**ENGN/PHYS 207—Fall 2018**
**Assignment #3**
**Lab work must be completed by 5pm Wed Oct 10.**
**Final Report Due Date: 5pm Wed Oct 17, 2018**

## Circuits You'll Build

1. RC high pass filter (1-stage) for audio/speech applications
2. 2nd-order RC high pass filter
3. Bandpass filter for biomedical applications
4. Audio volume control

## Lab Skills You'll Learn

1. Designing and building passive RC filters—they are classic and ubiquitous.
2. Using the oscilloscope–our new best friend in the circuits lab!

# 1 Communicating with Aliens


(a) Alien the "claw has chosen", (b) Buzz Lightyear ready for blastoff

Figure 1: Two Toy Story icons: the chosen alien and Buzz Lightyear.

### 1.1 Problem Statement

Time for a real-life application of amplifiers and RC filters! One of the Toy Story aliens has been "chosen by the claw" (c.f.: `https://www.youtube.com/watch?v=W9t5ZqeHcYk`). The cuddly lil' green guy is peacefully departing with some final words, an oratorical offering of solace to his fellow aliens—in the ever familiar fairly high-pitched Toy Story alien voice. But Buzz Lightyear will have none of it! He decides to save the alien from the claw. Immediately, he fires his jet pack, blasts upward and tries to snatch the alien from The Claw. [1] Amidst all of the commotion, another alien was recording his the final words of the departing friend for posterity. But wait, there's a serious problem! The low frequency, dull rumbling noise of Buzz's rockets are so loud that they nearly completely drown out the aliens parting words. Buzz Lightyear to the rescue? Hardly.

***Your mission is to design and test two RC filter circuits to selectively reduce the rocket's noise of the rockets and make clearly audible the alien's parting words. One of the circuits must be a 1-stage filter. The other must be a 2-stage filter.***

This is open-ended design problem, there is no one single correct answer. However, there are some designs that work better than others. As a hint: the HPFs shown in the slides in class (see course website under Supplemental) are likely a very good starting point. Revise/iterate upon the design as you wish.

**You must provide a live demonstration of the your circuit to officially complete this lab. You can do this either in person (preferred) or in video format.**

### 1.2 Equipment and Components

You may use any components found in the Circuits lab. The sound file `chosen_w_noise.wav` of the alien talking plus Buzz's rocket pack firing can be downloaded from the course web page under the "Labs" heading. You'll certainly want to make use of some audio equipment to hear the output from your circuit to assess how well the filter is functioning. You'll also want to use the scope to view the input (original sound file signal) and output (filtered output signal). Once you have your filter designed to your liking, be surely to clearly measure the magnitude $|H(f)|$ and phase response $\phi(f)$ over a sufficiently wide range of frequencies for both the 1- and 2-stage HPFs. A good rule of thumb is to measure two orders of magnitude above and below the cutoff frequency $f_o$.

[1] OK, Toy Story aficionados, this is heresy, I know. It's not really how the movie plays out. The original plot line has been modified to fit conveniently into the Circuits pedagogy.

# 2 Surface electromyography (sEMG) and Prosthetic Devices

## 2.1 Intro to the sEMG

Surface electromyography (sEMG) measures the electrical potentials generated by muscles as they contract. The sEMG finds diverse application in studies of biomechanics of aging and fatigude, sports rehabilitation, and prosthetics. The prosthetics field is undergoing something of a revolution the past several years, thanks to advances in miniaturized electronics, high performance batteries, and improved pattern recognition techniques (for example, see Figure 2). One common control paradigm is to use to measure the surface **e**lectro**m**yo**g**ram (EMG)—electrical activity present at the skin surface associated with underlying muscular contractions. When a user flexes, the electronics system records and recognizes certain types of EMG signals to drive motors and actuators in the prosthetic for different grips. The EMG is processed and interpreted by microcontroller to convert a sEMG pattern of muscular activity into commands that move motors in a desired manner. For instance, flexing the biceps twice in quick succession might be interpreted as: "Move robotic arm forward-right to grab green squishy ball." A good prosthetic hand can help perform functions like grasping a water bottle, picking up a pencil, and buttoning clothes, thus restoring a high-quality of life to an amputee. [2]

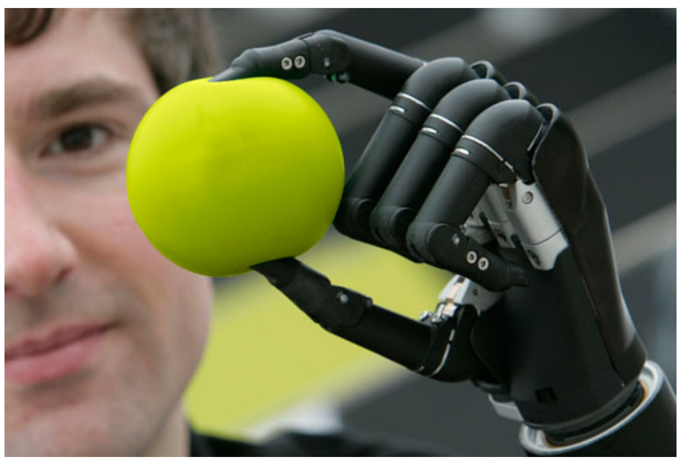

Figure 2: Touch Bionics iLimb Ultra. Dexterity is sufficient to squish a foam ball. The motion/grip of the prosthetic hand is driven by the EMG measured on the existing part of the amputee's forearm. Image credit: `http://www.touchbionics.com/products/active-prostheses/i-limb-ultra`

## 2.2 Band pass filter design application

The prerequisite for such a prosthetic device is to non-invasively measure the electrical activity associated with muscle contractions (see Figure 3). The aim of this experiment is to build, test, and analyze a ***bandpass filter (BPF)*** suitable for surface EMG applications.

[2] For example of hot new research, see: Lobo-Prat et al. "Evaluation of EMG, force and joystick as control interfaces for active arm supports". *Journal of Neuroengineering and Rehabilitation*, 2014.`http://www.biomedcentral.com/content/pdf/1743-0003-11-68.pdf`

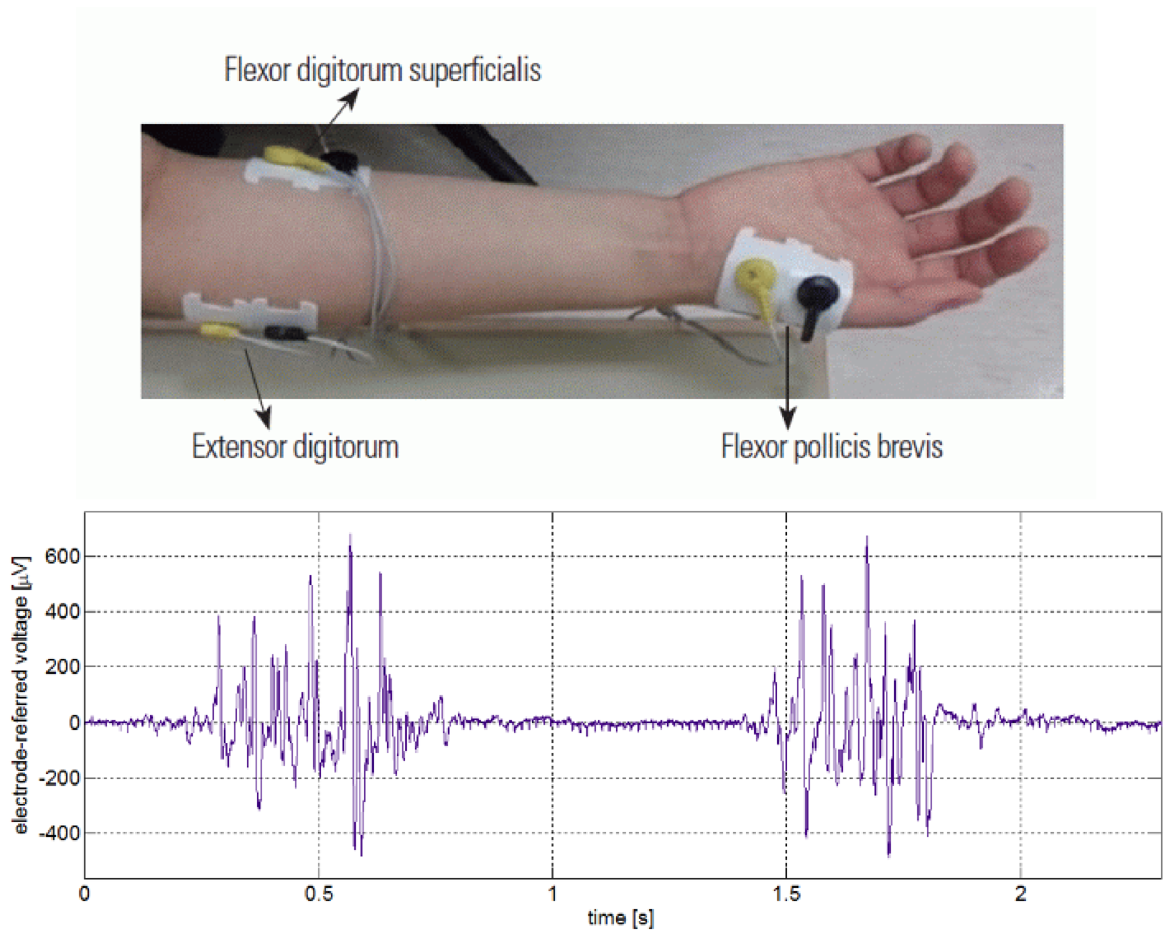


Figure 3: Top: Measuring the EMG in the lab. Three adhesive electrode pairs are attached to the forearm and hand. Image credit: `https://tbirehabilitation.wordpress.com/2015/09/05/article-analysis-of-surface-emg-activation-in-hand-percussion-playing-depending-on-the-graspi` Bottom: Sample EMG signal measure with Intan RHD2000-series bioamplifier chip configured for $f_L = 2.0$ Hz and $f_H = 1.0$ kHz. Image credit: Intan Technologies `http://intantech.com/files/Intan_RHD2000_series_datasheet.pdf`

In this case we need a BPF to reject some low- and high-frequency unwanted signal components. The BPF will pass components sEMG signals that are typically in the frequency band of $f = 10-400$ Hz. The low-frequency artifacts ($f \leq 10$ Hz) typically arises from breathing and wiggling of cables during flexing. Some sources of high frequency noise ($f \geq 500$ Hz) are Johnson noise (thermal noise due to statistical properties of electrons sloshing around in conductors) and high frequency RF communication devices, such as monitors refreshing at a high rate. The low-frequency noise sources are typically much more severe (higher amplitude). For today, we'll build a simple BPF that cascades a 1-stage LPF to a 1-stage HPF. (It is not uncommon to build a BPF with a 2-stage HPF to more strongly reject the lower frequency noise components. We'll revisit this problem later in the term.)

***Your task is to design, build, characterize, and perform proof of concept experiments for a circuit that is capable of cleanly measuring the EMG per the above design requirements.***

For a strong hint of where to get started, check out the BPF design in the class slides for RC filters (on the course website under supplemental). Once you have your filter designed to your liking, be surely to clearly measure the magnitude $|H(f)|$ and phase response $\phi(f)$ over a sufficiently wide range of frequencies for BPF. A good rule of thumb is to measure two orders of magnitude above the high cutoff frequency $f_H$ and two orders of magnitude below the low cutoff frequency $f_L$.

## 3 Written Report

Your written report should consist of a single document broken into two chapters of the same book, so to speak—one for the aliens audio portion, and one for the sEMG portion. Include the standard pillars of a complete circuits lab report: Intro, Circuit design and measurment methods; Results; Discussion/Conclusion. Keep it short, sweet, and to the point. Aim for 4 pages; 5-page absolute max limit, please (not including appendices).

To help get you started, some items you should absolutely include are:

- Aliens audio portion: Single plot of decibel gain vs. frequency comparing BOTH filters ($G(f)$ vs. $\log_{10} f$) This means you should have 2 theoretical curves and 2 sets of data points (your experimental values) overlaid.
- Aliens audio portion: Ditto for the phase response vs. frequency ($\phi(f)$ vs $\log_{10} f$).
- Biomedical portion: Single plot of decibel gain vs. frequency with data points overlaid. Another plot for phase vs. frequency.
- Illustrate the filtering action in photos–perhaps a series of a few oscilloscope screenshots or carefully hand drawn sketches would work well comparing input (unfiltered) and output (filtered) signals.
- Some tips of where to get quantitative in your analysis: What was the cutoff frequency in each case? What did you expect it to be based on the canonical formula for $f_o$? What was the slope in the roll-off region? How do these compare to the theoretical values (integer multiples of 20 dB/dec)?
- In the discussion also include some subjective/aesthetic assessment of how well the filter design met the needs of the problem statement. What might you change in the future to improve upon the design?