



Experiment No.11

Frequency and Phase Angle Measurement Using Cathode Ray Tube

Object

To perform amplitude, frequency, and phase measurements using a calibrated cathode ray oscilloscope and to make use of Lissajous figures for phase and frequency measurements.

Theory

- **Measurement of Voltage Using CRO**

A voltage can be measured by noting the Y deflection produced by the voltage; using this deflection in conjunction with the Y-gain setting, the voltage can be calculated as follows:

$$V = (\text{no. of boxes in cm.}) \times (\text{selected Volts/cm scale})$$

- **Measurement of Current and Resistance Using a CRO:**

Using the general method, a correctly calibrated CRO can be used in conjunction with a known value of resistance R to determine the current I flowing through the resistor.

- **Measurement of Frequency Using a CRO:**

A simple method of determining the frequency of a signal is to estimate its periodic time from the trace on the screen of a CRT. However, this method has limited accuracy, and should only be used where other methods are not available. To calculate the frequency of the observed signal, one has to measure the period, i.e. the time taken for 1 complete cycle, using the calibrated sweep scale. The period could be calculated by

$$T = (\text{no. of squares in cm}) \times (\text{selected Time/cm scale})$$

Once the period T is known, the frequency is given by

$$f \text{ (Hz)} = 1/T(\text{sec})$$

- **Measurement of Phase:**

The calibrated time scales can be used to calculate the phase shift between two sinusoidal signals of the same frequency. If a dual trace or beam CRO is available to display the two signals simultaneously (one of the signals is used for synchronization), both of the signals will appear in proper time perspective and the amount of time difference between the waveforms can be measured.

This, in turn can be utilized to calculate the phase angle θ , between the two signals.

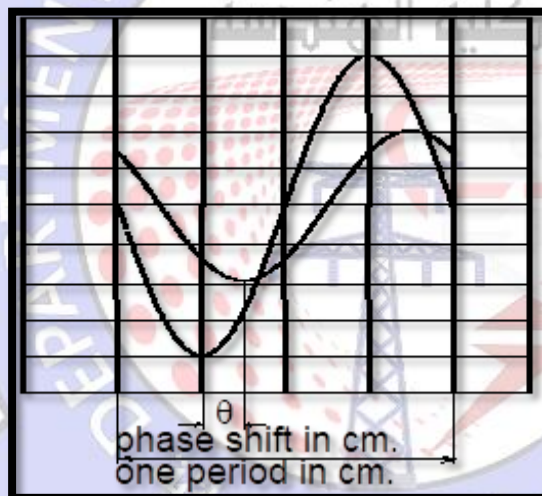


Figure.1 Phase shift between two signals

Referring to figure.1, the phase shift can be calculated by the formula;

$$\theta = \frac{\text{Phase shift in cm.}}{\text{One period in cm.}} \times 360^\circ$$

Note that the calculation does not involve the actual calibrated Timebase setting. In fact, the observed waveforms can be varied using the horizontal amplifier venire adjustment to obtain as many boxes for one full scale as desired. Another



method for fast calculation is to multiply the scale factor by the phase difference (in cm) where the scale factor is degrees per box or degrees per cm.

• **Use of Lissajous Patterns to Calculate Phase Shift:**

Lissajous patterns are obtained on the scope simultaneously by applying the two sinusoidal inputs to be compared at the vertical and horizontal channels. The phase shift is then determined using measured values taken from resulting Lissajous pattern. This pattern on the CRT screen may be either a straight line or a circle or an ellipse depending on the amount of phase shift.

Figure.2 shows the resulting closed curve if the phase shift is between 0° and 180° . This pattern is an ellipse (inclined at θ if the two amplitudes are the same). The angle of inclination at which the ellipse is generated is of no importance in the phase angle calculation. Noting that the vertical signal amplitude at instant 1 is

$N = A \sin(\theta)$, θ can be computed by

$$\theta = 180^\circ - \sin^{-1}(N / M)$$

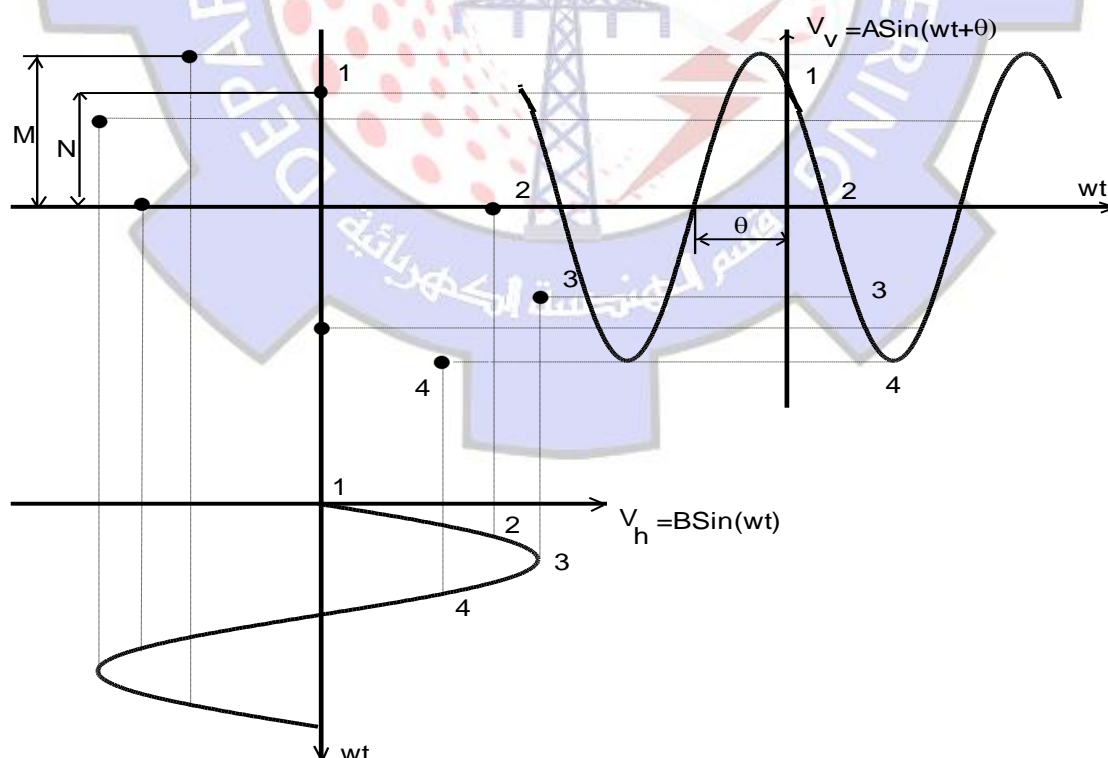




Figure.2 Lissajous Pattern

Phase angles between $0^\circ - 90^\circ$, the ellipse has a positive slope and angle calculated by the following formula:

$$\theta = \sin^{-1}(N / M)$$

The actual scale settings do not change the ratio (N/M). Hence try to get an ellipse of maximum possible size on the CRO for increased accuracy. For phase angles of $90^\circ - 180^\circ$, the ellipse has a negative slope and the angle calculated by the above method must be subtracted from 180° to obtain the phase shift. Phase angles between $180^\circ - 270^\circ$ result in Lissajous patterns similar to those for $\theta : 90^\circ - 180^\circ$, and cannot be directly distinguished. One technique for determining, if the phase shift is less or more than 180° , is to add an extra slight phase shift to the signal Vv. If the phase angle measured increases, then the angle is less than 180° . If it decreases, the angle is greater than 180° . Figure 3 shows how to compute the required phase angle.

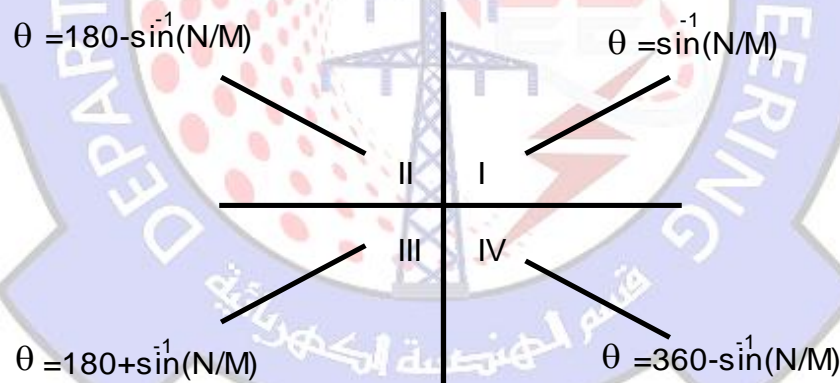


Figure.3 Phase angle calculation in 4 quadrants

• **Use of Lissajous Patterns for Frequency Measurements:**

If a well calibrated CRO Timebase is not available, a signal generator can be used to measure the frequency of an unknown sinusoidal signal. It is connected to the vertical channel (or horizontal) and the calibrated signal source is fed to the horizontal channel (or vertical). The frequency of the signal generator is adjusted so that a steady Lissajous pattern is obtained. The Lissajous pattern can



be very involved to analyze. However, for the frequency measurement, all that is needed is the number of tangencies (points at the edge of arcs) along the vertical and horizontal lines.

The frequency relationship between the horizontal and vertical inputs is given by;

$$\frac{f_h}{f_v} = \frac{\text{No. of tangencies (vertical)}}{\text{No. of tangencies (horizontal)}}$$

from which f_v , the unknown frequency can be calculated.

Procedure

1. The Lissajous pattern shown in figure.4 is observed on the CRT screen. Find the phase shift between the signals applied to the X and Y inputs of the scope.

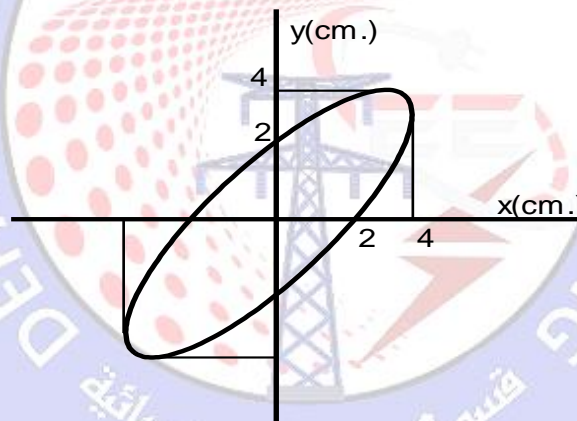


Figure.4

2. Figure 5 shows a Lissajous pattern observed on the CRT screen. Determine the frequency relationship between the signals applied to the X and Y inputs of the scope.

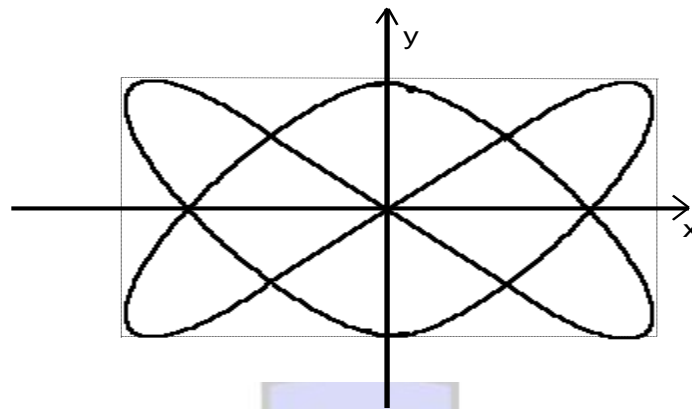


Figure.5

3. Two sinusoidal inputs having the same amplitudes but different period, are applied to the X and Y inputs of the CRO. Draw the Lissajous pattern which will be observed on the CRT, for $T_y = 4T_x$.
4. The signals given V_1 and V_2 are applied to the X and Y inputs of the scope. Sketch the Lissajous pattern and calculate the phase difference between the two signals.
 $V_1 = 10\cos(\omega t)$
 $V_2 = 15\sin(\omega t - 180)$

Discussion

1. Set-up the circuit shown in figure.6, connect the probes to the indicated points. Measure the phase angles between these two signals and draw them.

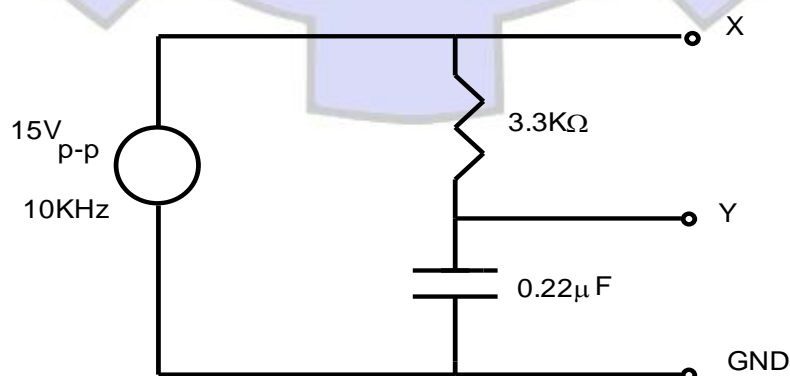


Figure.6



2. Set-up the circuit shown in figure below, connect the probes to the indicated points. Measure the phase angles between these two signals and draw them.

