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.

$\sin(t+2\pi) = \sin(t)$
$\cos(t+2\pi) = \cos(t)$
$\tan(t+\pi) = \tan(t)$

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

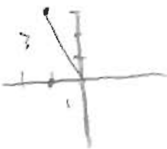
$\dfrac{\frac{a+bj}{c+dj}}{\phi = -\left[\tan^{-1}\left(\frac{b}{a}\right) - \tan^{-1}\left(\frac{d}{c}\right)\right]}$

  - $c = 1 + j$

$\phi = 45^\circ$ or $\frac{\pi}{4}{}^r$

  - $d = -j$

$\phi = \frac{3\pi}{2}{}^r$



  - $a = \dfrac{2+j}{1-j} = \dfrac{(2+j)(1+j)}{(1-j)(1+j)} = \dfrac{2-1+3j}{2} = -\frac{1}{2} + \frac{3}{2}j \Rightarrow \phi = \frac{\pi}{2} + \tan^{-1}\left(\frac{1}{3}\right)$
$= 1.89^r$

-- or -- $\phi = -\left[\tan^{-1}\left(\frac{1}{2}\right) - \tan(-1) + \pi\right] = 1.89^r$

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

$e^{jt} = \cos(t) + \sin(t) \cdot j$

$= \frac{-j}{2}\left[\cos(4\pi t) + j\sin(4\pi t) - \cos(4\pi t) - j\sin(4\pi t)\right]$

$= -j \cdot j\sin(4\pi t) = \sin(4\pi t)$

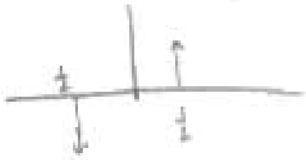
Exercise 6. Here we will explore the frequency domain representation of signals.

Answer the following questions:

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

1. $\sin(6\pi t)$ 3 Hz
2. $\sin(6\pi t) + 2\cos(10\pi t)$ 3 Hz, 5 Hz
3. $\sin^2(\pi t)$ 1 Hz

fft sin(πt)



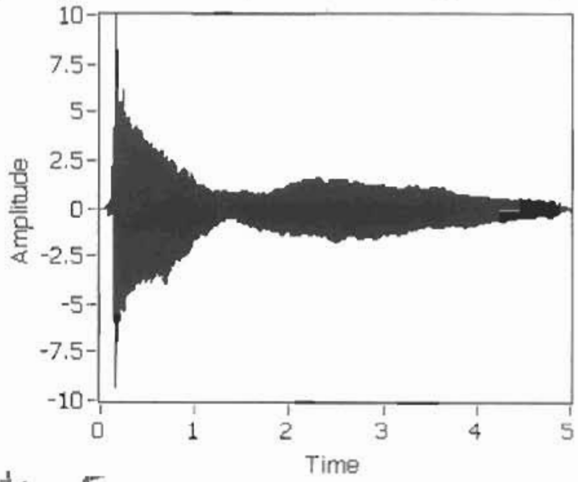
In freq. domain, multiplication $\Leftrightarrow$ convolution

fft{sin(πt)} $\circledast$ fft{sin(πt)}

one frequency only

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. Fundamental (lowest) freq at 261 Hz.
2. Other frequency components at multiples of 261 Hz
3. There is a pattern to scaling the magnitude of each freq. component.

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

Contains mainly a 261 Hz component but has other frequency components (multiples of 261 Hz) as well.

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.

The instrument does not just produce a sine wave — that is how instruments differ!