EXPERIMENT 7

AC Measurements

Introduction to Oscilloscope and Signal Generator

Purpose:

- To examine the alternating current and voltage varying in magnitude and direction over time.
- To learn physical quantities of a wave such as period, frequency, amplitude, phase, $V_{average}$, V_{RMS} and, the use of signal generator and oscilloscope.

Instruments for the Experiment:

- Signal Generator
- Oscilloscope
- Connection cable
- Resistor
- Diode
- Multimeter

Theoretical Information:

Alternating current (AC) is the flow of electric charge that periodically reverses direction. It starts from zero, grows to a maximum, decreases to zero, reverses, reaches a maximum in the opposite direction becoming zero again, and repeats this cycle periodically.

The time taken for one complete cycle of a repeating waveform is called the **period**, the number of cycles or periods per second is called the **frequency**, and the maximum value in either direction is called the **amplitude** of the wave in AC form.

AC has a distinct advantage over direct current (DC; a steady flow of electric charge in one direction) in terms that it transmits power over large distances without great loss of energy to resistance. The power transmitted is equal to the current times the voltage; however, the power lost is equal to the resistance times the square of the current. Changing voltages was very difficult with the first DC electric power grids in the late 19th century. Because of the power loss, these grids used low voltages to maintain high current and thus could only transmit usable power over short distances. DC power transmission was soon supplanted by AC systems that transmit power at very high voltages (and correspondingly low current) and easily use transformers to change the voltage. Current systems transmit power from generators at hundreds of thousands of volts and use transformers to lower the voltage to 220 volts (as in much of the world including Turkey) or 120 volts (as in North America) for individual customers.

Alternating voltage is generally given by

$$V(t) = V_0 \sin \omega t \tag{7.1}$$

where V_0 is amplitude of the signal and ω is angular frequency of the signal.

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$$\omega = 2\pi f = \frac{2\pi}{T} \quad \Rightarrow \quad V(t) = V_0 \sin 2\pi f t \tag{7.2}$$

The value of the alternating current or voltage at any time is called as instantaneous value. The average of the instantaneous values that the signal has over a period of time is called the mean value. The average value is also the DC value of the signal. Average voltage value is calculated as given by

$$V_{av} = \frac{1}{T}\int_0^T V(t)dt \tag{7.3}$$

In this case, it is clear that the average value of a non-rectified alternating current or voltage will be zero because the area above the positive half cycle is the same as the area below of the negative half cycle and thus cancel each other out.

To calculate the power produced by an AC voltage, we must use the effective voltage, called the "Root Mean Square voltage" (abbreviated as V_{RMS}). Effective V_{RMS} is also called "True V_{RMS}" by many instrument manufacturers. The DC current or voltage value that can generate the amount of heat produced by the AC current flowing through an R resistor in a certain time interval over the same resistance is called the effective value of the alternating current / voltage. In other words, an R.M.S. value is defined as the square root of means of squares of instantaneous values. Effective AC voltage is given by

$$V_{RMS} = \left(\frac{1}{T}\int_0^T [V(t)]^2 dt\right)^{1/2} \tag{7.4}$$

For the Sine waveform;

$$V_{RMS} = \left(\frac{1}{T}\int_0^T [V_0 sin\omega t]^2 dt\right)^{\frac{1}{2}}$$

$$= \left(\frac{V_0^2}{T}\int_0^T sin^2\omega t dt\right)^{\frac{1}{2}}$$

$$= \left(\frac{V_0^2}{T}\left[\frac{t}{2} - \frac{sin2\omega t}{4\omega}\right]_0^T\right)^{\frac{1}{2}} = \frac{V_0}{\sqrt{2}} \tag{7.5}$$

This RMS value is measured when the multimeter is in the AC measurement range. If the multimeter is in the DC measurement stage, it will measure the average value of the voltage or current.

In a circuit connected to the signal generator (i.e. AC power source), the measuring instrument that measures both the amplitude and period of the current or voltage on any circuit element as well as the waveform of the signal is called an oscilloscope, as shown in Figure 7.1.

A DC power supply is required to operate electronic devices. The most practical and economical way to obtain DC voltage is to convert the AC voltage from the mains to a DC voltage. This conversion is done by a series of rectifier circuits designed using diodes.

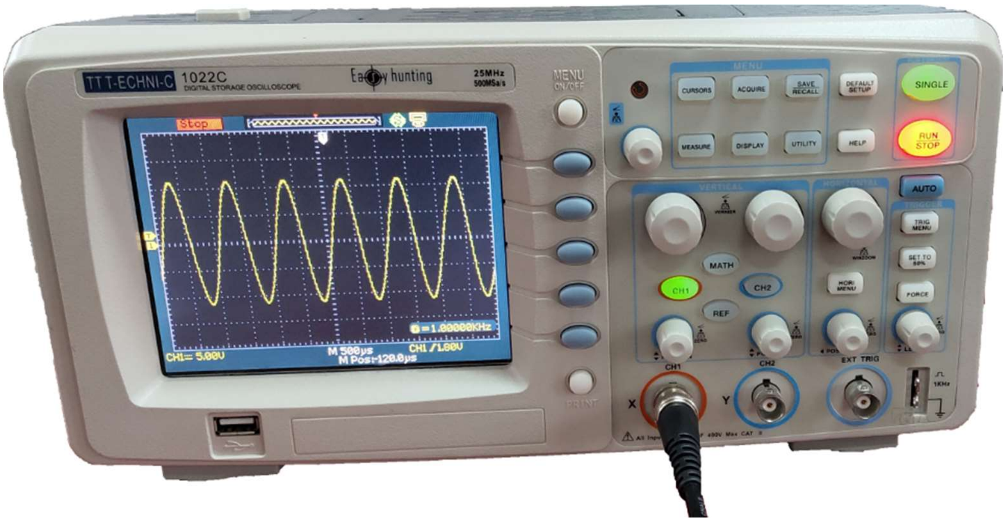

Figure 7.1 An oscilloscope.

If a single diode is connected to an AC voltage source as in Figure 7.2, here the diode passes the current in the positive half-cycle of the signal, while in the negative half-cycle it prevents the current flow. This circuit is called a Half-Wave Rectifier.

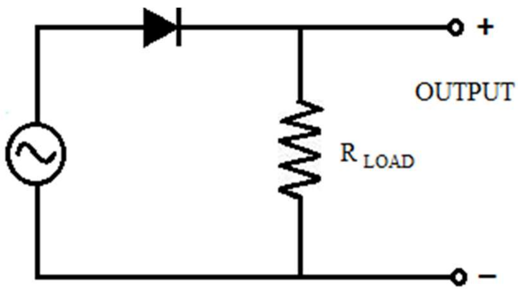

Figure 7.2 Half-wave rectifier

The average of this output signal is not zero because the negative half of the signal is destroyed by the diode. Average value of voltage for positive half is calculated by

$$V_{av} = \frac{1}{T/2}\int_0^{T/2} V_0 sin2\pi ftdt = \frac{2V_0}{\pi} \qquad (7.6)$$

Since the negative half of the wave is zero, its average value is zero. In this case, the average of the entire period is half the average of the positive part. The average of a half-sine wave voltage in a period is given by,

$$V_{av} = \frac{V_0}{\pi} \qquad (7.7)$$

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Experiment Expectation	

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CALCULATIONS AND RESULTS:

1. Use a signal generator to obtain a sine wave voltage with 400Hz frequency and 5 V amplitude. Calculate the frequency of the signal you are observing on the oscilloscope screen and compare it with the value you see on the signal generator screen.

2. Measure the V_{RMS} and V_{av} values of signal and record to the Table 7.1.

Table 7.1. Experimental and theoretical values of V_{RMS} and V_{av} for different frequencies.

		experimental	theoretical
400 Hz	V_{RMS}		
	V_{av}		
600 Hz	V_{RMS}		
	V_{av}		

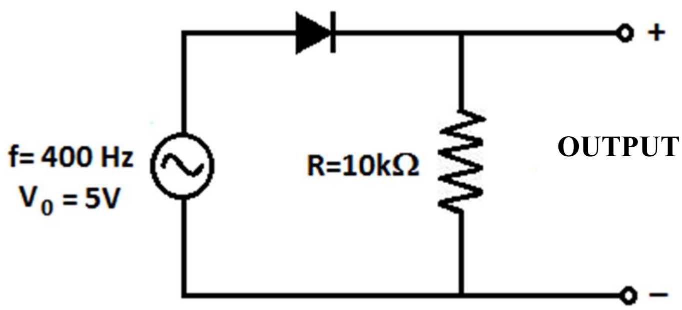

Figure 7.3 Half-wave rectifier circuit for the experiment.

3. Make the circuit shown in Figure 7.3. Observe the output of the circuit by the oscilloscope. Draw the signal seen in monitor of the oscilloscope into the following space.

DISCUSSION AND COMMENTS:

1) What are the functions of oscilloscopes and why do we use them?
2) Derive the RMS value of a half-wave rectifier voltage in a period.

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