Experiment #4 Introduction to Digital Multimeters, Oscilloscopes & Function Generators

4.1 Introduction:

At each station in our electric-circuits laboratories a standard set of instruments is available to enable you to conduct your investigations of circuit behaviour. These instruments are capable of providing the following:

a) Generate test signals such as sinusoidal, triangular, and square waveforms with adjustable amplitude and frequency. These signals can be level-shifted [up or down] with the addition of a dc-offset component,
b) Measure dc and/or ac voltage & current, resistance, and frequency, and
c) Display voltage waveforms on a CRT.

This experiment introduces these instruments and demonstrates their capabilities and limitations.

4.2 Prelab Assignment:

Read the Appendix-section associated with this experiment and familiarize yourself with the various controls of each instrument.

4.3 Procedure:

1- Connect the dc-circuit shown in Fig (4.1). Set the oscilloscope controls as follows: Signal Coupling (<u>CHx MENU</u>→<u>*Coupling*</u>) ☛ **dc,** Y-Position (VERTICAL <u>**POSITION**</u> knobs) ☛ **screen centre,** and Vertical Sensitivity (<u>**VOLTS/DIV**</u> knobs) ☛ **1V/div** for both channels **"1" & "2".**
Connect channels "1" & "2" to display the voltage waveforms @ nodes **(1) & (2)** respectively.

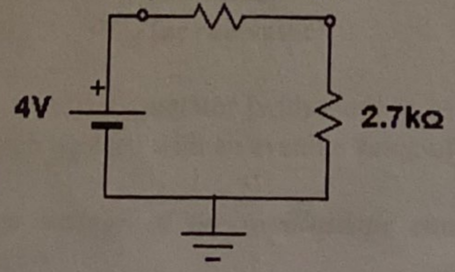

Fig (4.1)

2- Use the oscilloscope to measure the voltages @ nodes **(1) & (2).**

$V_{(1)}$= 4.000 V & $V_{(2)}$= 1.459 V

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3- Use the DMM to measure the voltages @ nodes **(1)** & **(2)**.

$V_{(1)}$= 4 V & $V_{(2)}$= 1.459 V

4- With the oscilloscope connected as in step #1, set the following additional controls as: Horizontal Sensitivity (<u>**SEC/DIV**</u> knob) ☛ **0.2 msec/div,** Trigger Source (<u>**TRIG MENU**</u>→<u>*Source*</u>) ☛ **CH1,** and Trigger Slope (<u>**TRIG MENU**</u>→<u>*Slope*</u>) ☛ **Rising.**

Replace the dc-source in the circuit of Fig (4.1) with the **function generator.** Set the controls of the function generator to provide a **sinusoidal** voltage of **2V (peak)** with a frequency of about **1kHz** @ node **(1).**
Use the DMM to measure the **voltage & frequency** [*using the dual display of the DMM*] of the signal @ node **(1).** Adjust the frequency of the function generator to exactly **1kHz.**

[DMM readings: Frequency = 10^3 **Hz &** $V_{(1)}$ = 4.702 **V.]**

5- Set the **"waveform-select"** control of the function generator to **square wave,** and use the DMM to measure the voltage & frequency @ node **(1).**

[DMM readings: Frequency = 10^3 **Hz &** $V_{(1)}$ = 8.000 **V.]**

6- Set the waveform-select control of the function generator to **triangular wave,** and use the DMM to measure the voltage & frequency @ node **(1).**

[DMM readings: Frequency = 10^3 **Hz &** $V_{(1)}$ = 2.919 **V.]**

7- Use the **"dc-offset"** control of the function generator to provide a <u>**triangular**</u> wave of **4V (peak-to-peak)** with an **average value of 2V** at a frequency of **1kHz** @ node **(1).** Note that the amplitude of the waveform is now fluctuating in the voltage range: **0.0V to 4V** @ 1kHz. Use the DMM to measure each of the following voltage entities @ node **(1):**

a) The dc-component...... $V_{(1)}$ **[dc-value]** = 1.532 V,
b) The ac-component...... $V_{(1)}$ **[ac-value]** = 2.578 V, and
c) The [ac + dc]-value... $V_{(1)}$ **[ac+dc-value]** = 2.999 V.

8- Set the controls of the function generator [with the help of the oscilloscope] to provide a sinusoidal signal of **20mV (peak)** with an average value of **2V** at a frequency of **1kHz** @ node **(1).**
{Note that the present settings of the oscilloscope controls will not enable you to perform the above step !!}

[Hint: Use the **dc/ac**-coupling & Vertical (Voltage) Sensitivity controls of Channel **"1"** to separately set accurately the dc & ac components of the desired signal]

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Use the DMM to measure the dc & ac components of the voltage @ node (1), and record your measurements in table (4.1).

9- Set the "frequency" control of function generator to each of the values listed in table (4.1), and repeat the above step.

Table (4.1) [DMM measurements]

Frequency (kHz)	DC Component (V)	AC Component (mV)
1.0	2	14.9
10.0	1.515	14.97
100.0	1.514	14.559
1000.0	1.510	14.507

10- Connect the circuit shown in Fig (4.2). Connect channels **"1"** & **"2"** of the oscilloscope to node **(1) & (2),** respectively. Note Channel 2 will now display a scaled-up version of the current = **(10,000)** × **i (t).** Set the oscilloscope controls as follows:
Signal Coupling (**CHx MENU**→*Coupling*) ☛ **ac,** Y-Position (VERTICAL **POSITION** knobs) ☛ **screen centre,** and Vertical Sensitivity (**VOLTS/DIV** knobs) ☛ **1V/div** for both channels **"1"** & **"2",** Horizontal Sensitivity (**SEC/DIV** knob) ☛ **0.1 msec/div,** Trigger Source (**TRIG MENU**→*Source*) ☛ **CH1,** and Trigger Slope (**TRIG MENU**→*Slope*) ☛ **Rising.**
Set the controls of the function generator to provide a **sinusoidal** voltage of **4V (peak)** with a frequency of about **1kHz** @ node **(1).**
Note the displays of the waveforms of $V_{(1)}(t)$ and **i(t)** are both sinusoids with the same frequency, but with a different magnitude and phase angle.

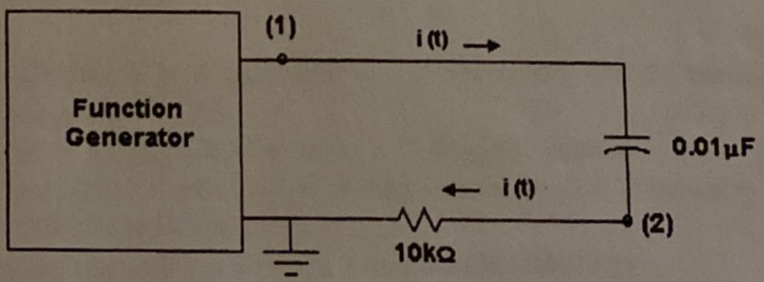

Fig (4.2)

11- Use the oscilloscope to measure the phase angle **(θ°)** of **i(t)** relative to $V_{(1)}(t)$. This measurement can be performed in **one-out-of-two** ways depending on the mode of operation of the oscilloscope [**(Y-Time)** or **(X-Y)** mode]:

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Phase Measurement

A) With The Oscilloscope In The Y-Time Display Mode:

Proceed by setting the oscilloscope controls as follows:

First: Set the Y-Position (VERTICAL **POSITION** knobs) for both "1" & "2" ☛ **screen centre,** and Horizontal Sensitivity (**SEC/DIV** knob) to display about **one period** of the **Channel 1** display. Adjust Trigger Level (**LEVEL** knob) to trigger the **Channel 1** display @ the positive-going **zero crossing** instant, and move this point (with **X-Position** (HORIZONTAL **POSITION** knob) adjustment) to the left end of the display.

Second: Using Horizontal Controls (**HORIZ MENU**→*Window Zone*) to set **one-half period** of the **Channel 1** display to occupy **exactly nine divisions** along the x-axis.

[***The x-axis is now calibrated for phase-angle measurements with a scale of 20°/div.***]

Measure the phase angle (**θ°**) and record your result in table (4.2).

B) With The Oscilloscope In The X-Y Display Mode:

Proceed by setting the oscilloscope controls as follows:

Set Display Format (**DISPLAY**→*Format*) of the oscilloscope to **XY** mode. Note that the oscilloscope is now using the signal from Channel 1 to control the X coordinate and the signal from Channel 2 to control the Y coordinate. The oscilloscope is now operating in the X-Y display mode.

The vertical deflection is now controlled by the current **i(t),** and the horizontal deflection is controlled by the voltage $\mathbf{V_{(1)}(t)}$.
Generally, the X-Y display [usually called a **"Lissajous pattern"**] is an ellipse; the ratio of [its intersection with the Y-axis (y_0)]-to-[its maximum vertical deflection (y_m)] is used to find the phase angle (**θ°**) as indicated in Fig (4.3).
Measure the phase angle (**θ°**) and record your result in table (4.2)

(Table 4.2) [Phase angle (**θ°**) of **i(t)** wrt $\mathbf{V_{(1)}(t)}$]

Y-Time-display mode	X-Y-dispaly mode

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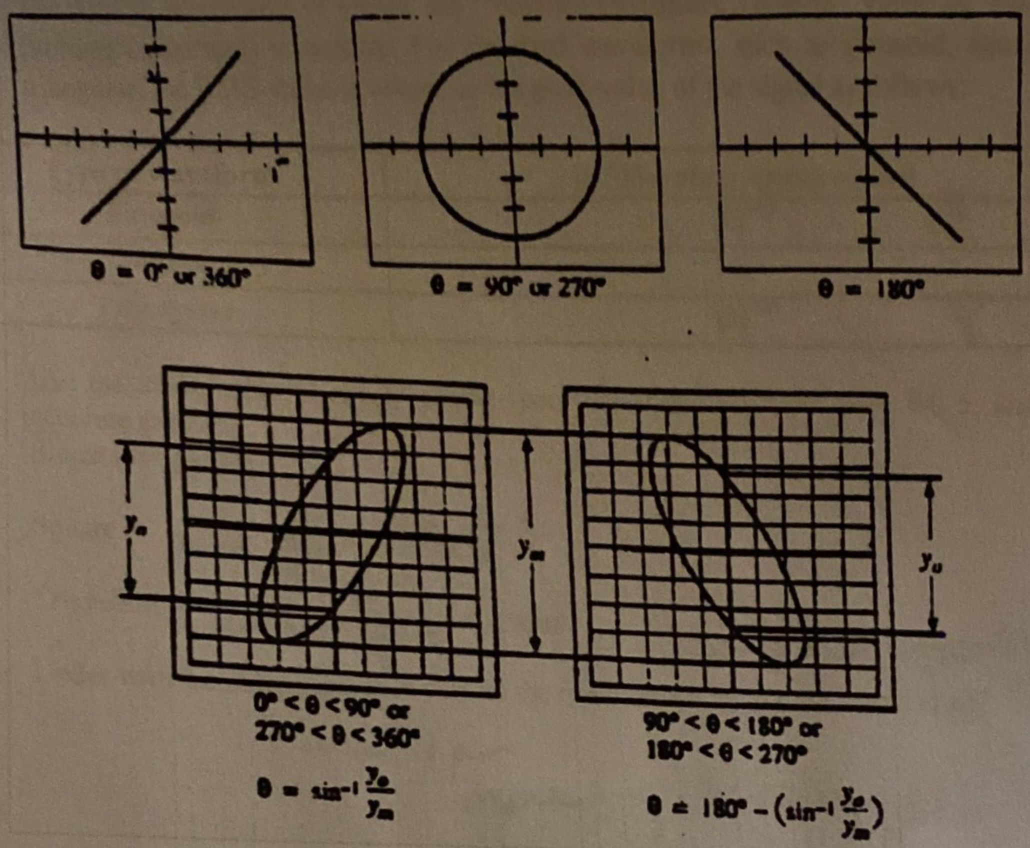

Fig (4.3)

4.4 Conclusion:

1- Compare your measurements from steps #2 & 3. Which set of measurements would you consider to be more accurate, and why?

both gave the exact same value so both are equally accurate

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2- The DMM ac-reading is called the **"root-mean-square (RMS)"** value of the signal (voltage or current) waveform. For standard waveforms, such as sinusoid, square, and triangular, the RMS-value is related to the peak-value of the signal as follows:

Type of waveform	[RMS-value] /[peak-value]	
Sinusoid	$[2]^{-0.5}$	$\frac{\sqrt{2}}{2}$
Square	1	1
Triangular	$[3]^{-0.5}$	$\frac{\sqrt{3}}{3}$

Use the above table to check whether your measurements from steps #4, 5, and 6 are accurate enough.

Sinusoid: 4.702

Square: $\frac{4.702 \times \sqrt{2}}{2} = 3.325$

Triangular: $4.702 \times \frac{\sqrt{3}}{3} = 2.714$

no my measurments were not accurate

3- Under which conditions would you set the oscilloscope coupling-control to **ac**?

when I am measuring Ac voltage

4- Discuss the results of your measurements listed in table (4.1).

Frequency has little to no change one the Ac and DC Values

5- In comparing the two methods of phase measurement [step #11], which one do you think is more accurate, and why?

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