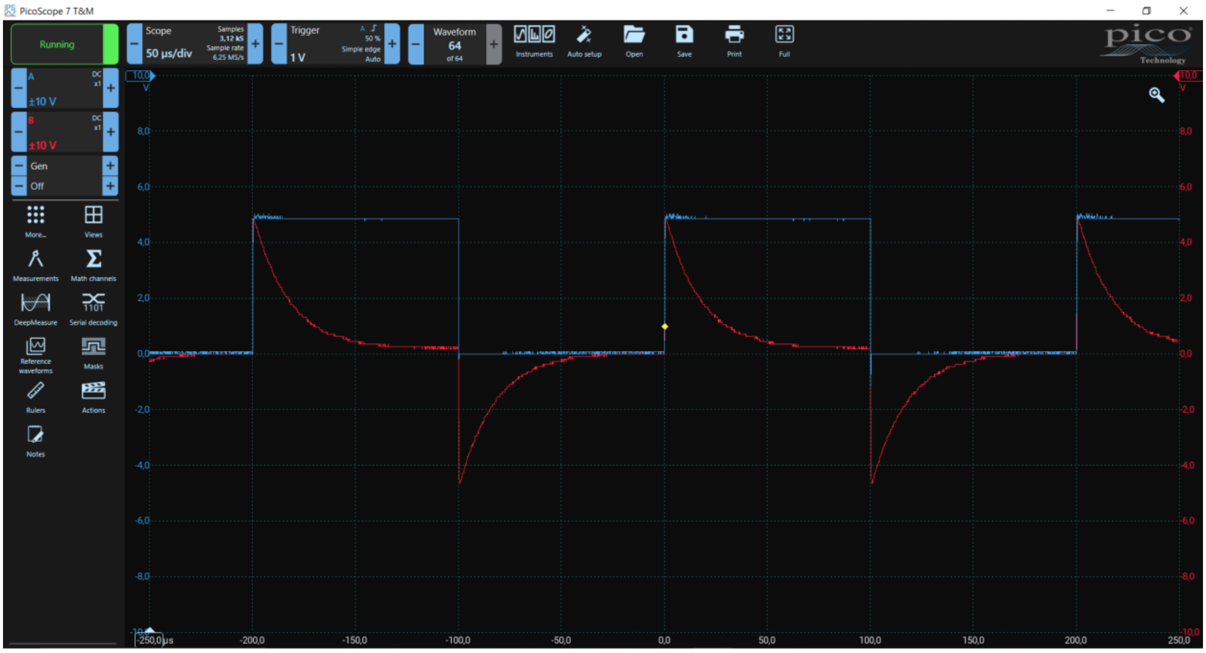


In parallel, there is less current change (the current gets divided between the two inductors) and therefore the inductors reach full charge quicker. This is why the voltage curve is steeper, since they become two “shorts” quicker. The time constant is now 4.9 us.

If we instead add an inductor in series like so,

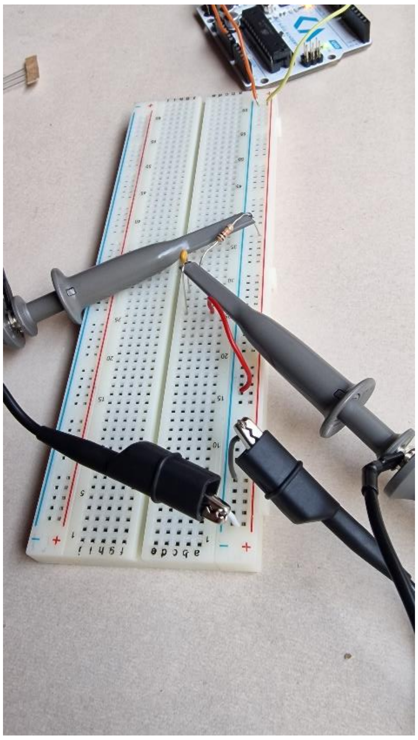


we get the following:



Here we have the opposite effect. Since we must charge two inductors with the same amount of current one after another, they will reach max charge much slower. This is a little like a traffic jam where a car must wait for the car in front of it to start moving before it starts moving. This is why we take a while before we see their voltage fizzle out to 0. The time constant is now 19.49 us.

2.2.



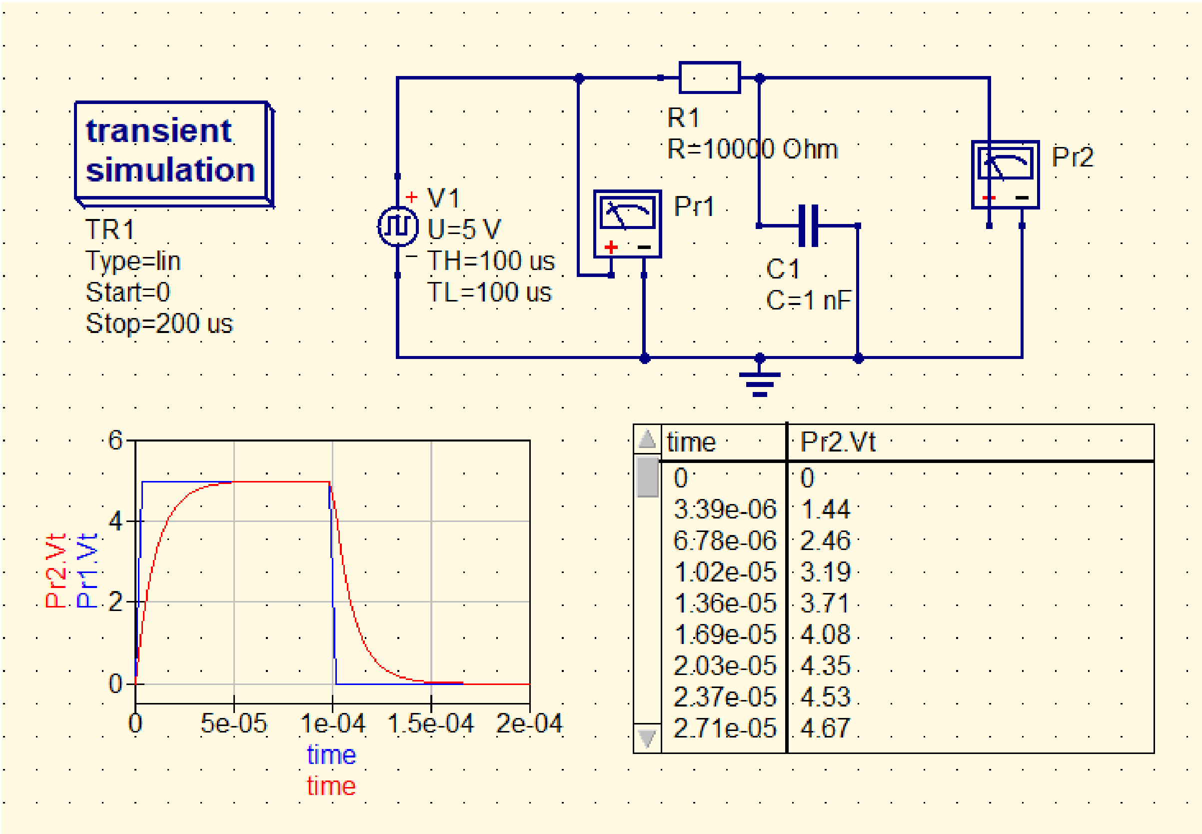
Calculated Time Constant:

T = RC

T = 10 kOhms * 1 nF

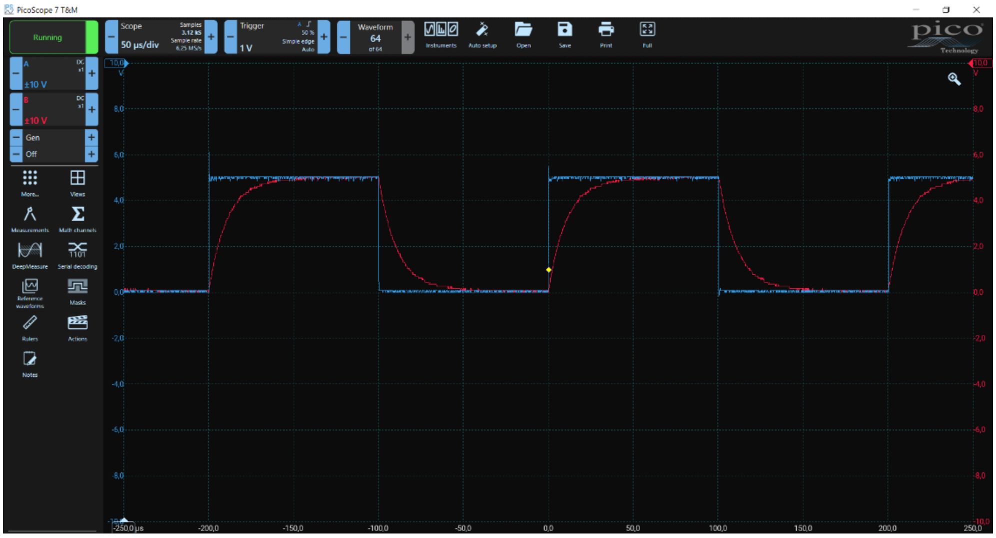
T = 10 us

Simulated:

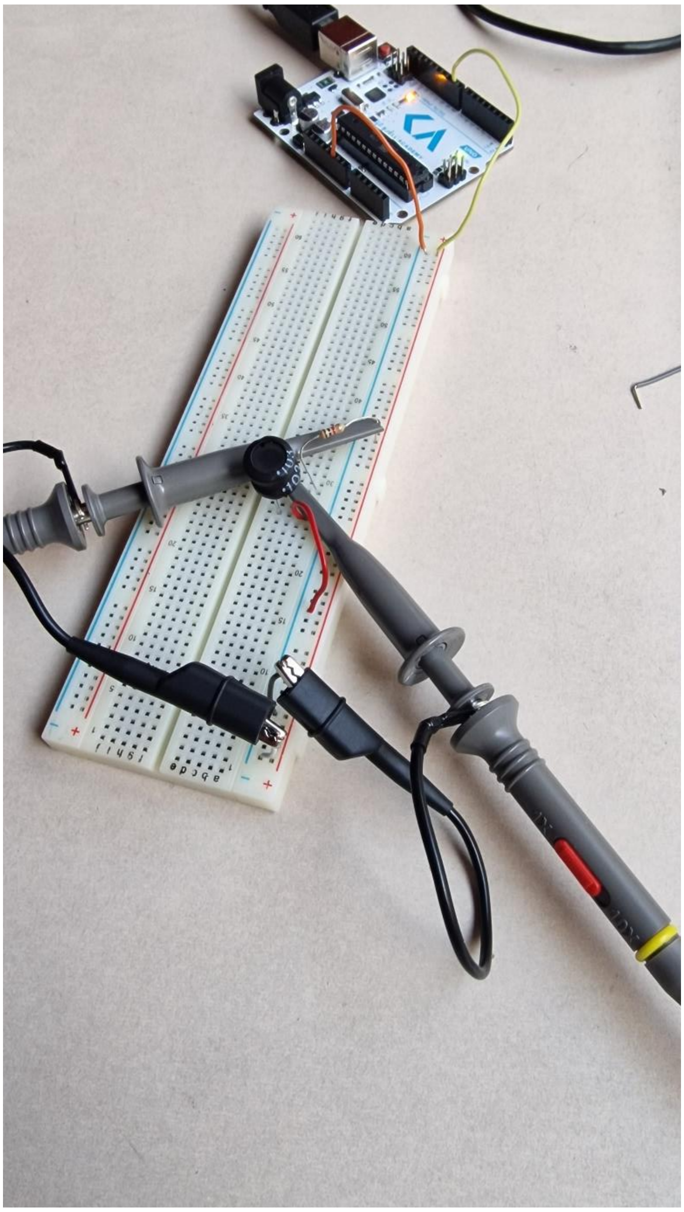


The time constant according to this table is the time it takes to get to 63% of max voltage. This is 3.15V since max voltage is 5V. We reach max 3.19V at 1.02e-05 seconds, which is 10.2 us. This is consistent with our calculation of 10us.

Measured:



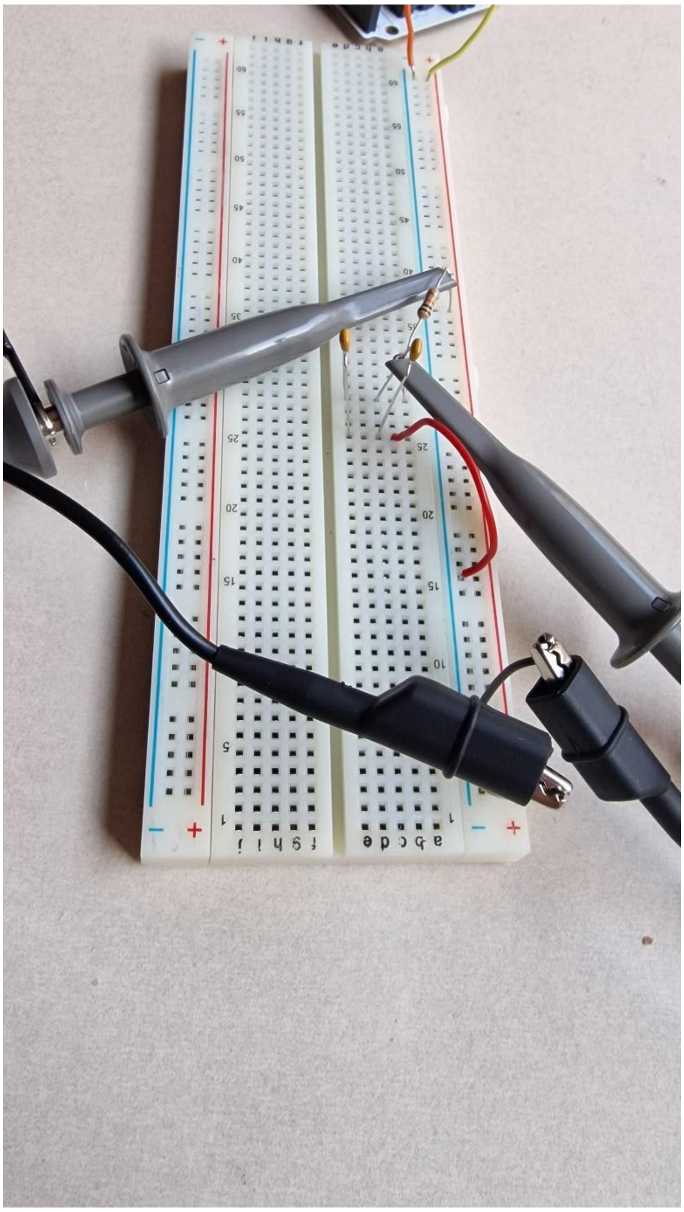
PicoScope 7 T&M
Running
Scope
50 µs/div
Trigger
1 V
Waveform
64
±10 V
±10 V
Gen
Off



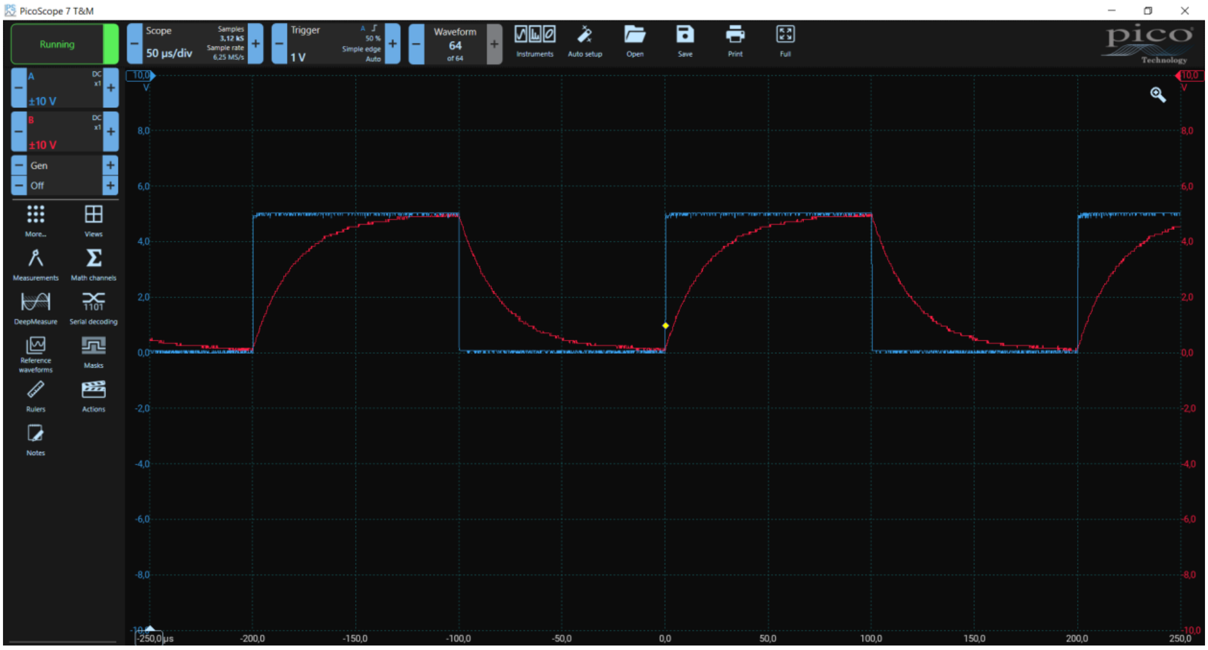
Once again, similar to the simulated value, we can see that the graph reaches 3.15V at approximately 10us. This is the expected result.

The graph looks this way because, inversely to the inductor, the voltage directly correlates with how charged a capacitor is. As we feed it constant 5V of input voltage, it charges exponentially and the voltage across it also increases exponentially.

When we add a capacitor in parallel, like so,

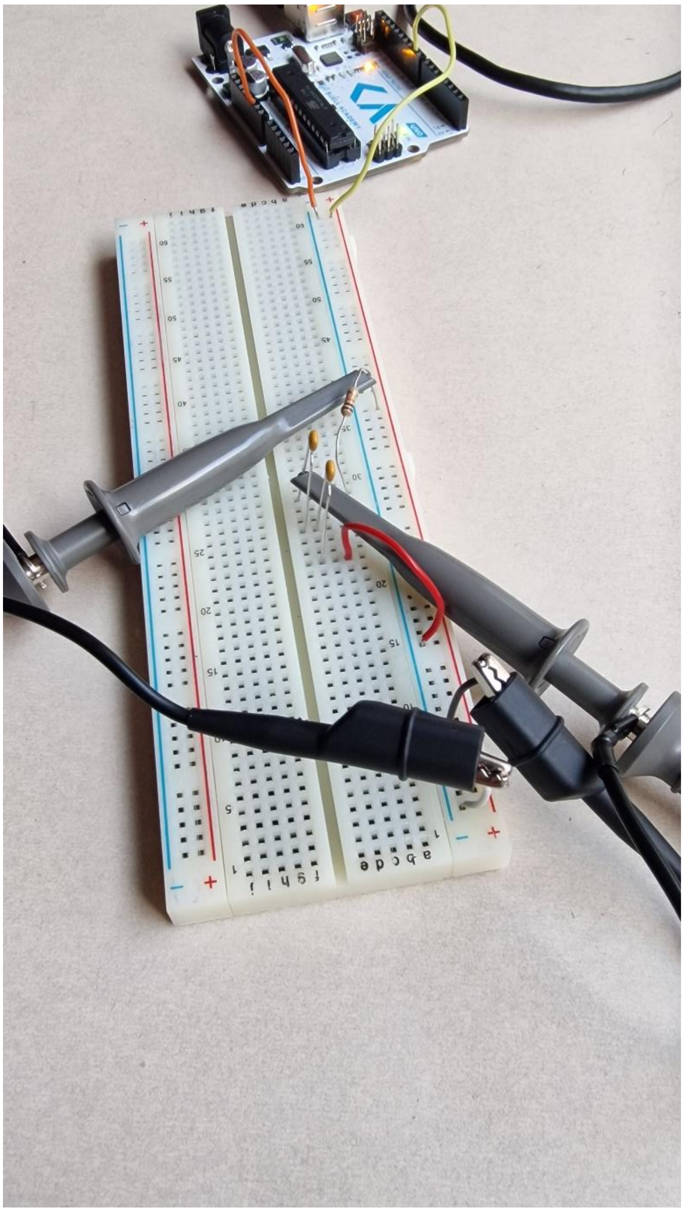


the graph looks like the following:

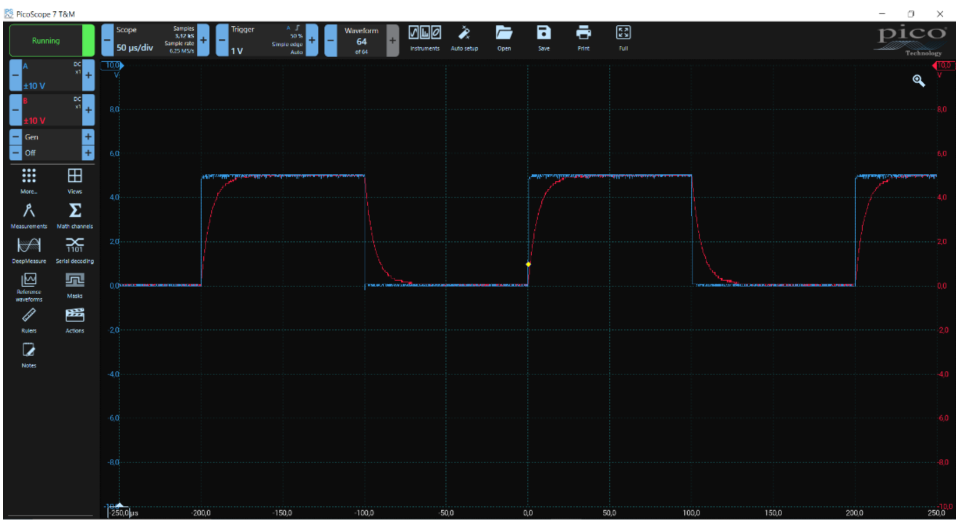


Because we added a capacitor in parallel, the current gets divided between the two capacitors which means it takes longer for them to reach max charge. Hence, the time constant is later, and following this graph it's about 20.95 us.

If we add the capacitors in series, however,

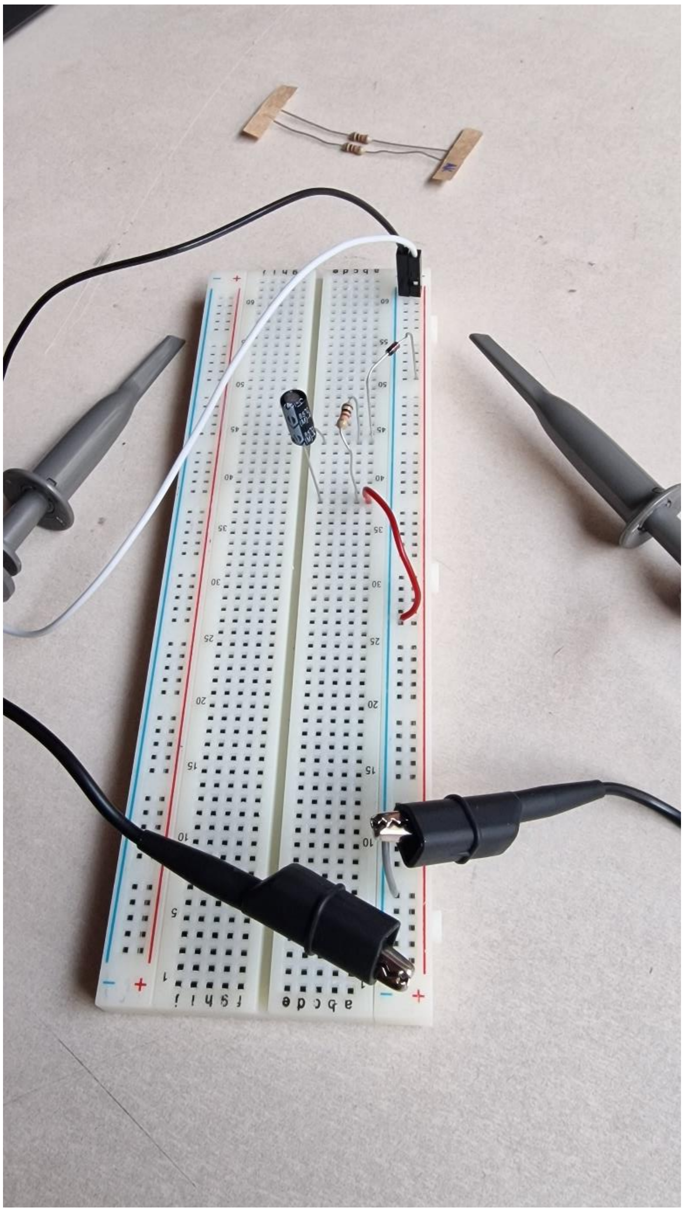


we get the following graph:

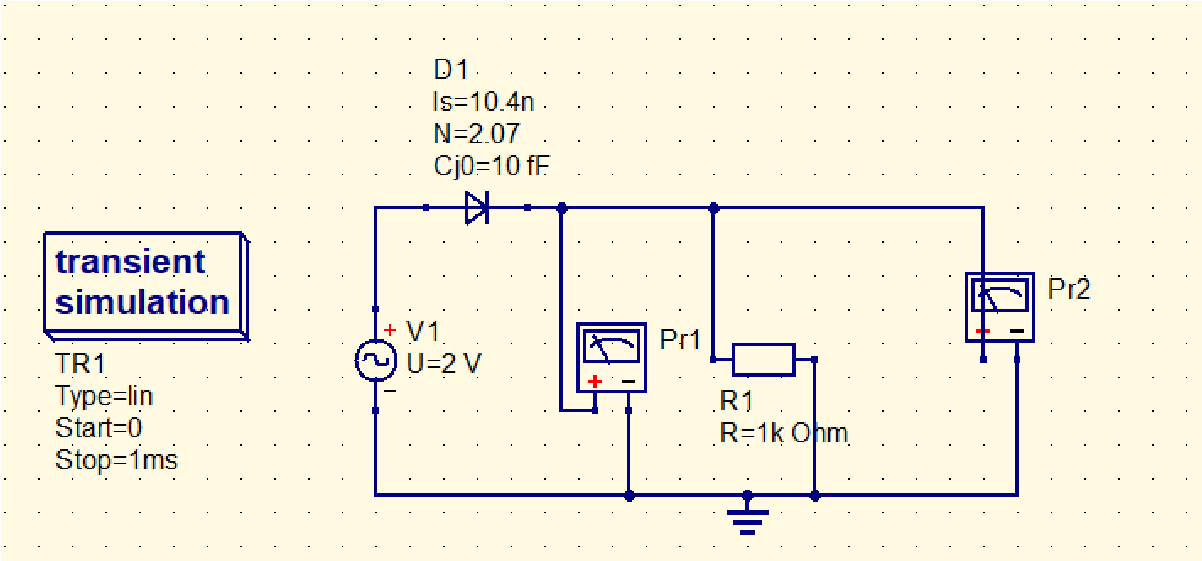


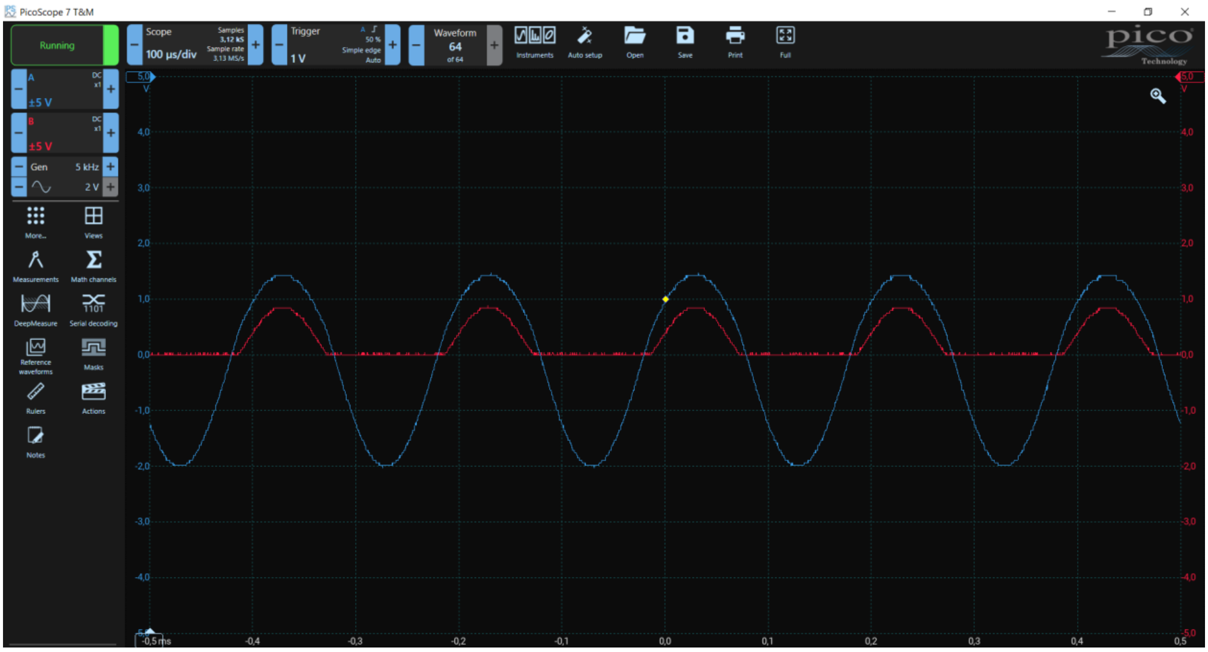
When you have two capacitors in series they act as a voltage divider, similar to having inductors in parallel. Therefore they will have a smaller total capacitance and charge faster. The time constant here is approximately 6.1 us.

2.3.

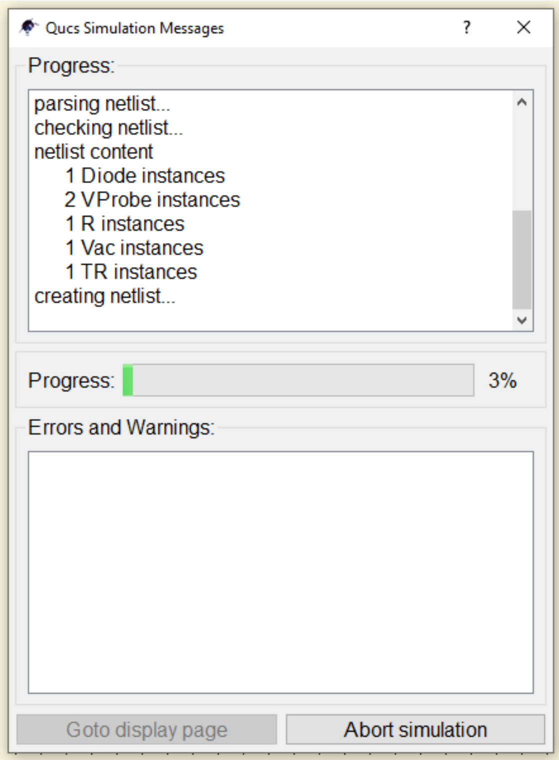


Without the capacitor:



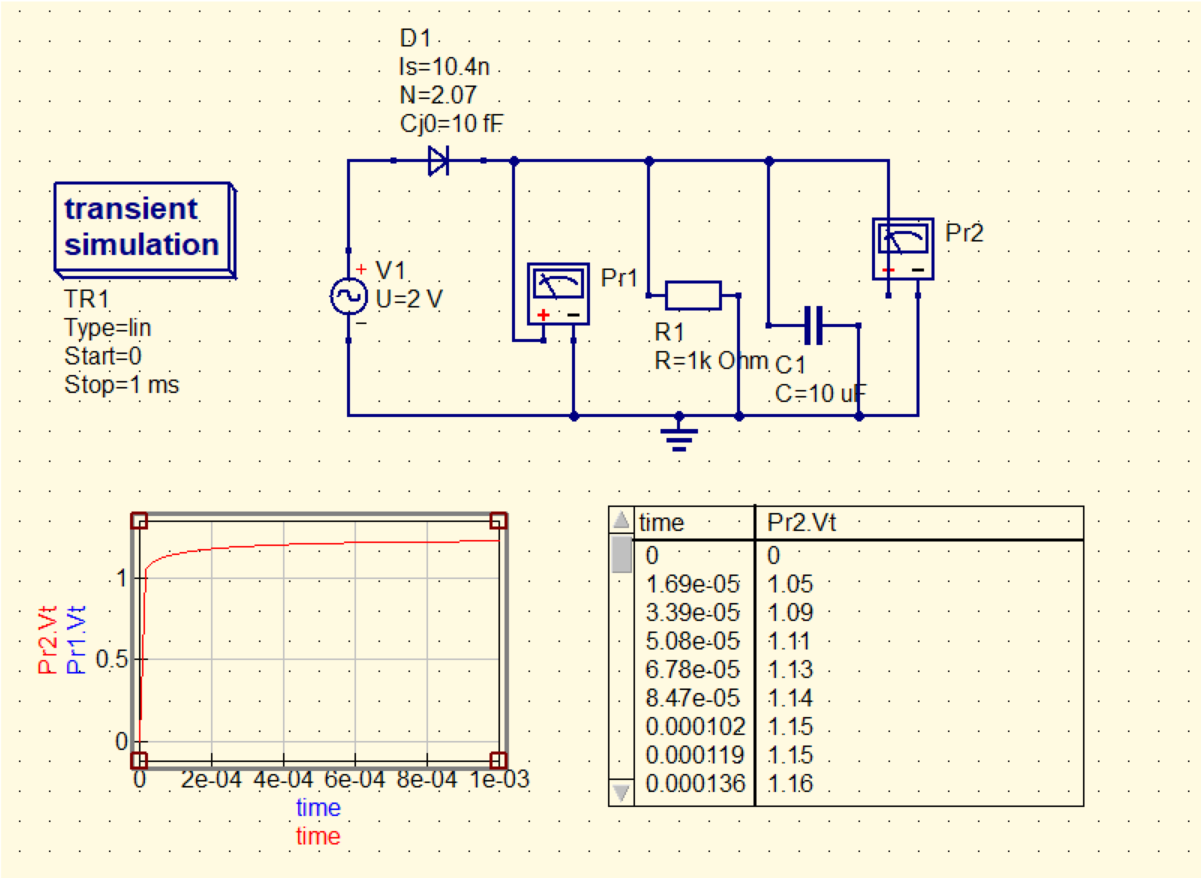


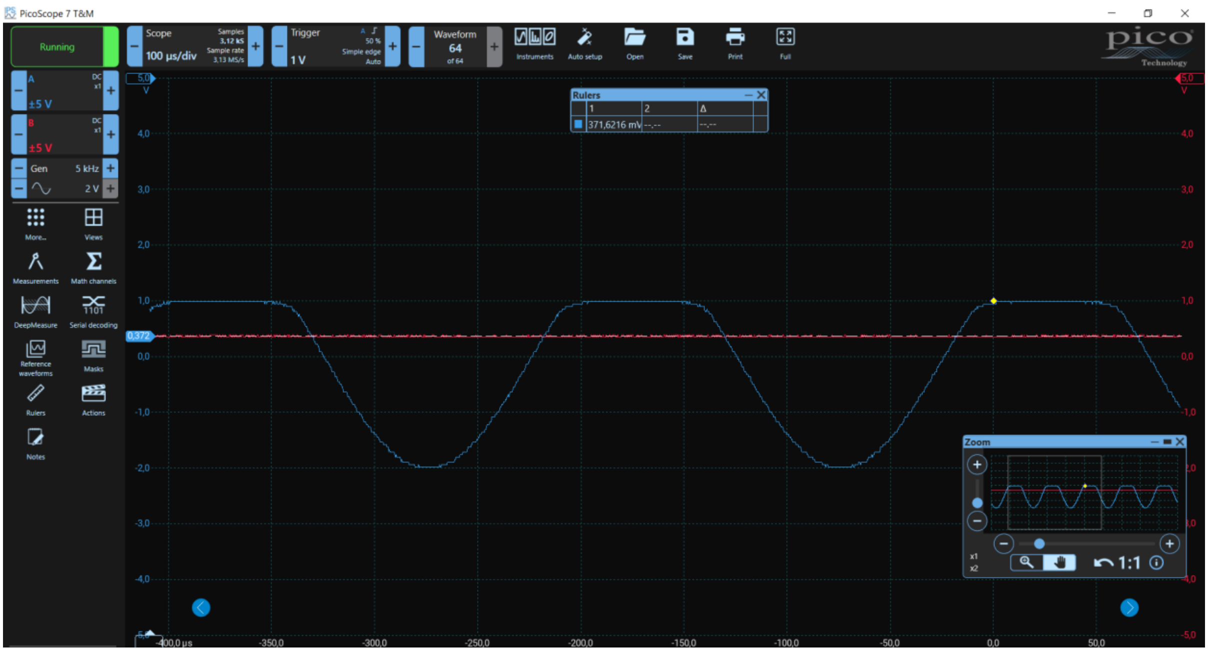
Unfortunately, for whatever reason by computer was taking several minutes just to move the “loading” bar when simulating (check the following image).



I wasn't able to get a proper graph of the wave, but I assume it looks like the wave above. The wave looks this way because below the diode's threshold voltage, no current passes through it. Therefore, every time the sine wave goes below that threshold, the voltage across the resistor is 0.

With the capacitor:





Again, unfortunately like above, I wasn't able to get a better graph than the one I show (after leaving my PC running all day to render it). Regardless, my measured graph is also peculiar and I'm still unsure why the blue line isn't a normal sine wave, since it's simply measuring the voltage source directly compared to ground. Apart from that, as expected we get a constant voltage over the capacitor/resistor. The reason for this is an infinite cycle that can be described as the following:

1. Sine wave reaches threshold voltage, diode conducts current, capacitor is charged
2. Sine wave goes below threshold voltage, diode stops conducting current, capacitor acts as a voltage source

This repeats infinitely, giving us a constant voltage.

The constant voltage I get is 0.372 V.

$V_{TH} = 0.372$ V

To find R_{TH} of the Thevenin voltage source I connected the 220 Ohm resistor in parallel with the other components (capacitor/resistor). The voltage drop I got over that resistor was 0.62 mV.

$V_{R2} = 0.062$ V

$V_{TH} = I_{TH} * R_{TH} + V_{R2}$

$I_{TH} * R_{TH} = V_{TH} – V_{RT}$

$R_{TH} = (V_{TH} – V_{RT}) / I_{TH}$

$R_{TH} = (0.372 – 0.062) / I_{TH}$

$I_{TH} = V_{R2} / R_2 = 0.062 / 220 = 0.28$ mA

$R_{TH} = (0.372 – 0.062) / 0.00028$

$R_{TH} = 1107$ Ohms = 1.1 kOhms

LAB 3

3.1.

f_c = (1/T) / (2*PI)

f_c = (1/(L_1 / R_1)) / (2 * PI)

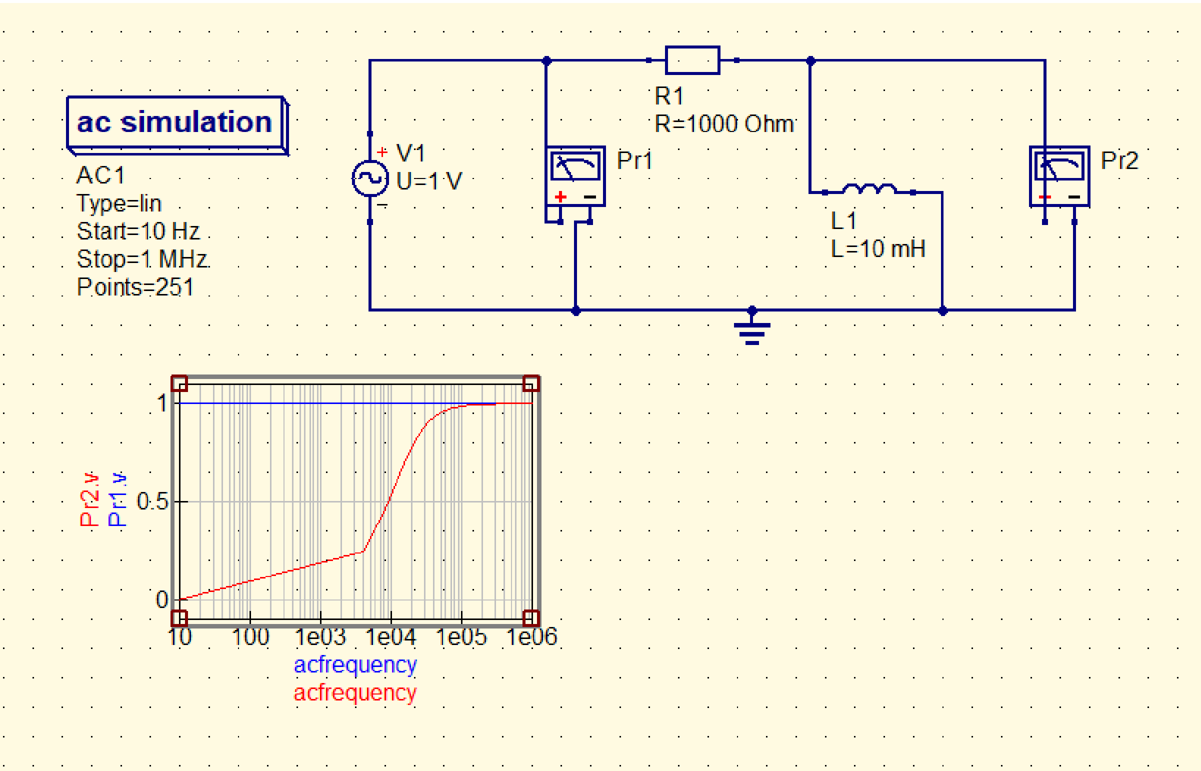
f_c = (1/(0.01 / 1000)) / (2 * PI)

f_c = 100,000 / 2*PI

f_c = 50,000 / PI

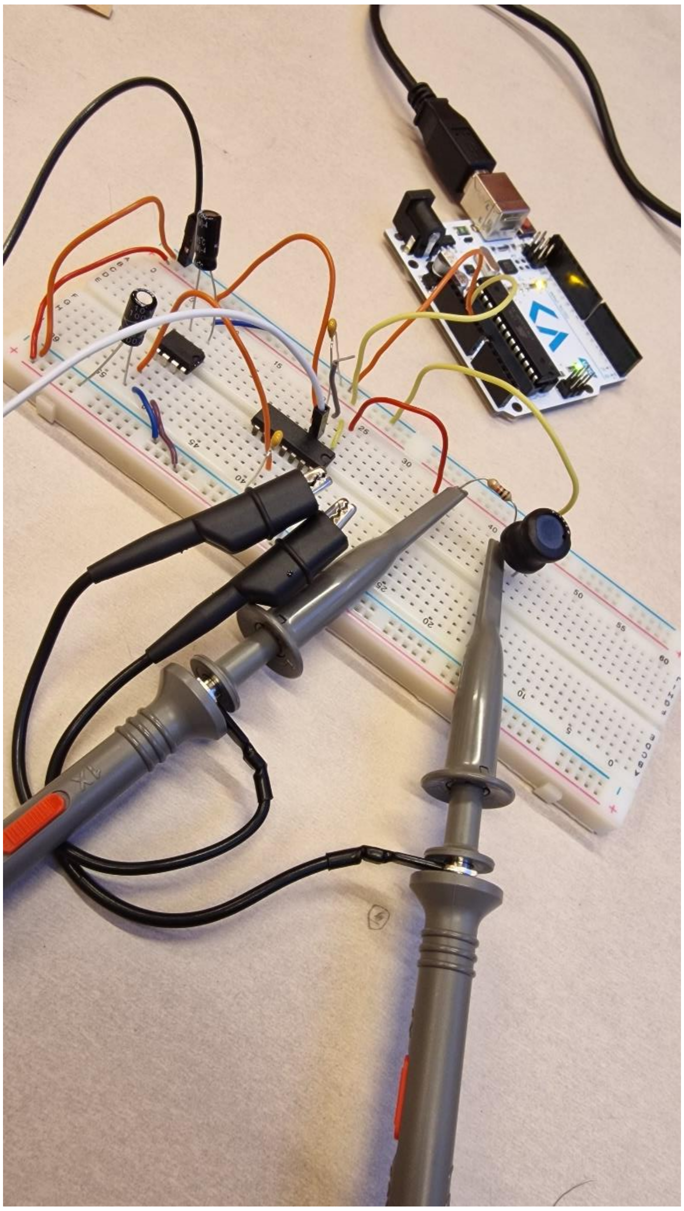
f_c = 15915 Hz

f_c = 15.9 kHz

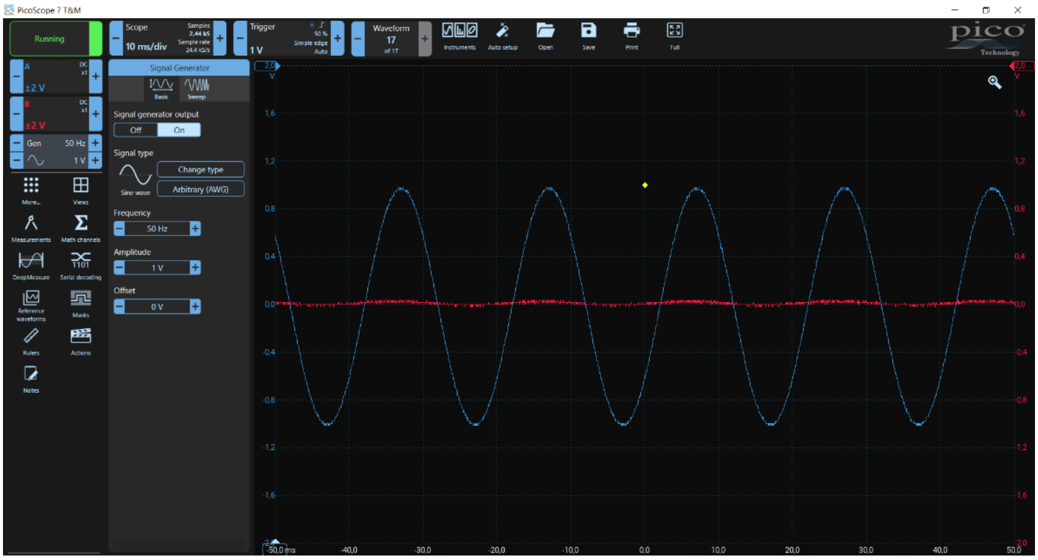
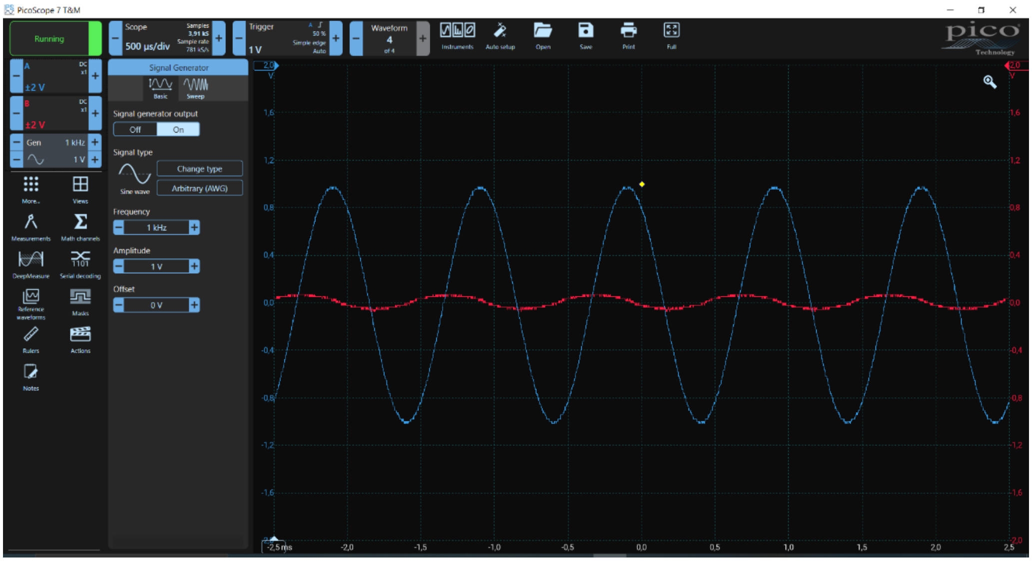
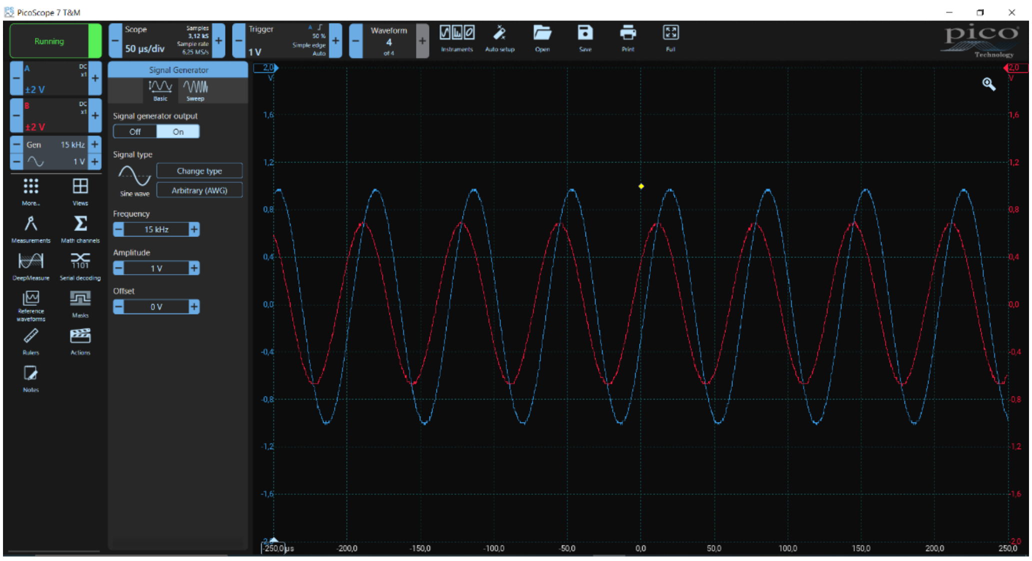


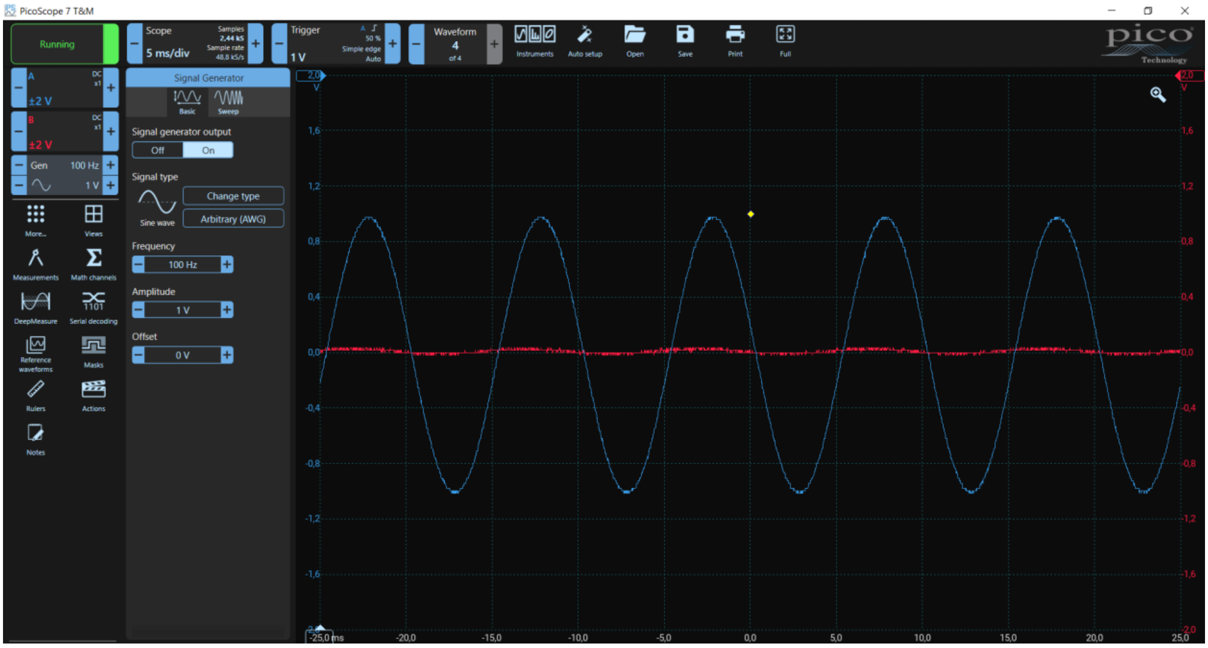
Our AC simulation shows that the cutoff frequency is approximately in the 15kHz range. This confirms our calculation.

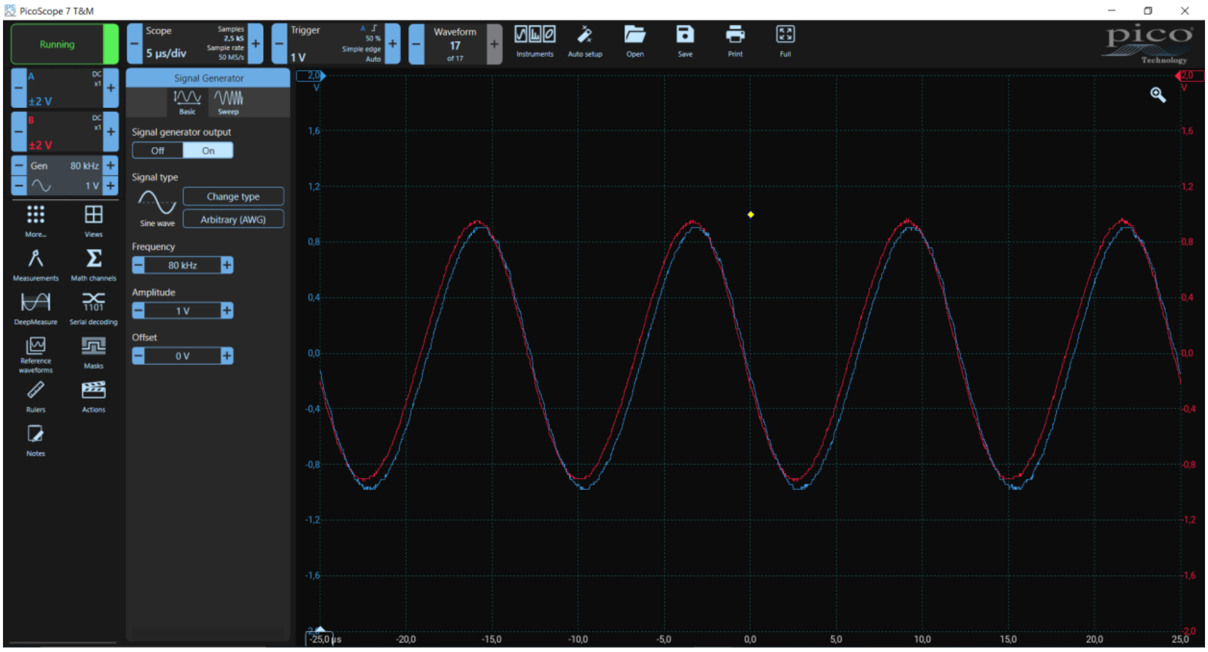
We then built the circuit like so,



and got the following graphs, varying the frequencies:


PicoScope 7 T&M
Running
Scope
10 ms/div
Trigger
1 V
Waveform
17
Signal Generator
Signal generator output
Off
On
Signal type
Change type
Arbitrary (AWG)
Sine wave
Frequency
50 Hz
Amplitude
1 V
Offset
0 V
pico
Technology

PicoScope 7 T&M
Running
Scope
500 µs/div
Trigger
1 V
Waveform
4
Signal Generator
Signal generator output
Off
On
Signal type
Change type
Arbitrary (AWG)
Sine wave
Frequency
1 kHz
Amplitude
1 V
Offset
0 V
pico
Technology

PicoScope 7 T&M
Running
Scope
50 µs/div
Trigger
1 V
Waveform
4
Signal Generator
Signal generator output
Off
On
Signal type
Change type
Arbitrary (AWG)
Sine wave
Frequency
15 kHz
Amplitude
1 V
Offset
0 V
pico
Technology





As you can see, the amplitude is filtered for smaller frequencies and remains the same for higher frequencies, making this a high pass filter. 80 kHz frequencies didn't get filtered whereas 100Hz did.

3.2.

f_c = (1 / T) / (2 * PI)

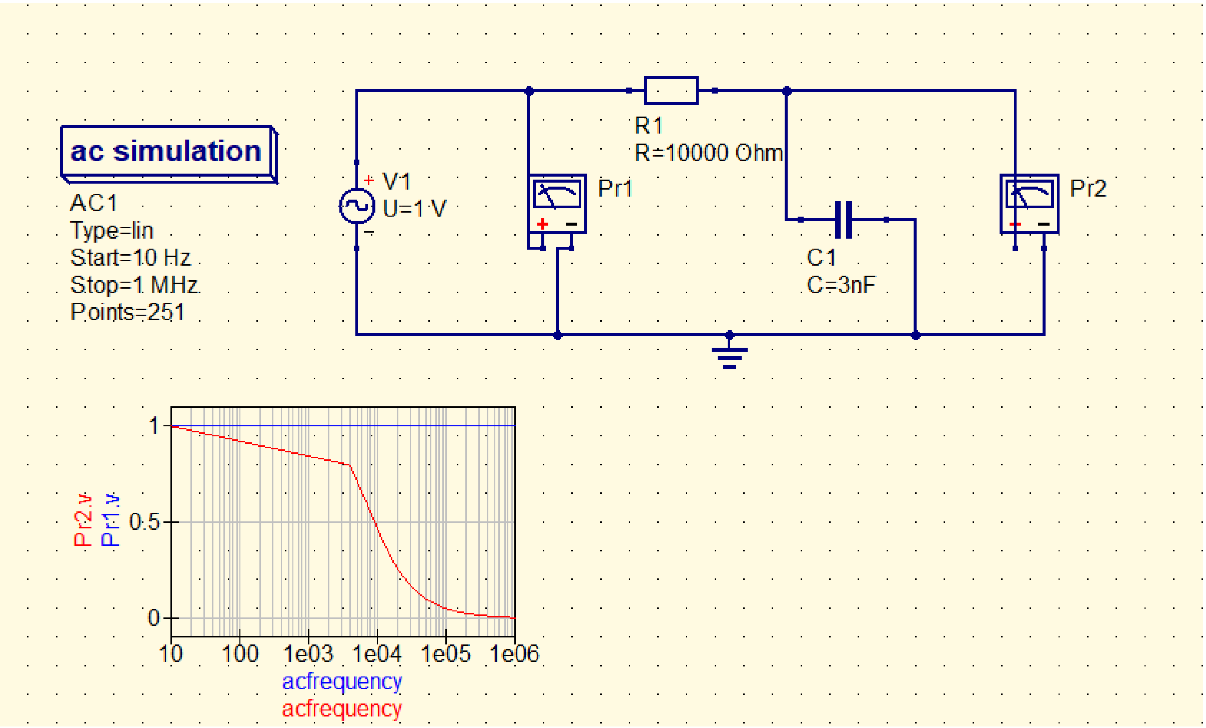
T = C * R

f_c = (1 / (C * R)) / (2 * PI)

f_c = (1 / (3nF *10 kOhms)) / (2 * PI)

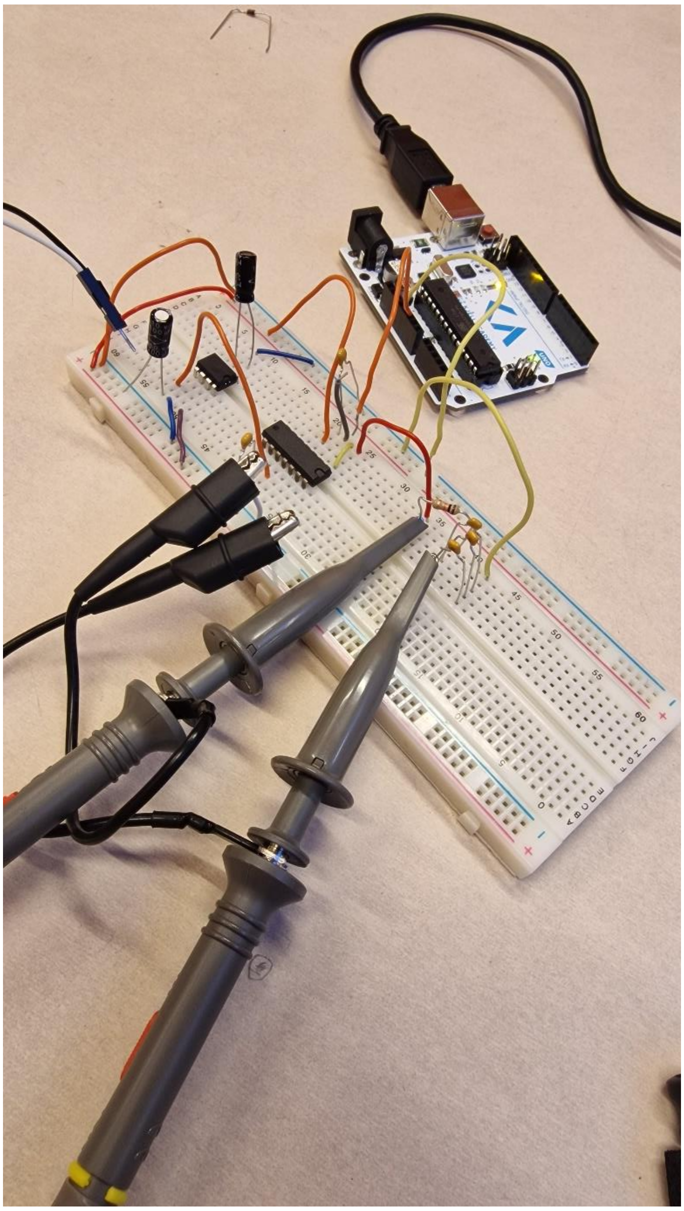
f_c = (1 / 0.00003) / (2*PI)

f_c = 5305 Hz

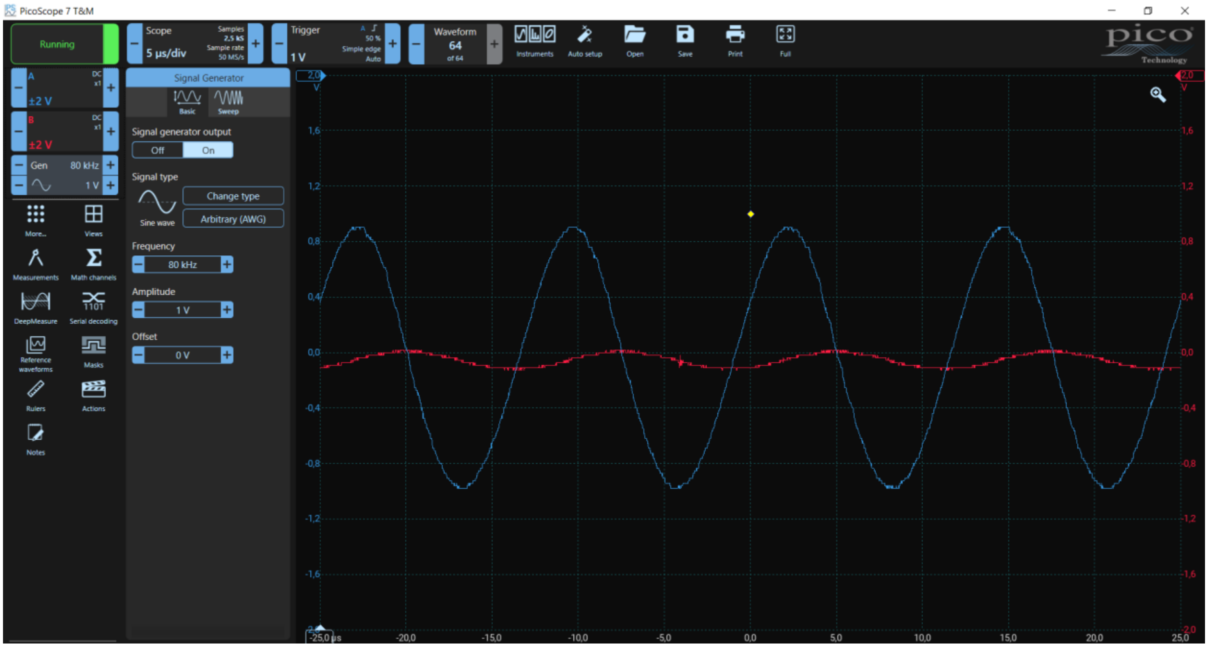


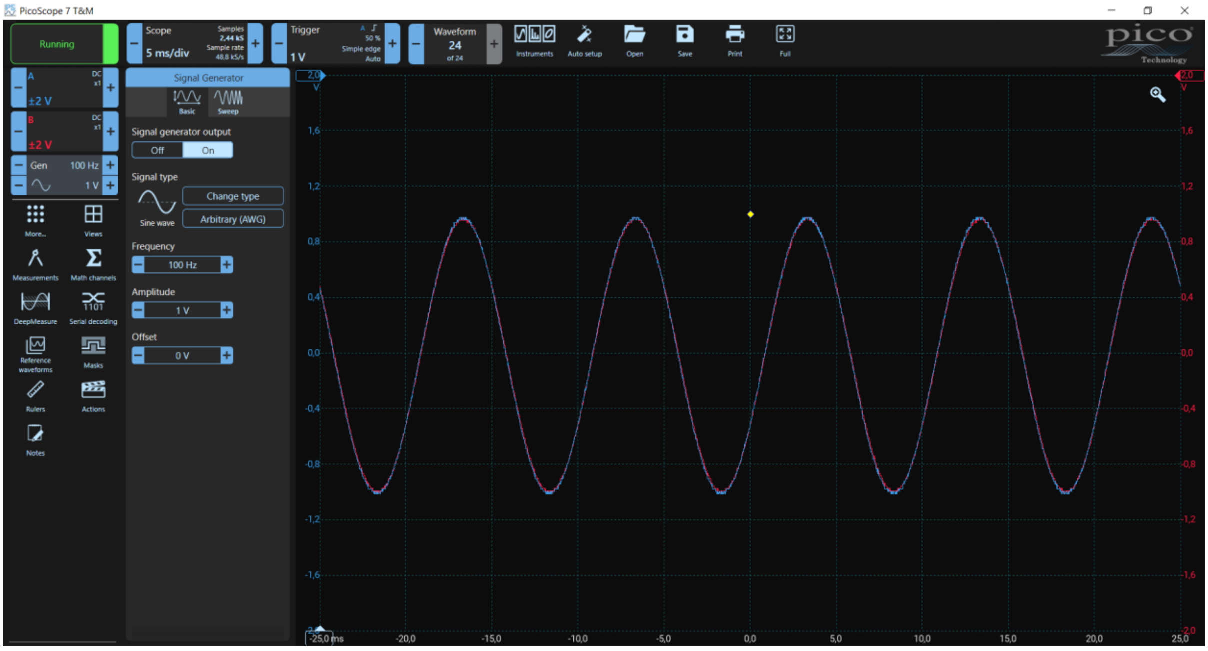
Our simulation gives us a graph that is a direct inverse of the inductor one. The cutoff frequency is once again shown to be around d 5 kHz, consistent with the calculated one.

When we build the circuit like so,



and we got the following measurements from it





as can be seen, this is a low pass filter, since the 80 kHz signal gets filtered but the 100 Hz signal does not.

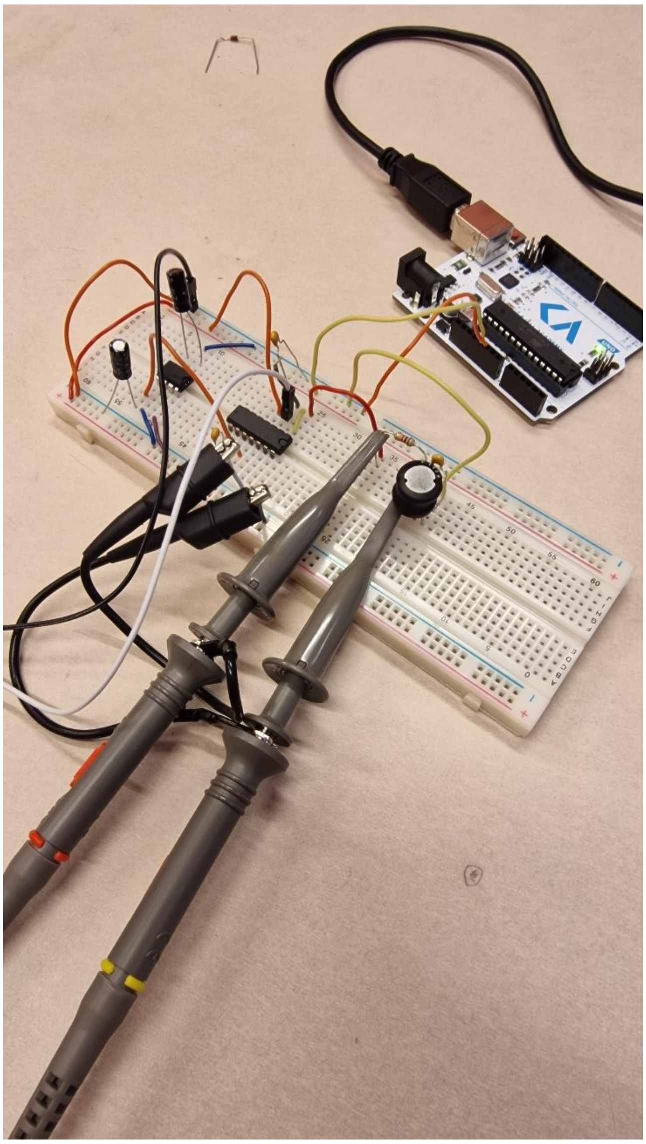
3.3.

f_c = 1 / (2 * PI * sqrt(L * C))

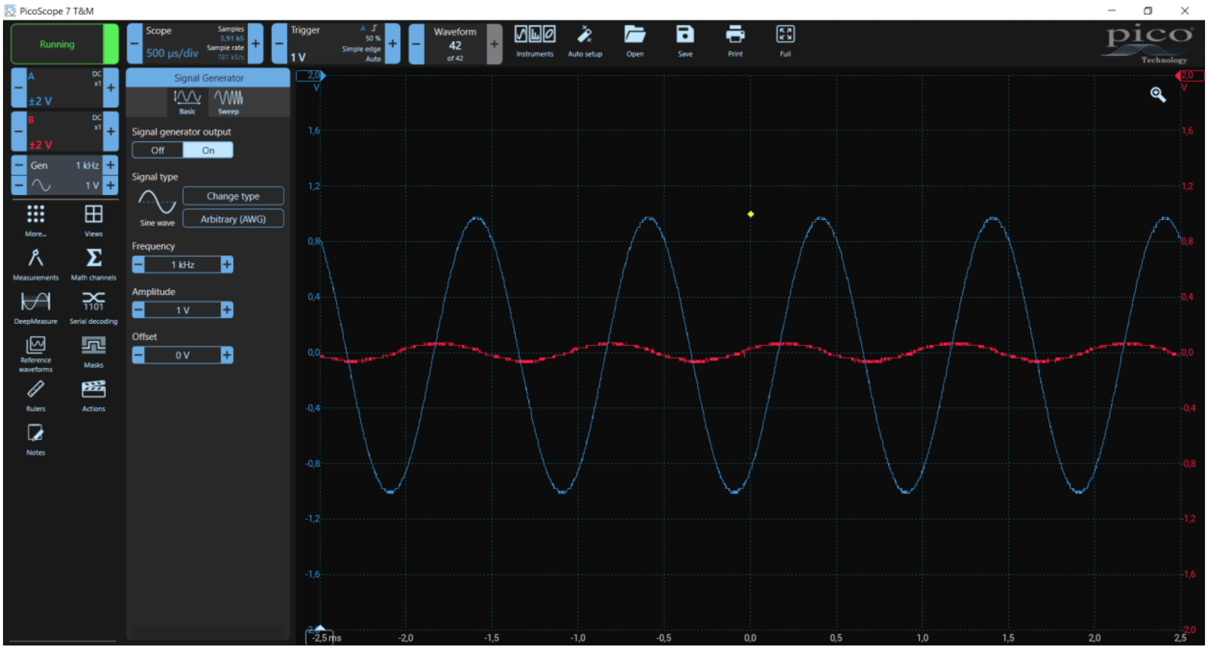
f_c = 1 / (2 * PI * sqrt(10mH * 100nF))

f_c = 1 / (2 * PI * sqrt(1e-9))

f_c = 5032 Hz = 5.03 kHz



I got the following measurements with a sine wave:


PicoScope 7 T&M
Running
Scope
500 µs/div
Trigger
1 V
Simple edge
Auto
Waveform
42
of 42
Instruments
Auto setup
Open
Save
Print
Full
Signal Generator
Basic
Sweep
Signal generator output
Off
On
Signal type
Sine wave
Change type
Arbitrary (AWG)
Frequency
1 kHz
Amplitude
1 V
Offset
0 V
±2 V
Gen
1 kHz
More...
Views
Measurements
Math channels
DeepMeasure
Serial decoding
Reference waveforms
Masks
Rulers
Actions
Notes
-2,5 ms
-2,0
-1,5
-1,0
-0,5
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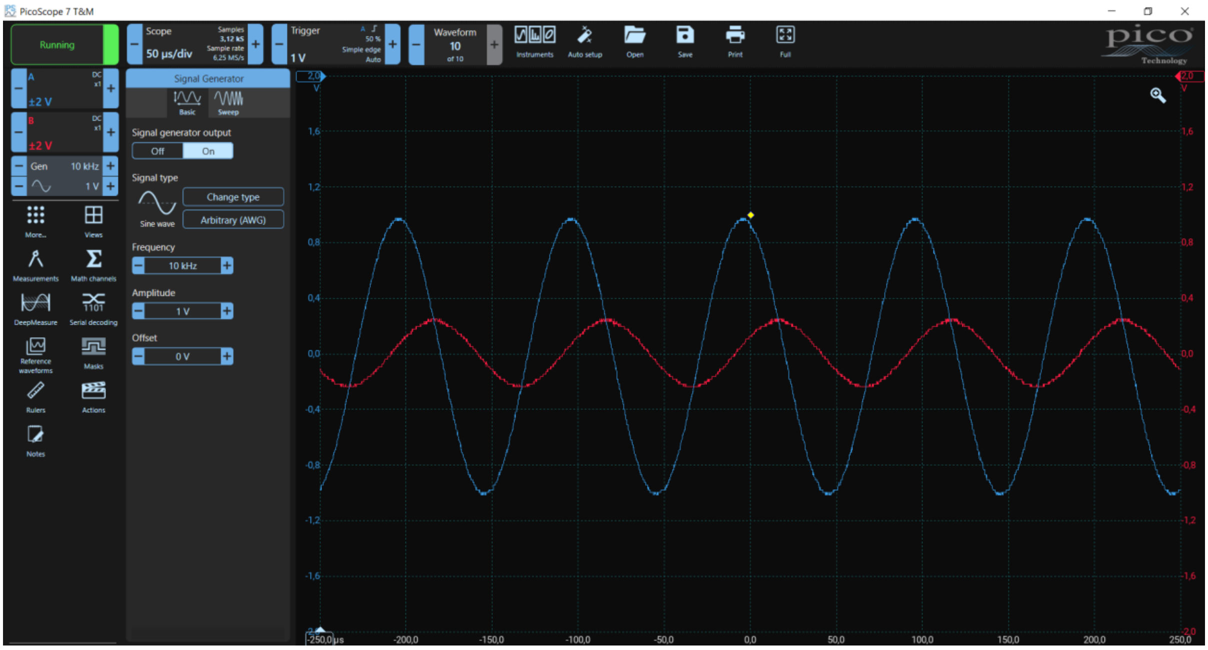
0,5
1,0
1,5
2,0
2,5


PicoScope 7 T&M
Running
Scope
50 µs/div
Trigger
1 V
Simple edge
Auto
Waveform
10
of 10
Instruments
Auto setup
Open
Save
Print
Full
Signal Generator
Basic
Sweep
Signal generator output
Off
On
Signal type
Sine wave
Change type
Arbitrary (AWG)
Frequency
10 kHz
Amplitude
1 V
Offset
0 V
±2 V
Gen
10 kHz
More...
Views
Measurements
Math channels
DeepMeasure
Serial decoding
Reference waveforms
Masks
Rulers
Actions
Notes
-250,0 µs
-200,0
-150,0
-100,0
-50,0
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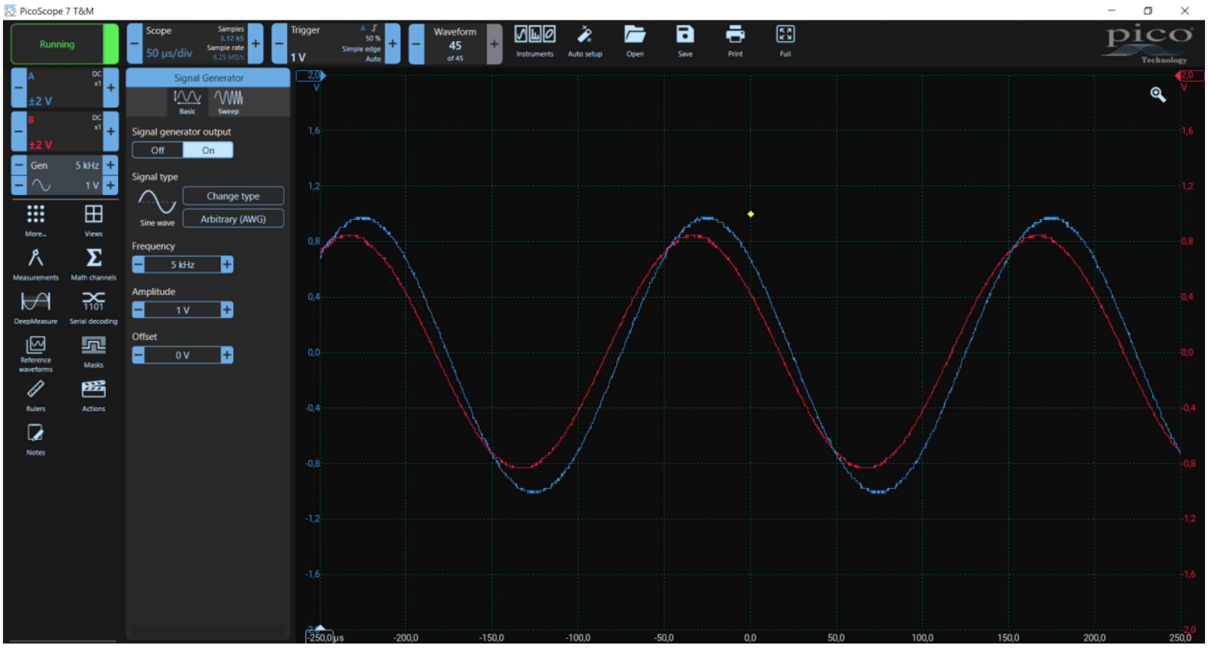
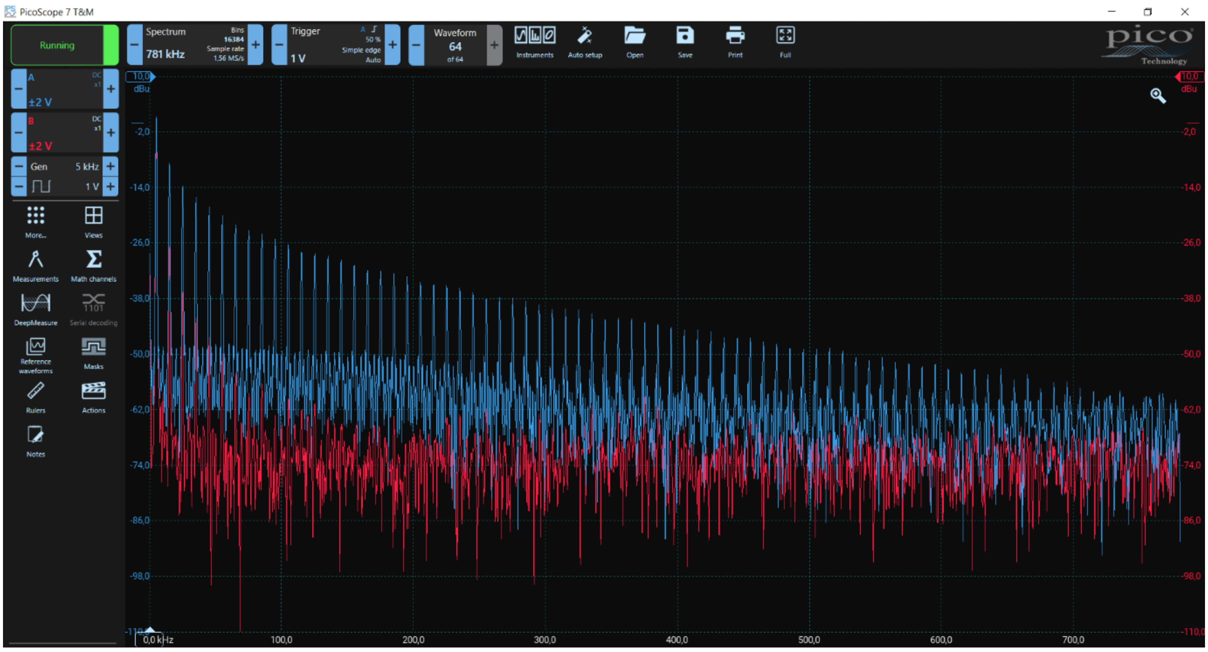
50,0
100,0
150,0
200,0
250,0

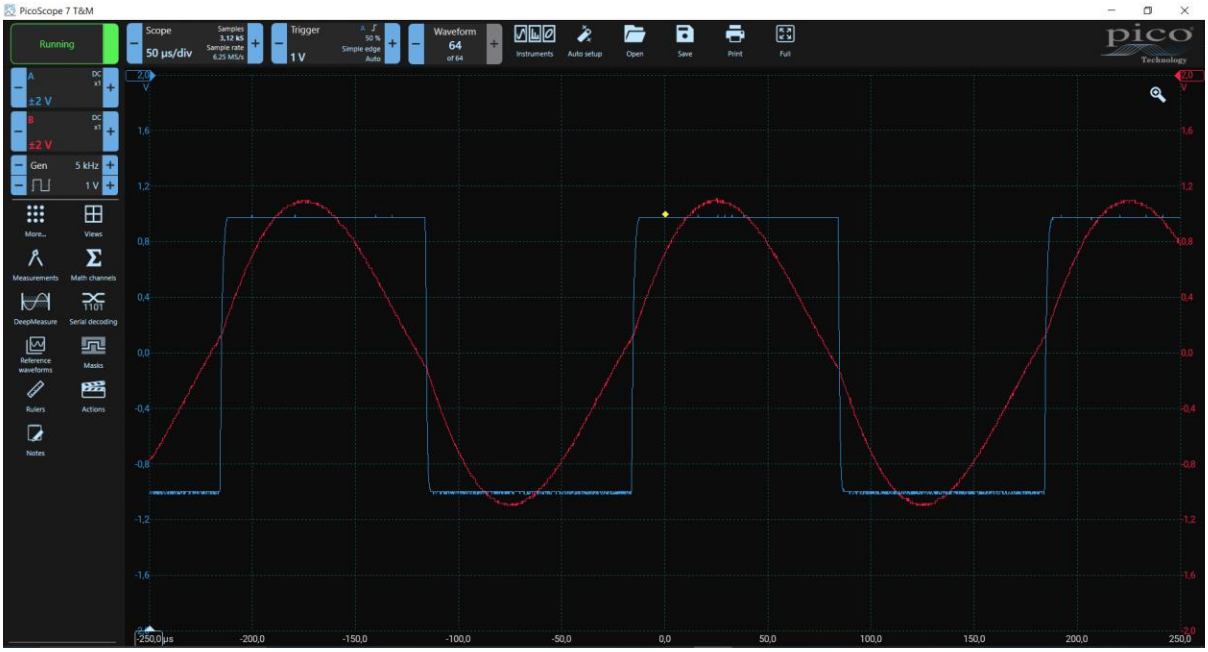


I got the following measurements with a spectrum wave:



This is clearly the graph of a band pass filter. I see peaks approximately every 10 kHz.

I got the following measurements with a square wave:



I found out that apparently logarithmic scale was removed from newer version of the Picoscope program, so I wasn't able to graph this logarithmically.