Experiment #5  AC Measurements

Objectives

To acquaint students with the operation of the function generator (FG) and AC measurements using the digital multimeter (DMM).

Introduction

The function generator (also called Waveform Generator) is capable of generating square, triangular, and sinusoidal voltage waveforms of various frequencies and magnitudes. The waveforms are selected by pushbuttons. The frequency, amplitude, and DC offset of the waveform are determined by pushbuttons or the control knob.

In addition to the free-running mode described above, the function generator also permits the control of the output frequency by an externally applied voltage via the SYNC connector. It also allows a single cycle output per each trigger signal (triggered mode) or a burst of waveform with a gating signal (gated mode). You will not be using these modes of operations in this course so they will not be discussed any further. The functions of the front panel controls and connectors are given in Appendix G.

The digital multimeter (DMM) can measure ac voltages and currents by activating the appropriate function button. Since the value of an ac signal changes with time, the meter displays its rms (root-mean-square) value. The rms value for a sinusoidal voltage function is $v_{rms} = \frac{v_s}{\sqrt{2}}$ where $v_s$ is the peak value (amplitude) of the waveform. Likewise the ac ammeter would measure the rms value of the current. Note that the rms value is independent of the frequency or the phase angle of the waveform.

Appendix E provides some information about capacitors.
**Laboratory Work**

**IMPORTANT:**
*Use oscilloscope to verify amplitude of AC waveforms, not the function generator.*

1) Select the function generator to output a 1 kHz sinusoidal waveform. The output, \( v(t) \), as a function of time, \( t \), can be represented by the following mathematical expression:

\[
v(t) = v_s \sin(2\pi ft) + V_0
\]

where \( v_s \) is the peak amplitude of the sinusoidal function, \( f \) is the frequency, and \( V_0 \) is the DC offset (i.e., vertical shift of the sine wave.)

2) Use the DMM to measure the AC voltage at the function generator output. Adjust the generator output amplitude control for a reading of \( v_s \) on the DMM. Remember that the DMM in AC mode measures the RMS value of the sinusoidal function.

\[
V_{\text{RMS}} = \frac{v_s}{\sqrt{2}}
\]

Change the OFFSET and observe its effect on the ac meter reading.

3) Adjust the DMM to measure dc voltage at the function generator output. Adjust the offset so that the meter reads 5 Vdc. This is also the average value of the function generator output since the average value of a pure sinusoidal function is zero. Now adjust the AMPL and observe its effect on the dc meter reading. Leave the offset at 5 Vdc and switch the DMM to ac voltage measurement again. Adjust the AMPL knob so that the output again reads \( v_s \) on the DMM.

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**Fig. 1. Circuit for AC measurements**

\[ V_{\text{offset}} = 5 \text{Vdc} \]

\[ v_s = 3 \text{V} \]

FREQ = 1kHz
4) Construct the circuit of Fig. 1. Set $v_s(t)$ to $3\, V$ at 1 kHz and 5Vdc offset. Measure both ac and dc voltages across each element. Does KVL hold for both ac and dc voltages?

Measure both ac and dc currents in all branches associated with the node A. Does KCL hold for both ac and dc currents at node A? Based on your observations so far, do you think that, in a resistive circuit, voltage division and current division work with ac signals as well? Explain how you would test the validity of Thevenin's and Norton's theorems for ac resistive circuits.

5) Replace the two vertical resistor branches in Fig. 1 by two 0.1 $\mu$F capacitors to make it a RC circuit as shown in Fig. 2. Set $v_s(t)$ to $3\, V$ at 1 kHz and 5Vdc offset as before. Measure both ac and dc voltages across each element. Are the readings what you expected? Does KVL hold for both AC and DC voltages? Why? Measure both ac and dc currents in all branches associated with the node A. Are the readings what you expected? Does KCL hold for both AC and DC currents at node A? Why?
6) Phasors and impedances are generally used in AC circuit analysis. However, if the circuit is composed of just one type of passive component, then some simplified techniques can be used.

For example, a simple way to find the value of an unknown component is to connect it in series (or in parallel) with a known one and use the principle of voltage (or current) division to compute the value of the unknown component.

![Circuit diagram](image)

**Fig. 3. Circuit for measuring an unknown capacitor**

One such circuit is shown in Fig. 3. Based on voltage division for capacitors, \( v_o = v_s \frac{C_1}{C_1 + C_x} \).

For best result, the value of \( C_1 \) should be relatively close to that of \( C_x \). (Why?) Set \( v_o \) to 5 V at 1 kHz, offset=0Vdc. Obtain a capacitor of unknown value from your instructor and find its value by using the voltage divider circuit. If possible, use a \( C_1 \) so that the rms reading of \( v_o \) is between 10% and 90% of the \( v_s \) rms value.