

# **EECE 2150 - Circuits and Signals: Biomedical Applications**

## **Lab 4, Basics of Signals: Frequency**

### **INTRODUCTION:**

In this lab we will begin exploring signals. In electrical and computer engineering signals are most often voltages or currents, but they might also be sound (pressure), force, position, temperature, power, light intensity, chemical concentration, stress or any number of other variables. Electrical engineers use many kinds of sensors and transducers to convert signals from other domains to voltage and current or from voltage and current to other domains. The first part of the lab asks you to experiment with the oscilloscope that you can use to view signals that vary rapidly in time. You will use the oscilloscope to look at the shape, amplitude, and period of some typical signal waveforms as a function of time (or in the time domain, as ECEs sometimes say). You will also experiment with how these signals sound.

Next, you will continue to use Orcad Capture to analyze circuits. You will be looking at a circuit with a periodic, time varying signal, rather than at a dc circuit. You will do a Fourier analysis in Orcad Capture, which will give you the frequency components making up the periodic signal.

In a future lab you will use MATLAB to generate sounds and explore the frequency content of sounds you record.

## PART I - FREQUENCY

1. In this part of the experiment you will use a function generator (sometimes called a waveform generator) to drive an audio speaker. The waveform generator that is on your workbench can produce a sinusoidal waveform, a square wave or a ramp wave.

a. First, set the function generator to produce a sinusoidal signal at a frequency of  $600\text{ Hz}$  with a  $0.10$  volt peak-to-peak amplitude. Make sure the function generator is set to High Z mode. To set it to the high Z mode, press the function key 'Utility', then press the soft key, 'Output Setup', then toggle the left soft key to change to High Z mode. Observe the function generator output waveform on the oscilloscope by connecting them using a BNC cable. Determine the frequency of the waveform using the oscilloscope. How well do the oscilloscope and the signal generator agree? Q1: What settings should you use for the time per division, the voltage per division, and the sync parameters (mode, source, slope).

b. Use the BNC "T" to connect the function generator output signal to both the oscilloscope and to the input of the computer speaker (figure out which part of the plug to connect it to!). You can also use the speaker provided in your cables/connectors box. What happens when you change the amplitude of the signal coming from the signal generator? What happens when you change the frequency of the signal coming from the signal generator?

2. Determine the upper and lower frequency limits of the speaker/human ear system. What is the highest frequency that you can hear? Do all members of your team have comparable low and high frequency limits on what they can hear? The commonly quoted limits of human hearing are  $20\text{ Hz}$  to  $20\text{ kHz}$ . Can you get close to those values? If not, any idea why not? How does the apparent loudness of the sound change as you change frequencies? Which frequencies sound loudest? Why do you think this is? Are your results explained entirely by the sensitivity of the human ear, or does the speaker have something to do with it?

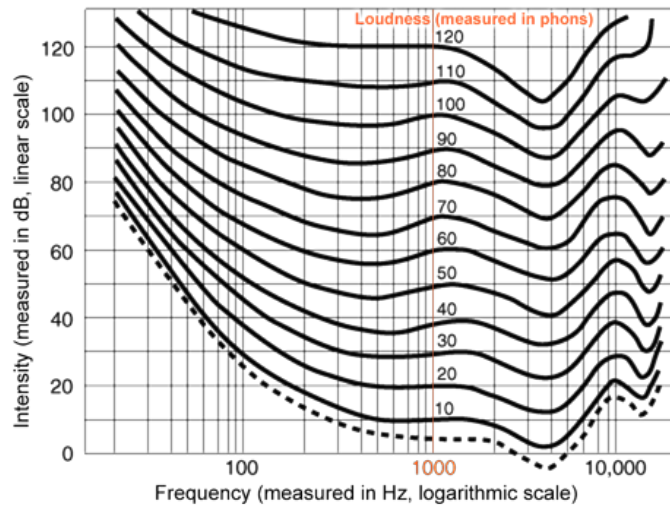


Figure 1. Human hearing sensitivity. This is a plot of the sound intensity required to reach a given perceived loudness as a function of frequency. This is known as the Fletcher-Munson curve.

3. For this part, you will work with another group at a nearby work bench. Have one team drive a speaker with a sinusoidal waveform at a frequency between  $500\text{ Hz}$  and  $2\text{ kHz}$ . Without knowing the frequency, the second group should try to match its frequency to the first group's frequency by ear. How closely can you match up the tones using your ears? Record your quantitative results, that is, how close you got to matching frequencies, and describe how you got the frequency match as close as you could.

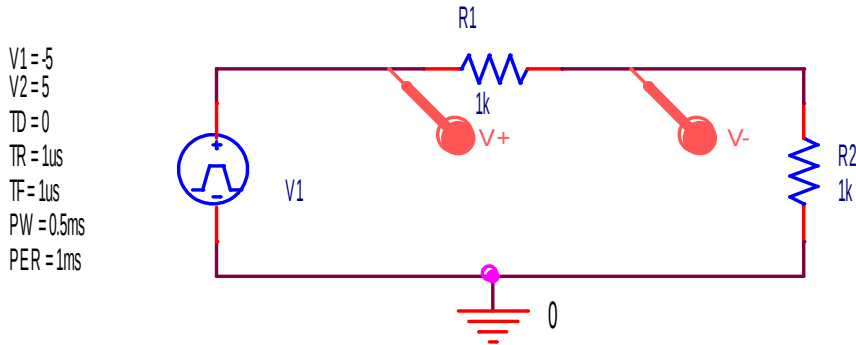
6. Change the frequency back to  $600\text{ Hz}$ . Compare the sounds emitted by your speaker when the driving signal with a sine wave versus a square wave versus a ramp wave. Describe how the waveforms sound different in addition to whether they sound louder or softer. Why do the waveforms sound different? Discuss this with the instructors.

7. Repeat 6 at  $6\text{ kHz}$ . What differences do you hear this time? Why is this result different? (There is an EE/Bio explanation!!). Again discuss with your classmates and instructors.

8. Set the signal generator to  $60\text{ Hz}$  and set the scope sync source to "line." Can you adjust the signal generator to stop the trace? Discuss what you learn from this.

## PART 2, PSpICE, TRANSIENT AND FOURIER ANALYSIS

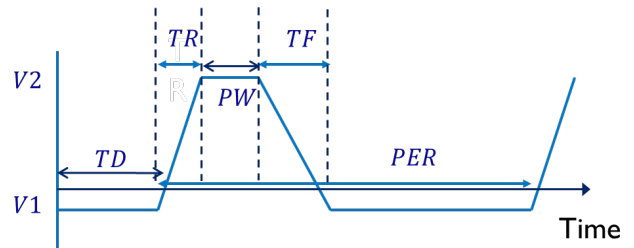
1. Build the following circuit. Use a VPULSE source found in the



source library.

2. Do a transient analysis. The voltage across  $R_1$  as a function of time should be plotted if you use the differential voltage probes as above.

Use a frequency of  $1000\text{ Hz}$  (period  $1\text{ ms}$ ). The analysis time for 5 cycles of the input waveform is  $5\text{ ms}$ . When you are looking at the plot, click the FFT button to view the frequency components of the signal. Remember that any periodic signal other than a sine wave has frequencies at multiples of the fundamental frequency. The FFT (or



V1	Voltage level at the start of the pulse
V2	Voltage level at the peak of the pulse
TD	Time delay before the start of the pulse
TR	Pulse rise time

fast Fourier transform) takes the signal in the simulation and shows you what frequency components are present (you hear these when listening to a square wave vs a sine wave, for example).

Take a screen shot of the plot

so that you can compare it with what you get in step 3. Hit the FFT button again to go back to the time-domain view of the signal.

3. Repeat the analysis after changing the pulse width (PW) to  $0.05\text{ ms}$ . What is different in the frequency components plot?

4. Change the source to a sinusoid at the same frequency and repeat. Use VSIN as the source with a  $5\text{ V}$  amplitude and set  $AC=0$ .

5. Think about and discuss what all this means!! Discuss how this corresponds to what you heard in the lab. You will learn more about this in this course and over the next few years!!!!

6. If you have time, Change  $R_1$  to a 1 microFarad capacitor and repeat #2 above, with the square wave source. Compare the Fourier components of the source voltage and the voltage across the capacitor.

**IMPORTANT: BEFORE YOU LEAVE THE LAB:**

- a. Turn off all of the equipment you have used on your workbench.
- b. Make sure you return your protoboard, the equipment wires and your reusable container to the front window.
- c. Make sure to have your notebook signed by an instructor before you leave the lab.

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