LAB 1(a,b) –Instrumentation and Measurement

1. Objective

The objective of this lab session is to get you familiarized with the operation of various pieces of electronic instrument that will be used in future lab sessions.

2. Component and Instrumentation

a. USB Oscilloscope (LOTO Instruments OSC 482S) (Appendix A, Item-1)
b. Digital Multimeter (VC890C) (Appendix A, Item-2)
c. Breadboard (Appendix A, Item-3)

3. Background Information

3.1 Digital Multimeter (VICTOR VC890C)

A Digital MultiMeter (DMM) is a handy tool for measurement. It can measure voltage, current, and resistance. Some meters can even measure capacitance. The measured signal should be either dc (direct current) or low-frequency ac (alternating current).

1) How does a DMM measure voltage, current and resistance?
The DMM converts the quantity to be measured into a voltage, which is then converted to a digital number and shown displayed on the display. To measure voltage, the DMM scales the voltage and converts the output to a digital number. To measure resistance, a known constant current is injected into the measured device, and the voltage across the device is measured. To measure current, the measured current is allowed to flow through a small fixed resistance and the DMM measures the voltage across the resistance.

2) How accurate is the measurement?
It is not true that the least digit in the display represents the accuracy that can be achieved. Always refer to the instruction manual for the accuracy specification. Generally speaking, accuracy is increased as the smaller range is selected.

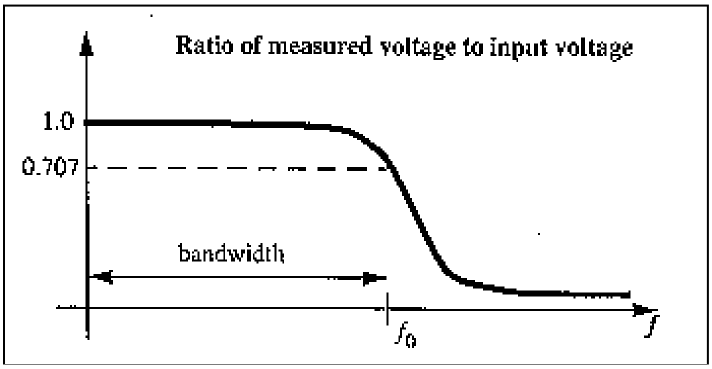
3) What value does a DMM display when measuring an AC signal?
When measuring the voltage or current of an AC signal, the DMM shows the rms value of the quantity measured. Some good-quality DMM can measure true rms values by measuring the power of the signal, while other DMMs just calculate the rms value by scaling the peak amplitude with a factor that applies only correctly to a sine wave, but the reading is inaccurate if the signal is not a pure sine wave.

4) Can a DMM measure a high-frequency signal?
The frequency response or bandwidth describes the range of frequencies for which an electronic instrument can measure reliably. Outside this range, the measurement shown on the instrument will be inaccurate. Typically, electronic instruments can measure all the way down to 0Hz (DC). Thus, if the bandwidth of a given instrument is 10MHz, it means that it can measure signals from DC all the way up to 10MHz fairly accurately. Above 10MHz, the measurement will be severely attenuated (i.e. it will be much smaller than the actual value). The typical bandwidth of a DMM is around 10kHz. Normally, for the sake of accuracy, a DMM is not used to measure a signal with a few hundred Hertz.

3.2 Oscilloscope

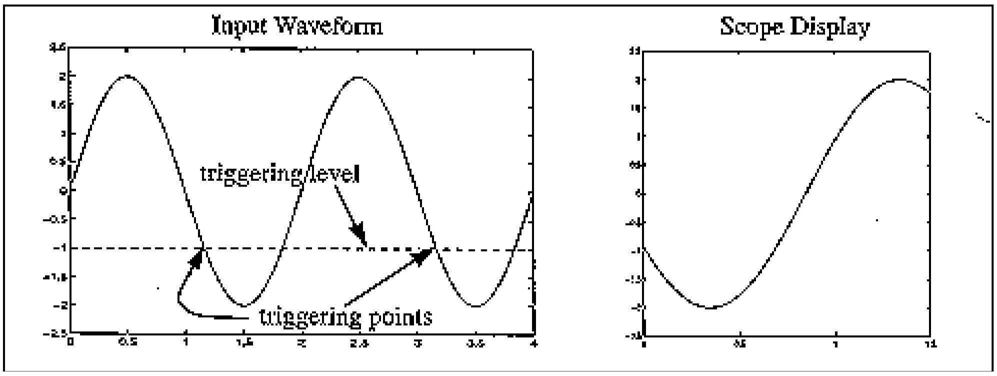
The oscilloscope (scope) is a powerful tool for waveform capture and measurement. Unlike the DMM, it can be used to study the time behaviour of a voltage and to measure high-frequency signals. However, the scope can only measure voltage. Other quantities must be converted to voltage in order to be displayed on the scope.

1) How do we choose a scope?
An analogue scope can only capture a periodic, long-lasting signal. It has no memory and is much cheaper. A digital storage scope can capture transient and single-shot (one-time) signals by digitizing and storing the waveform in its built-in memory (RAM). It can be used as an analogue scope by disabling its storage function.



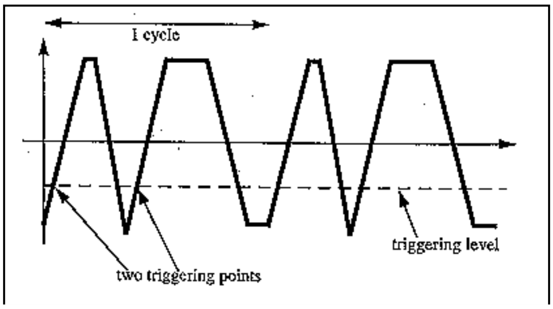
Select a scope with the appropriate bandwidth (e.g. 20MHz, 40MHz, and 100MHz.). Recall from above that the bandwidth indicates the maximum frequency of the input signal to which it can measure without severe attenuation. The attenuation of magnitude is about 0.707 at the bandwidth frequency, and the attenuation increases as frequency increases, as shown above. For example, if a 100MHz scope is used to measure a 100MHz 1V-amplitude sine wave, the waveform captured/displayed will only be a 100MHz 0.707V amplitude sine wave. A scope with large bandwidth can be used to measure high-frequency signals, such as those used in radio. The scopes in our laboratory are 60MHz digital scopes.

2) What is triggering?
The trigger determines when the oscilloscope starts to acquire data and display a waveform. The triggering circuitry detects the signal when it crosses through a given level called the triggering level with a given slope (positive and negative) and starts the sweep at that time. For example, the left figure below shows a 4Vpp (4V peak-to-peak) sine wave. If the triggering point is set to –1V and the triggering slope is set to be negative, then the waveform displayed is as shown in the right figure below.

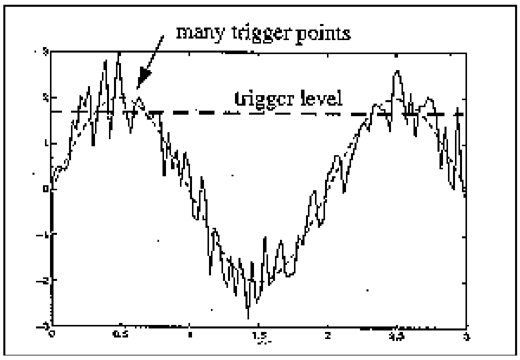


The simple scheme works for a large number of waveforms. The triggering level can be changed accordingly. The duration of the display frame can be computed from the time base setting of the scope. There are 10 divisions in total across the screen, and multiply the time base setting (in time-unit per division) by 10 gives the duration of the triggering frame.

3) Why do the waveforms sometimes appear to be unstable on the screen?
A major cause is that the input signal is not periodic and the waveforms in the triggering frames are not identical, resulting in an unstable waveform which is the overlap of many non-identical waveforms.
A second possible cause is that the signal is periodic but has a complex shape. In this case, the triggering circuitry may find more than one triggering point that satisfies the triggering slope and triggering level requirement, within any one cycle of the input signal. The situation is shown below.



A third possible cause is that the input signal is contaminated by external noise, which again leads to a complex waveform. The situation is illustrated below. The solution is to remove the source of noise or select the triggering point with a steepest slope, which can help to decrease the noise sensitivity.



4) What is a ×10 probe used for?
It is a good practice to use a ×10 probe to measure signals. The ×10 probe is used to increase the equivalent input impedance of the scope. The input impedance of the scope is about 0.89MΩ measured at 1kHz and decreases down to about 73kΩ measured at 100kHz. The

decrease of input impedance at high frequency (due to probe capacitance) implies the current will flow from the circuit into the input circuitry of the scope. The scope becomes a significant load to the measured circuitry and leads to an inaccurate result.

The ×10 probe has an internal passive circuitry and can increase the input impedance of the scope by 10 times. Thus a ×10 probe is often used in high-frequency measurements. Also, when the impedance of the measured circuit is comparable to the scope input impedance, a ×10 probe can be used to reduce the loading effect. However, when using a ×10 probe, the measured voltage will only be one-tenth of the voltage when using ×1 probe. So, read the range values specially designated for use of a ×10 probe. A ×10 probe needs to be calibrated from time to time. A ×1 probe is just a conducting wire, but includes a lot of capacitance, which increases the load on the measured circuit at high frequencies.

3.3 Synthesized Function Generator

A function generator is an electronic signal source that can generate different kinds of waveforms, such as sine, triangular and rectangular waves. The frequency and the duty cycle of the generated waveform can be adjusted via panel controls.

4. Prelab

In this section, you are required to read the background of this lab before the lab session. Since we will always use these electronic instruments in future lab sessions, you have to get familiar with their operation.

LAB 1(a) –Instrumentation and Measurement

5. Procedure

5.1 Phase Measurement

Because the SCOPE can display the time behavior of a waveform, we can use it to measure the time between events. In this experiment, we use the SCOPE to measure the phase difference between two sinusoidal waveforms.

Use C = 1 μF , R = 1 kΩ

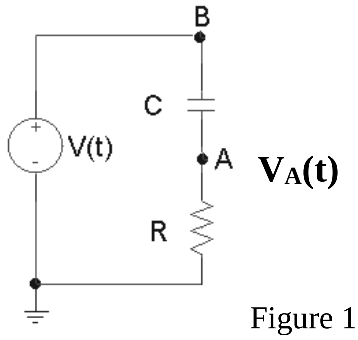


Figure 1

1. Connect the circuit shown in Figure 1. Apply a 1kHz 2Vp-p (+/– 1V) sine wave from the function generator to V(t). Use the oscilloscope to ensure that the frequency of the waveform is correct.
2. Connect node ' A ' to channel 1 and ' B ' to channel 2 of the oscilloscope.
3. Measure the phase difference in time t (shown in Figure 2). Then find the phase difference θ between the sine waves using $\theta = t * 360^{o} / T$.

Q1. What is the phase difference θ between the sine waves? θ = _______________

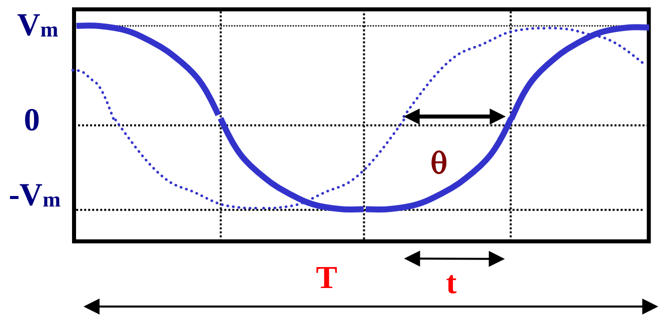


Figure 2

Q2. Capture the corresponding waveform of $V_A(t)$ and V(t) when you measure the phase difference θ in Q1.

4. Select the 'Format-XY' type in oscilloscope. <The 'XY' format displays a dot each time a sample is acquired on channel 1 and channel 2. Channel 1 voltage determines the X coordinate of the dot (horizontal) and the channel 2 voltage determines the Y coordinate (vertical) >.
5. Find the phase difference θ using the Lissajous plot (use X-Y mode of scope) shown in Figure 3, using sin θ = a/b.

Q3. What is the phase difference θ using the Lissajous plot? θ = _______________

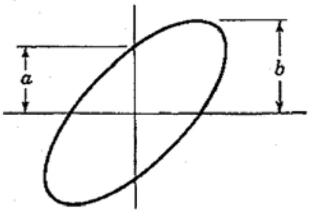


Figure 3.

Q4. Capture the corresponding waveform of $V_A(t)$ and V(t) when you measure the phase difference θ in Q3.

Q5. What is $V_A(t)$, when V(t) is $1*\cos(2\pi 1000\ t)$ V?

Q6. Show all the circuits and waveform to TA.

Appendix A

 		
Item-1 - USB Oscillscope	Item-2 - Digital Multimeter (VC890C)	Item-3 - Breadboard x 3