EE3253: ELECTRICAL AND ELECTRONIC MEASUREMENTS

LABORATORY 02

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SEMESTER: 03

DATE : 20/01/2024

Table 1.1: Summative Laboratory Form

Semester	03
Module Code	EE3253
Module Name	Electrical and Electronic measurements
Lab Number	02
Lab Name	Oscilloscope Probe Testing
Lab conduction date	2023.12.0
Report Submission date	2024.01.20

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1.1.1 Probe at x1

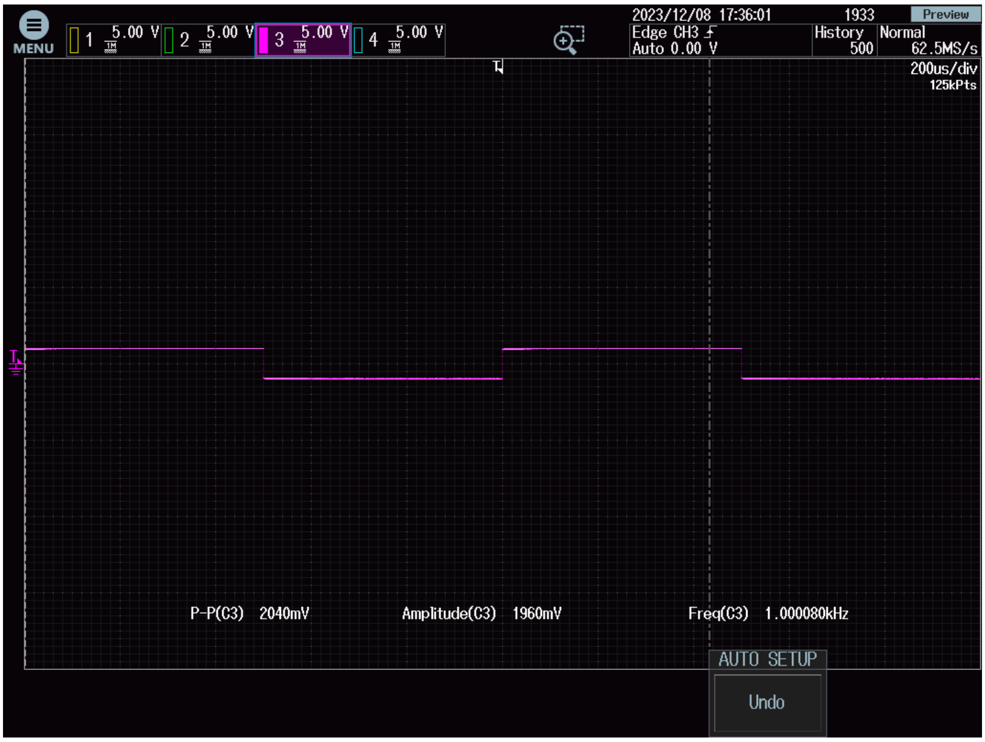

Figure 1 : Square wave with 1kHz and oscilloscope vertical sensitivity 5V/div

1.1.2 Probe at x10

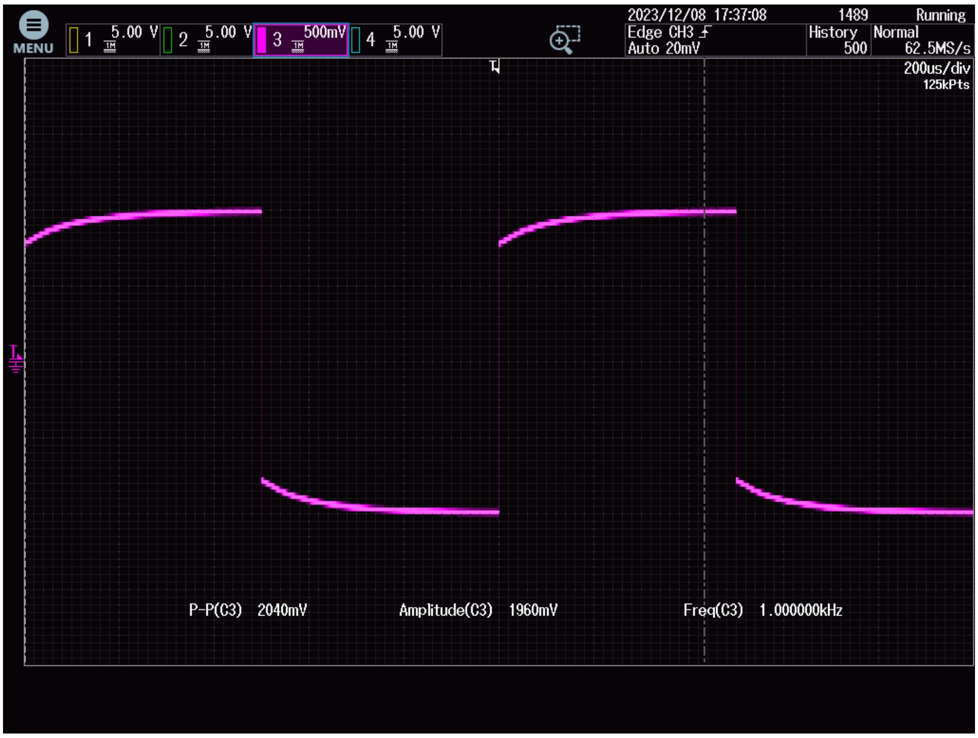

Figure 2 : Square wave with 1kHz and probe at 10x

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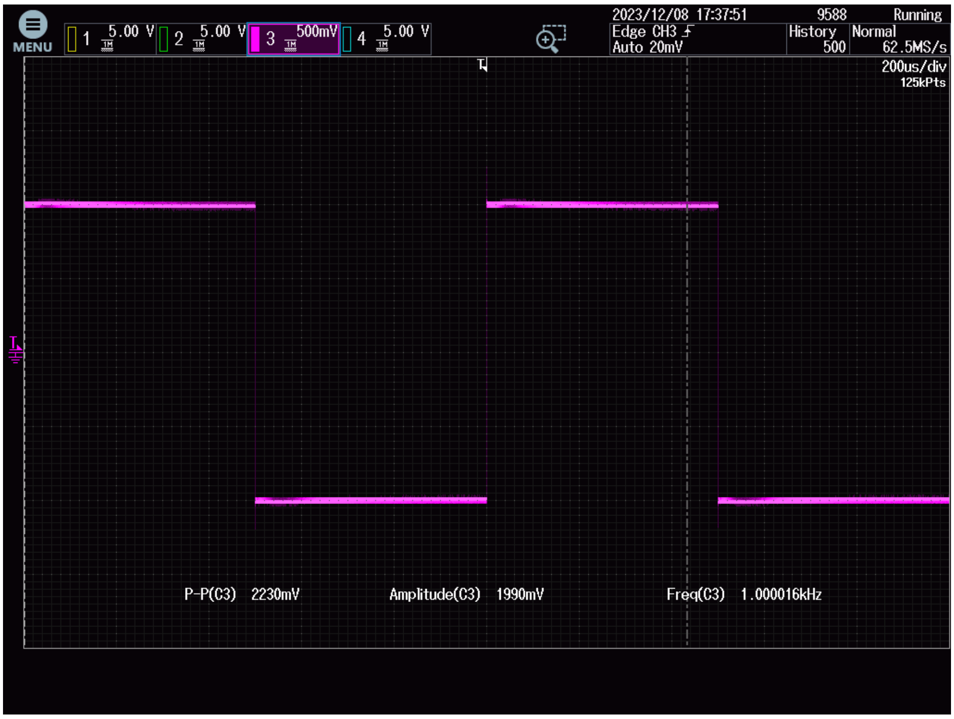

Figure 3 : Output after the tuning the probe

1.2 Observe the output of the low impedance sine wave source.

Table 2 : Peak to Peak Amplitudes According to Probe Positions at low impedance

	Probe at x1	Probe at x10
1 kHz	5.96 V	598 mV
10 kHz	5.87 V	597 mV
100 kHz	5.85 V	598 mV
1 MHz	5.93 V	610 mV

1.2.1 Probe at x1

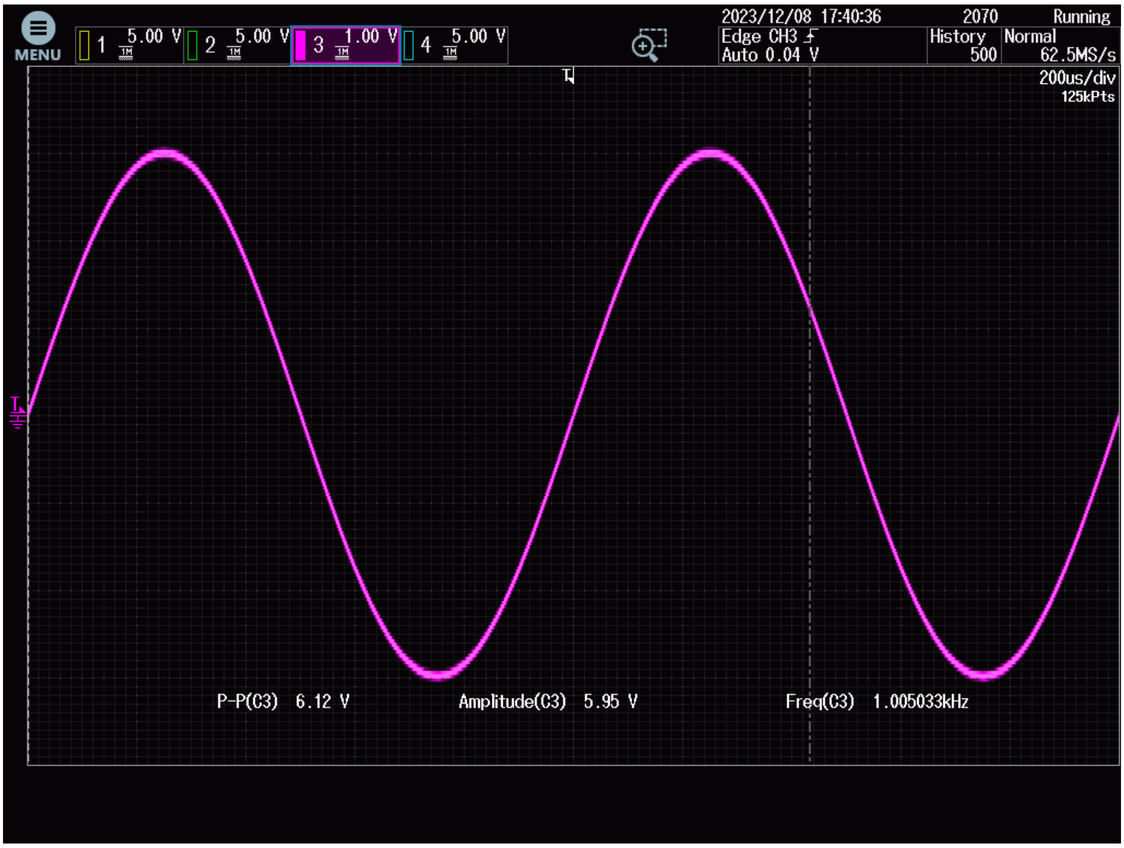

Figure 4 : low impedance sine wave source Frequency at 1kHz and Probe at x1

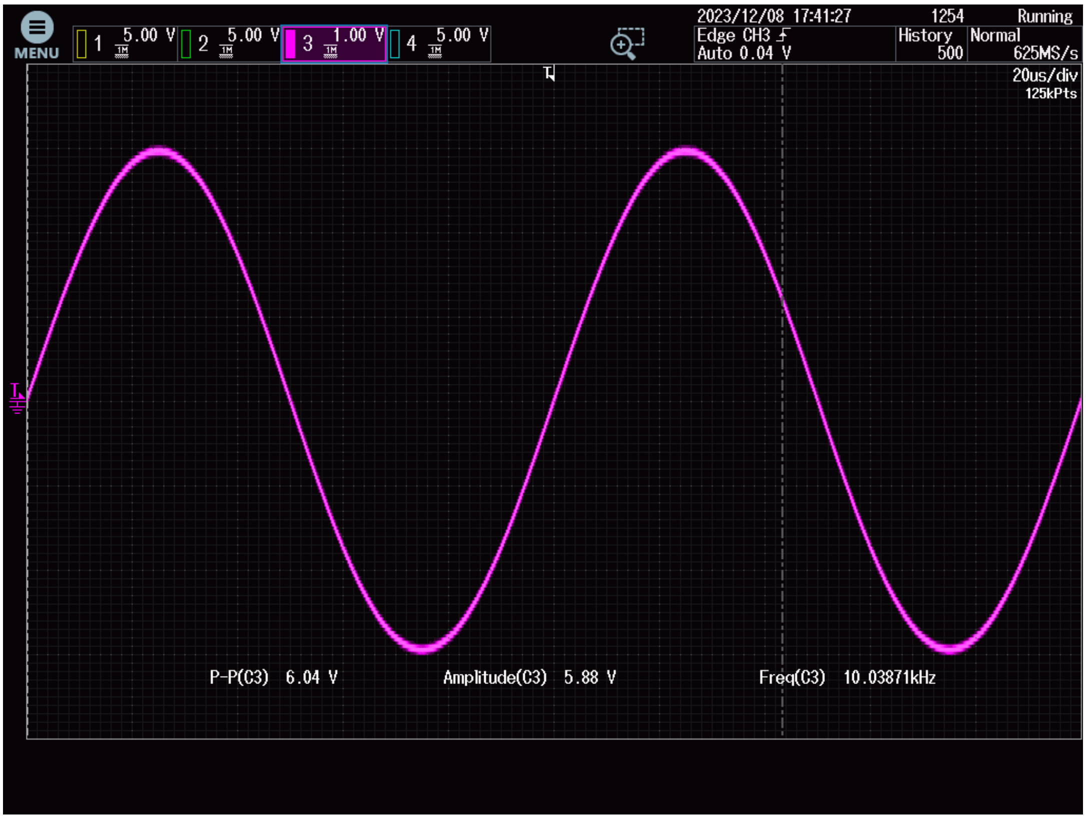

Figure 5 : low impedance sine wave source Frequency at 10kHz and Probe at x1

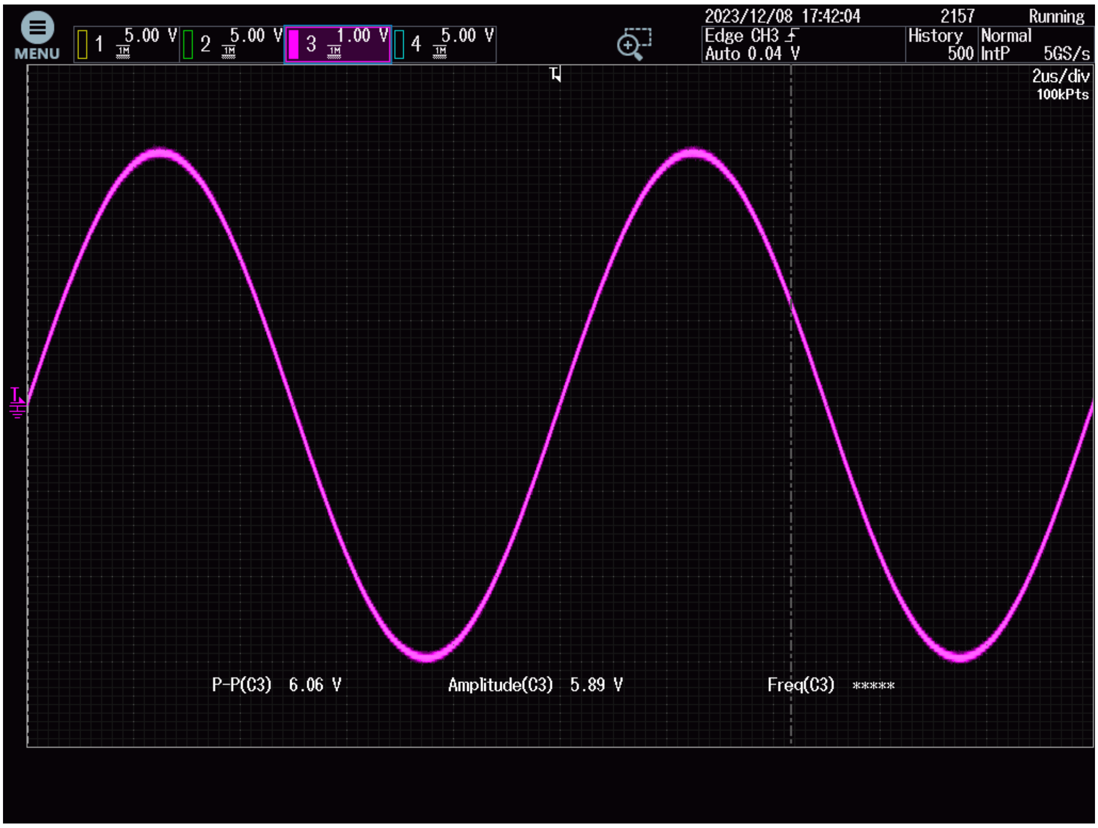

Figure 6 : low impedance sine wave source Frequency at 100kHz and Probe at x1

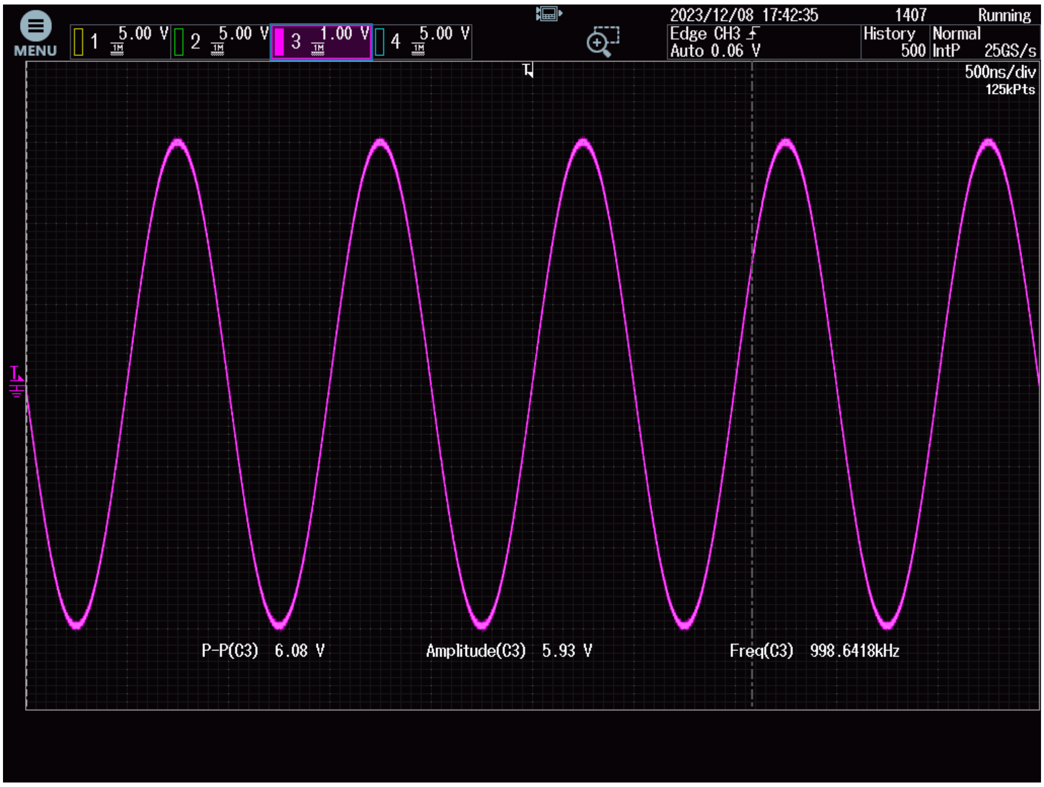

Figure 7 : low impedance sine wave source frequency at 1kHz and Probe at x1

1.2.2 Probe at x10

Figure 8 : low impedance sine wave source Frequency at 1kHz and Probe at x10

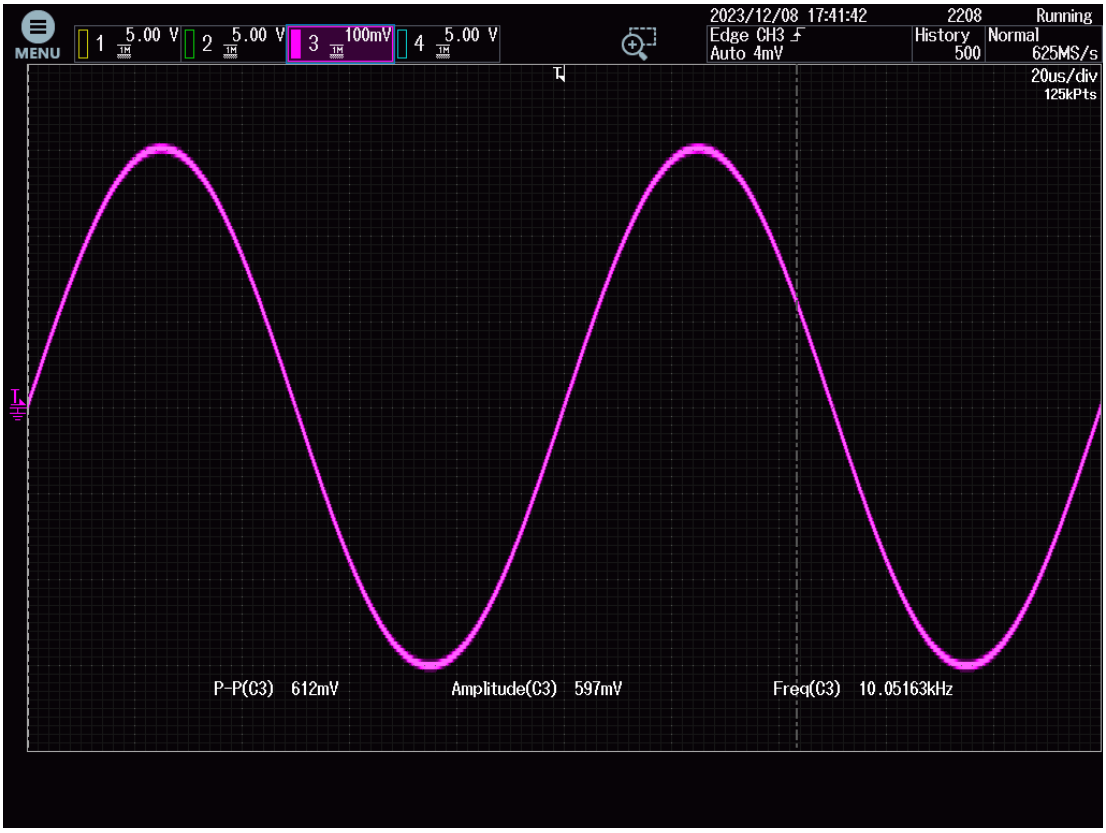

Figure 9 : low impedance sine wave source Frequency at 10kHz and Probe at x10

Figure 10 : low impedance sine wave source Frequency at 100kHz and Probe at x10

Figure 11 : low impedance sine wave source Frequency at 1MHz and Probe at x10

1.3 Observe the output of high Impedance Sine wave source

Table 3 : Peak to Peak Amplitudes According to Probe Positions at high impedance

	Probe at x1	Probe at x10
1 kHz	5.67 V	595 mV
10 kHz	5.34 V	594 mV
100 kHz	1720 mV	526 mV
1 MHz	185 mV	115.6 mV

1.3.1 Probe at x1

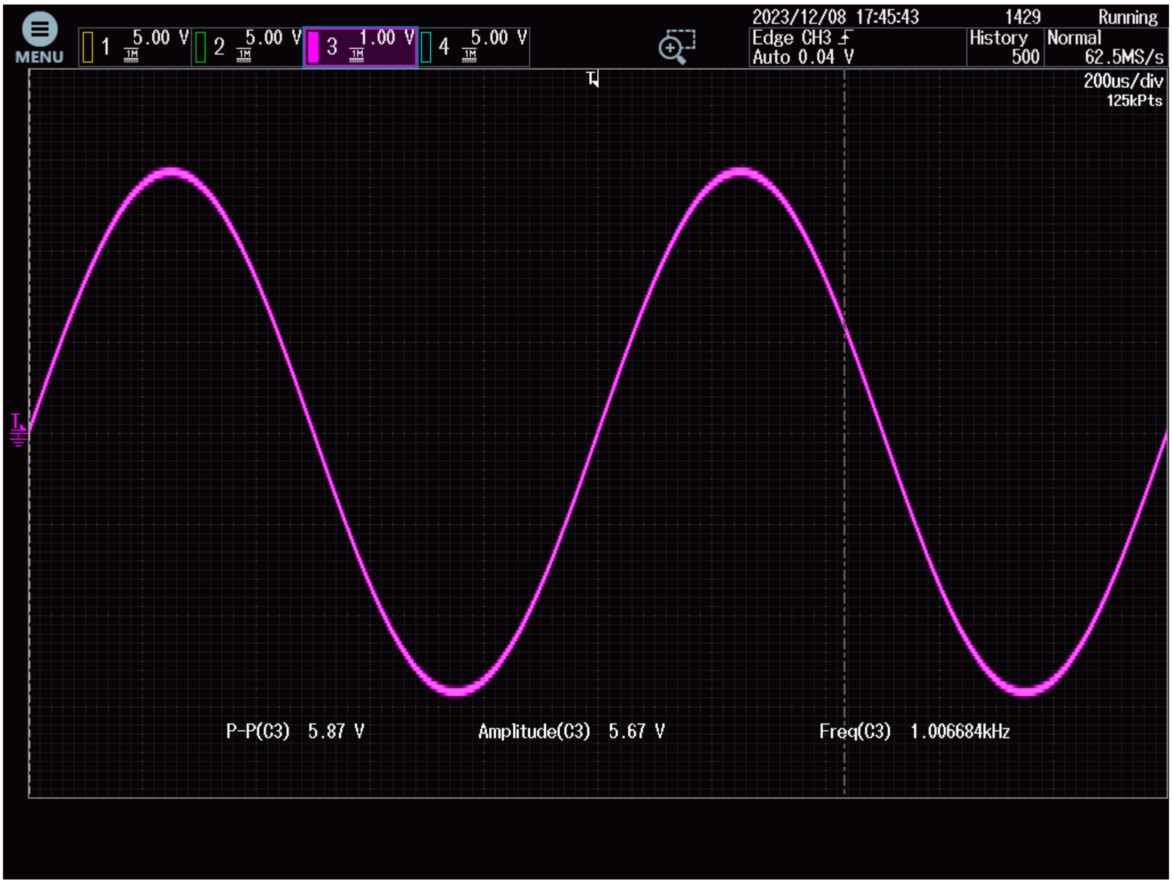

Figure 12 : High Impedance Sine wave source Frequency at 1kHz and Probe at x1

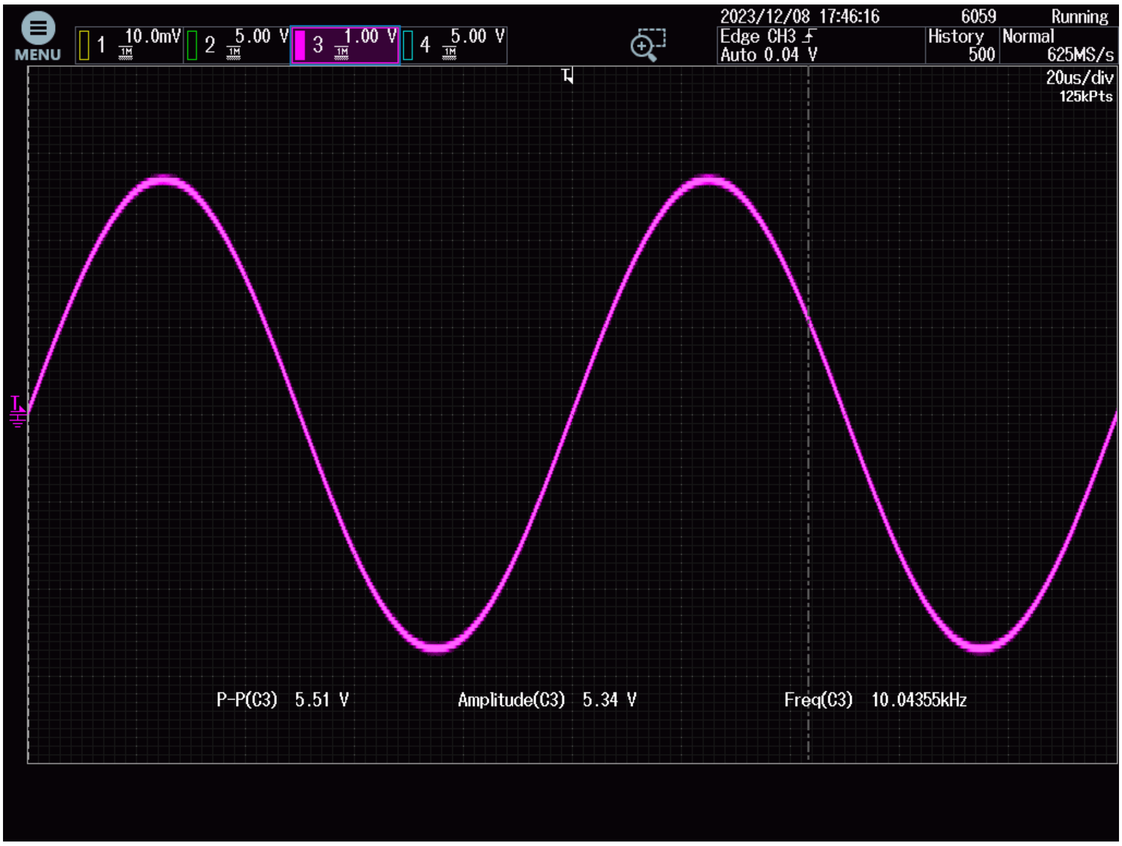

Figure 13 : High Impedance Sine wave source Frequency at 10kHz and Probe at x1

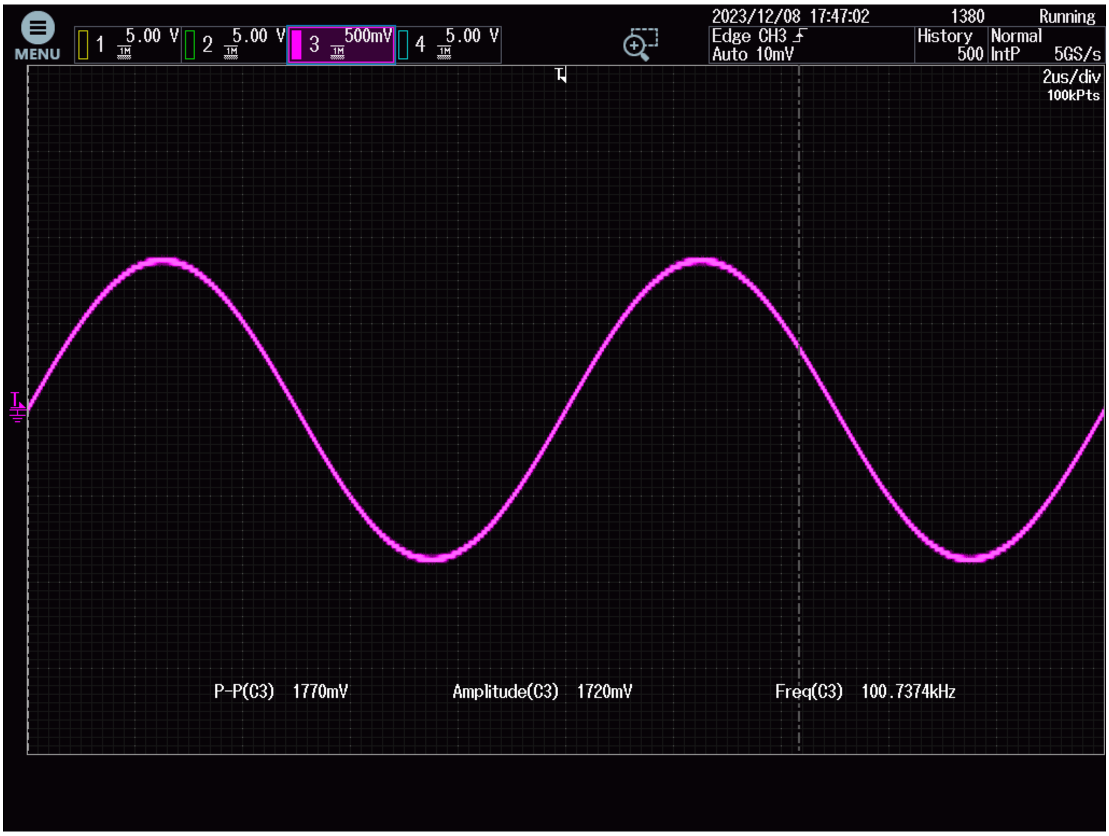

Figure 14 : High Impedance Sine wave source Frequency at 100kHz and Probe at x1

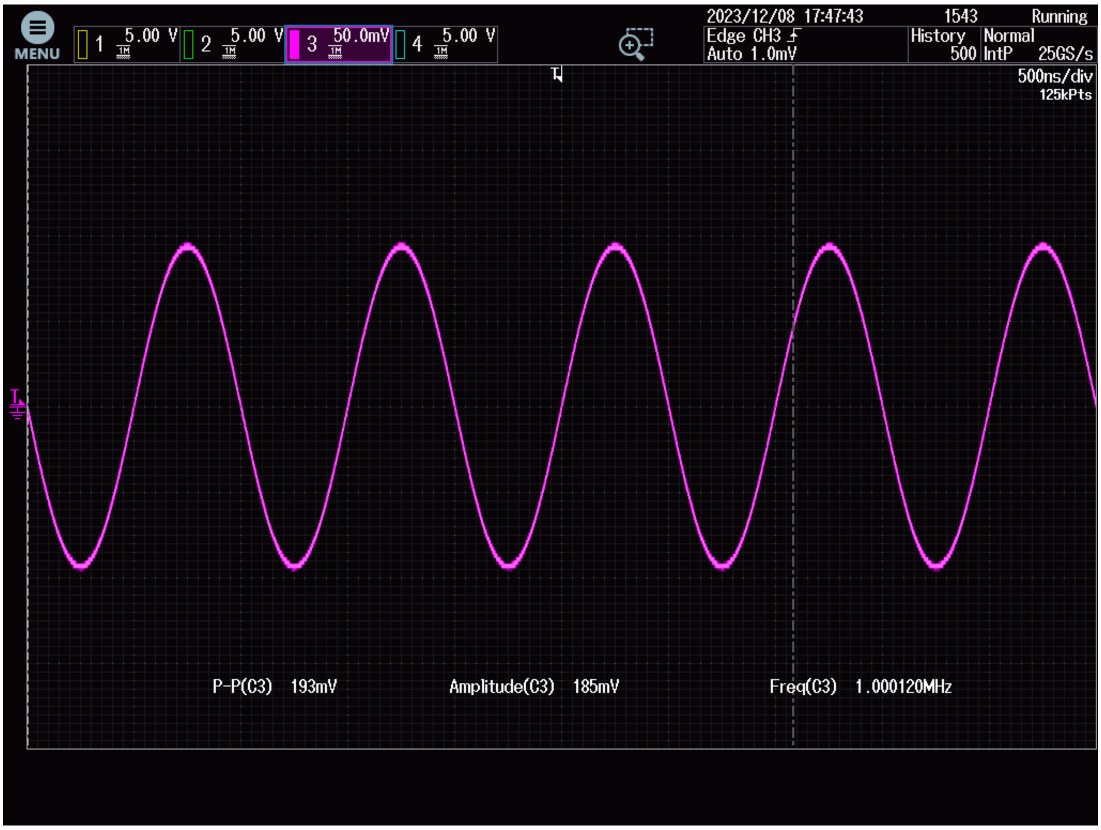

Figure 15 : High Impedance Sine wave source Frequency at 1MHz and Probe at x1

1.3.2 Probe at x10

Figure 16 : High Impedance Sine wave source Frequency at 1kHz and Probe at x10

Figure 17 : High Impedance Sine wave source Frequency at 10kHz and Probe at x10

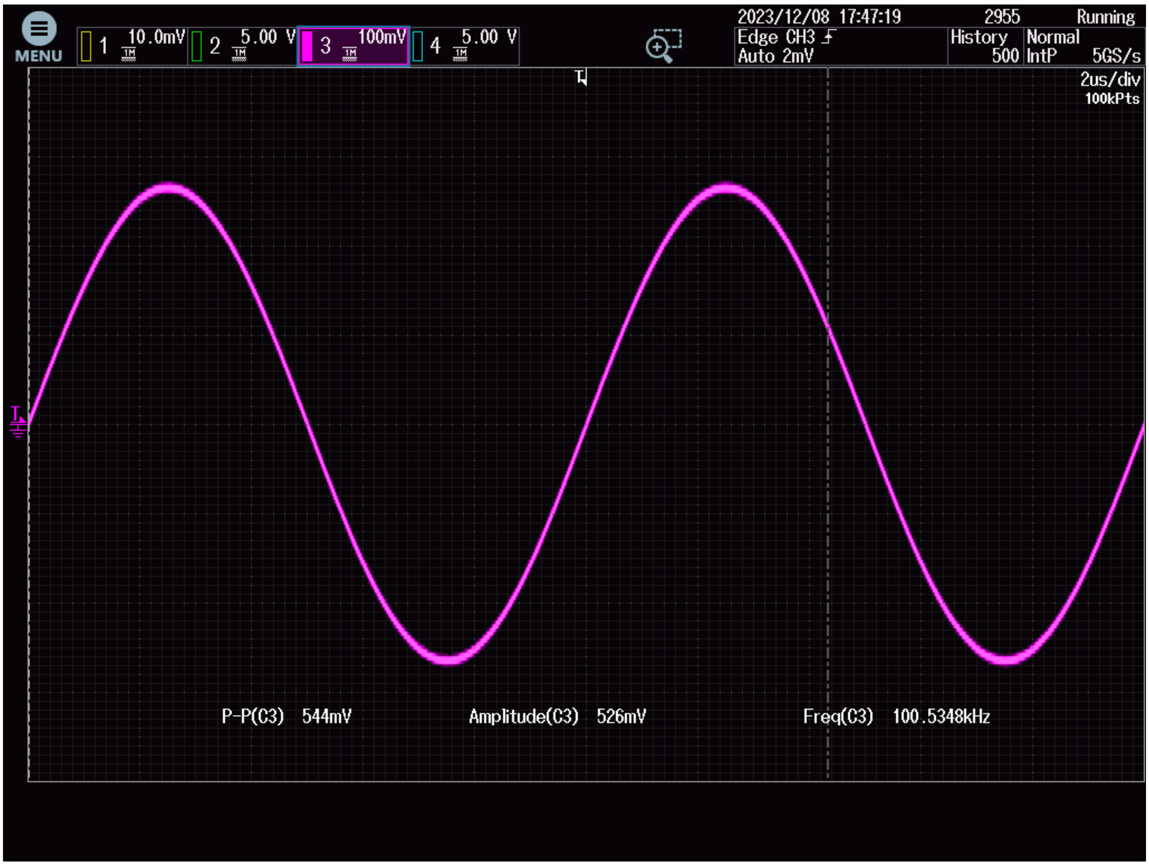

Figure 18 : High Impedance Sine wave source Frequency at 100kHz and Probe at x10

Figure 19 : High Impedance Sine wave source Frequency at 1MHz and Probe at x10

1.4 Rise time & fall time of the CRO

1.4.1 Probe at x1

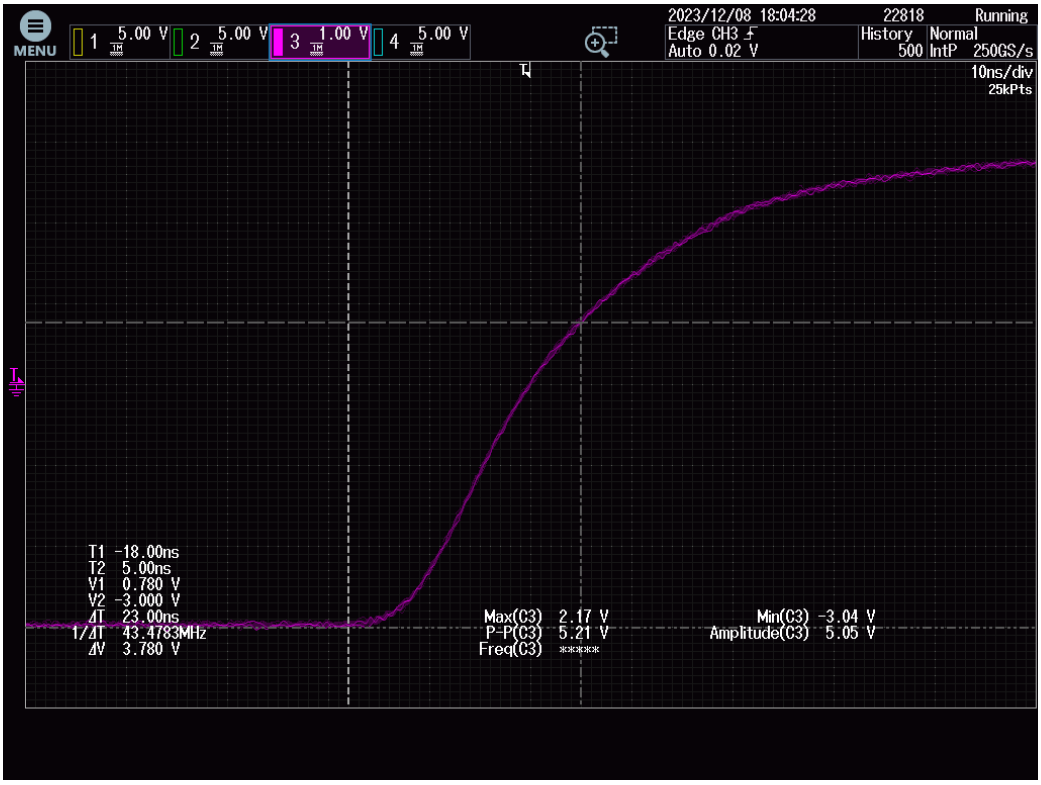

Figure 20 : 1. Rise time & fall time of the CRO in Probe at x1

1.4.2 Probe at x10

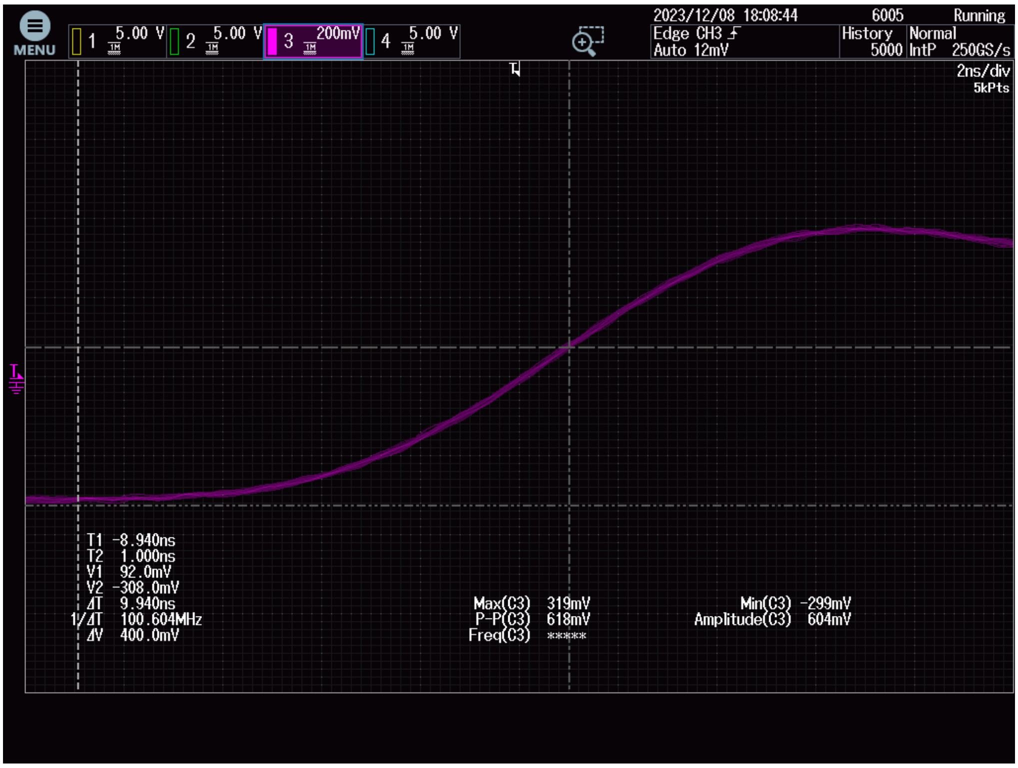

Figure 21 : 1. Rise time & fall time of the CRO in Probe at x10

1.5 Effect of source impedance on the rise time and fall time of the CRO

1.5.1 Probe at x1

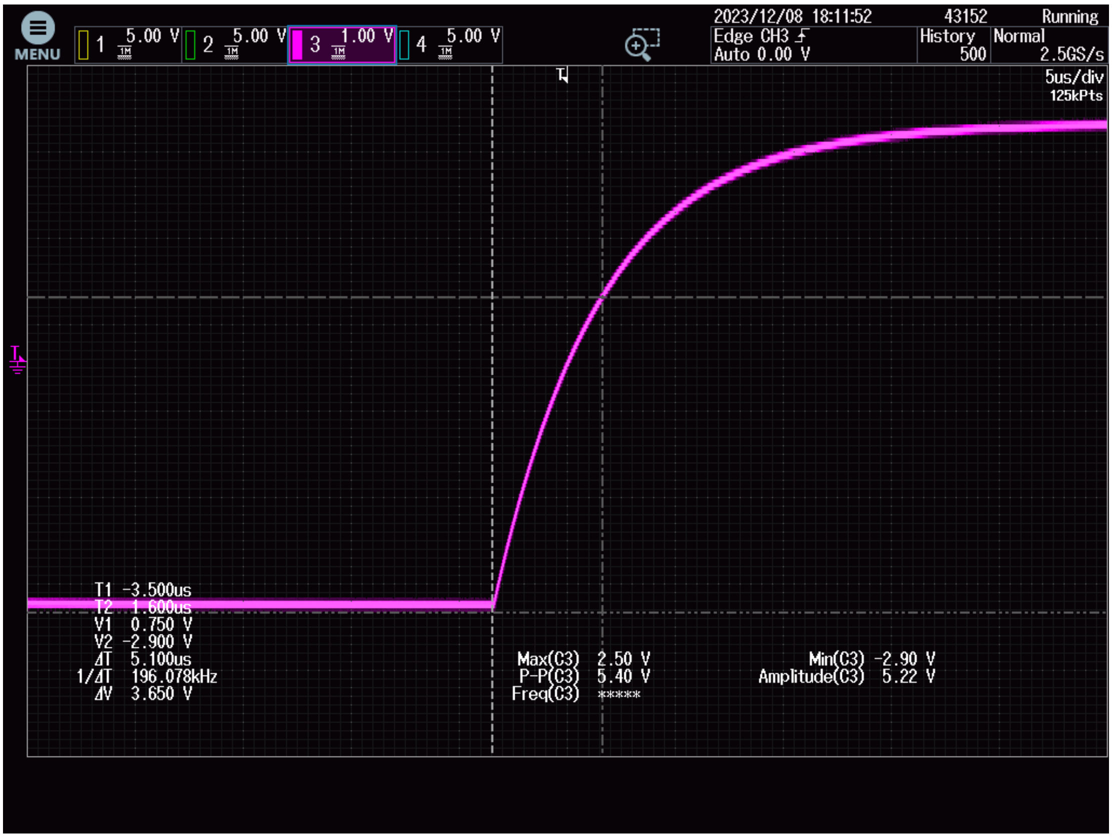

Figure 22 : Effect of source impedance on the rise time and fall time of the CRO Probe at x1

$$
\begin{aligned}
Rise\ Time &= T_2 - T_1 \\
&= 1.6\ \mu s - (-3.5)\ \mu s \\
&= 5.100 \mu s
\end{aligned}
$$

1.5.2 Probe at x10

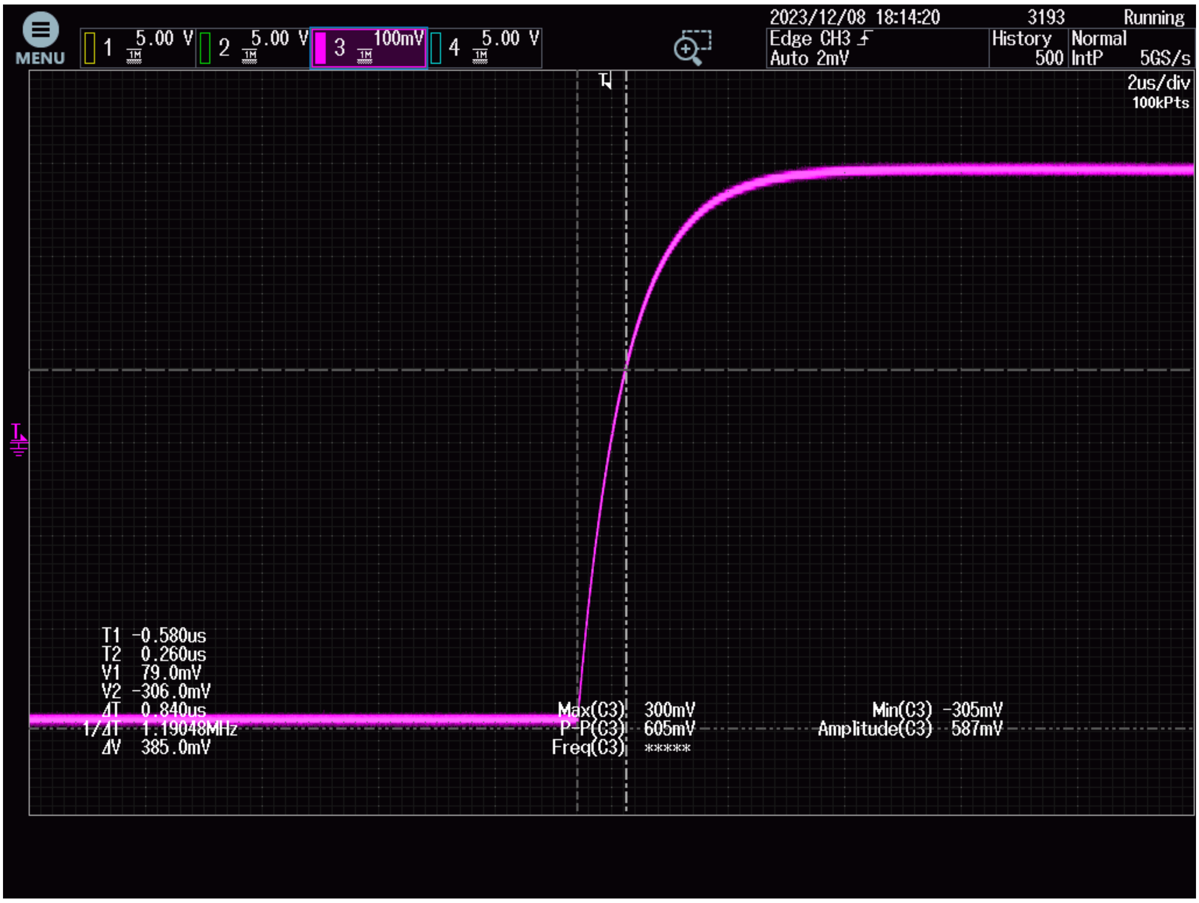

Figure 23 : Effect of source impedance on the rise time and fall time of the CRO Probe at x10

$$
\begin{aligned}
Rise\ Time\ &= T_2 - T_1 \\
&= 0.260\ \mu s - (-0.580)\ \mu s \\
&= 0.840\ \mu s
\end{aligned}
$$

1.6 Effect of over compensation of x10 probe

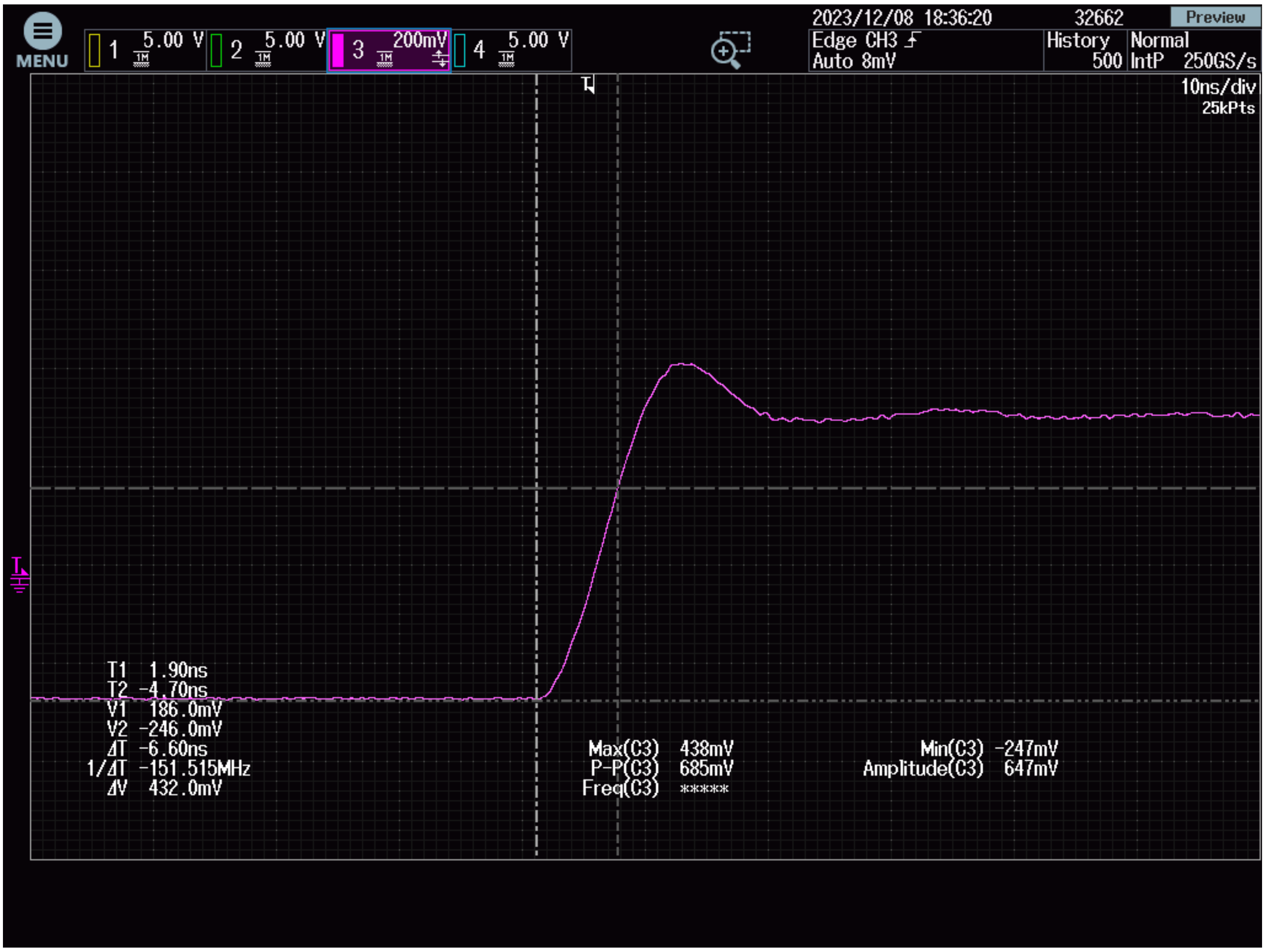

Figure 24 : Effect of over compensation of x10 probe rise time

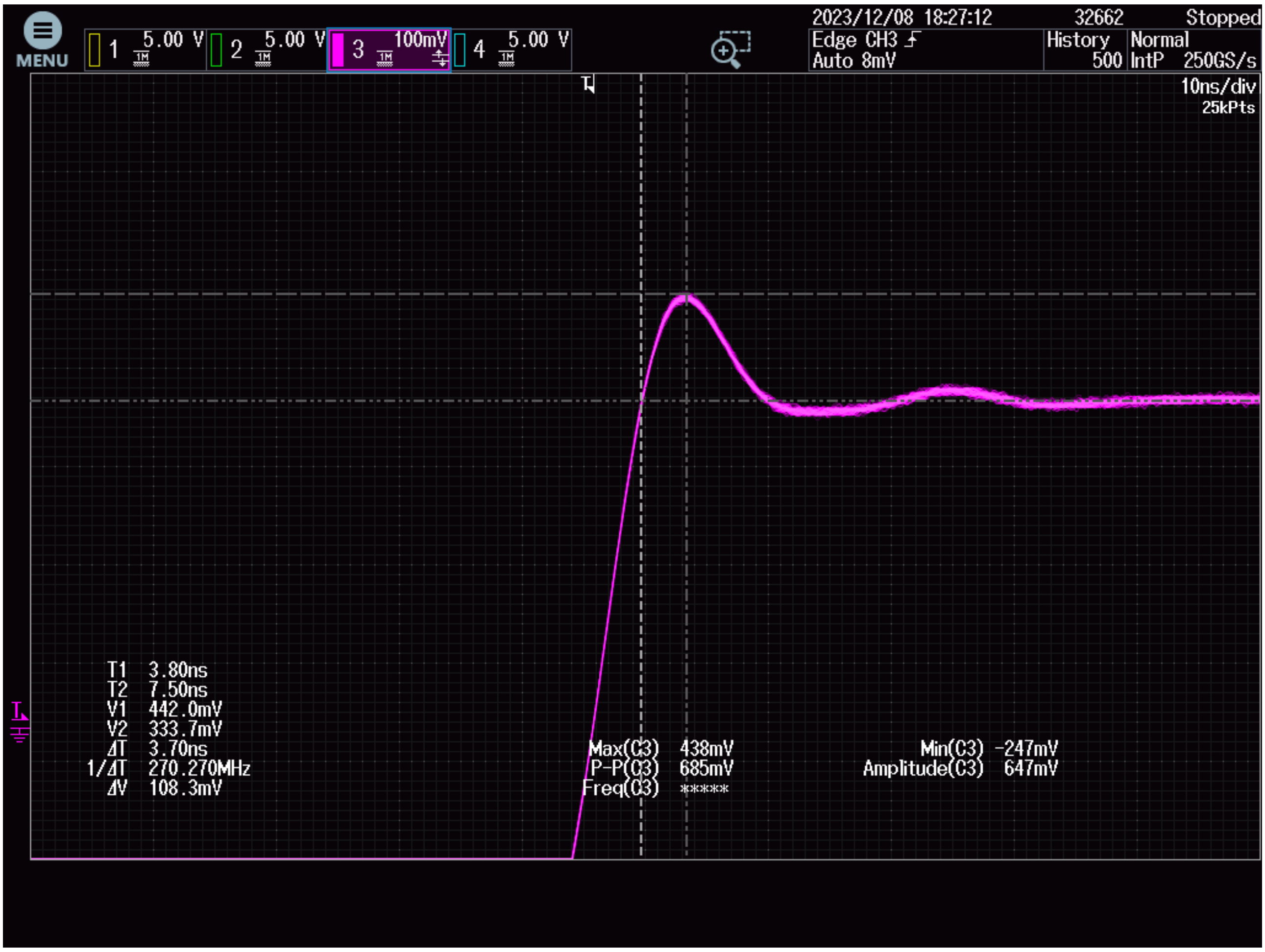

Figure 25 : Effect of over compensation of x10 probe height of over shoot

	Probe at x10
Source output voltage	$6V_{pp}$
Input voltage	685 mV
Rise time	6.60 ns
Height of over shoot	108.3 mV

1.7 Effect of under compensation of x10 probe

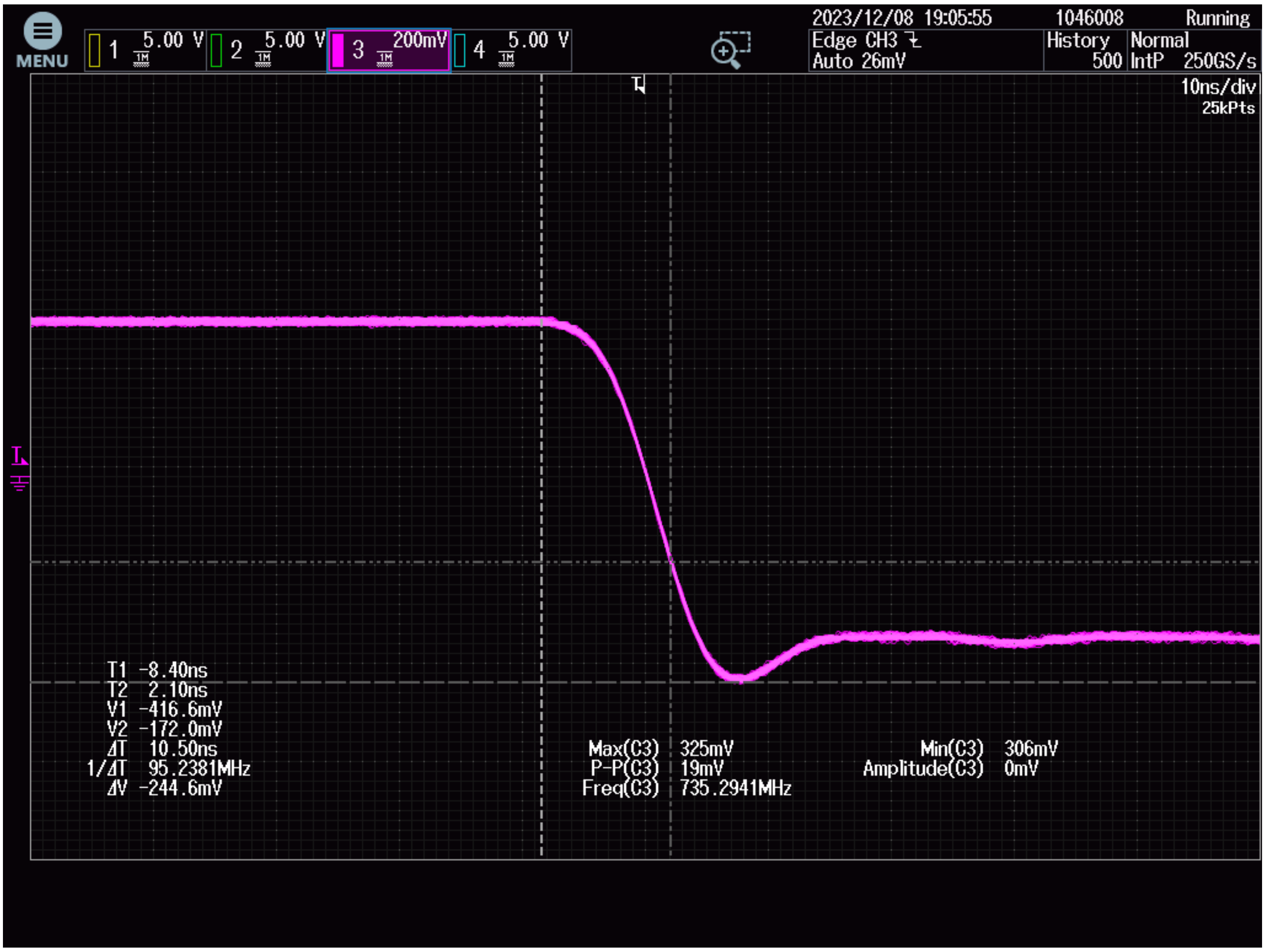

Figure 26 : 1.1 Effect of under compensation of x10 probe Fall time

	Probe at x10
Source output voltage	6 V_{pp}
Input voltage	19 mV
Fall time	10.50 ns
Height of under shoot	50 mV

2 Calculation

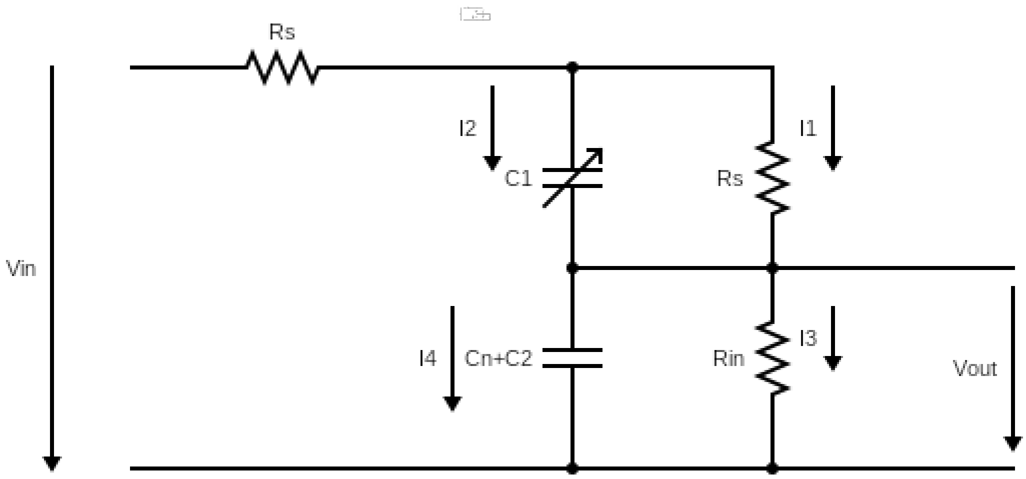

Figure 27 : Circuit diagram of oscilloscope probe

Assume the C_2=0

Considering above circuits

$$i_1 = C_1 \frac{dv_p}{dt}$$

$$i_2 = \frac{V_p}{R_1}$$

$$i_3 = C_2 \frac{dv_0}{dt}$$

$$i_4 = \frac{V_0}{R_2}$$

Apply the KCL low

$$I_1 + I_2 = I_3 + I_4$$

Using $I = C\frac{dV}{dt}$

Apply the KVL low

$$V_{in} = V + V_{out}$$

By using above two equations

$$\frac{V_{in}-V_{out}}{R_1} + C_1 \frac{d(V_{in}-V_{out})}{dt} = \frac{V_{out}}{R_{in}} + C_{in}\frac{dV_{out}}{dt}$$

V_{in} is constant value

$C_1 <<<< C_{in}$

So $$C_1 + C_{in} = C_1 = C$$

$R_1 <<<< R_{in}$

$$\frac{1}{R_1} + \frac{1}{R_n} = \frac{1}{R_1} + \frac{1}{R}$$

We get

$$C\frac{dV_{out}}{dt} = V_{out} \times \frac{1}{R} - \frac{V_{in}}{R}$$

By solving above differential equation

$$\frac{V_{in} - V_{out}}{V_{in}} = \frac{V_{in} - V_{in}\frac{t}{RC}}{V_{in}}$$

$$= \frac{1}{1 + \frac{t}{RC}}$$

$$V_{out} = V_{in}(1 - e^{-\frac{t}{RC}})$$

2.1 Specimen Calculation

2.1.1 Rise time and fall time of CRO

Considering Figure 20 for probe at ×

Rise time = $23.0ns$

Rise time = RC

RC =$23.0ns$

Considering Figure 21 for probe at ×10

Rise time = RC

RC = 9.420 ns

2.1.2 Effect of source impedance on the rise time and fall time of CRO

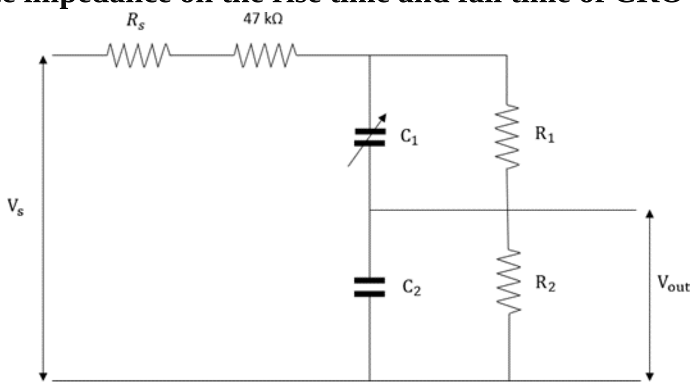

Figure 28 : Equivalent Circuit of The Oscilloscope Probe

Considering the probe at x1;

Considering Figure 22

Let's assume that the input resistance of the CRO is 1MΩ. ;

$$V_{out} = \left[\frac{1 \times 10^6 \Omega.}{R1 + R2 + Rs + 47 \times 10^3 \Omega.}\right] Vs$$

$$5.40 \text{ V} = \left[\frac{1 \times 10^6 \Omega.}{R1 + 1 \times 10^6 \Omega. + Rs + 47 \times 10^3 \Omega.}\right] 6V$$

$$R1 + Rs = 64111.111 \ \ \Omega.$$

Considering the equation;

RC = Rise time

RC =5.100µs

For the resistance R;

$$\frac{1}{R.} = \frac{1}{R2.} + \frac{1.}{R1 + Rs + 47 \times 10^3 \Omega.}$$

$$\frac{1}{R} = \frac{1}{10^6 \Omega} + \frac{1}{64111.11 + 47000\Omega}$$

$$R = 1.000 \times 10^5$$

But we obtained RC as;

RC = 5.1µs

Then;

C = $(5.1 \times 10^{-6})/1.000 \times 10^5$

C = 51.00pF

Considering the probe at x10;

Considering Figure 23

Let's assume that the input resistance of the CRO is 1MΩ. ;

$$V_{out} = \left[\frac{1 \times 10^{6}\Omega.}{R1 + R2 + Rs + 47 \times 10^{3}\Omega.}\right] Vs$$

$$605 \text{ mV} = \left[\frac{1 \times 10^{6}\Omega.}{R1 + 1 \times 10^{6}\Omega. + Rs + 47 \times 10^{3}\Omega.}\right] 6V$$

$$R1 + Rs = 8.8703 \text{ M}\Omega.$$

Considering the equation;

RC = Rise time

RC = 0.840 μs

For the resistance R;

$$\frac{1}{R.} = \frac{1}{R2.} + \frac{1.}{R1+Rs+47\times10^{3}\Omega.}$$

$$\frac{1}{R} = \frac{1}{10^{6}} + \frac{1}{8.8703\ M\Omega+47000\Omega}$$

$$R = 900.90 \text{ k}\,\Omega$$

But we obtained RC as;

RC = 5003.955ns

Then;

C = $(0.840 \times 10^{-6} s)$/ 900.90 k Ω

C = 0.932 pF

3 Tabulation

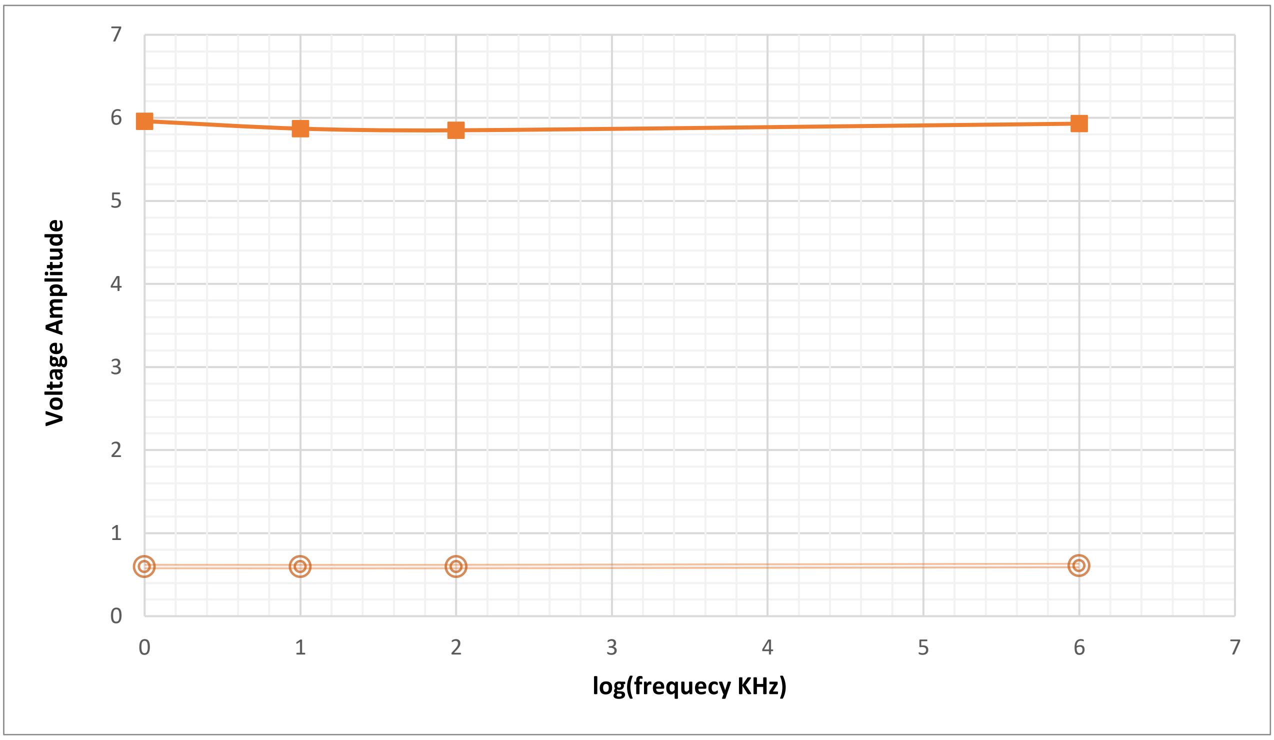

Figure 29 : The graph of amplitude vs log frequency for low impedance sine wave source

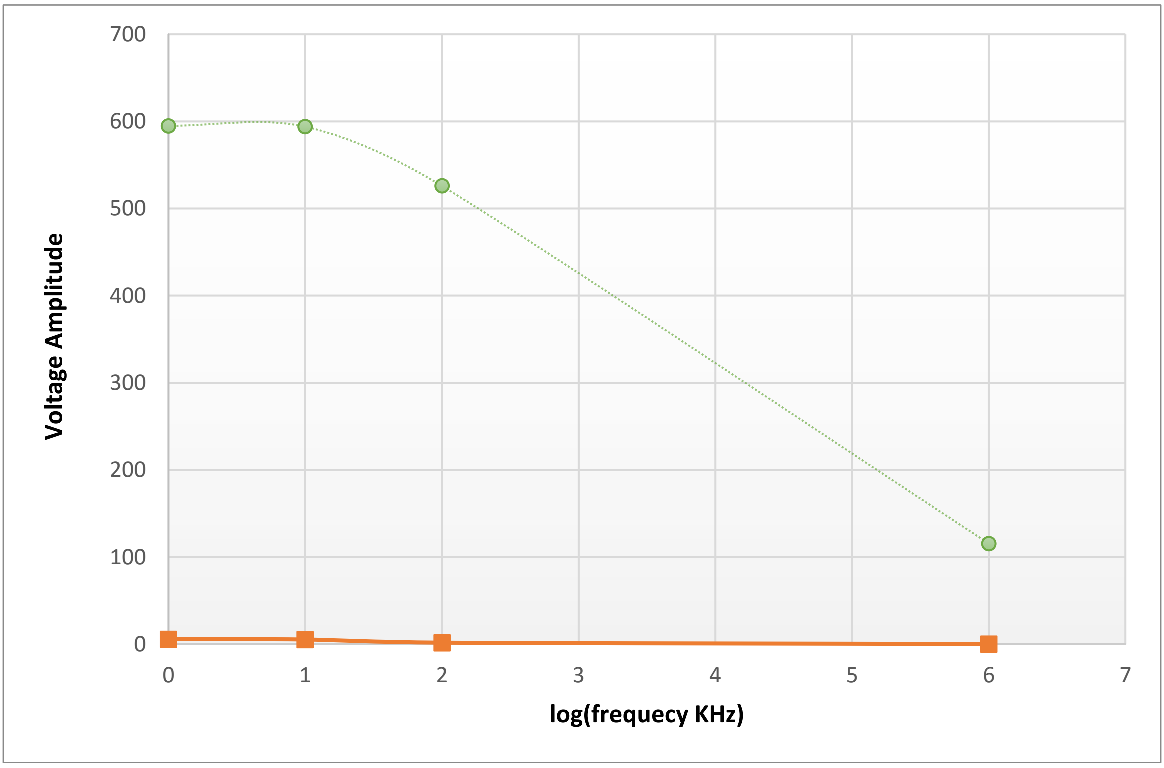

Figure 30 : The graph of amplitude vs log frequency for high impedance sine wave source

4 Discussion

Q1.What is rise time?

Rise time is defined as the time taken for a signal to cross from a specific low value to a specified high value. In practices, the specified lower value and the specified higher value are 0% and 63% of the final steady values. So rise time can be defined as how long it takes for a signal to g from 0% to 63% of its final value.

Mathematically, rise time(t_r) is defined as the time it takes for the signal to rise from the lower threshold(V_L) to the upper thresholds (V_H), and it is measured between the points where the signal crosses these thresholds.

$$t_r = t_H + t_L$$

The rise time is a critical parameter in analog and digital systems. It describes the time taken for the output to rise from one level to another in another system, which has many real-world implications. The rise time represents how long a signal spends in the intermediate state between two deference logic levels. In a digital system. [1]

Q2.Discuss the effect of source impedance on the rise time and fall time.

The electrical resistance or reactance of the source generating the signal is known as the source impedance. It may have an impact on a signal's rise time and fall time, which indicate how quickly a signal changes levels.

The source impedance is the electrical resistance or reactance of the source that is producing the signal. It might affect a signal's rise time and fall time, which show how fast a signal shifts in strength.

Take into consideration, for instance, a circuit powered by a signal source with a high source impedance and a load capacitance. The load capacitance can only be charged or discharged with a limited amount of current due to the high source impedance. This will cause the signal's rise and fall times to be slower. The signal will rise and fall more quickly, however, if the signal source has a low source impedance because more current will be available to charge or discharge the load capacitance.

The load impedance of the circuit, the rise and fall times of the signal source, and the bandwidth of the circuit can all have an impact on a signal's rise and fall times in addition to the source impedance. Engineers need to take these things into account when planning and maximizing systems customized for particular uses.

Q3.What are compensation and under-compensation?

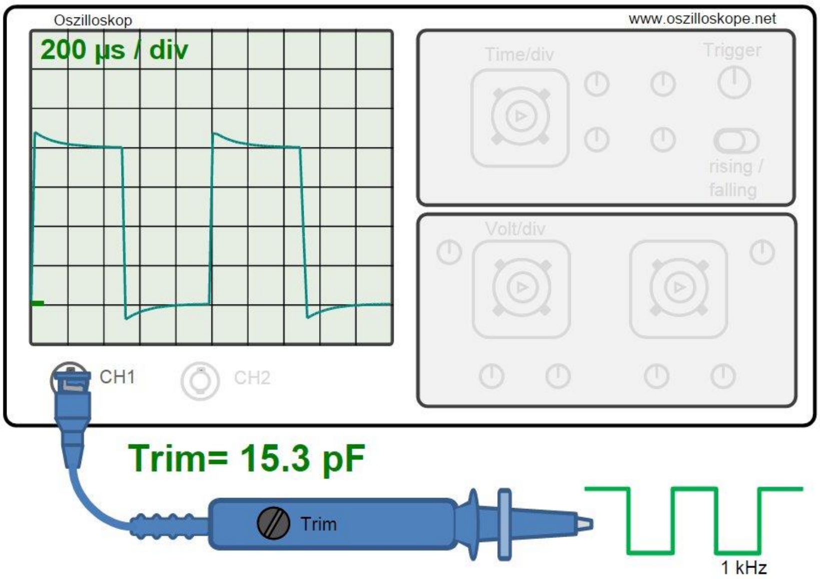

Figure 31: Over compensation

In Figure 31 you can see the over-compensation wave. Overcompensation occurs when the trim capacity is too high. In this case, the rising edge shoots above the target value. The falling edge goes below the zero level before the curve slowly approaches the zero line. We can use the observations.

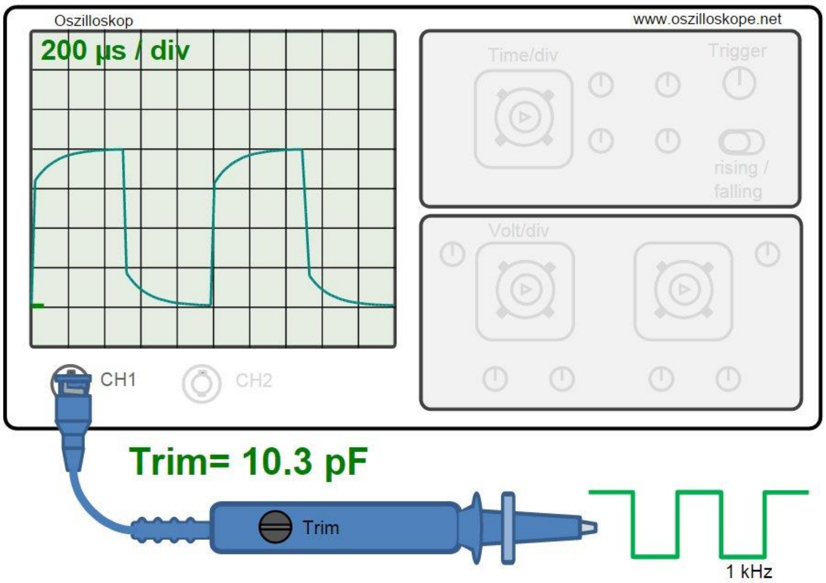

Figure 32: Under Compensation

The figure simulates the observed input signal at the oscilloscope in the case of a square wave voltage present at a frequency of 1000 Hz. The scenario of inadequate compensation is depicted in the simulation. The capacitor's cutting capacitance is inadequate. The signal is rising and declining too slowly. [2]

Q4. What are the reason/reasons for over-compensation and under-compensation?

There are many reasons for over and under-compensation. Some of them are

- Frequency Response Issues
- Ringing
- Attenuation of High Frequencies
- Roll-Off

Overcompensation happens when the compensation is set very high. This may result in a probe that is too fast or the actual system being measured. Because of that, high-frequency components of the signal may be distorted or attenuated. Overcompensation can cause the signal to overshoot and undershoot, ringing the waveform. Because of this, precisely analysing the waveform may be difficult.

The probe might not be able to adequately adjust for the high-frequency components of the signal if the compensation is set too low. At higher frequencies, this may lead to a loss of signal fidelity. Inaccurate amplitude measurements for high-frequency components can result from under-compensation, which can produce a roll-off in the frequency response.

5 References

[1] Sweetwater, "Rise Time/Fall Time,," inSync, 2006. [Online]. Available: https://www.sweetwater.com/insync/rise-time-fall-time/#:~:text=Rise%20time%20is%20typically%20measured,value%20to%20the%20lowest%20value.. [Accessed 11 January 2024].

[2] Oszi-Admin, "Probe compensation,," Oszilloskope.net., 2019. [Online]. Available: https://www.oszilloskope.net/en/probe-compensation/. [Accessed 05 January 2014].