GEORGIA INSTITUTE OF TECHNOLOGY

SCHOOL of ELECTRICAL and COMPUTER ENGINEERING

ECE 2025 Spring 2006

Lab #12: Interference Removal from Electro-Cardiogram (ECG) Signals

Date: 24–27 April 2006

The Warm-up section of each lab must be completed **during your assigned Lab time**. After completing the warm-up section, turn in the verification sheet to your TA. No lab report is required.

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1 Warm-up: Introduction

A common heart test is an electrocardiogram which records electrical activity that changes during the cardiac cycle. Metal electrodes placed at several locations on the body "pick up" these cardiac electrical signals. Unfortunately, these electrodes also pick up signals from other electrical sources, most notably the 60-Hz power signal (or 50-Hz in some other countries). The objective of this short lab is to show that you can remove a sinusoidal interference from a corrupted ECG signal, and produce a cleaned-up signal. This will tap into your 2025 skills as an accomplished "filter designer."

1.1 IIR Notch Filters

An IIR notch filters will null out one frequency, while having a frequency response that is relatively flat across the rest of the frequency band. It can be obtained with one complex zero pair and one complex pole pair.

$$\text{Zeros at } e^{\pm j\theta} \qquad \text{Poles at } re^{\pm j\theta}$$

where r is a number slightly less than one. You can use **PeZ** to exhibit a typical frequency response for a notch filter. To see an example, select $r = 0.95$ and $\theta = \pi/4$.

1.2 Notch Filter Removes Sinusoidal Interference

The ECG signal (plus interference) will be generated by the MATLAB function `ECGmake06.p`. The `ECGmake06.p` function reads data from a file `Lab12ECGdata.mat`, changes the sampling rate and then adds a sinusoidal interference. These ECG signals were recorded by ECE-2025 students Josh Hammel and Chris Clarke, see Fig. 1. The output of this function will depend on your `gtxxxx` number—here is the calling template.

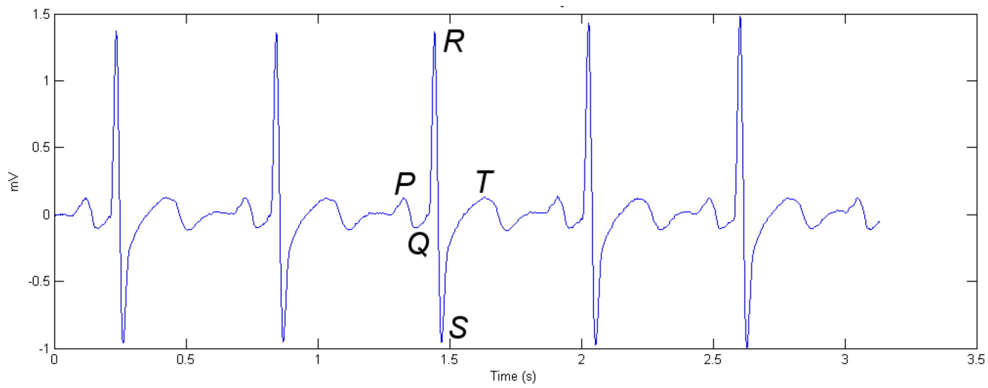
```
function [ecgsig,fs,fint] = ECGmake06( gtstring, dur )
%
%   ecgsig = vector of signal samples at fs samples/sec
%     fint = frequency of the interfering sinusoid (near 50 or 60 Hz)
% gtstring = your gt number as a string, e.g., 'gtg555q'
%      dur = duration of the signal (optional); default = 15 secs.
%               (dur<0 gives an interference-free ECG of length abs(dur))
```

(a) Run `ECGmake` and note the values for the sampling rate (f_s) and interference frequency (f_{int}).

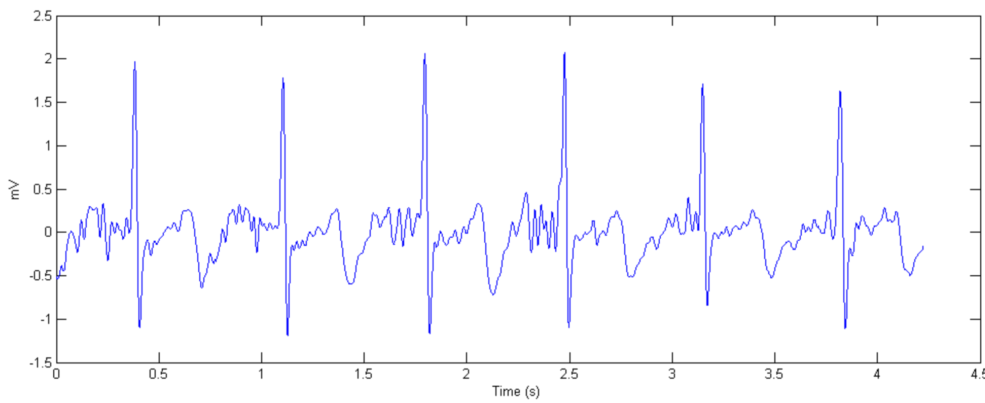
(b) Design the notch filter by specifying its poles and zeros. Explain how the angle (θ) of the poles and zeros is determined by the interference frequency (f_{int}) and the sampling rate (f_s). Draw the pole-zero diagram on the verification sheet. Convert the poles and zeros to filter coefficients.

(c) Compute the frequency response of the notch filter, and plot the frequency response magnitude versus ***analog frequency*** f in Hz. Make a sketch of what you see on the screen (no print out is needed).

(d) Apply the notch filter to the ECG signal and show that you can remove all the interference. Make a two panel subplot comparing the signals "before" and "after" filtering. Show three or four periods of the ECG at the same time in both signals.



(a)



(b)

Figure 1: (a) The first ECG is very regular and follows the classic pattern. The P-wave, QRS complex, and T-wave are labeled. The P-wave results from depolarization of the sinoatrial (SA) node in the heart, leading to depolarization and contraction of the atrial cardiac muscle tissues. The QRS complex arises from depolarization of the atrioventricular (AV) node and resulting depolarization and contraction of the ventricular muscle tissue. The Q and S components of the complex are not always exhibited in a normal ECG. The T-wave results from repolarization of the ventricular tissue. (b) The second ECG is nonstandard. In place of the P and Q waves there is an irregular waveform. It appears that, in this case, the heart is in a constant state of atrial fibrillation. This normally is not a problem, as the atria contribute very little to the overall pumping ability of the heart, however it can present problems during strenuous exercise. (Recorded and described by Josh Hammel and Chris Clarke, April 2006.)

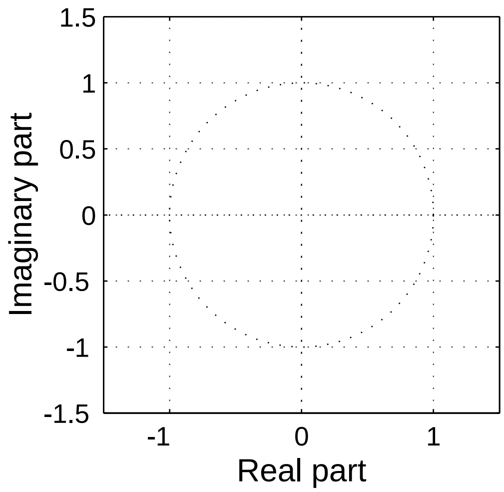
Lab #12
ECE-2025
Spring-2006
INSTRUCTOR VERIFICATION PAGE

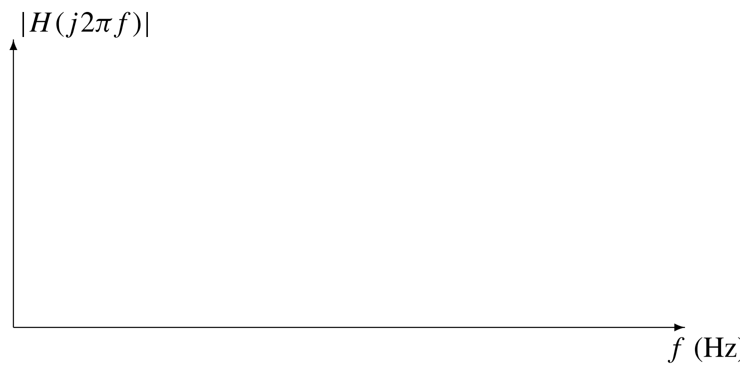
For each verification, be prepared to explain your answer and respond to other related questions that the lab TA's or professors might ask. Turn this page in at the end of your lab period.

Name: ______________________________________ Date of Lab: __________

Part 1.2(a): Record the values of the sampling rate and interference frequency.

$f_s =$ [ ] $\quad f_{\text{int}} =$ [ ]





Parts 1.2(b) and (c): Plot the poles and zeros of your notch filter on the z-plane grid above. In addition, sketch the frequency response in the space to the right of the pole-zero plot. Use a frequency range of 0 to $f_s/2$.

Verified:____________________ Date/Time:__________

Part 1.2(b): List the filter coefficients of the IIR filter by filling in the IIR difference equation below.

Verified:____________________ Date/Time:__________

$y[n] =$ [ ] $y[n-1] +$ [ ] $y[n-2] +$ [ ] $x[n] +$ [ ] $x[n-1] +$ [ ] $x[n-2]$

Part 1.2(d): Apply the notch filter to the ECG signal and show that you can remove all the interference. Show the two panel subplot that compares the signals "before" and "after" filtering to your TA. ***Zoom in to verify that all interference has been removed completely.***

Verified:____________________ Date/Time:__________