

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
22.071/6.071 Introduction to Electronics, Signals and Measurement
Spring 2006

Lab2. Introduction to signals.

Goals for this Lab:

Further explore the lab hardware. The oscilloscope

Measure time varying signals

Explore time domain and frequency domain representation of signals

Explore noise and signal to noise characteristics

Practice complex arithmetic.

Explore the sound of a piano note. Listen to the sound, look at the time domain representation of it. Explore its frequency content. This will be a great motivation for the next lesson on Fourier transforms and Fourier series.

Exercise 1.

Before we begin with the experimentation part of the lab let's do a bit of complex algebra on order to recall some of the fundamentals.

- Determine the phase of the complex numbers

- $c = 1 + j$

- $d = -j$

- $a = \frac{2 + j}{1 - j}$

Exercise 2. Graph the following function $(-j) \frac{e^{j4\pi t} - e^{-j4\pi t}}{2}$

Exercise 3. The oscilloscope: Measure time varying signals.

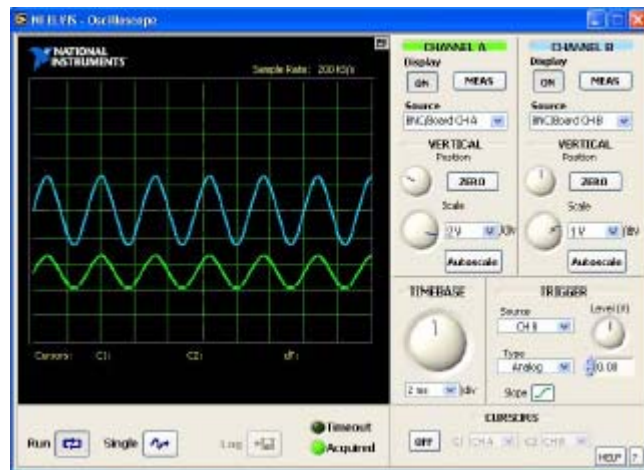
We will use the oscilloscope feature of our software. Upon initialization, the following appears on your screen.



Courtesy of National Instruments. Used with permission.

Once started, the oscilloscope screen looks like the example shown here ⇒

The oscilloscope is basically a graph displaying apparatus and it represents an electrical signal such as voltage as a function of time.



Courtesy of National Instruments. Used with permission.

Our oscilloscope has two channels and the ability to perform the basic functions of Triggering and scaling both in the vertical and the horizontal axes. In the laboratory environment one usually finds oscilloscopes that perform a variety of specialized functions including various mathematical operations on signals. The features of our scope corresponds to the most basic and important characteristics of these instruments.

For our first experiment with the scope we will measure the various signals from the function generator.

Start by setting the function generator to manual mode and generate a sinusoidal signal with a frequency of 1 kHz. Measure that signal on CHANNEL A of your scope. Adjust the TIMEBASE until you see the signal.

Your signal at this point may be drifting along the horizontal axis at an annoying rate. This is because the specified time base on the scope does not match perfectly with the frequency of signal. In order to correct this problem and thus provide a stable trace of the signal we must use the TRIGGER feature of our scope.

TRIGGER synchronizes the tracing of the signal on the screen with a specified event. The event may be provided externally by some other well defined signal or it may be associated with a certain characteristic of the signal under investigation. For example the trigger event may be the raising or the falling edge of a pulse or it might be the zero crossing of the signal in the positive or negative direction.

Naturally the best way to learn how this actually works is to try it. Look at the TRIGGER menu and along with the “Slope” and “Type” option try to stop the drift of your 1 kHz signal.

Change the frequency and see what happens.

What is the highest frequency that you can measure with your scope? (see specifications)

Now that you have a steady signal that you can read, adjust the amplitude of your sinusoidal signal until you have a signal with an amplitude of 2 Volts.

Now turn on CHANNEL B and use it to measure a DC signal from the Variable Power Supply.

Try to trigger your scope for a specific voltage value.

Exercise 4.

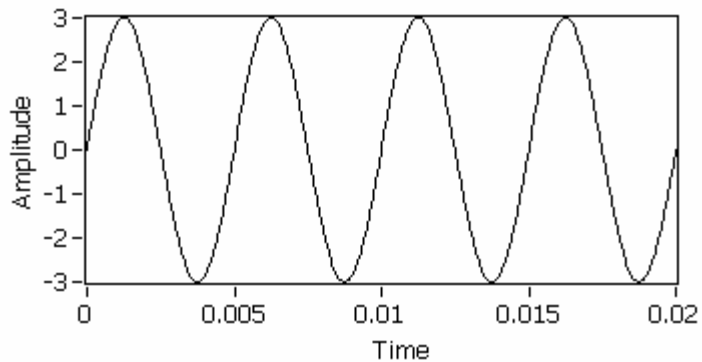
As we just learned in class, the RMS value of a periodic signal is related to the energy content of the signal. For sinusoidal signals the RMS value is $\frac{1}{\sqrt{2}}$ of the amplitude. For other periodic signals ($X(t)$) we calculate the RMS value by performing the integration

$$X_{RMS} = \sqrt{\frac{1}{T} \int_0^T X^2(t) dt} .$$

Consider the sinusoidal signal shown here on the right with an RMS value of $\frac{3}{\sqrt{2}}$.

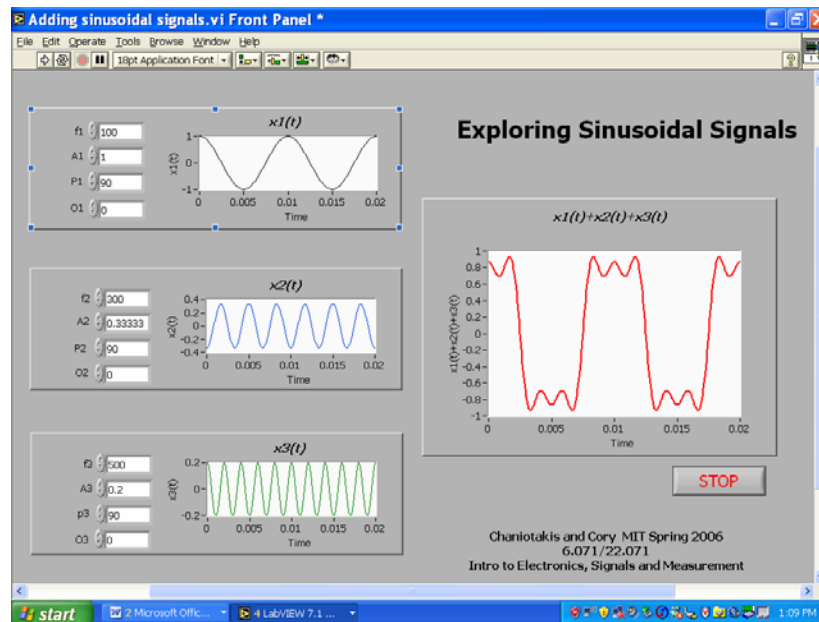
Construct periodic square wave signals that vary between 0 and 5 and have the following RMS values:

1. $\frac{3}{\sqrt{2}}$
2. $\frac{30}{\sqrt{2}}$
3. $\frac{-10}{\sqrt{2}}$



Exercise 5. Exploring Sinusoidal Signals

For this exercise we will use a simulation based on LabView. The program called “Adding Sinusoidal Signals” may be downloaded from the class web site it is located in the Material section. Start the program by double clicking on the icon of the downloaded file. To start the simulation click on the right going arrow on the upper left hand corner of the virtual instrument. To stop the simulation click on the STOP button on the lower right hand corner of the instrument.



Courtesy of National Instruments. Used with permission.

The signals $x_1(t)$, $x_2(t)$ and $x_3(t)$ are added together resulting in the signal displayed on the right.

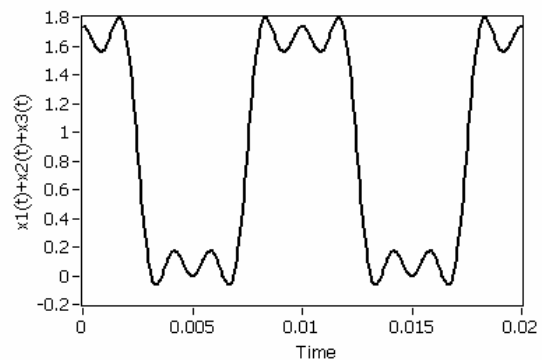
Notice the resulting signal obtained with the default parameters. What does it remind you of?

We will see starting next time that the three default sinusoidal signals represent the first three harmonics of the Fourier series expansion of a square wave signal.

Feel free to play around. Change the various parameters of the signals and observe the effect.

Determine the values of the various signal parameters in order to obtain the signal shown here \Rightarrow

f1=	f2=	f3=
A1=	A2=	A3=
P1=	P2=	P3=
O1=	O2=	O3=



Exercise 6. Here we will explore the frequency domain representation of signals.

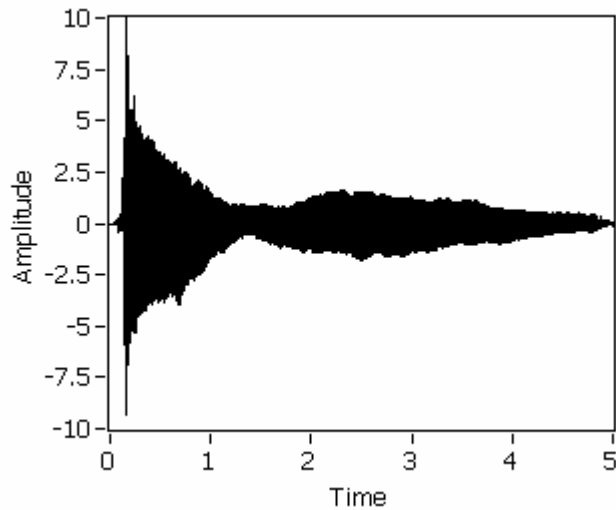
Answer the following questions:

Determine the value - in Hz - and the number of frequencies contained in the following signals.

1. $\sin(6\pi t)$
2. $\sin(6\pi t) + 2\cos(10\pi t)$
3. $\sin^2(\pi t)$

Exercise 7. Listen and Look at Sound.

For this exercise we will use an actual recorded music note from a piano. The note is the middle C which has a well known frequency of 261 Hz. A plot of the voltage coming out of the microphone that made the recording is shown on the plot to the right.



It looks interesting but what does it really tell us about the sound.

Make and record below your own observation of this signal by looking at this plot.

- 1.
- 2.
- 3.

What can you say about the frequency content of this signal?

The musicians in the group know already that the note coming out of a musical instrument contains a number of frequencies besides the main frequency. Where do these additional frequencies come from? What is their value?

At this point we do not know how to answer these questions but at least we are asking them which, for engineering which is a field of discovery and innovation, is the most fundamental step.

We will explore the frequency content (or the spectral characteristics) of the signal by using a simple instrument created for you by the class staff. This instrument will give us the opportunity to **hear** and **see** the characteristics of the signal corresponding to the middle C note.

You may download the program that runs this instrument from the Labs section under the Materials section. The program is called Sound_Signal.vi and the file containing the piano signal is called Pianoc.wav. Place both of these files on your desk top and prepare to run the program by double clicking on the Sound_Signal icon.

For the last step we will connect a speaker to our protoboard at the pin labeled DAC0. Connect the other lead of the speaker to ground.

Turn on the power on your protoboard and start the instrument. The following should now appear on your screen:

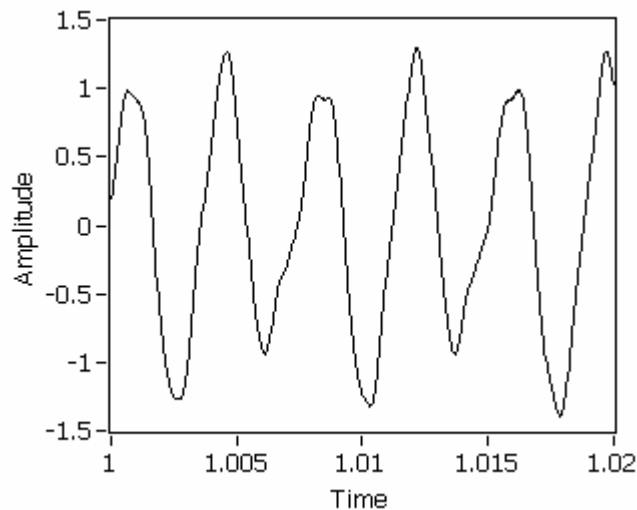


Courtesy of National Instruments. Used with permission.

The plot on the right side of the instrument front panel shows the frequency characteristics of your piano note. What do you observe?

- 1.
- 2.
- 3.

If we now look a bit closer at the signal we observe some very interesting details. Let's look at a 20 msec time interval between 1.00 sec and 1.02 sec. The signal in that part looks like:



What do you think the frequency content of this signal is?

Can you see the middle C frequency of the piano?

Could you use 3 sinusoidal signals of various amplitudes and frequencies to represent this signal?