2141274 Electrical and Electronic Laboratory
Faculty of Engineering
Chulalongkorn University

Cathode-Ray Oscilloscope (CRO)

Objectives

You will be able to use an oscilloscope to measure voltage, frequency and phase on a variety of displayed waveforms

Introduction

The oscilloscope is the basic instrument for the study of all types of waveforms. It is capable of generating a graph of an input signal versus time (Voltage-time mode), or a second variable (X-Y mode). It can be employed to measure such quantities as peak voltage, frequency or period, phase difference, pulse width, delay time, rise time and fall time. Essentially, an oscilloscope consists of a cathode-ray tube (CRT), and its associated control and input circuitry (a time-base generator, vertical and horizontal amplifiers) as shown in Fig.1. In a conventional CRT tube, there are an electron gun, deflection plates and the phosphorescent screen.

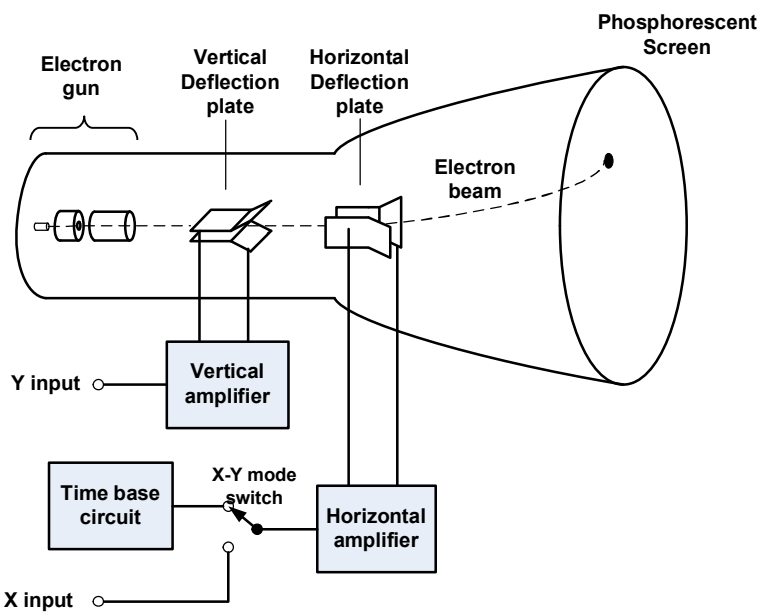


Fig. 1 Simple oscilloscope construction.

Principle of operation

The electron beam generated from an electron gun will be accelerated toward a phosphorous screen by a potential difference between the electron gun and the screen. As

the beam emerges from the gun, it passes through a set of parallel plates (the **vertical deflection plates**) oriented horizontally. The voltage to be displayed is amplified by a **vertical amplifier**, and applied across these plates producing an electric field which deflects the path of the electron vertically. The polarity of the signal of interest determines whether the deflections will be up or down and the magnitude of the signal determines the amount of vertical displacement of the electrons. Fig. 2 shows the deflection of an electron in a uniform electric field.

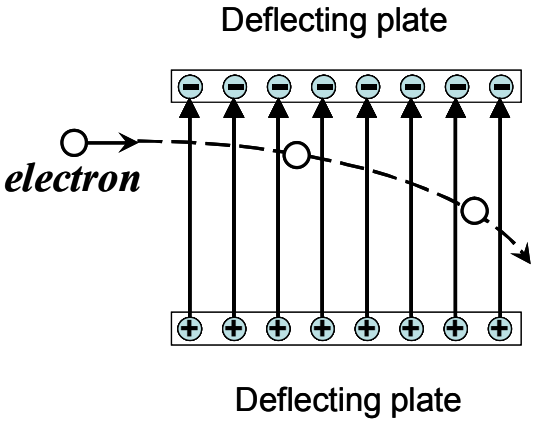


Fig. 2 Deflection of an electron in a uniform electric field.

After the beam has passed through the **vertical deflection Plates**, it passed through a second set of similar plates that are oriented vertically. A potential difference applied to these plates produce an electric field which deflects left or right. Under normal configuration (one common exception is XY mode to be discussed later), these **horizontal deflection plates** are connected to **a time-base circuitry**. This circuit can control how fast the electron beam sweeps from the left to right (**use Sweep Knob**). Adjusting the sweep speed, the resulting trace on the screen can be spread out or compressed.

If the two deflection voltages were held constant, the electron beam would strike a fixed point on the phosphorescent film and a stationary point would be visible on the screen. However, most voltages of interested are time-varying and so the voltage applied to the Horizontal deflection plates is varied with time in such a way that the spot moves from left to right on the screen as time passes. Since the phosphorescent material has the property of emitting light for several milliseconds after the electrons have passed, the total effect is for the electrons to leave behind a visible trail –a time-varying signal.

The horizontal deflection voltage (of "sweep voltage") is also varied in such a way that when the beam reaches the right-hand edge of the screen, it starts over at the left-right side. If the signal to be displayed varies periodically in time, it is possible to synchronize the sweep voltage with the signal so that the curve appears motionless on the screen. This is done with the **Trigger Level** control which sets the oscilloscope to begin a trace when the voltage it measures reaches a certain value. If a trace that is running across the screen can usually be stabilized by adjusting the trigger level (as long as the waveform is periodic!).

Waveform Display

When an alternating voltage is applied to the vertical deflecting plates and no input is applied to the horizontal plates, the spot on the tube face moves up and down continuously. If a constantly increasing voltage is also applied to the horizontal deflecting plates, then as well

as moving vertically, the spot on the tube face moves horizontally. Consider fig. 3, in which sine wave is applied to the vertical deflecting plates and a **sawtooth** (or repetitive ramp) is applied to the horizontal plates. If the wave forms are perfectly synchronized (the trigger level has been set properly)., then at time $t = 0$, the vertical deflection voltage is zero and the horizontal deflecting voltage is -2 V. Therefore, assuming a deflecting sensitivity of 2 cm/V, the vertical deflection is zero and the horizontal deflection is 4 cm left from the center of the screen [point 1]. When $t = 0.5$ ms, the horizontal deflecting voltage has become -1.5 V; therefore, the horizontal deflection is 3 cm left from the screen center. The vertical deflecting voltage has now become +1.4 V, and this causes a vertical deflection +2.8 cm above the center of the screen. The spot is now 2.8 cm up and 3 cm left from the screen center, point 2 on Fig. 3.

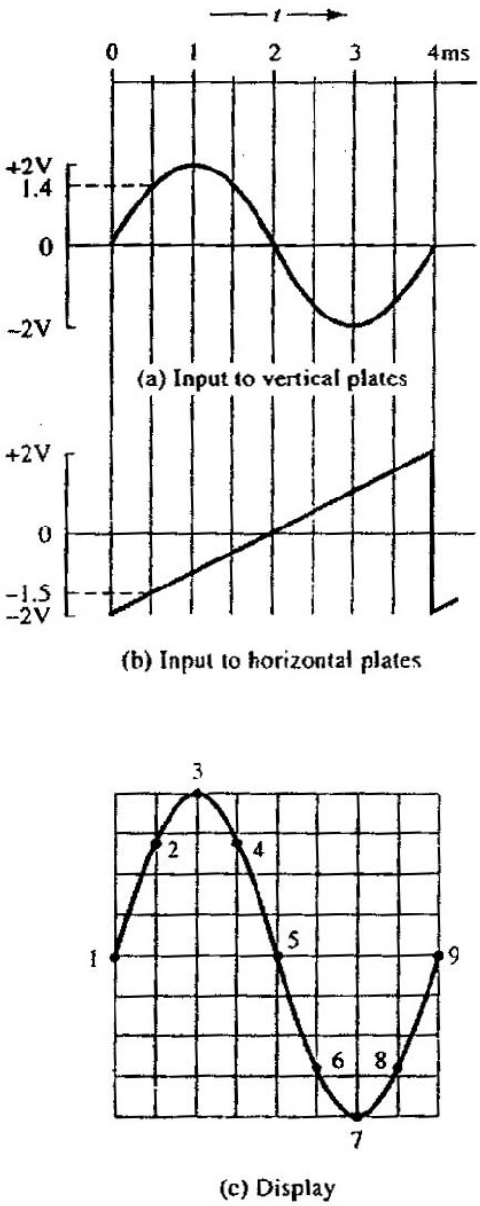


Fig. 3 The synchronization of a sine wave with a sawtooth wave resulting in a graphical display on the screen.

The following table gives deflection voltages and deflection at various is instants for the waveform in Fig. 3.

***t* (ms)**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**
Vertical voltage (V)	**+2**	**+1.4**	**0**	**-1.4**	**-2**	**-1.4**	**0**
Vertical deflection (cm)	**+4**	**+2.8**	**0**	**-2.8**	**-4**	**-2.8**	**0**
Horizontal voltage (V)	**-1**	**-0.5**	**0**	**+0.5**	**+1**	**+1.5**	**+2**
Horizontal deflection (cm)	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**+4**
Point	**3**	**4**	**5**	**6**	**7**	**8**	**9**

At point 9 the horizontal deflecting voltage rapidly goes to -2V again, so the beam returns to the left side of the screen. From here it is ready to repeat the waveform trace. It is seen that with a sawtooth applied to the horizontal deflecting plates, any waveform applied to the vertical plates will be displayed on the screen of the CRT.

X-Y Mode

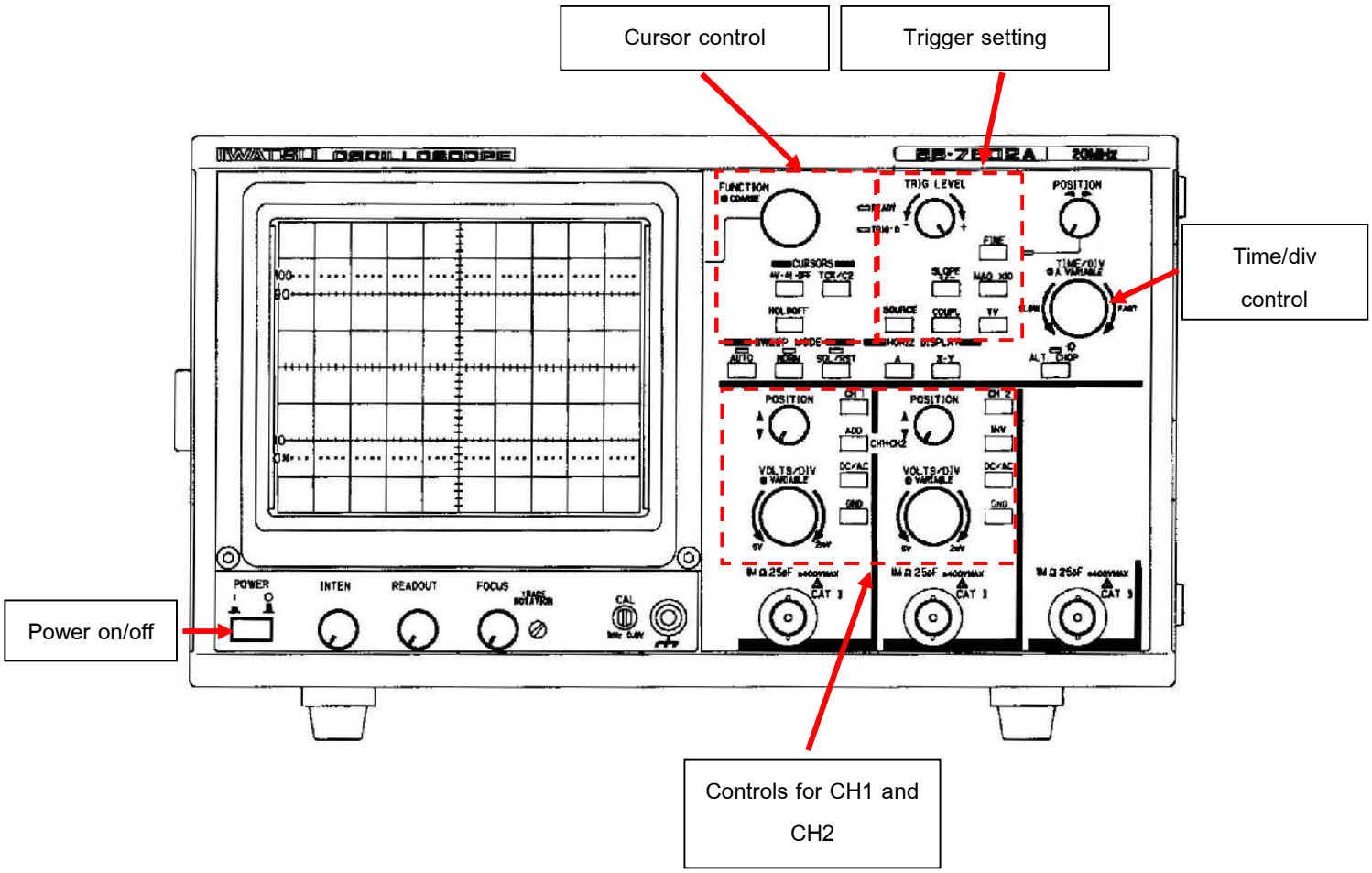
Beside of showing a time-varying signal, the oscilloscope also lets you display an input signal rather than the time base on the horizontal axis. This setup is called XY mode because both the X and Y axis are tracing input voltage. As a note of interest, the waveform resulting from XY arrangement of two periodic signals of different periods in called Lissajous pattern, from the shape of Lissajous pattern, we can determine the information about the relative phases of the signals, as well as frequency ratio.

Common Oscilloscope Controls.

Most oscilloscope comes with two input channels (Channel 1 and 2 or Channel A and B), therefore, two waveforms can display simultaneously on the screen. In this section, we will introduce the most common controls in an oscilloscope.

VOLTS/DIV selector switch: (separate controls available for Channel 1 and 2)	Set the sensitivity of the display to input voltages, adjusting this control makes the displayed waveform to compress and expand in the vertical axis.
VERTICAL POSITION control: (separate controls available for Channel 1 and 2)	Use to move each waveform vertically up or down the screen to set it in the best position for viewing
INPUT SELECTOR switch: (AC, DC, GND) (separate controls available for Channel 1 and 2)	Set at DC where all ac and dc components will be both displayed on the screen. Set at AC where a coupling capacitor passes the ac quantity and blocks the dc component. Set at GND to disconnect the input signal and grounds the input terminal.
HORIZONTAL TIME/DIV selector switch: (apply to both Channel 1 and 2)	Adjust the rate at which a waveform is draw across the screen
HORIZONTAL POSITION control: (apply to both Channel 1 and 2)	Use to move all waveforms horizontal left or right to set them in the best position for viewing
TRIGGER LEVEL control:	Adjust the triggering point of the input wave
TRIGGER SOURCE selector switch:	Use to select the source of the triggering, normally select INT (internal trigger source), which means the time base is triggered from one of the input waveforms.
X-Y MODE selector switch	Use to change between V-T and X-Y mode

Positions of Common Controls in CRO Used in the experiments



Basic Measurement Procedures

1) Ground the input terminal or oscilloscope probe, set the position of each waveform to obtain the best viewing.
2) Connect the oscilloscope probe to the measuring point. Special care must be taken for the ground of the probe and the reference point of the circuit- under-test)
3) if the waveform is running across the screen, adjust TRIGGER SOURCE selector switch and/or TRIGGER LEVEL controls to stabilize the waveform.
4) Adjust VOLTS/DIV selector switch and/or HORIZONTAL TIME/DIV selector to obtain the proper view.

Note: the sequence of the above guidelines can be changed or modify properly to obtain the best results. Consult the scope manual for more details or fine adjustments.

Experimental Instructions:

<u>Exp1</u> Waveform Monitoring & Measurement of Amplitude, Frequency and Period of an Alternative Signal

1) Set the INPUT SELECTOR of CH1 to the AC position.
2) Connect the function generator to the input terminal of CH1, set the function generator to give a sinusoidal wave.
3) Adjust the Oscilloscope control until the screen shows the best viewing of the sine wave with two or three periods.

<u>Exp2</u> Measurement of Amplitude, Frequency and Period of a Signal with both DC and AC Components

1) Set the INPUT SELECTOR of CH1 to the DC position.
2) Connect the function generator to the input terminal of CH1, set the function generator to give a sinusoidal wave and also set the DC offset to an appropriate value (the dc value should not be so different with the amplitude of the sine wave)
3) Adjust the Oscilloscope control until the screen shows the best viewing of the sine wave with two or three periods

<u>Exp 3</u> Measurement of Frequency Ratio (Lissajous Figures)

1) Set CRO to the X-Y Mode (normally X for CH1 and Y for CH2)
2) Applied the output from the step-down transformer to the X-input of CRO and the output from the function generator to the Y-input of CRO. The output from the transformer is about 6 V_{rms} with the frequency of 50 Hz. Make sure that the function generator has been set give a sinusoidal wave and DC offset has been set to zero.
3) Set the frequency of the function to 50 Hz (read from the function generator)
4) Adjust the CRO control to obtain a clear figure on the screen. If the setting is proper, you will see an elliptic or circular or line pattern on the screen. (If no, repeat the previous process again)
5) Change the frequency of the function generator to 25, 50, 75 and 100 Hz. Record the graph on the screen for each case.
6) Verify that the frequency ratios obtained from the experiments are consistent with the theoretical values

<u>Exp 4</u> Measurement of Phase Difference (Lissajous Figures VS Voltage-Time)

1) Connect the function generator to the phase shift circuit as shown in Fig. 4. Set frequency to 1000 Hz, amplitude to 2-4 V_{peak} and the output waveform to sinusoidal wave.
2) Use CRO to record the amplitude of the input voltage, the voltage drop across R and C respectively. (These values will be used to verify the experimental results)

3) Use the following table to connect the CRO probes to the circuit.
4) Record the displayed waveforms on the screen in both **V-T and X-Y mode**. In V-T mode, set the CRO to display CH 1 and 2 simultaneously.

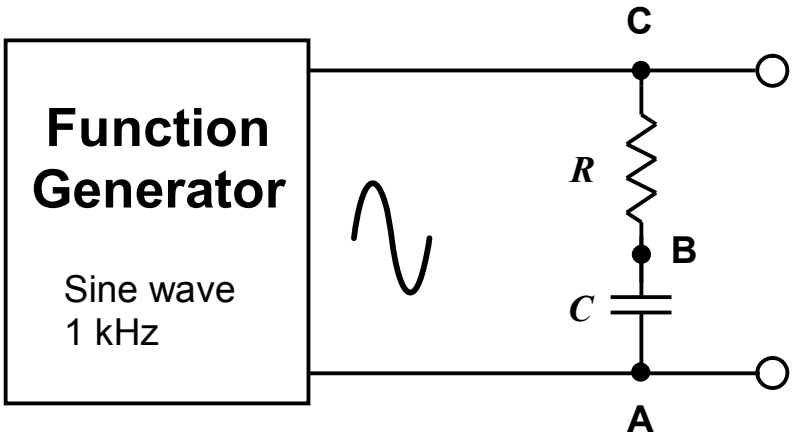
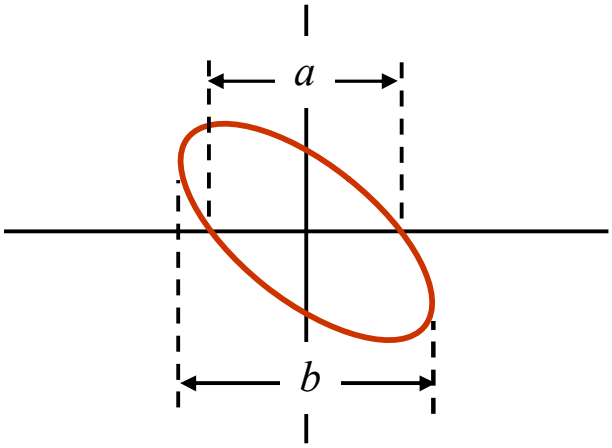


Fig.4 Circuit used in the experiment

Table 1: Probe connections

Case	CH 1	CH 2	CRO Ground
I	A	A	C
II	A	B	C
III	A	C	B
IV	Same as case III, Use the Invert switch for the CH 2		

The Lissajous figures can be used to calculate the phase difference of two sinusoidal with the same frequency as shown in Fig. 5.



Phase difference = arcsin (*a*/*b*)

Fig. 5 Calculation of phase difference using Lissajous figure

Student Name: _____ID: _____
Date: _____Group: _____Instructor signature:_____

Experimental Report

Cathode-Ray Oscilloscope (CRO)

<u>Exp1</u> Waveform Monitoring & Measurement of Amplitude, Frequency and Period of an Alternative Signal

CH1: VOLT/DIV switch = V/div

TIME/DIV switch = /div

The peak-to-peak amplitude = $V_{peak\text{-}peak}$

The peak amplitude = V_{peak}

The root-mean-square amplitude = V_{rms} (Calculated value)

The root-mean-square amplitude = V_{rms} (Read from a multi-meter)

Period of the Displayed signal = Sec

Frequency of the Displayed signal = Hz (Calculated value)

Frequency read from function generator = Hz

Frequency read from multi-meter = Hz

<u>Discussion</u>

<u>Exp2</u> Measurement of Amplitude, Frequency and Period of a Signal with both DC and AC Components

INPUT SELECTOR at DC position

CH1: VOLT/DIV switch = V/div

TIME/DIV switch = /div

INPUT SELECTOR at AC position

CH1: VOLT/DIV switch = V/div

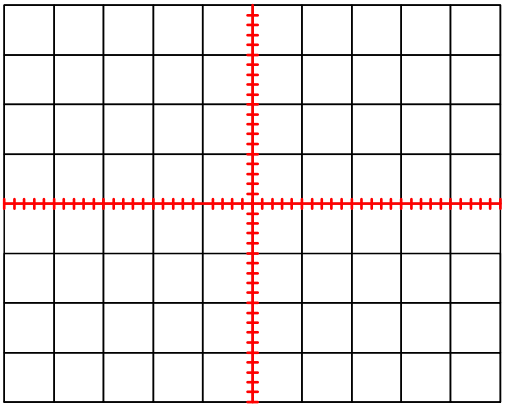
TIME/DIV switch = /div

The peak amplitude of the AC component	=	V_{peak}
The rms value of the AC component	=	V_{rms} (Calculated value)
The rms value read from a multi-meter	=	V_{rms}
The value of the DC component	=	V
The DC value read from a multi-meter	=	V

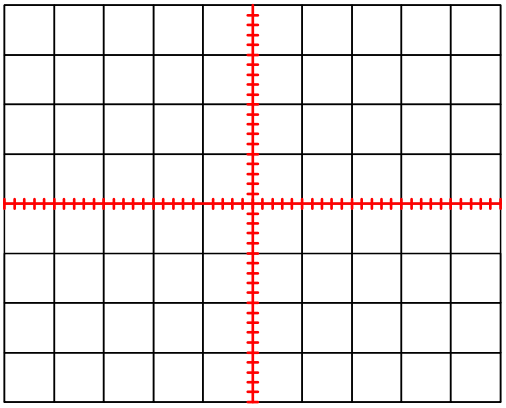
<u>Discussion</u>

<u>Exp 3</u> Measurement of Frequency Ratio (Lissajous Figures)

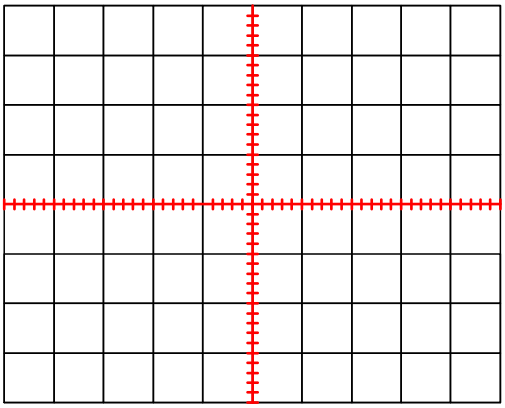
Case I: frequency of the function generator = 25 Hz



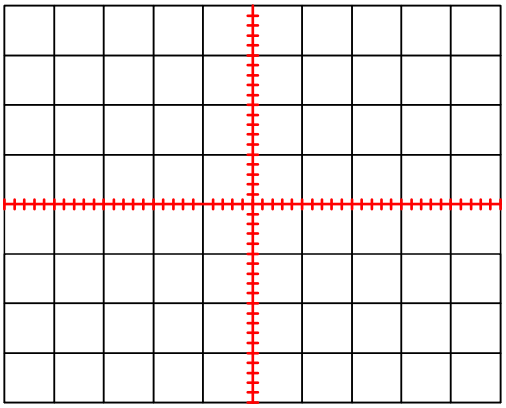
Case III: frequency of the function generator = 75 Hz



Case II: frequency of the function generator = 50 Hz



Case IV: frequency of the function generator = 100 Hz



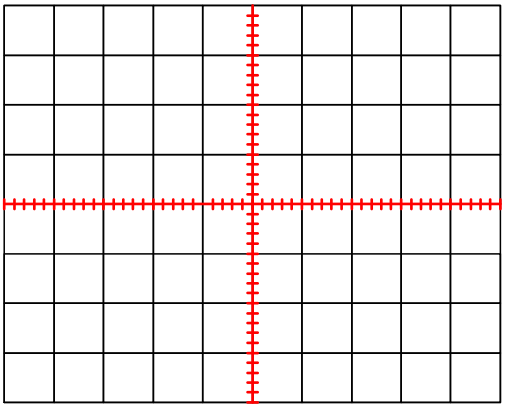
CH1: VOLT/DIV switch = V/div

CH2: VOLT/DIV switch = V/div

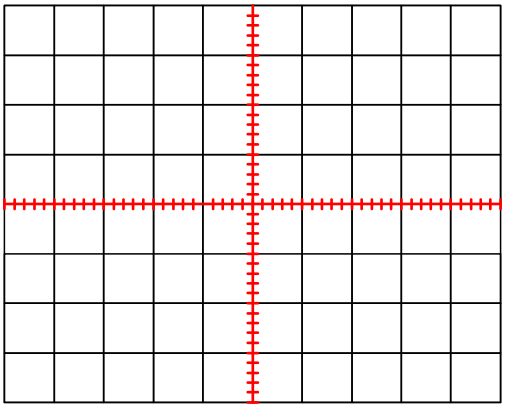
<u>Discussion</u>

<u>Exp 4</u> Measurement of Phase Difference (Lissajous Figures VS Voltage-Time)

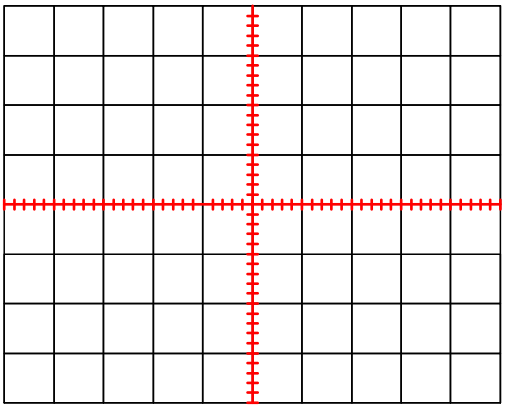
Case I: X-Y Mode



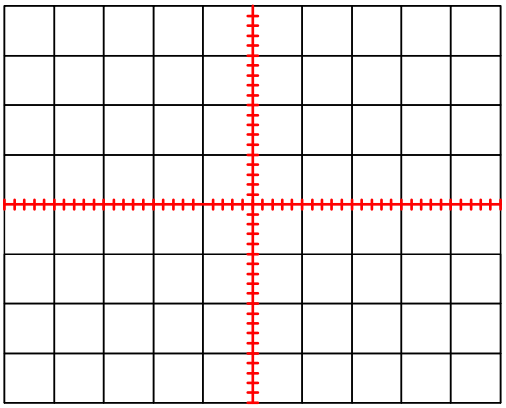
Case I: V-T Mode



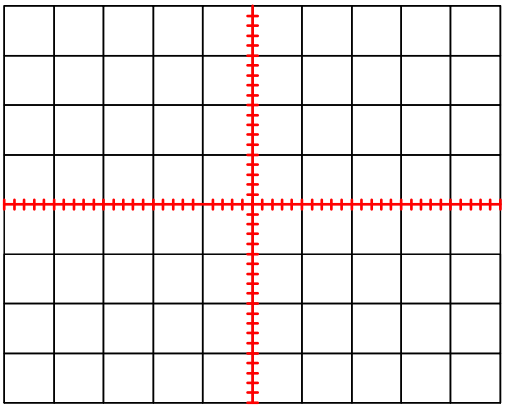
Case II: X-Y Mode



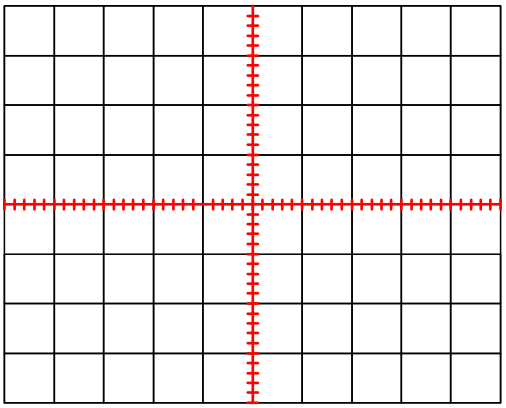
Case II: V-T Mode



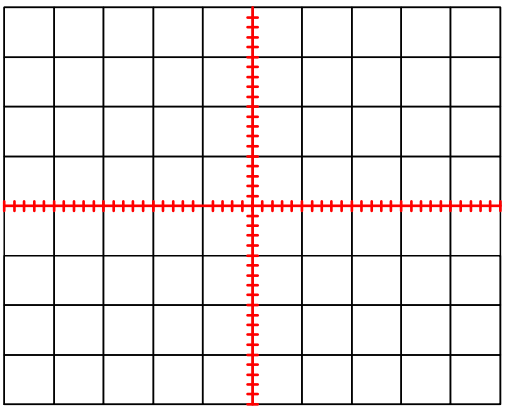
Case III: X-Y Mode



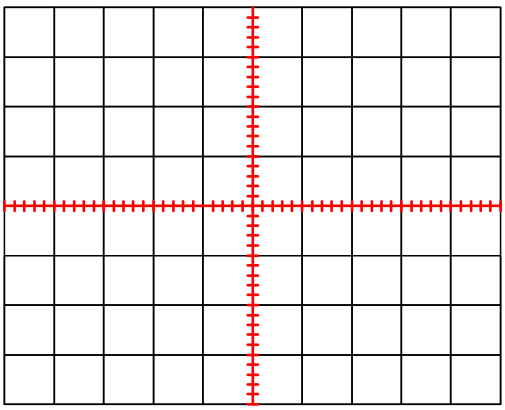
Case III: V-T Mode



Case IV: X-Y Mode



Case IV: V-T Mode



X-Y Mode

CH1: VOLT/DIV switch = V/div

CH2: VOLT/DIV switch = V/div

V-T Mode

CH1: VOLT/DIV switch = V/div

CH2: VOLT/DIV switch = V/div

TIME/DIV switch = /div

Discussion

Conclusions