**Learning Objectives**

Students will develop skills with use of a digital oscilloscope, a multimeter, a function generator, and RC circuit to prepare and collect data for time varying signals. Completing this lab will help ensure the student can:

1. operate basic functions of a laboratory oscilloscope to perform voltage and frequency measurements on a time varying waveform from a function generator,
2. apply the concepts and definitions of RMS Voltage, Peak-to-Peak Voltage, and Voltage Amplitude and demonstrate how they are related for a sinusoidal waveform,
3. use a multimeter to measure RMS voltage and frequency output from a function generator, and
4. determine appropriate statements of uncertainty for oscilloscope and multimeter measurements, and
5. collect and analyze data to characterize an RC filter circuit

**Background**

See documents provided for Challenge 3, listed below. It is also recommended you find some video tutorials on-line for use of Tektronix TDS1000B oscilloscopes. You may also want to ensure you know how to make plots in Excel that have a semi-log scale axis. And be sure you know the relationships (from Circuits or Physics) between Vpk-pk and Vrms and Vpk for sinusoidally varying waveforms.

* Signal Filtering
* Operating Manual for Oscilloscope
* Operating Manual for Function Generator

**Activity 1 – Basic Use of Digital Oscilloscope**

Connect the Function Generator output to Channel 1 of the oscilloscope and simultaneously connect the same signal to the Multimeter. Hint: Using a t-joint BNC connector will make this easy.

Use the function generator to produce a **240 Hz** sinusoidal waveform with a magnitude of ***3 Vpk-to-*pk**. Adjust the time scale on the oscilloscope using the **Time/Div** control to display approximately 5 cycles of the waveform. Adjust the **Volts/Div** knob so the waveform fills 6 vertical divisions (see Fig. 1).

*Sinusoidal wave form:*

*5 cycles, 6 div vertically*

**Figure 1:** Sinusoidal Waveform

From the oscilloscope visual display, visually measure magnitude of the waveform and the time period for fire complete waveforms. Consider the resolution of the scales of the window display. Don’t forget units in your answers. Be sure to include a photo image from the scope in your write-up.

Waveform amplitude: Vpk = Time period for 5 cycles: T5 cycles =

Using the visual measurements above, compute the values listed below. Show all calculations!

RMS Voltage: Vrms = Waveform frequency: f =

Adjust the trigger and slope settings so the displayed sweep is triggered as shown in Figures 2 and 3. Indicate in your writeup what the voltage trigger sign (+ or – ) and slope sign (+ or – ) must be to produce each waveform.

*Trigger point*

*Trigger point*

**Figure 2:** Triggering Lesson 1 **Figure 3:** Triggering Lesson 2

Using the special features of the TEK scope, under the **MEASURE** menu options, set up four boxes in the right hand column on the screen to show the Channel 1 measurements of Pk-Pk, Cyc RMS, Period, and Freq. Write down the values from each box. Units must be included in your answers. Be sure to include a photo image of the o-scope screen in your write-up.

Pk-Pk: \_\_\_\_\_\_\_\_\_\_ Cyc RMS: \_\_\_\_\_\_\_\_\_\_\_\_\_

Freq: \_\_\_\_\_\_\_\_\_\_\_\_\_ Period: \_\_\_\_\_\_\_\_\_\_\_\_\_

Determine appropriate statements of uncertainty for the oscilloscope measurements. Justify your values with reference to user manual page(s), consideration of accuracy, digital display resolution, etc. Be sure to show all calculations.

**Activity 2 - Comparing Oscilloscope to Multimeter**

Without changing the function generator settings, use the multimeter to assess the same output signal from the function generator. Don’t forget the units.

From the multimeter, record the values for the measured amplitude and frequency of the signal

Amplitude, VAC: \_\_\_\_\_\_\_\_\_\_\_\_\_ Frequency, F: \_\_\_\_\_\_\_\_\_\_\_\_\_

Determine an appropriate statement of uncertainty for each measured value above, showing all work.

Compare the multimeter results with the oscilloscope results and discuss what you observe from the comparison.

**Activity 3 – Frequency response of an RC filter circuit**

Construct the filter circuit shown (Fig 4).

*Component Values*

**R = 100 kΩ** and **C = 0.022 μF**

**Function Generator**

**Oscilloscope**

**Ch 1**

**Ch 2**

**R**

**C**

**+**

**+**

**−**

**−**

**Figure 4**. RC Filtered Signal Setup

Using a tee-connector, send one signal to Ch. 1 of the oscilloscope (non-filtered signal) and the other through the filter circuit and then to Ch. 2 of the oscilloscope (filtered signal).

Use the function generator to produce a **5 Vpk-pk** sinusoidal waveform with an initial frequency of **10,000 Hz**. From this point onward, **DO NOT change** the function generator magnitude, only adjust the frequency of the function generator signal, now referred to as the input signal for the filter.

***Note:***  *Check to make sure your RC circuit is functioning correctly by skipping ahead to the 40 Hz frequency. At 40 Hz, you should visually observe a significant reduction in amplitude of the filtered signal, as well as a noticeable shift in time between the two signals. If you do not, then the circuit needs to be checked, as it is not functioning correctly.*

From the oscilloscope display (Fig 5), measure the magnitude (Vpk-pk) and the time shift (Δt) of the filtered signal relative to the non-filtered signal. You can setup **cursor bands** to easily find the time shift. Read the user manual to learn how to use cursor bands. Report your process in your write-up.

Vpk-pk (non-filtered)

Vpk-pk (filtered)

Δt

Ch 1

Ch 2

**Figure 5**. Sample O-scope Display of RC Filter Input and Output

Repeat the procedure to collect data for a range of input frequencies starting at 10,000 Hz down to 10 Hz. Prepare a table in Excel, using the headings shown below to organize the data. The left column is the independent variable, f. The second and third columns are the direct measurements. The fourth column can either be directly measured, or calculated from f, since f = 1/T. The fifth and sixth column are to be computed and are thus considered to be indirect measurements of the system

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Frequency of Input signal*f* ***(Hz)*** | **Magnitude of Filtered Signal, Vout**  ***(Vpk-pk)*** | **Time Shift**  ***Δ t***  ***(sec)*** | Period*T* ***(sec)*** | **Gain**  ***G***  ***(Vout / Vin)*** | **Phase Shift *(deg)***  ***φ***  ***(Δ t / T ) × 360o*** |

Collect data for the following input frequencies: 10,000 Hz, 1000 Hz, 500 Hz, 300 Hz, 100 Hz, 40 Hz, and 10 Hz.

Plot the Gain vs. Frequency data on semi-log axes in Excel.

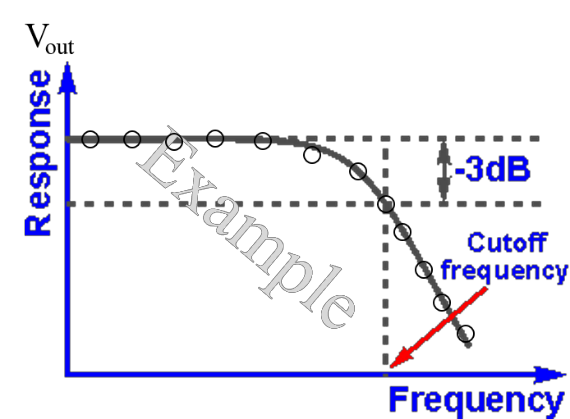
Discuss your observations of the data from the table of data and the plot. Possible observations you can make are: effect of the RC circuit on the voltage input, classification of the RC circuit (low-pass, high-pass, band pass), comparison of experimental data to theoretical behavior of RC circuits, see Background Notes for Challenge 3.

Note: The Optional Activity is to be attempted only if your team has enough time during your regular lab section.

**Optional Activity)**

* Design a low pass filter with a cutoff frequency of 1kHz (approximately) and prove it works using a sinusoidal input of 1 Vpk.

Hints: First, select R and C from the relationship *fcutoff*. Second, build a circuit on the breadboard. Third, apply a signal V*in*, 1V sin(wt), and measure Vout while increasing the frequency from 1Hz to 100kHz (1, 10, 100, 1,000, 10,000, 100,000Hz). Last, plot Vout with respect to input frequency. The cutoff frequency will be determined when the response Vout drops to 0.7V (when input voltage is 1.0V).



* Design a high pass filter with a cutoff frequency of 10kHz (approximately) and prove it works using a sinusoidal input of 1 Vpk.

Hints: First, select R and C from the relationship *fcutoff*. Second, build a circuit on the breadboard. Third, apply a signal V*in*, 1V sin(wt), and measure Vout while increasing the frequency from 1Hz to 100kHz (1, 10, 100, 1,000, 10,000, 100,000Hz). Last, plot Vout with respect to input frequency. The cutoff frequency will be determined when the response Vout rises to 0.7V (when input voltage is 1.0V).

