

RUTGERS UNIVERSITY
 The State University of New Jersey
 School of Engineering
 Department Of Electrical and Computer Engineering

**332:223 Principles of Electrical Engineering | Laboratory
 Experiment #2**

Title: Function Generators and Oscilloscopes

Suggested Equipment:

TEKTRONIX FG 501A 2MHZ Function Generator
 Hitachi V-202F Oscilloscope
 Keithly 179A TRMS Multimeter
 TEKTRONIX DC 504A Counter/Timer

1-INTRODUCTION:

The main objective of this laboratory experiment is to get acquainted with Function Generators and Oscilloscopes. In order to get familiar with Pspice or Multisim, for your laboratory report, you will also be asked to simulate in Pspice or Multisim the behavior of certain circuits. If you need more time for such simulations, first submit the report except possibly the simulations, and then at a later time specified by the instructor submit the simulations.

2.1 FUNCTION GENERATOR:

The Function generator is used to produce AC signals. Usually, they can produce several different waveforms including a sine wave, square wave, and triangular wave. Controls on the front of the function generator also provide a means to adjust the frequency f_o of the signal and the amplitude V_A and the DC offset V_{avg} . These parameters do not completely describe the waveform. For this reason they are called as the partial descriptors. For example a sine wave is completely described by the equation

$$V(t) = V_A \text{Cos}(\omega t + \Phi) + V_{avg}$$

The phase angle Φ describes the phase shift of this *waveform compared with a time origin*. If the origin is defined to be the zero crossing when the sinusoid has a positive slope, the phase angle $\Phi = -90^\circ$ and thus $\text{Cos}(\omega t - 90^\circ)$ equals $\text{Sin}(\omega t)$.

The frequency ω in the above equation is in radians/sec. In the laboratory we usually refer to the cyclic frequency of the wave (or for short, frequency), in terms of Hertz. The relationship between Hertz and radians is defined as

$$\omega = 2\pi f_o.$$

Rewriting the equation for the voltage of a sine wave in terms of Hertz and with a phase shift of -90° , yields:

$$V(t) = V_A \text{Cos} (2\pi f_o t - 90^\circ) + V_{avg}$$

There are three variable or partial descriptors in the above equation over which we have control - the amplitude V_A , the frequency f_o , and the average value or DC offset of the waveform V_{avg} . These are the basic adjustments of any function generator.

Waveform Select: Most function generators can produce three or more distinct waveforms. Typically these include the sine, square and triangular waves. The waveform selector consists of either a set of push buttons or a knob with several discrete settings, one for each available waveform.

Frequency Adjust: The frequency adjust typically consists of several push buttons or a Multi-position rotary switch and a continuously variable called vernier. The switch or push buttons select the desired range of frequencies usually slightly more than one decade in width. A decade of frequencies is a factor range where the frequency is a factor of 10 larger than the lowest frequency in that range. The vernier control is used to dial in any frequency within the selected range. To ensure that there are no missing frequencies between the ranges the frequency vernier usually allows you to adjust the frequency over a range slightly more than one decade.

Amplitude: The amplitude of output voltage is usually set by the range select buttons and a continuously variable vernier. The smaller amplitude range is used to accurately control small amplitude signals, e.g. testing a high gain amplifier. The higher voltage range provides larger amplitudes, but has coarser control.

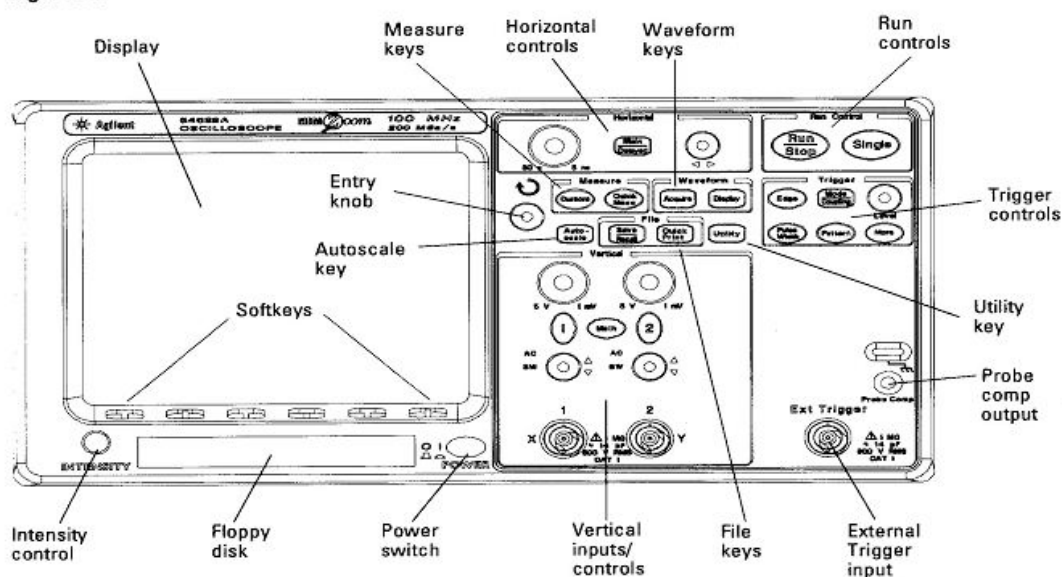
DC Offset: The controls for setting V_{avg} or DC Offset are quite similar to those used for setting the output amplitude. The user typically has a couple of ranges available with a vernier that allows the actual value to be adjusted throughout the selected range. There may also be a switch to set the DC offset precisely to zero.

Other controls: With more sophisticated function generators the user can create specialized waveforms and provide a synchronization signal to an oscilloscope.

3- USE OF THE OSCILLOSCOPE:

54620-series Oscilloscope Front Panels

Figure 2-1



54621A and 54622A 2-Channel Oscilloscopes Front Panel

The above diagram describes the oscilloscope that you will use for at least the remainder of this semester and possibly for several more ECE Laboratories. It is critical that you

understand the basics of the oscilloscope that will be demonstrated in this lab. An oscilloscope is mainly used in order to display AC (alternating current) signals. Note that alternating voltages and currents are often simply called "signals". AC signals differ from the DC currents (which were used in the 1st lab). In the latter the charge flows continuously in one direction whereas in AC signals the flow of charge carriers reverses direction periodically. As mentioned before, the function generator can produce AC signals of three different (periodical) types, namely sine waves, triangular waves, and square waves.

The oscilloscope that you will use in this laboratory is called the digital oscilloscope. The digital oscilloscope differs from its analog oscilloscope counterpart in that it "digitizes" or converts the analog input waveform into a digital signal that is stored in a semiconductor memory and then converted back into analog form for display on a conventional CRT. Typical digitizing-scope architecture applies extensive processing power to waveform acquisition, measurement, and display. A wide variety of plug-in modules are available for special timing functions and additional channels. The data are displayed most frequently in the form of individual dots that collectively make up the CRT trace. The vertical screen position of each dot is given a binary number stored in each memory location, and the horizontal screen position is derived from the binary address of that memory location. The number of dots displayed depends on the frequency of the input signal relative to the digitizing rate, on the memory size and on the rate at which the memory contents are read out. The greater the frequency of the input signals with respect to the digitizing rate, the fewer the data points captured by the oscilloscope memory in a single pass and the fewer the dots available in the reconstructed waveform.

Digital and analog oscilloscope each have distinct advantages, but digital oscilloscope are fast replacing analog scopes because they are more versatile.

3.1 Preliminary:

Locate the following button and knobs that would normally be used in an experiment:

- a. ***Power*** button, and ***Intensity*** control. Located at the bottom left of the oscilloscope.
- b. ***Quick Measure***, ***Auto Scale*** and an unlabeled knob right next to the Auto Scale button (in the diagram above it is called the entry knob) located at the middle section of the oscilloscope.
- c. Locate a group of knobs and buttons grouped under ***Vertical***. Notice that there are two identical sets of knobs. This is provided because the oscilloscope can display two input signals simultaneously.
- d. Also locate another group of knobs and buttons grouped under ***Horizontal***.
- e. Turn the scope on and also locate the remaining control tabs and soft keys.

3.2 Display:

The display of the oscilloscope will exhibit changing voltage vs. time. The x-axis is the time axis and the y-axis is the voltage axis where the level of the input voltage is displayed.

The scale of the x-axis (which can range from 5ns to 50s) can be changed by manipulating the big round knob of the group labeled ***Horizontal***. The scale units of time/division are displayed on the strip at the upper edge of the screen.

Likewise the scale of the y-axis (which varies from 1mV/div to 5V/div) can be changed by manipulating the knobs in the group labeled ***Vertical***. As you noticed there are two knobs to change the y-axis each referring to the y-axis of the 1st or the 2nd channel. The scales of the 1st and 2nd channel can be set independently of one another. The units of the volt/div are also displayed on the strip at the upper edge of the screen.

3.3 Frequency And Period Measurement Using The Counter:

Because of the inaccuracy of the oscillator frequency knobs of the function generator, it is essential to obtain the exact frequency or period of the signal generated. The counter or the digital oscilloscope can be used for this purpose. Start by using the counter first.

- On the counter, set the function knobs to either “Freq to 10 MHz” or “Freq to 100 MHz”, and set the Time/Avgs to any of the four Time/Avgs positions. Set ATTEN to X1.
- With the signal frequency = 1KHz as indicated by the settings on the function generator, connect the output of the function generator to the input of the counter-timer.
- Have the “Display Update” on Run. If no value is showing in the counter, move the “Trigger Level” knob on the counter so a reading is available. Push the Reset button if a new run is needed.
- If the frequency of the signals is 1 KHz, the counter should indicate a reading of 1.00 KHz. If not, adjust the oscillator frequency dial on the function generator so 1.00 KHz is indicated on the counter. In this case, the frequency of the signal is 1 KHz.
- To measure the period of the signal, move the function knobs on the counter to “Period”, the counter should indicate a value of 1000 μ s.

The counter or the digital oscilloscope should be used in all experiments where a frequency or a period reading is required, in order to obtain a correct and accurate result.

3.4 Frequency And Period Measurement Using The Scope:

The oscilloscope can also be used to read the period, the frequency and the voltage level of a signal.

- Connect the input of Channel 1 of the oscilloscope with the output of the function generator. (Keep the same setup on the function generator as for the last measurement.)
- Press the **Auto Scale** key to display the waveform. If you are not happy with the scale (either the time or voltage scale) use the knobs in the *Horizontal* and *Vertical* group to accurately view the waveform.
- Press the **Quick Measure** key to display the automatic measurement menu.
- Press the **Source** soft key (below the screen) to select channel 1 input.
- Press the soft key on the right of the **Source** soft key. A number of options will be displayed, scroll down or use the entry knob to select either period or frequency.
- Record the value of either.

3.5 Voltage Measurement:

- Repeat steps a – d from the previous section. In step (e) however instead of choosing period select V peak to peak and V RMS from the menu. Record the voltages and explain if they are consistent. We will learn in the class what RMS value means. In fact, RMS stands for Root Mean Square value. If $x(t)$ is a periodic signal with period T, then

the RMS value of $x(t)$ is $\sqrt{\frac{1}{T} \int_{t_o}^{t_o+T} x^2(t) dt}$ where t_o is any appropriate value

including 0 and $-T/2$ which are commonly used. The RMS value of a balanced sinusoidal wave signal with peak amplitude A is $\frac{A}{\sqrt{2}}$. The RMS value of a

balanced square wave signal with amplitude A is A itself. The RMS value of a balanced triangular wave signal with amplitude A is $\frac{A}{\sqrt{3}}$.

- b) Adjust the amplitude of the sine wave in the function generator so that its peak to peak voltage is about 6V. Read and record the output of the Digital Volt Meter (DVM). Then also use the oscilloscope to measure the voltage. Which measurement agrees with the DMV? The RMS or the peak-to-peak?
- c) Switch to square wave. Adjust the waveform so that its peak-to-peak voltage on the oscilloscope is 6V. Read and record the output of the DVM. Also use the oscilloscope to measure its peak-to-peak and RMS voltage. Are they consistent?
- d) Switch to triangular wave. Adjust the waveform in the oscilloscope so that its peak-to-peak voltage is 6V. Read and record the output of the DVM. Also use the oscilloscope to measure its peak-to-peak and RMS voltage. Are they consistent?

3.6 Impedance:

Impedance is a concept that is used in the s-domain or the phasor ($j\omega$) domain about which you will learn later on. It is not essential for students to know about the s-domain circuit analysis at this stage. It is enough to know that s-domain representations are obtained by applying the Laplace transform to the time-domain equations. And that the variable s is a complex number whose real part is zero and whose imaginary part is $j\omega$ for sinusoidal signals. In the $j\omega$ domain (i.e, when s is set to equal $j\omega$), impedance is, in general, a complex number. A complex number is represented in rectangular form as $Z=X+jY$ (where $j^2=-1$) and in polar form as $Z = M \angle \phi$ (where M is the magnitude and ϕ is the phase angle). Magnitude is usually represented as the modulus of a complex number ($|Z|$).

You will learn, in detail, about impedance later on in the course. Roughly stated, impedance is the ratio of a voltage function to the current function across a circuit element (again, in s-domain or $j\omega$ -domain) with all initial conditions set to zero. It is a complex number. For a resistor the i-v relationship is $V = IR$ and hence its impedance is

$Z_R = \frac{V}{I} = R$, i.e, a real number for a simple resistance. For a capacitor the i-v

relationship is: $i_c(t) = C \frac{d[v_c(t)]}{dt}$. The time derivative implies that the current is zero

(open-circuit) when the voltage across the capacitor is constant and vice-versa. The

impedance of a capacitor is given by $Z_C = \frac{V_c(s)}{I_c(s)} = \frac{1}{Cs}$ (this is the s-domain

representation of the time domain representation given above). So the impedance of a capacitor is the reciprocal of capacitance (a constant) times the variable s (For sinusoidal signals, $s = j\omega$ where ω is the angular frequency $2\pi f$, represented in radians/ seconds at

which the input voltage varies. So $Z_C = \frac{1}{j\omega C}$ and its magnitude is given by $|Z_C| = \frac{1}{\omega C}$.

Similarly, the impedance of an inductor is given by $Z_L = j\omega L$ while the magnitude of the impedance is given by $|Z_L| = \omega L$.

3.7 Decoupling:

The scope electrically looks like a $1\text{ M}\Omega$ resistance shunted by a 14 pF capacitor. Comparing $\frac{1}{\omega C}$ to R , we realize that the capacitance has a negligible effect as long as ω is small enough to make $\frac{1}{\omega C} \gg R$. This is true below the frequency of about 1 kHz . Therefore, the input looks like a simple $1\text{ M}\Omega$ resistance at low frequencies.

One often wants to take a close look at an AC signal that is superimposed on a relatively large DC voltage. If you use the sensitivity you would need to accurately display the AC component, the image will likely be driven off the screen by the DC voltage. Or perhaps the DC voltage is not so large but it is a nuisance because it shifts the image up or down as it changes value.

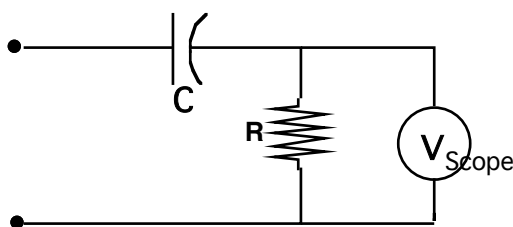


Fig. 1 DC Decoupler

These problems can be circumvented mostly by connecting a so-called **decoupling capacitor** in series with the input. The input now looks at an RC series circuit, shown in Fig1. with the scope seeing only the voltage across R . If there is a DC component in the signal, the decoupling capacitor quickly charges up to that DC value. In other words the capacitor is a simple open circuit for the DC components and has finite impedance for AC components. So, the DC component of the source contributes no current and the voltage at R depends only on the AC signal.

However, there is a penalty to pay for introducing another capacitor to the circuit when choosing AC coupling. As the frequency is decreased, a larger fraction of the AC signals appears across C and the voltage value at R is less than the actual input (voltage divider). It can be shown that when $\frac{1}{\omega C} = R$, $|V_R|$ will be only 0.707 of the signals at the input terminals. This is called the half-power point (also the -3 dB point).

- Switch generator to sine wave. Press the autoscale button. Adjust the output for 3 volts peak (in other words 6 volts peak-to-peak). Set the frequency multiplier to 1 in your function generator. With the coupling soft key choose AC, reduce the frequency on the dial until the picture on the screen indicates a peak to peak voltage of 4.24 (6×0.707). This is the half-power point and should occur at a few Hz.
- With the soft keys change the coupling to DC on Ch1. and notice that, since now the decoupling capacitor is shorted, there is no loss of signal voltage to the capacitor. Record the peak to peak value of the sine wave.
- Change the DC offset from the function generator until the waveform is off the screen.

The following principle specifications should be kept in mind:

The upper frequency limit is 20 MHz

The input impedance is $(1\text{ M}\Omega // 14\text{ pF})$

Max input voltage is $(300\text{ V DC} + \text{AC peak at } 1\text{ kHz})$

Max sensitivity is (1 mV/div)

4- REPORT:

- 4.1 Assume that the peaks of a sine wave are exactly 3 time divisions apart. Calculate the period of the waveform for three time/div values: 0.1 ms, 0.2ms, and 0.5ms.
- 4.2 Use the appropriate equation to comment on the consistency between the DVM and Oscilloscope measurements and on the other questions posed in Sections 3.5b, 3.5c, and 3.5d.
- 4.3 If the output of the function generator for a sinusoidal waveform is 6 voltage divisions peak to peak and the voltmeter reads 2.12V, find the volts/div scale that is being used. If the frequency is 1KHz and the peaks are 5 horizontal divisions apart, find the sensitivity (ms/div) that is being used.
- 4.4 Use PSPICE or MULTISIM to graph the following waveforms in the interval of $0 < t < 0.05$ s:
- $v = (5 \times 10^5)t$ V
 - $i = 5e^{-100t}$ A
 - $v = 3 \sin(5t)$ V
 - $i = 10[u(t) - u(t-0.01s)]$ A
 - $v = -12u(t) + 10[u(t-0.001)]$ V
- 4.5 Use the Bias Point Analysis command to find V_1 in fig. 2 if V_s is increased from 10 V to 20 V in 2 V increments.

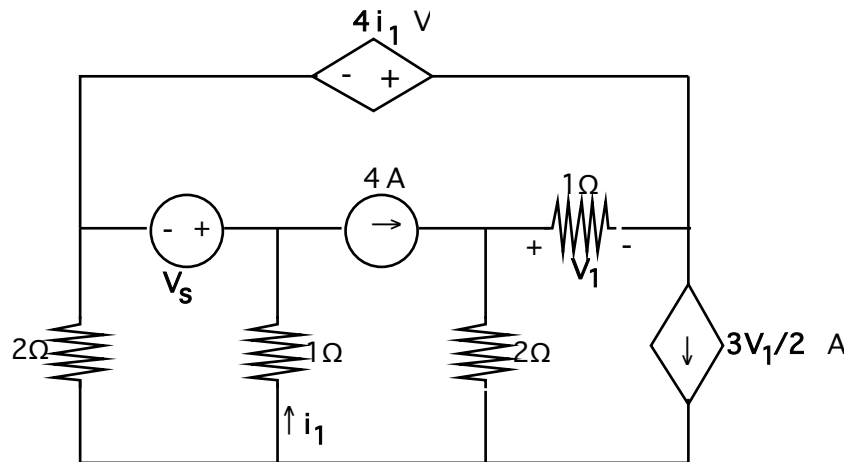


Fig. 2

- 4.6** Consider the R-C circuit in Fig.1 without the presence of the scope. Let $R = 1K\Omega$ and $C = 1mF$. Also, let the initial voltage across the capacitor be zero. The input to the circuit is a pulse voltage with the parameters as given below. Use PSPICE or MULTISIM transient analysis to simulate the voltage across the resistor from 0 to 20 sec with an increment of 1 sec.

The parameters of the pulse source

($V_s = V_{\text{pulse}}$) are:

$V_{\text{min}} = 0V$

$V_{\text{max}} = 15V$

Delay Time $T_D = 1\text{sec}$

Rising Time $T_R = 2\text{sec}$

Peak Width $PW = 3\text{sec}$

Falling Time $T_F = 2\text{sec}$

Period $PER = 10\text{sec}$

- 4.7** Prepare a summary

Some new function generators and oscilloscopes may not exactly conform to the description given here. However, they are user friendly. Your lab instructor will explain them.

