1 What is expected from me, and how can I get a high grade?

1. Read this document carefully.
2. Copy the wave files from the class website:
   http://ecee.colorado.edu/~fmeyer/class/ecen4632/project.zip
3. Familiarize yourself with the data, and the MATLAB functions for loading the data and playing the wav files.
4. Submit your report by7:00 PM, on Thursday, December 17, 2015.

1.1 Deliverable and schedule

A detailed report in PDF format should be emailed to **fmeyer@colorado.edu** by 7:00 PM, on Thursday, December 17, 2015. The name of the PDF file should be of the form: `firstname_lastname.pdf`.

1.2 Grading policy

In order to receive a high grade for this project your report should include all the items described below.

1. A brief theoretical description of each filter method, and its connection to the course material.
2. When applicable, a detailed description of the choice of parameters.
3. An in-depth discussion of the experimental results. You should compare the experimental results with the advertised properties of the filter.
4. The MATLAB code, with comments.

2 Noise cancellation

Noise-cancellation headphones measure the external ambient noise with a microphone, and generate a signal that matches the noise, but with the opposite amplitude. This "anti-noise" is added to the original music signal and effectively interfere destructively with the ambient noise. The success of the approach relies on the fact that the noise is narrowband. This assumption is a realistic assumption for the vibration of the engine of an airplane, but will fail to apply for the cry of a baby in the same airplane.

In this project you will tackle the problem of removing a narrow-band noise created by the engine of an airplane. You will use a passive approach, and design a narrow-band bandstop filter to remove the frequencies that match the frequency range of the noise. The audio signal that you will process has been sampled at 11,025 Hz. You are told that the noise is in the frequency range [1,600-1,700] Hz.

You will design several band stop filters remove the noise in this narrow frequency range, while leaving the rest of the signal intact.

1. Load the noisy audio file using the following MATLAB command:

```
>> [song,fs,nb]= audioread('noisy.wav');
```

This is a (low-quality) mono signal with sampling frequency of 11025 Hz. Listen to the signal with the MATLAB command

```
>> sound(song,fs)
```

Can you discern any voice? the goal of the project is to remove the noise and discover the voice!

2. You will design a bandstop filter with the following specifications:

   - passbands: $[0 - 1400]$Hz and $[1,900 - 5,512.5]$Hz
   - stopband $[1,600 - 1,700]$Hz,
   - tolerance in the passband: 0.5 dB,
   - Maximum gain in the stopband: -100 dB.

   You will implement the filter using each of the following design methods:

   - Butterworth,
   - Chebyshev Type I,
   - Chebyshev Type II,
   - Elliptic,
   - Kaiser,
   - Parks-McClellan.

   For each of the designs, you will compute

   (a) the order of the filter.

   (b) the number of add/multiply operations per input sample required to implement the filter. Be sure to explain the structure you assume;

   (c) the magnitude response (in dB) using `freqz`;

   (d) a magnified plot of the magnitude response, focusing on the passband ripple (linear scale);

   (e) the group delay (in samples) using `grpdelay`;

   (f) the pole-zero diagram;

   (g) the impulse response using `filter` and `stem` for 100 samples.

3. Filter the noisy signal using each of your de-noising filters. Listen to the filtered and original files. How do they compare? you will need to re-calibrate the denoised signal so that its dynamic range is in $[-1,1]$ before playing it with the command `sound`.

4. (Extra credit.) After filtering the signal still contains some minute amounts of noise. Unfortunately, part of the song in the range $[1,600 - 1,700]$Hz has also been removed. Suggest a method to improve the filtered signal by removing more noise while adding back some of the signal.