

6.2.1: Time-varying Signals

Overview:

This assignment will focus on using an arbitrary waveform generator to generate time-varying signals and using an oscilloscope to measure time varying signals.

In chapter 6 of the text book, we deal analytically only with step functions and exponential functions. This lab will, however introduce us to a larger class of time-varying waveforms.

The ability to apply and measure time varying signals will be crucial throughout the remainder of your career. It is strongly recommended that you not only complete the specific steps outlined in this assignment, but that you spend some additional time “playing with” the tools we introduce in this assignment – it is guaranteed to be time well spent!

Before beginning this lab, you should be able to:

- Define a step function.
- State Ohm’s law for time-varying signals

After completing this lab, you should be able to:

- Use a switch to create a step function
- Use the Analog Discovery waveform generator to apply square, triangular, and sinusoidal waveforms
- Use the Analog Discovery oscilloscope to measure and display time-varying waveforms

This lab exercise requires:

- Analog Discovery module
- Diligent Analog Parts Kit

Symbol Key:

	Demonstrate circuit operation to teaching assistant; teaching assistant should initial lab notebook and grade sheet, indicating that circuit operation is acceptable.
	Analysis; include principle results of analysis in laboratory report.
	Numerical simulation (using PSPICE or MATLAB as indicated); include results of MATLAB numerical analysis and/or simulation in laboratory report.
	Record data in your lab notebook.

General Discussion:

Once we begin to deal in earnest with systems which include energy storage elements, it will be crucial apply time-varying power to our electrical circuits and measure the circuits' responses as functions of time. This lab introduces the concepts necessary for application, measurement, and interpretation of time-varying signals.

Since we have not yet been introduced to dynamic systems, the electrical circuit of interest in this assignment will be the voltage divider shown in Figure 1.

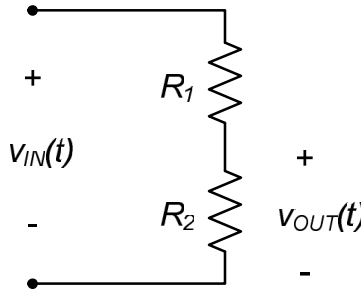


Figure 1. Voltage divider circuit.

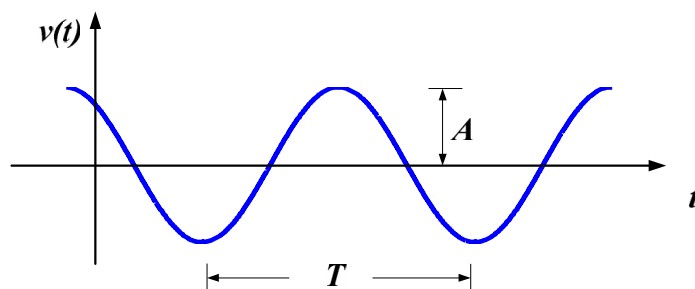
In Figure 1, the output voltage, $v_{OUT}(t)$ is related to the input voltage $v_{IN}(t)$ via the voltage divider relation:

$$v_{OUT}(t) = v_{IN}(t) \frac{R_2}{R_1 + R_2} \quad (1)$$

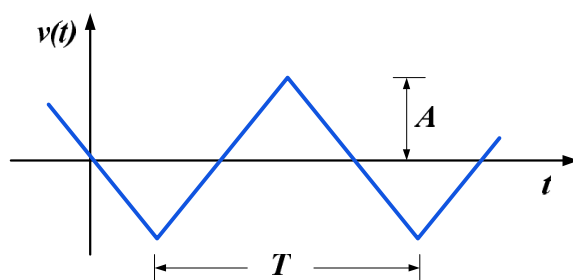
Notice that the relationship between $v_{IN}(t)$ and $v_{OUT}(t)$ is *algebraic* – the value of v_{OUT} at a particular time depends only upon the value of v_{IN} at that same time.

In order to familiarize ourselves with the fundamentals of applying and measuring time-varying signals, we will restrict ourselves to some of the most common signals encountered in engineering applications: sinusoidal waves, square waves, and triangular waves. The basic shapes of these signals are shown in Figure 2. The signals of Figure 2 are all *periodic* signals – that is, they repeat themselves at regular intervals. This interval is called the *period* (commonly denoted mathematically as T). The period of each of the signals of interest to us is indicated on Figure 2. The other primary attribute of the signals we will be dealing with is their amplitude (which we will denote as A). The amplitude of the signal is essentially the maximum (and minimum) value that the signal achieves¹.

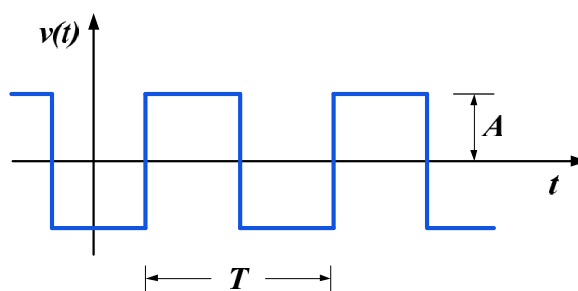
¹ For now, our signals will be symmetric with respect to the time axis. That is, their average value (also called the *offset*) will be zero. For the signals of immediate interest to us, this means that their minimum value will be the negative of their maximum value. Later labs will explore the effects of a non-zero offset to the signal, and signals which are not symmetric with respect to the time axis.



(a) Sinusoidal wave.



(b) Triangular wave



(c) Square wave

Figure 2. Basic signal shapes.

Although we have used the signals period as a fundamental parameter defining the signal, it is more common for electrical instruments to use the *frequency* of the signal as a defining characteristic. The frequency provides essentially the same information as the period; the frequency is just the inverse of the period:

$$f = \frac{1}{T} \quad (2)$$

As defined in equation (2), the units of frequency are in Hertz (abbreviated Hz) or cycles per second. Sinusoidal signals, however, are more accurately defined mathematically in terms of their *radian frequency*, denoted as ω . Since there are 2π radians in one cycle, the conversion between frequency and radian frequency is:

$$\omega = 2\pi f = \frac{2\pi}{T} \quad (3)$$

Mathematically, the sinusoidal wave of Figure 2(a) can be represented as:

$$v(t) = A \cos(\omega t + \theta) = A \cos(2\pi f t + \theta) \quad (4)$$

Where θ is the *phase angle* of the signal; it translates the sinusoid in time. We will concern ourselves with phase later in the course.

Pre-lab:

In the circuit of Figure 1, if $R_1 = R_2$, overlay sketches using the input and output voltages ($v_{IN}(t)$ and $v_{OUT}(t)$) for the following cases:

ANALYSIS

(a) $v_{IN}(t)$ is a sinusoidal wave with amplitude A and period T .

ANALYSIS

(b) $v_{IN}(t)$ is a triangular wave with amplitude A and period T .

ANALYSIS

(c) $v_{IN}(t)$ is a square wave with amplitude A and period T .

Label the amplitude and period of both the input and output waveforms on your sketch. These values may be functions of A , T , R_1 and R_2 .

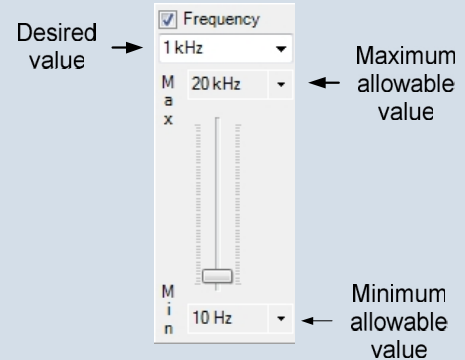
Lab Procedures:

- (a) Test the response of the circuit to a sinusoidal input voltage with 2kHz frequency and 2V amplitude. Details are below:
 - i. Set $v_{IN}(t)$ in the circuit of Figure 1 to be a sinusoidal voltage with amplitude 2V and frequency 1kHz across the voltage divider. The average value of the sinusoid should be zero volts. To do this, open the *WaveGen* instrument in the waveforms file. Click on the **Basic** tab (if it is not already selected) and then click on the **Standard** option. There should be a series of icons in a column below this option, indicating the shape of the associated waveform. Click on the  icon to select a sinusoidal waveform. Choose 1kHz as the frequency (you can choose the desired frequency by selecting it from the drop-down menu, typing the desired value in the text box, or using the slider bar) and 2V as the amplitude². The plot window on the waveform generator instrument will display one period the waveform you have set. Use this plot window to double check that your signal has the correct frequency and amplitude.

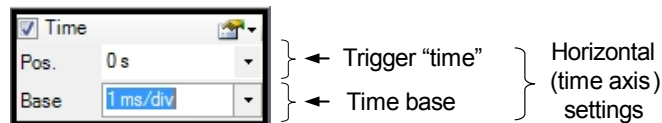
² The offset should be zero, the symmetry 50%, and the phase 0 degrees. These are the default values, and should not need to be re-set.

Note on selecting parameters:

When choosing parameters describing signals (e.g. frequency, amplitude, offset, and symmetry) the allowable values are limited to the range specified by the values above and below the slider bar, as indicated on the figure to the right for the frequency parameter. When selecting a value, the desired value must be between the maximum and minimum values shown. If you want a value outside the displayed range, simply re-set the range using the appropriate drop-down menus. If the waveform generator will not let you set a desired value, be sure to check that the desired value is within the allowable range.

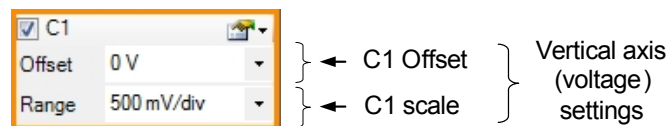


- ii. Use the oscilloscope to display the voltages $v_{IN}(t)$ and $v_{OUT}(t)$ of Figure 1. To do this, open the *Scope* instrument. Set the horizontal scale (or the time axis scale) to be 1msec/div. Horizontal axis settings are set in the time axis settings box on the oscilloscope window; this box and the desired settings for this lab are shown below:



Set the vertical axis settings on both channel 1 and channel 2 (C1 and C2) to 500mv/div.

Vertical axis settings are set in the channel axis settings boxes on the oscilloscope window; the settings box for channel 1 and its desired settings are shown below. Use the same settings for channel 2.



DATA

Click on  to acquire and display the data. Record an image of the oscilloscope main time window to a file for later documentation.

- iii. From the time plots displayed in the oscilloscope window, determine the period and amplitude of $v_{IN}(t)$ and $v_{OUT}(t)$. From your measured period, calculate the signal's frequency in Hertz. Create a table, showing the expected amplitude and frequency of $v_{IN}(t)$ and $v_{OUT}(t)$ and your measured amplitude and frequency of $v_{IN}(t)$ and $v_{OUT}(t)$.

DATA

ANALYSIS

DEMO

ANALYSIS

DEMO

DEMO

- iv. Click on the  **Measure** button on the oscilloscope window to open a measurements window. Use the measurement window to measure the amplitude, period, and frequency of $v_{IN}(t)$ and $v_{OUT}(t)$. Record the image of the oscilloscope window, showing the waveforms and their measured amplitudes, periods, and frequencies³. Comment on the agreement between the oscilloscope's measurements and the measurements you made in part iii above.
 - v. Demonstrate operation of your circuit to the Teaching Assistant. Have the TA initial the appropriate page(s) of your lab notebook and the lab checklist.
 - vi. Vary the amplitude and frequency of the sinusoidal waveform using the waveform generator. Change the horizontal and vertical axis scales in the oscilloscope. Verify that the changes result in data that agree with your expectations. Familiarizing yourself with these instruments now will be rewarded in later experiments – you can only interpret the results of future experiments if you are comfortable with measuring the data upon which the results depend!
- (b) Test the response of the circuit to a triangular input voltage with 1kHz frequency and 3V amplitude.
- i. Perform all the steps you did above for the sinusoidal input.
 - ii. Demonstrate operation of your circuit to the Teaching Assistant. Have the TA initial the appropriate page(s) of your lab notebook and the lab checklist.
- (c) Test the response of the circuit to a square wave input voltage with 500Hz frequency and 2.5V amplitude.
- i. Perform all the steps you did above for the sinusoidal input.
 - ii. Demonstrate operation of your circuit to the Teaching Assistant. Have the TA initial the appropriate page(s) of your lab notebook and the lab checklist.

³ Holding down the “Alt” key and pressing “Print Screen” (commonly labeled as “PrtScn” or “PrtSc” on computer keyboards) will copy the currently active window to the clipboard. You can then paste this image to a document. The  **Export** button on the oscilloscope instrument allows you to copy an image of the main time window to the clipboard or save it to a file in a variety of formats. This option will not, however, display the measurement window – if you use this approach, you will want to record the measured values elsewhere.