Lab Assignment 1

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Abstract—This Lab Report details the experiments conducted to build and increase our understanding of the oscilloscope.

keywords—*Oscilloscope*

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1. Introduction

This is the lab report for Assignment 1, to understand the working principles of an oscilloscope, by using $X - Y$ mode and trigger-capture

2. Equipment Used

- Oscilloscope ×1
- Function Generator ×1

3. Theory

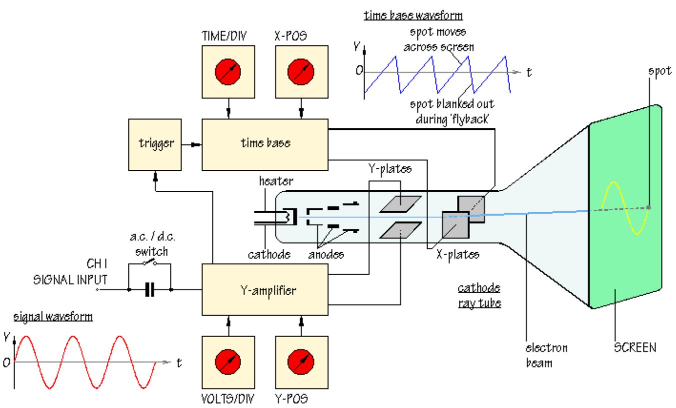

Figure 1. Design of an "Analog Oscilloscope"

An analog oscilloscope simply works by applying a voltage directly being measured to an electron beam that moves across the screen of the oscilloscope. The beam is directed at a phosphor-coated screen, which glows when struck by the beam. The beam is then deflected by the signal, tracing the waveform on the screen.The voltage will deflect the beam up and down proportionally for tracing the waveform on the display. If the 2nd probe of a 2 probe system is left empty, the Y plates are connected to the measured voltage by default, and the X plates are connected to a ramp generator, which can be varied based on TIME/DIV and X-POS. If the X is connected to something instead of being left open, The waveform displayed will be a graph of Y vs X.

Using this, we can construct figures called as the Lissajous Figures.

Lissajous Figures

A lissajous figure is the solution to the set of parametric equations.

$$x = A\sin(at), y = B\sin(bt + \phi)$$

The figures we chose for this purpose are with the following parameters ($A = B = 1$)

1. $a = b = 1, \phi = 0$
2. $a = b = 1, \phi = \frac{\pi}{4}$
3. $a = b = 1, \phi = \frac{\pi}{2}$
4. $a = 1, b = 2, \phi = 0$
5. $a = 1, b = 2, \phi = \frac{\pi}{4}$
6. $a = 1, b = 3, \phi = 0$
7. $a = 1, b = 3, \phi = \frac{\pi}{4}$
8. $a = 1, b = 3, \phi = \frac{\pi}{2}$
9. $a = 2, b = 3, \phi = 0$

Along with this, we can create figures from Triangle waves as well.

3.1. Solutions to the equations with the above parameters

1. $x(t) = \sin(\omega t), y(t) = \sin(\omega t)$
   We can see that the solution for this case would be the straight line $y = x$

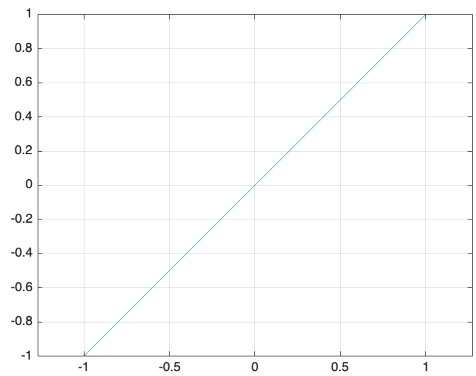

Figure 2. For the ratio 1:1 with no phase difference

2. $x(t) = \sin(\omega t), y(t) = \sin\left(\omega t + \frac{\pi}{4}\right)$

$$y = \sin\left(\omega t + \frac{\pi}{4}\right) = \frac{1}{\sqrt{2}}\sin(\omega t) + \frac{1}{\sqrt{2}}\cos(\omega t)$$

$$x = \sin(\omega t) \implies y = \frac{1}{\sqrt{2}}\left(x \pm \sqrt{1 - x^2}\right)$$

$$\sqrt{2}y - x = \pm\sqrt{1 - x^2}$$

$$2y^2 + x^2 - 2\sqrt{2}xy = 1 - x^2$$

$$\boxed{2x^2 + 2y^2 - 2\sqrt{2}xy = 1}$$

This is the equation to an ellipse

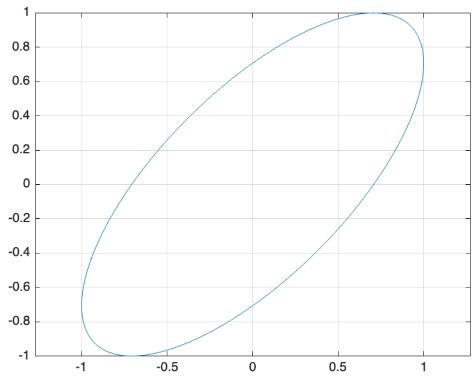

Figure 3. For the ratio 1:1 with phase difference $\frac{\pi}{4}$

3. $x(t) = \sin(\omega t),\ y(t) = \sin\left(\omega t + \frac{\pi}{2}\right)$

$$y = \sin\left(\omega t + \frac{\pi}{2}\right) = \cos(\omega t)$$

$$x = \sin(\omega t) \implies \boxed{x^2 + y^2 = 1}$$

This is the equation to a circle

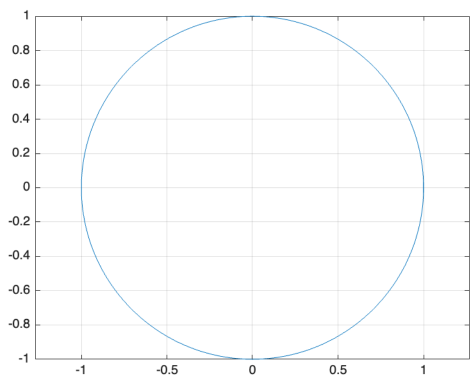

Figure 4. For the ratio 1:1 with phase difference $\frac{\pi}{2}$

4. $x(t) = \sin(\omega t),\ y = \sin(2\omega t)$

$$y(t) = \sin(2\omega t) = 2\sin(\omega t)\cos(\omega t)$$

$$x(t) = \sin(\omega t) \implies y = \pm 2x\sqrt{1 - x^2}$$

$$\boxed{y^2 = 4x^2\left(1 - x^2\right)}$$

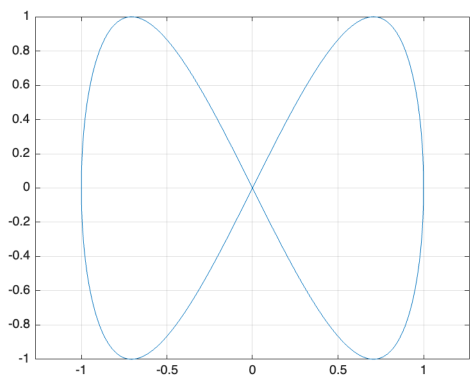

Figure 5. For the ratio 1:2 with no phase difference

5. $x(t) = \sin\left(\omega t + \frac{\pi}{4}\right),\ y = \sin(2\omega t)$

$$y(t) = \sin(2\omega t) = 2\sin(\omega t)\cos(\omega t)$$

$$x(t) = \sin\left(\omega t + \frac{\pi}{4}\right) \implies x^2 = \frac{1}{2}\left(1 + 2\sin(\omega t)\cos(\omega t)\right)$$

$$\boxed{x^2 = \frac{1}{2}(1 + y)}$$

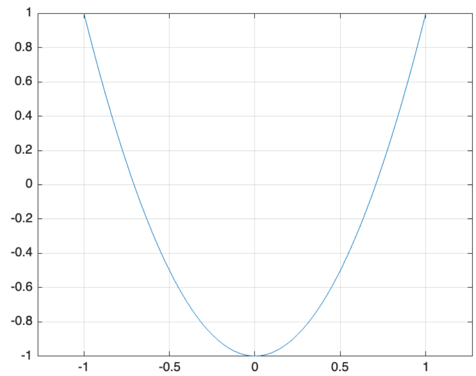

Figure 6. For the ratio 1:2 with phase difference $\frac{\pi}{4}$

6. $x(t) = \sin(\omega t),\ y = \sin(3\omega t)$

$$y(t) = \sin(3\omega t) = 3\sin(\omega t) - 4\sin^3(\omega t)$$

$$x(t) = \sin(\omega t) \implies y = 3x - 4x^3$$

$$\boxed{y = 3x - 4x^3}$$

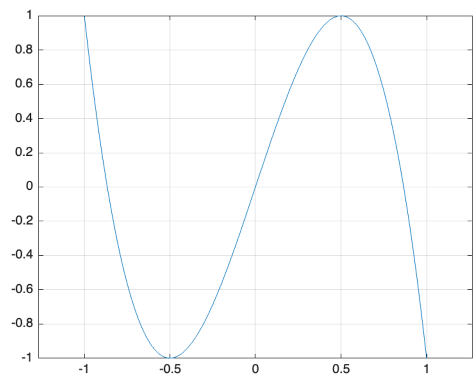

Figure 7. For the ratio 1:3 with no phase difference

7. $x(t) = \sin\left(\omega t + \frac{\pi}{4}\right),\ y = \sin(3\omega t)$

$$y(t) = \sin(3\omega t) = 3\sin(\omega t) - 4\sin^3(\omega t)$$

$$x(t) = \sin\left(\omega t + \frac{\pi}{4}\right) = \frac{1}{\sqrt{2}}\sin(\omega t) + \frac{1}{\sqrt{2}}\cos(\omega t)$$

$$2x^2 - 1 = \sin(2\omega t) \implies \cos(2\omega t) = \pm 2\sqrt{x^2 - x^4}$$

$$\sin(\omega t) = \pm\sqrt{\frac{1 \pm 2\sqrt{x^2 - x^4}}{2}}$$

$$y = \pm\sqrt{\frac{1 \pm 2\sqrt{x^2 - x^4}}{2}}\left(3 - 4\left(\frac{1 \pm 2\sqrt{x^2 - x^4}}{2}\right)^2\right)$$

$$\boxed{y = \pm\sqrt{\frac{1 \pm 2\sqrt{x^2 - x^4}}{2}}\left(3 - \left(1 \pm 2\sqrt{x^2 - x^4}\right)^2\right)}$$

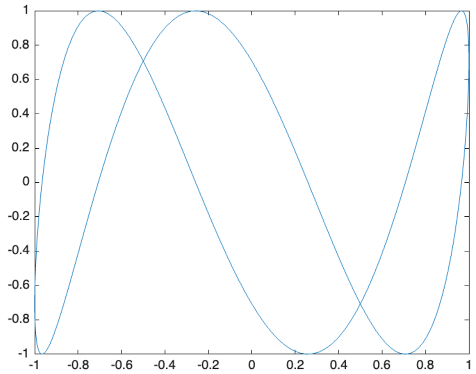

Figure 8. For the ratio 1:3 with phase difference $\frac{\pi}{4}$

8. $x(t) = \sin\left(\omega t + \frac{\pi}{2}\right), y = \sin(3\omega t)$

$$y(t) = \sin(3\omega t) = 3\sin(\omega t) - 4\sin^3(\omega t)$$

$$x(t) = \sin\left(\omega t + \frac{\pi}{2}\right) \implies y = 3\sqrt{1-x^2} - 4\left(1-x^2\right)^{\frac{3}{2}}$$

$$y^2 = \left(3 - 4\left(1-x^2\right)\right)^2\left(1-x^2\right)$$

$$\boxed{y^2 = \left(1-x^2\right)\left(4x^2-1\right)^2}$$

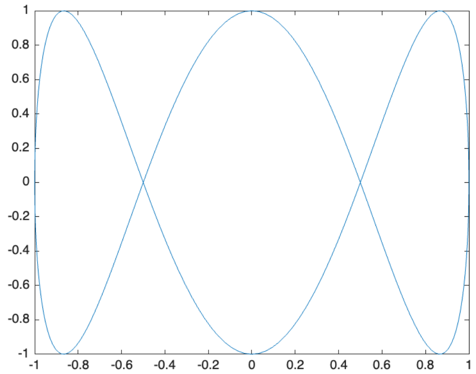

Figure 9. For the ratio 1:3 with phase difference $\frac{\pi}{2}$

9. $x(t) = \sin(2\omega t), y = \sin(3\omega t)$

$$y(t) = \sin(3\omega t) = 3\sin(\omega t) - 4\sin^3(\omega t)$$

$$x(t) = \sin(2\omega t) \implies \cos(2\omega t) = \pm\sqrt{1-x^2}$$

$$1 - 2\sin^2(\omega t) = \pm\sqrt{1-x^2}$$

$$\sin(\omega t) = \pm\sqrt{\frac{1\pm\sqrt{1-x^2}}{2}}$$

$$y = \pm\sqrt{\frac{1\pm\sqrt{1-x^2}}{2}}\left(3 - 4\left(\frac{1\pm\sqrt{1-x^2}}{2}\right)^2\right)$$

$$\boxed{y = \pm\sqrt{\frac{1\pm\sqrt{1-x^2}}{2}}\left(1\pm 2\sqrt{1-x^2}\right)}$$

Triangle waves can also generate such figures

3.2. Triggering an Oscilloscope

An oscilloscope can be set to trigger mode, to anticipate and stop when the input changes in a certain manner. There are multiple modes for this

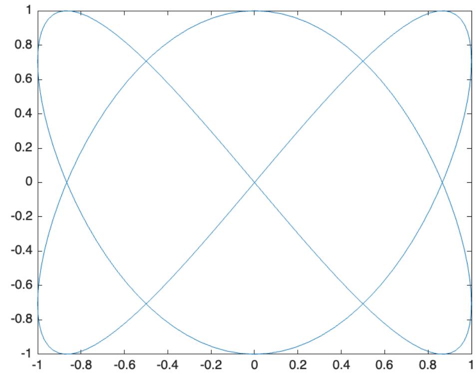

Figure 10. For the ratio 2:3 with no phase difference

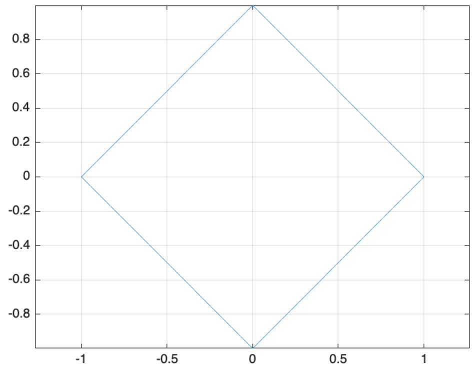

Figure 11. Making a Rectangle with 2 triangle waves offset by $\frac{\pi}{2}$

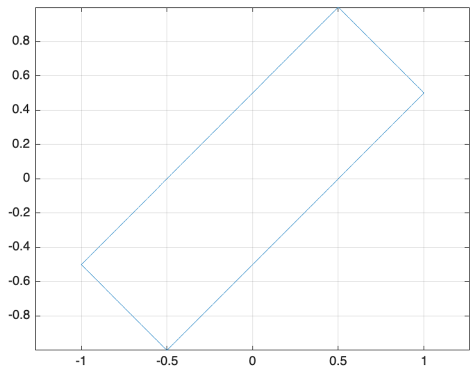

Figure 12. Making a Rectangle with 2 triangle waves offset by $\frac{\pi}{4}$

- **Auto Mode** : The oscilloscope sweeps the X plate irrespective of the input signal. This mode is useful for observing signals when no specific trigger event is present, but you still want to see some waveform activity on the screen.
- **Normal Mode** : In this mode, the oscilloscope looks for a specific trigger event, and only sweeps if the trigger condition is met. Useful for looking at specific events / abnormalities.
- **Single Mode** : In this, the oscilloscope will trigger and display the waveform once when the trigger condition is met, then freeze the display until manually reset. This mode is ideal for capturing one-time events, glitches, or transient signals

There are different types of events that the oscilloscope can look for. For example

- Edges (Rising and Falling)
- Pulses
- Video

4. The Observations

4.1. Lissajous Figures

Corresponding to the calculations given above, the test in the lab gave the following results. The images displayed on the oscilloscope are shown below. (Measured by connecting the output of a funcition generator to the probes of an oscilloscope and in $X - Y$ mode)

> Changing the frequencies generated by a function generator causes a phase difference between the 2 channel outputs. To circumvent this problem, the function generator has to be restarted everytime a frequency change is required

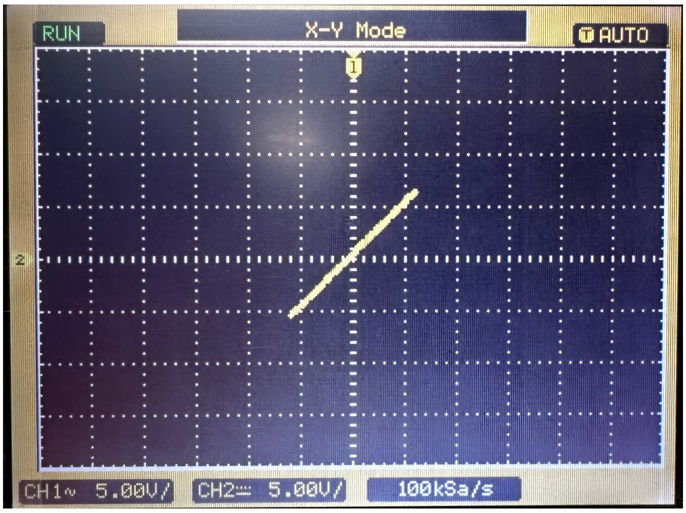

Figure 13. For the ratio 1:1 with no phase difference

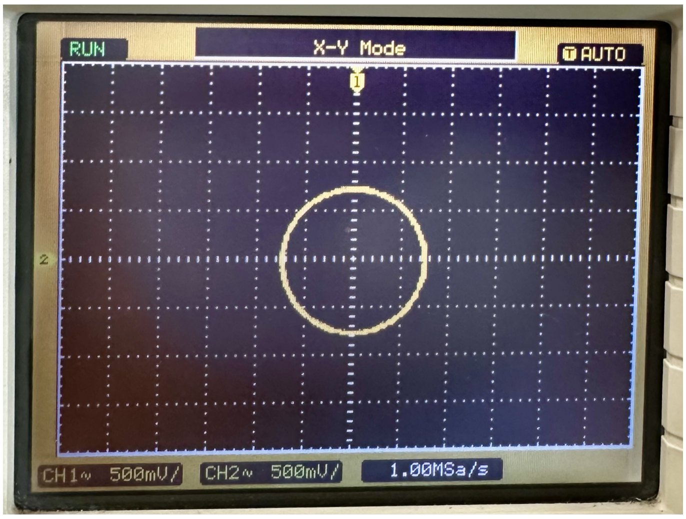

Figure 14. For the ratio 1:1 with phase difference $\frac{\pi}{2}$

Triangle waves in place of sine waves can also be used.

4.2. Oscilloscope Trigger

The event that was chosen for the test is the small spike when a function generator is switched on. The oscilloscope was set to **Normal Mode**, with **Single Trigger** and the function generator was switched on. The display was as follows.

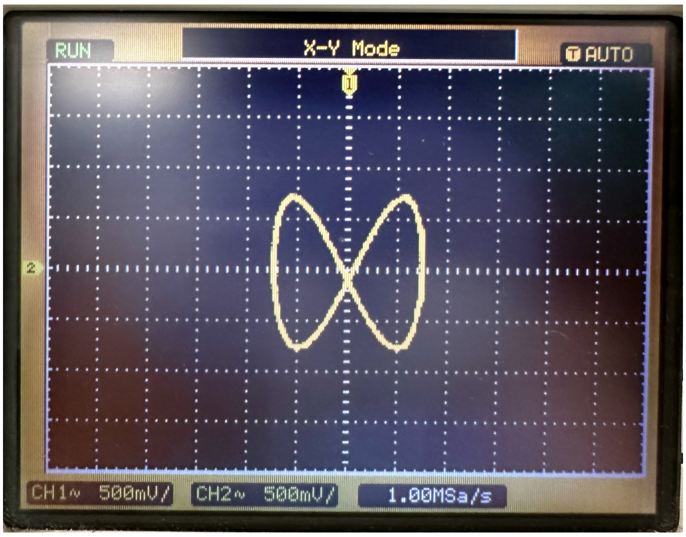

Figure 15. For the ratio 1:2 with no phase difference

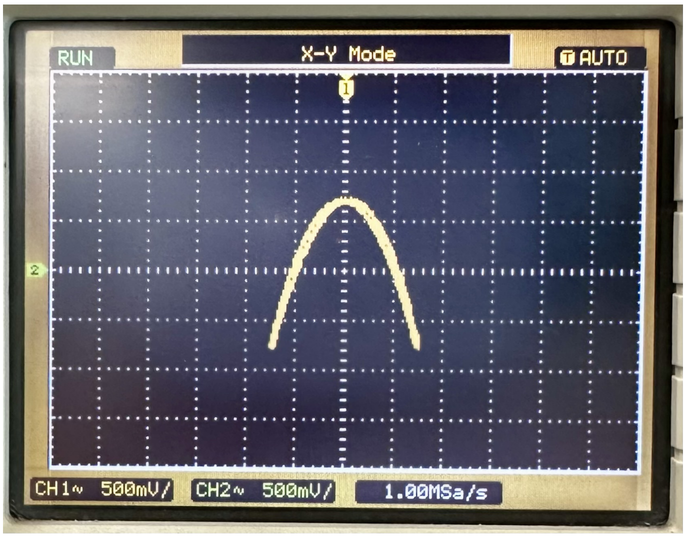

Figure 16. For the ratio 1:2 with phase difference $\frac{3\pi}{4}$

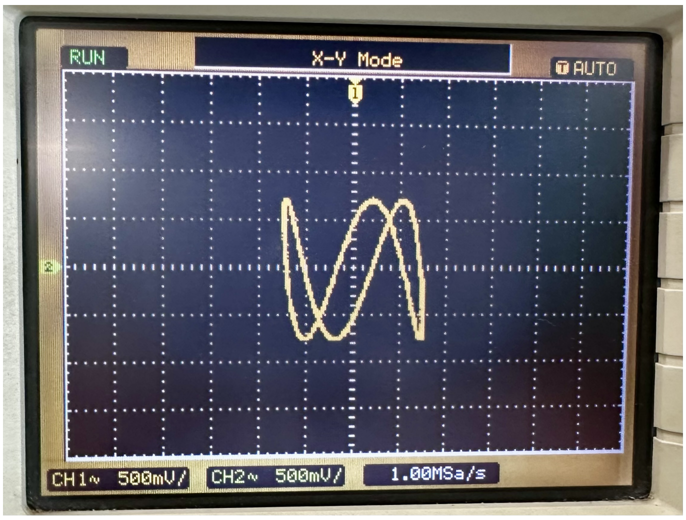

Figure 17. For the ratio 1:3 with phase difference $\frac{\pi}{4}$

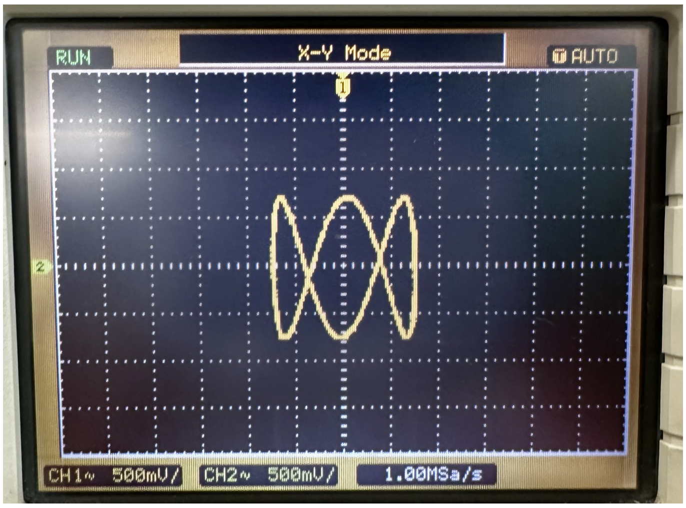

Figure 18. For the ratio 1:3 with phase difference $\frac{\pi}{2}$

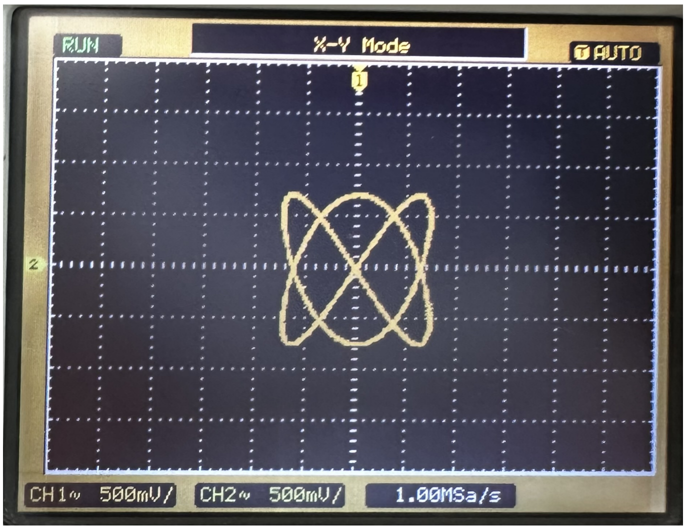

Figure 19. For the ratio 2:3 with no phase difference

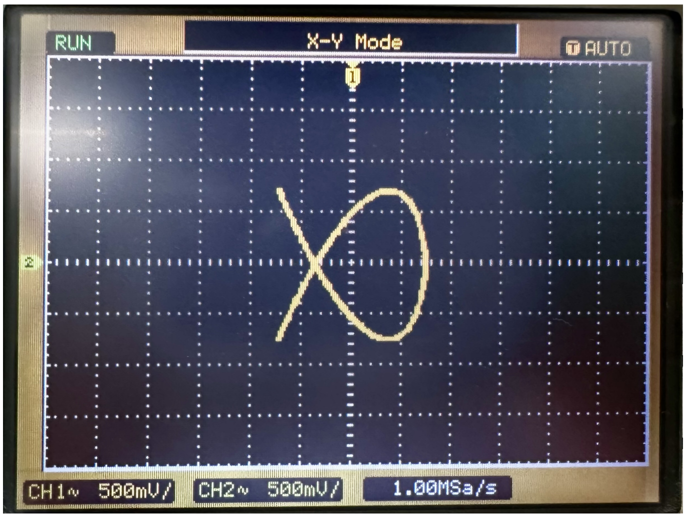

Figure 20. For the ratio 2:3 with phase difference $\frac{\pi}{4}$

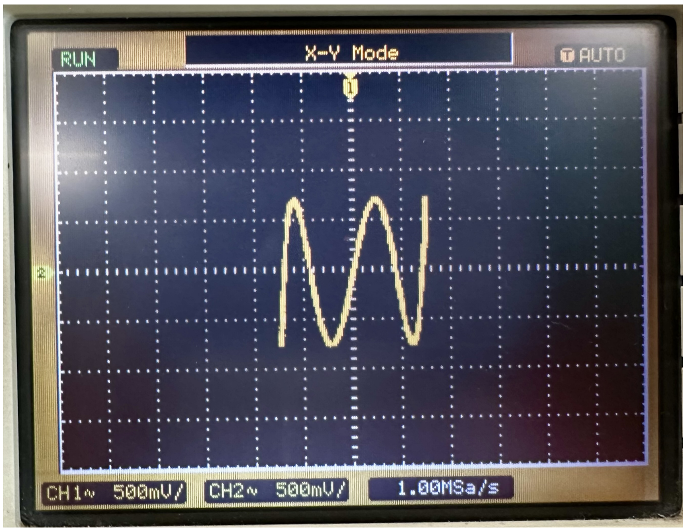

Figure 21. For the ratio 1:5 with no phase difference

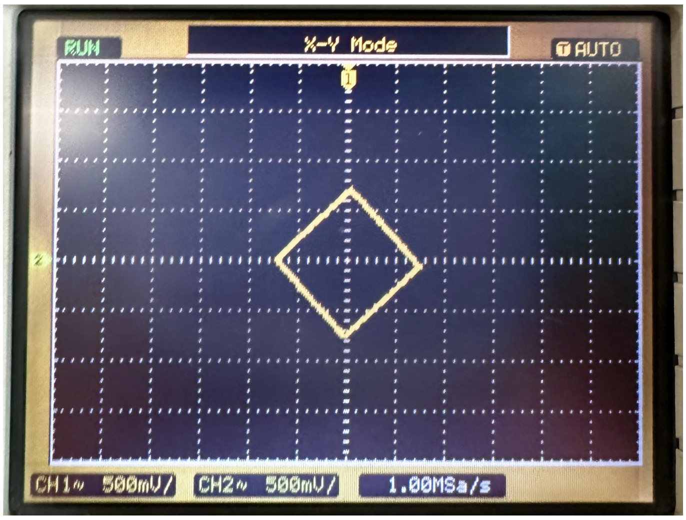

Figure 22. Making a square with 2 triangle waves offset by $\frac{\pi}{2}$

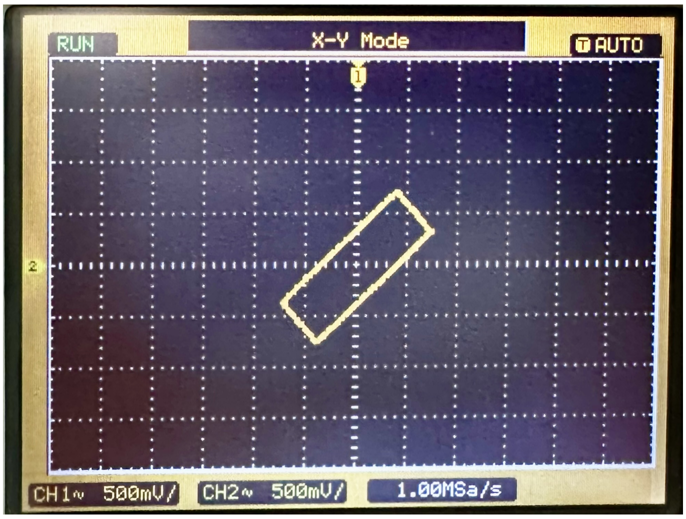

Figure 23. Making a Rectangle with 2 triangle waves offset by $\frac{\pi}{4}$

5. Conclusion

In this experiment, Lissajous figures were successfully produced on an oscilloscope by inputting two sinusoidal signals with varying frequencies and phase differences into the X and Y channels. By carefully adjusting the frequency and phase, we were able to create a wide range of patterns. The results aligned well with theoretical expectations, validating the use of an oscilloscope for this type of waveform analysis.

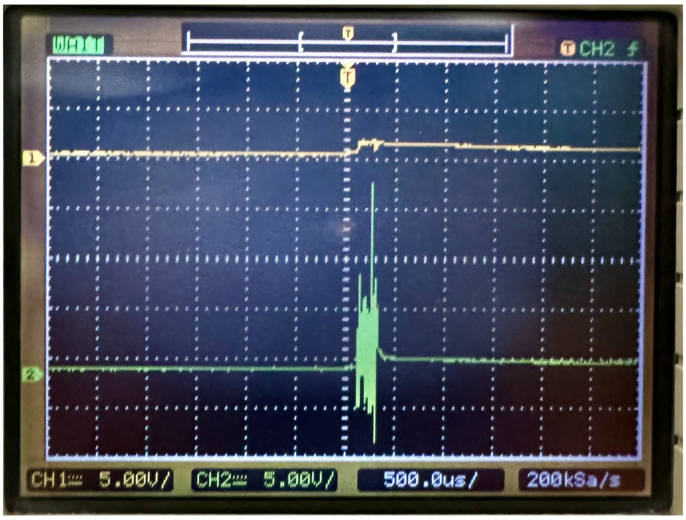

Figure 24. Trigger when a DC source was switched on

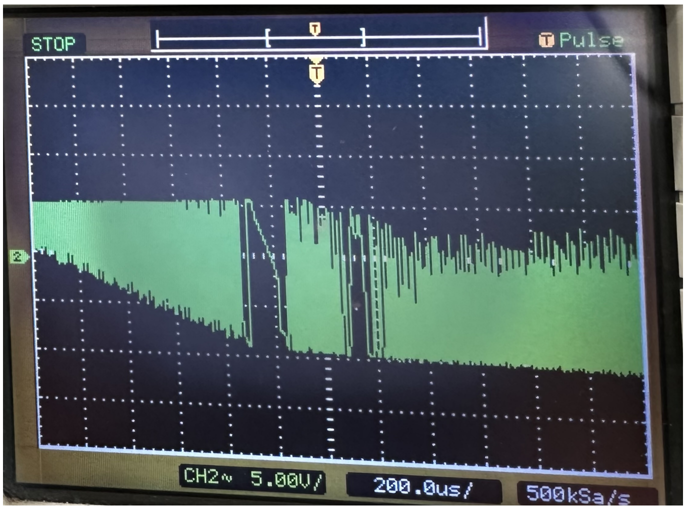

Figure 25. Trigger when a Function Generator was switched on