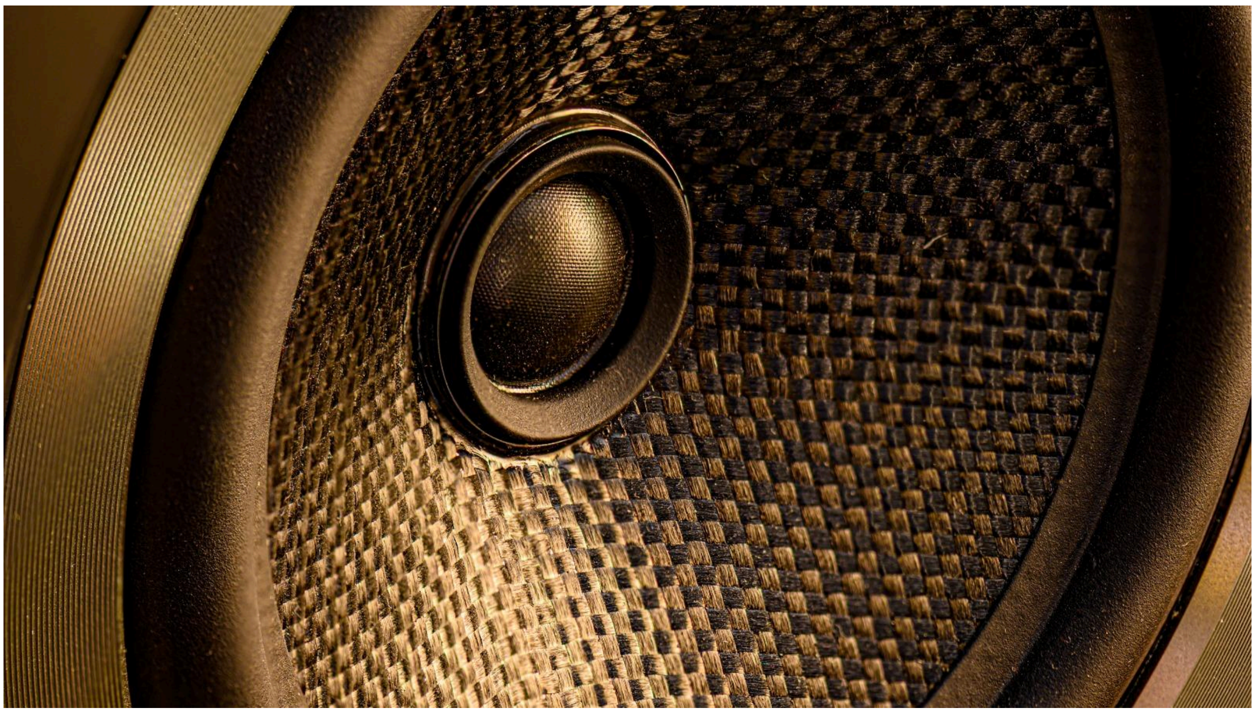
Intermediate report

Power Supply



Jesper van Helden
Nick van der Voort
TA: Leon Abelmann,
Tutor: Leon Abelmann

December 20, 2024

Contents

Introduction

The power supply for the audio system must meet specific design requirements to ensure its proper functioning in the system. The unloaded output voltage should be in the range of ±20-22 V DC (40-44 V DC total). Under a load current of 1.0 A, the average output voltage must not fall below 17-20 V DC. Additionally, the ripple voltage of the output must be kept below 5%, ensuring minimal distortion or noise in the audio output.

Theory and Analysis

The following is a schematic of the design

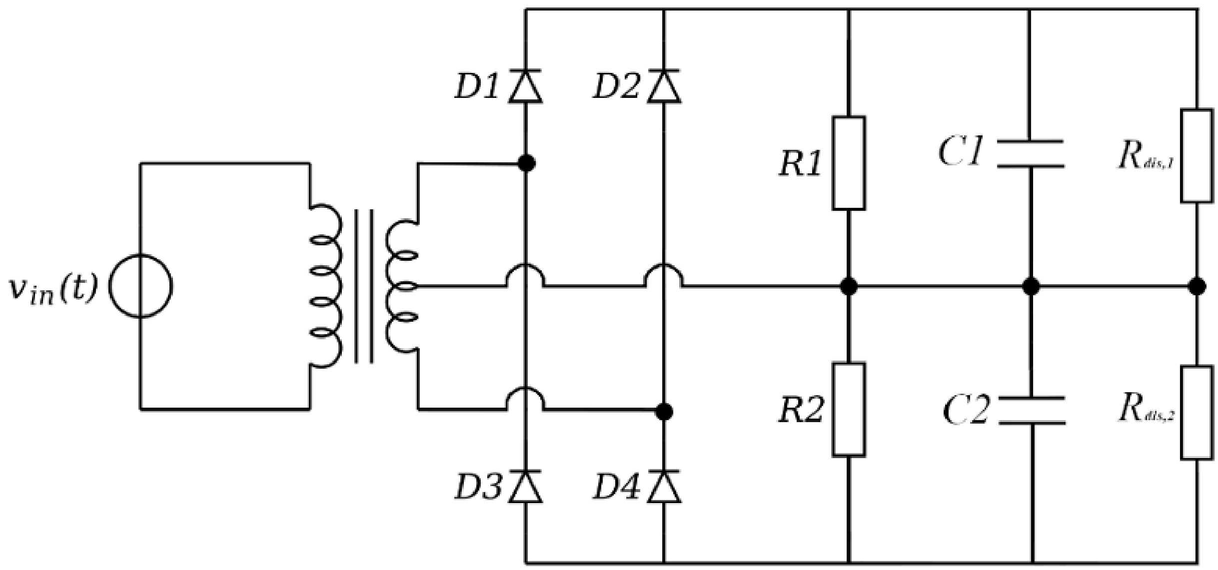


Figure 1

To meet the stated design requirements, a way must be found to keep the ripple voltage as small as practically possible. This can be achieved by carefully selecting the appropriate capacitors (C1, C2 in figure 1). Also, when the system is powered off, the capacitors must be able to discharge their capacitance. This is where the discharge resistors come in (Rdis1 and Rdis2 in figure 1). The right resistors with the appropriate resistances should be chosen and applied in the circuit.

In order to build the power supply circuit, the following steps had to done:

-Find the right capacitors and the right resistors by calculating their required capacitances and resistances.

-Design and simulate the full circuit is PSpice.

-build the circuit

-test and refine the circuit

Theory

The circuit consists of the following individual components:

- 2 capacitors (C1 & C2 in Figure 1)
- 4 diodes (D1, D2, D3 & D4 in Figure 1)
- 2 discharge resistors (Rdis1 & Rdis2 in Figure 1)
- resistors (R1 and R2 in Figure 1)

Resistors R1 and R2 were already installed on the circuit board. For that reason, they will not be examined further in this report.

The circuit should meet the following specifications:

- An average unloaded output voltage of ±20-22V DC
- The output voltage should be in a range of 17-20 VDC under a load current of 1.0 A
- A ripple voltage of the output voltage should not exceed a 5% ripple in the voltage
- A discharge time of less than 2.5 minutes

The ripple voltage is can be stated as

$$V_{ripple}\,(\%) = ((\,V_{max} - V_{average}) \,/\, V_{average}) \times 100\% \tag{2.1}$$

where V_{max} is the maximum peak voltage of the output and $V_{average}$ is the average output voltage of the power supply. This voltage should not account for more than 5% of the average voltage. The capacitors are installed to make the ripple voltage as small as possible. They do this because of the characteristic property of capacitors being that they resist voltage changes. To achieve a ripple voltage of less than 5 percent, the capacitor should have the biggest time constant (τ) possible. The time constant

$$\tau = RC \tag{2.2}$$

determines how quickly the capacitor charges or discharges, with R being the resistance and C the capacitance. A larger capacitor (higher C) acts like a bigger reservoir of energy. It can supply more energy during valleys of the ripple without a significant drop in voltage. This means the capacitor with the biggest capacitance would be the best for this use case.

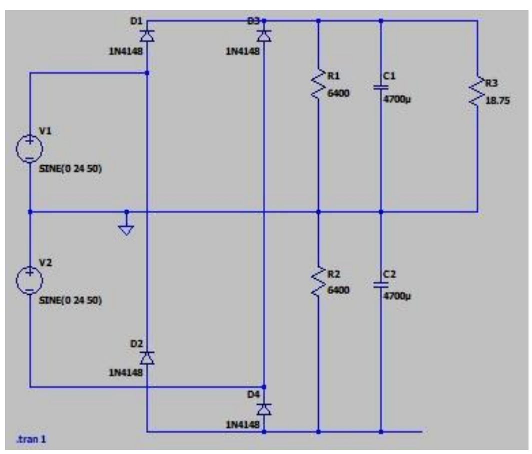
The specifications also state that the circuit must have a discharge time of less than 2.5 minutes. This means that the voltage must be equal or near zero when the load and the transformer are disconnected from the power supply circuit including the capacitors. Since the load will be disconnected from the capacitors, whilst they still hold charge, the capacitors will need a resistance to discharge their charge. For this reason, the discharge resistors have been installed. One for each capacitor. To calculate the time required for the capacitors to get rid of their charge, equation 2.2 can once again be used. If the capacitance of the capacitor is known, and the total discharge time is also known (being 150s or smaller (thus τ being 150s/5)), the required discharge resistance can be calculated. The results of those calculations for a 4700µF and a 6800µF capacitor are shown in table 2.3.

Capacitance (F)	**Required discharge resistance (Ω)**
4700µF	6400Ω
6800µF	4400Ω

Table 2.3

Simulations

The circuit as shown in figure 1 has been simulated in the program LTSpice. Once with 4700µF



capacitors and 6400Ω resistors, as shown in figure 2

Figure 2

And once with 6800μF capacitors and 4400Ω resistors, as shown in figure 3

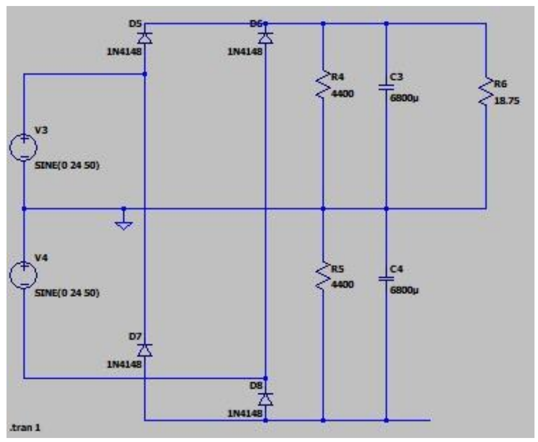
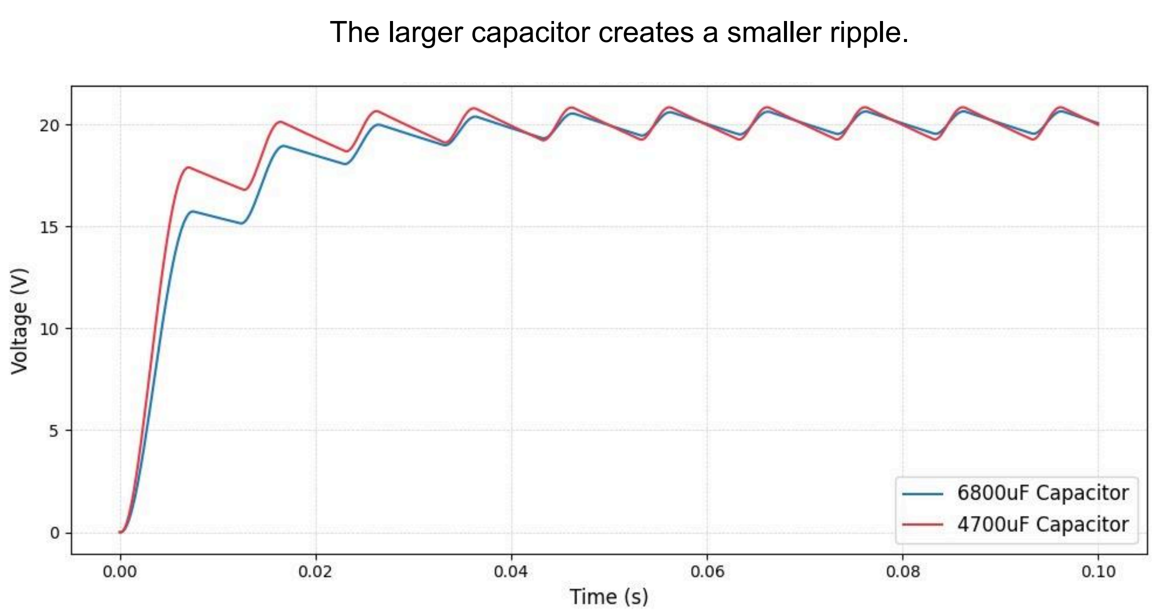


Figure 3

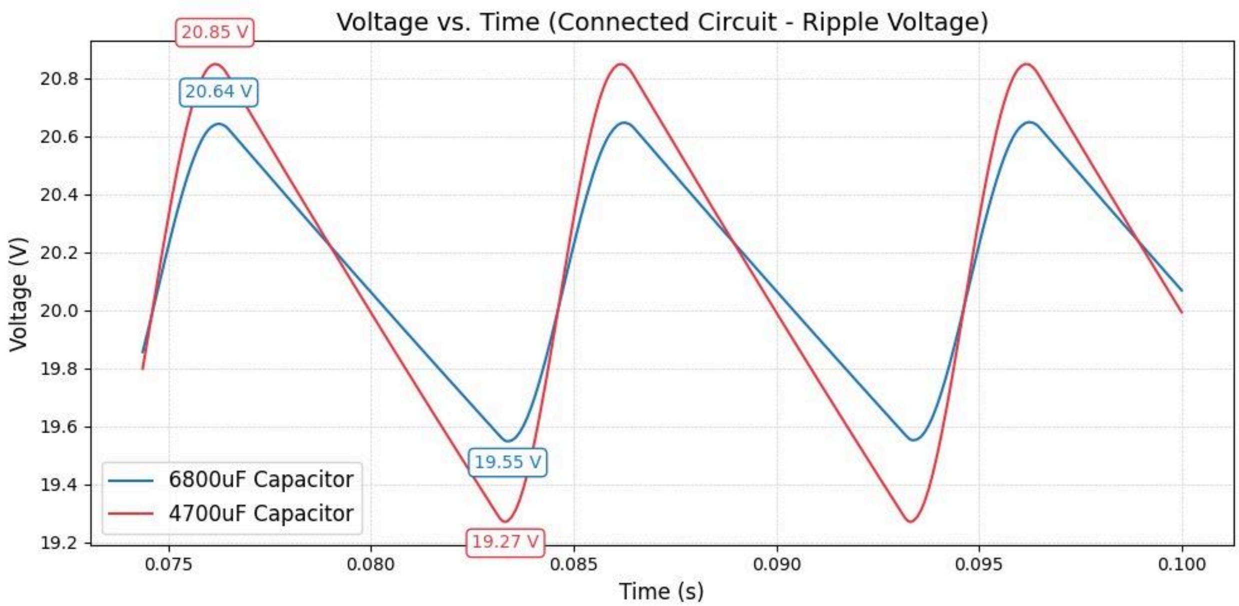
In both simulation circuits, the load has been connected to one terminal.

After running the simulations, the following graphs can be made of the output voltages, in which the red line represents the output voltage of the circuit with the 4700μF capacitors and the blue one the one with the 6800μF capacitors. The graphs below show that the bigger capacitor gives a smaller ripple.



Simulated output voltage of the power supply under a load of 1 A as a function of time, for a circuit with a 4.7 mF (red) and 6.8 mF (blue) capacitor. Plot made by Yücel Duzguncinar

Figure 4



Zoomed in version of the plot above. plot made by Yücel Duzguncinar

Figure 5

Figure 5 shows a close-up of the ripple shown in figure 4. From the data in these graphs, the ripple voltage can be calculated.

For the ripple of the capacitors we calculate the relative ratio between the peak-to-peak and the average voltage

$$Ripple\ 6800\mu F\ capacitor \approx 2{,}49\%$$

$$Ripple\ 4700\mu F\ capacitor \approx 4{,}00\%$$

As previously argued, the capacitor with the biggest capacitance has the smallest ripple voltage.

Measurements

The circuits was built with the 4700 micro F capacitors and the 6400 ohm capacitors. Although this is suboptimal, they were chosen because the other group making the power supply was already building it with the 6800 mirco F capacitors. By making both circuits, both LTSpice simulations can be tested on a real circuit. In this manner, both simulations can be verified.

The following voltages were measured during the testing using a multimeter:

Current output	Voltage with load (single terminal	Voltage with load (both terminals)	Voltage without load (single terminal)	Voltage without load (double terminal)
1.00A	20.3V	40.6V	23.6V	46.5V

Measurements from the oscilloscope gave a peak to peak voltage of 1.82V for a single terminal with load. Doing the calculations for the ripple current (equation 2.1) gives a ripple voltage of 4.5%. Figure 7 shows the graduate discharge of the capacitors after the load and power supply have been disconnected. It shows that after 150 seconds, the voltage drops to zero, as previously calculated.

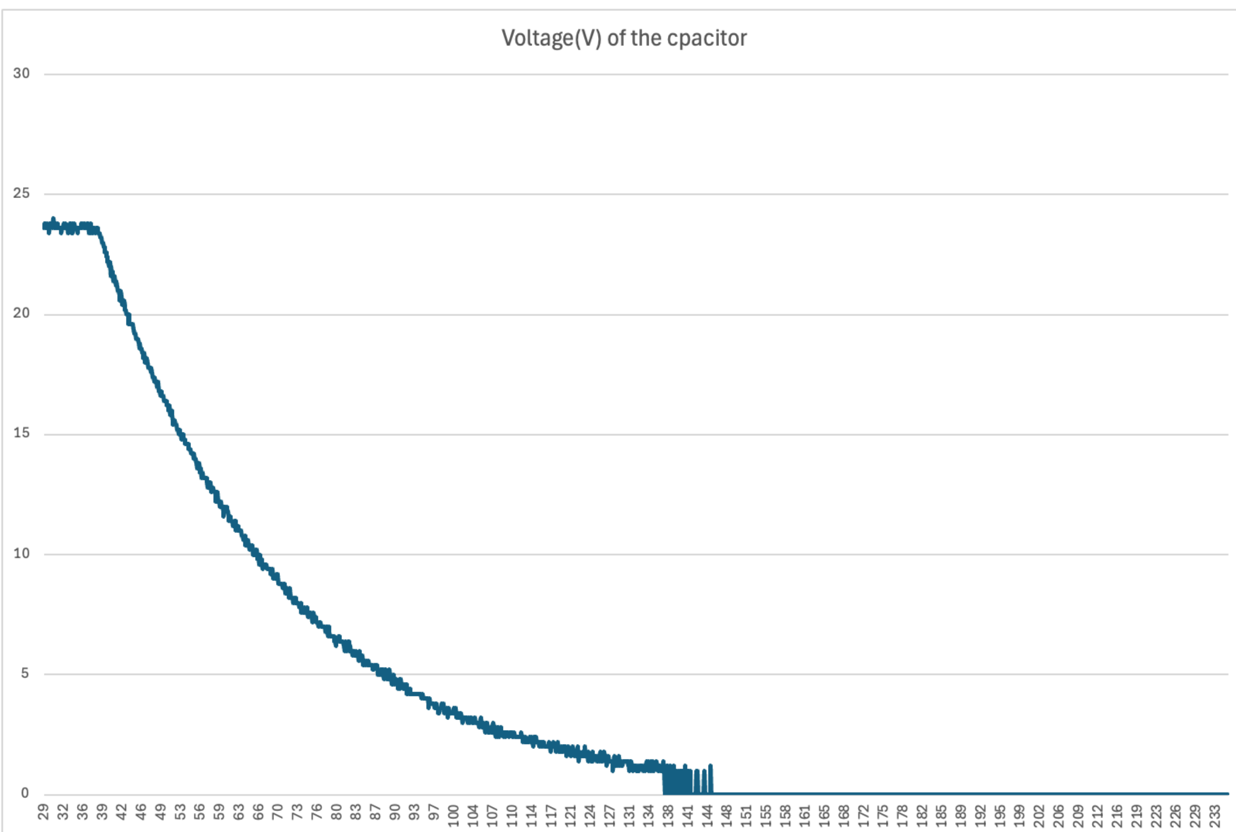


Figure 7

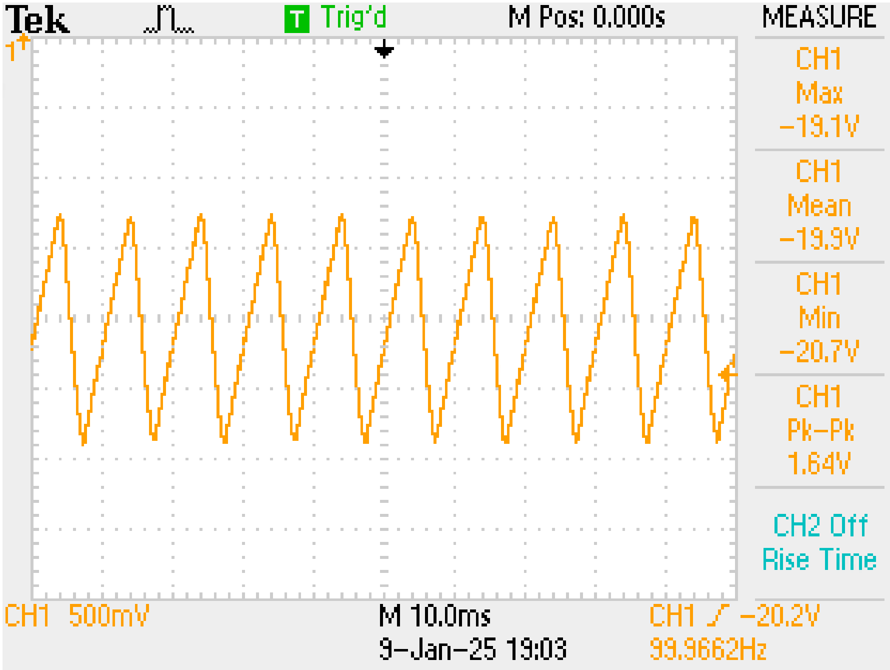


Figure 8

Figure 8 shows an image of the oscilloscope reading of the circuit with the load connected.

Conclusion

This report provided an analysis of the design, simulation and the construction of the power supply system. The power supply system shows a voltage of 20.3V under a load of 1 Ampere and a voltage of 23.6V unloaded with a ripple of 4.5% for the circuit with the 4700μF. According to the graphs it is more optimal to use the circuit with the 6800μF capacitor so that the ripple is under 5% and smaller than the ripple of the 4700μF capacitor. With that said the 4.4k Ohm resistor is fitted for this circuit because it ensures a discharge time of 2.5 minutes. The measurements were consistent with the values obtained from our calculations and simulations. All in all both circuits could be used but the circuit with the 6800μF is the more efficient option.

Bibliography

[1] G.J.M. Janssen et al. EE Quarter 2 Student Manual Integrated Project 1 (IP-1) EE1L1 “Booming Bass (Sound) System” Year 2024-2025.

Appendix 1

2.1

$Ripple\ (\%) = ((V_{max} - V_{average}) / V_{average}) \times 100\%$

2.1.A

$Ripple\ 6800\mu F\ capacitor = ((20.6 - 20.1) / 20.1) \times 100\%$

$Ripple\ 6800\mu F\ capacitor \approx 2{,}49\%$

2.1.B

$Ripple\ 4700\mu F\ capacitor = ((20.9 - 20.1)/20.1) \times 100\%$

$Ripple\ 4700\mu F\ capacitor \approx 3.98\%$

$\tau = RC$

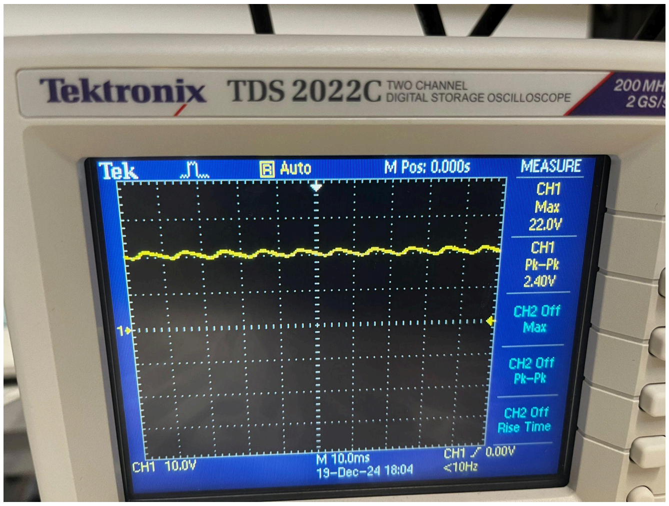
2.2.1

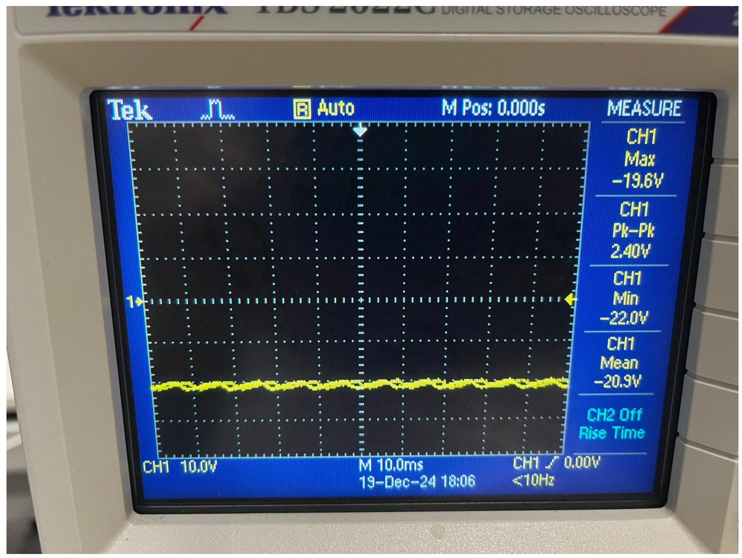
19.937x4700x10^-6=0.09375=τ

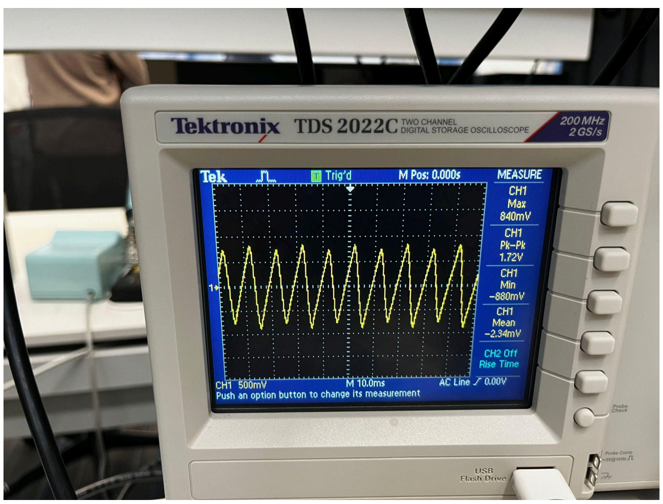
2.2.2

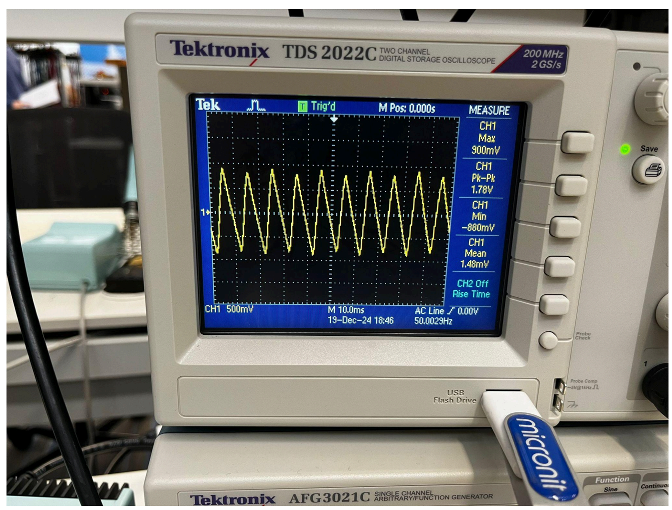
20x6800x10^-6=0.0945=τ

Appendix 2


Tektronix TDS 2022C TWO CHANNEL DIGITAL STORAGE OSCILLOSCOPE
Tek
Auto
M Pos: 0.000s
MEASURE
CH1 Max 22.0V
CH1 Pk-Pk 2.40V
CH2 Off Max
CH2 Off Pk-Pk
CH2 Off Rise Time
CH1 10.0V
M 10.0ms
19-Dec-24 18:04
CH1 ⁄ 0.00V
<10Hz


Tek
Auto
M Pos: 0.000s
MEASURE
CH1 Max -19.6V
CH1 Pk-Pk 2.40V
CH1 Min -22.0V
CH1 Mean -20.3V
CH2 Off Rise Time
CH1 10.0V
M 10.0ms
19-Dec-24 18:06
CH1 ⁄ 0.00V
<10Hz

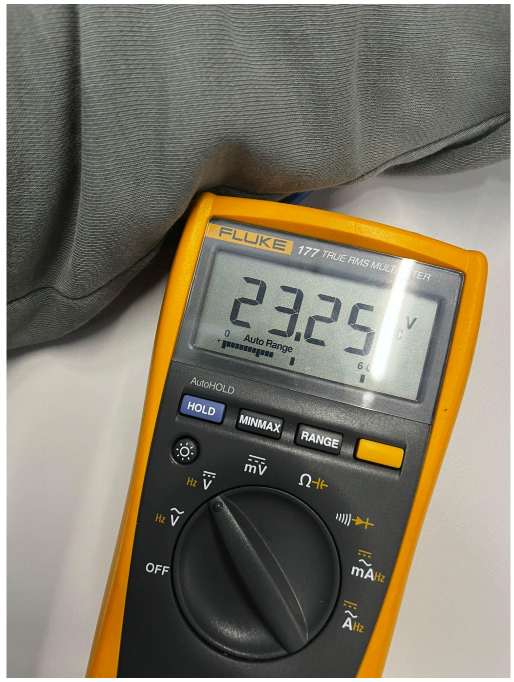

Tektronix TDS 2022C TWO CHANNEL DIGITAL STORAGE OSCILLOSCOPE
200 MHz 2 GS/s
Tek
Trig'd
M Pos: 0.000s
MEASURE
CH1 Max 840mV
CH1 Pk-Pk 1.72V
CH1 Min -880mV
CH1 Mean -2.34mV
CH2 Off Rise Time
CH1 500mV
M 10.0ms
AC Line ⁄ 0.00V
Push an option button to change its measurement


Tektronix TDS 2022C TWO CHANNEL DIGITAL STORAGE OSCILLOSCOPE
200 MHz 2 GS/s
Tek
Trig'd
M Pos: 0.000s
MEASURE
CH1 Max 900mV
CH1 Pk-Pk 1.78V
CH1 Min -880mV
CH1 Mean 1.48mV
CH2 Off Rise Time
CH1 500mV
M 10.0ms
19-Dec-24 18:46
AC Line ⁄ 0.00V
50.0023Hz
USB Flash Drive
Tektronix AFG3021C


FLUKE 177 TRUE RMS MULTIMETER
23.23 DC V
Auto Range
HOLD
MINMAX
RANGE


FLUKE 177 TRUE RMS MULTIMETER
46.51 DC V
HOLD
MINMAX
RANGE


FLUKE
177 TRUE RMS MULTIMETER
0.001
V
DC
Auto Range
AutoHOLD
HOLD
MINMAX
RANGE
OFF
400
mA
10A
FUSED
600V CAT IV
1000V CAT III
COM


FLUKE
23.25
V
Auto Range
AutoHOLD
HOLD
MINMAX
RANGE
OFF