Digital Signal Processing Projects

SEEE, 2020 Fall

Report Deadline: Week 1, (Feb. 27th), Spring Term, 2021

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Report Requirements:

The report should address the following questions:

（1） **Introduction**: Why did you design and write the software? For what will it be used?

（2） **Methods/Theory of operation**: How does the system work? Why did you choose the algorithms that you used? How do they work?

（3） **Methods/Test protocol:** What tests did you perform? How do they fit into the larger strategy?

（4） **Results:** What were the results of your tests? If theoretical analyses are available, provide them here for comparison.

（5） **Discussion**: Discuss any discrepancies between theory or expectations and results. How would you change the system? What would you do differently?

（6） **Conclusion**: Was the project a learning experience? How would you change it? How would you recommend that others approach similar problems

The report should include a **cover page** that contains a title, author names, and a table of contents. An **ABSTRACT** should follow on the second page.

The final report should be submitted in **both paper and electronic formats**. MS Word .docx is the preferred application for the electronic copy, but PDF's will be accepted as well.

Project-1: Higher Frequency Power Harmonics Filtering

Project-2: Removing power line interference from ECG signal

Project-3: Determining the sunspot cycle period

Project-4: Digital PLL applied for Single Phase or Three Phase Power Applications

Project-5: DSP application design originating from your research project

Project-1: Higher Frequency Power Harmonics Filtering

Nowadays, power electronic equipments are being applied widely in modern power systems. For their **nonlinear characteristics**, power electronics devices may pollute power network with **harmonic current or voltage**. Therefore, it is very important to analysis the harmonic components in power network.

The Aim of the Project:

Harmonic analysis concentrates on decomposing the signal in question in terms of a fundamental (frequency) signal and signals of integer multiples of that fundamental signals. In this work, we will encounter analysis of such signal which is a mixture of different frequency. We would like to get rid of other frequencies and concentrate on any particular frequency or frequency band. This can also be termed as **harmonic filtering**.

In this design project, we consider a signal originating from the 50Hz system. The signal in question is acquired by a digital instrument operating at a sampling frequency of 1000 samples per second. We want to suppress any frequencies **less than the third harmonic component**.

Instructions:

1）Write a Matlab(or Python) code to generate an AC current signal that contains fundamental frequency as well as 2^{nd}, 3^{rd}, 5^{th} harmonics. Please note that **the sampling rate is 1000Hz**, and **total number of the samples is 1000.** The parameters of all the components are given as following

Frequency(Hz)	50	100	150	250	Noise
Amplitude(p.u.)	1.0	0.3	0.2	0.1	0.05(Gaussian)
Phase(rad)	Define Yourself	Define Yourself	Define Yourself	Define Yourself	

2）Write a Matlab(or Python) code hat compute the frequency-domain representation of the signal. Plot the frequency spectrum of the signal. Locate the frequencies of all the sinusoidal components.

3）Design a suitable filter to filter out the 3^{rd} and 5^{th} harmonic components

4）Plot the refined signal in the time-domain.

5）Use the Matlab(or Python) code developed in step 2 to compute the frequency-domain representation of the refined signal. Plot the frequency spectrum of the refined signal.

6）You will find out that there is a compromise between the speed of the filter and its effectiveness. Repeat the experiment a few times with different filter parameters to show this compromise. In each case, present the refined signal in the time-domain and analysis the frequency response of the corresponding digital filter.

Design Guide:

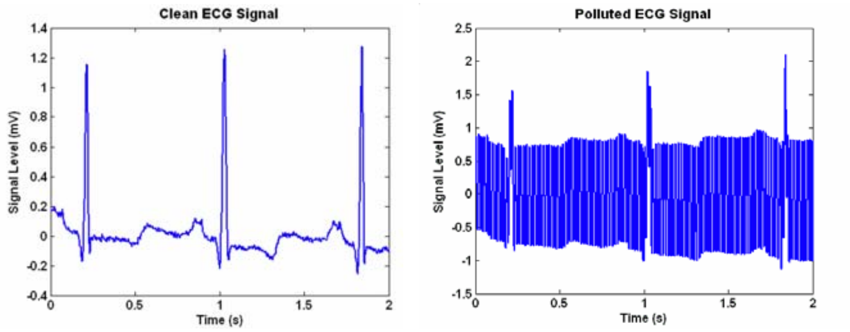
(1)Frequency-domain analysis of a signal can be implemented using FFT. (Matlab(or Python) fft function)

(2)Lowpass FIR filter using the **Window (Kaiser), Frequency Sampling methods or others**

(3)Lowpass IIR filter designed from **Analog Filter** using **Bilinear Transformation**

Project-2: Removing power line interference from ECG signal

Electrocardiogram (ECG) signal is some index of the functionality of the heart. For example, a physician can detect arrhythmia by studying abnormalities in the ECG signal. Since very fine features present in an ECG signal may convey important information, it is important to have the signal as clean as possible.



Cables carrying ECG signals from the examination room to the monitoring equipment are susceptible to electromagnetic interference of power frequency by ubiquitous supply lines and plugs, so that sometimes the ECG signal is totally masked by this type of noise/interference.

The Aim of the Project:

The aim of this design project is to design appropriate signal processing algorithms for the refinement of ECG signals so that their characteristics may be extracted: this involves the design of a digital filter for the elimination of the power line interference.

Instructions:

1）Download the input signal “ecg_sig.mat”. Once loaded into the Matlab(or Python) workspace, this file provides 10 seconds of real clinically recorded ECG signal. This signal is digitized at a sampling rate of 360 Hz.

2）Plot the signal in the time-domain.

3）Write a Matlab(or Python) code to compute the frequency-domain representation of the signal. Plot the frequency spectrum of the signal. **Locate the frequency of the interference**.

4）Design a suitable filter to filter out the power line interference.

5）Plot the refined signal in the time-domain.

6）Compute the interference signal and plot it in the time-domain.

7）Use the Matlab(or Python) code developed in step 3 to compute the frequency-domain representation of the refined signal. Plot the frequency spectrum of the refined signal. Locate the frequency of the interference. Comment on the effectiveness of your method.

8）You will find out that there is a compromise between the speed of the filter and its effectiveness. Repeat the experiment a few times with different filter parameters to show this compromise. In each case, present the refined signal in the time-domain and analysis the frequency response of the corresponding digital filter.

Design Guide:

(1) IIR Notch Filter with its center frequency equal to that of the power interference

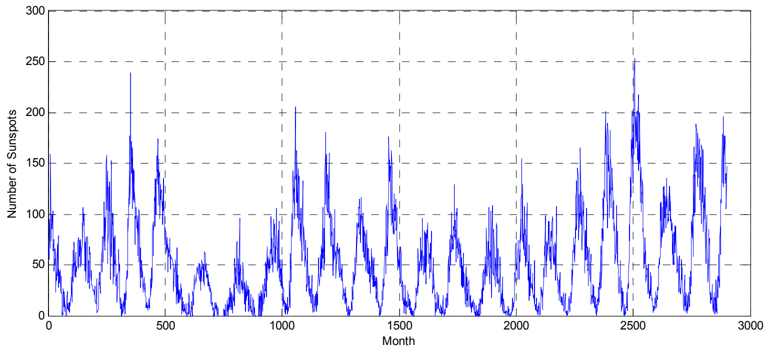
(2) FIR Bandstop Filter with suitable pass edge frequency and stop edge frequency

Project-3: Determining the sunspot cycle period

Determining the sunspot cycle period was and is important in order to compare the period estimate with disruptions to radio and satellite communications and with weather cycles. There are strong indications that the cooling and warming of the Earth might be due to the changes in the number of observed sunspots.

The Aim of the Project:

The aim of this design project is to design appropriate signal processing algorithms to estimate the sunspot cycle period so that the number of sunspots can be predicted.



Here is a plot of the number of sunspots per month over a period of 2899 months. The data are contained in the file sunspots.txt

Instructions:

1）Download the input signal “sunspots.txt”. Once loaded into the Matlab(or Python) workspace, this file provides the number of sunspots per month over a period of 2899 months.

2）Plot the data in the time-domain.

3）Use Matlab(or Python) code to compute the frequency-domain representation of the data.

4）Design a suitable low-pass filter to denoise the data and then plot the smoothed data.

5）By using **spectral analysis method**, you can estimate the sunspot cycle period.

6）If possible, can you get a result whose resolution is smaller than one month

Design Guide:

(1) The low-pass filter will be FIR or IIR, but the design method should be chosen among what we have learned from this course.

(2) The sunspot cycle period can be estimated by using some spectrum estimation method. However, a super-resolution result may be obtained from parametric spectrum or by interpolated DFT algorithms.

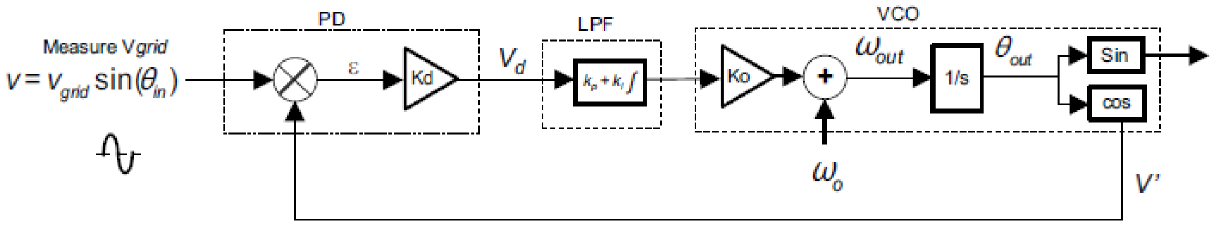
Project-4: Digital PLL applied for Single Phase or Three Phase Power Applications

The Aim of the Project:

Grid connected applications require an accurate estimate of the grid angle to feed power synchronously to the grid. This is achieved using a software phase locked loop (PLL). This project need you to implement a digital PLL by using an appropriate filter

Instructions:

The phase angle of the utility is a critical piece of information for the operation of power devices feeding power into the grid like PV inverters. A phase locked loop is a closed loop system in which an internal oscillator is controlled to keep the time and phase of an external periodical signal using a **feedback loop**. The PLL is simply a servo system that controls the phase of its output signal such that the phase error between the output phase and the reference phase is minimum. The quality of the lock directly affects the performance of the control loop in grid tied applications. As line notching, voltage unbalance, line dips, phase loss and frequency variations are common conditions faced by equipment interfacing with electric utility, the PLL needs to be able to reject these sources of error and maintain a clean phase lock to the grid voltage.



Phase Locked Loop Basic Structure

Note in the PLL, the PI serves dual purpose:

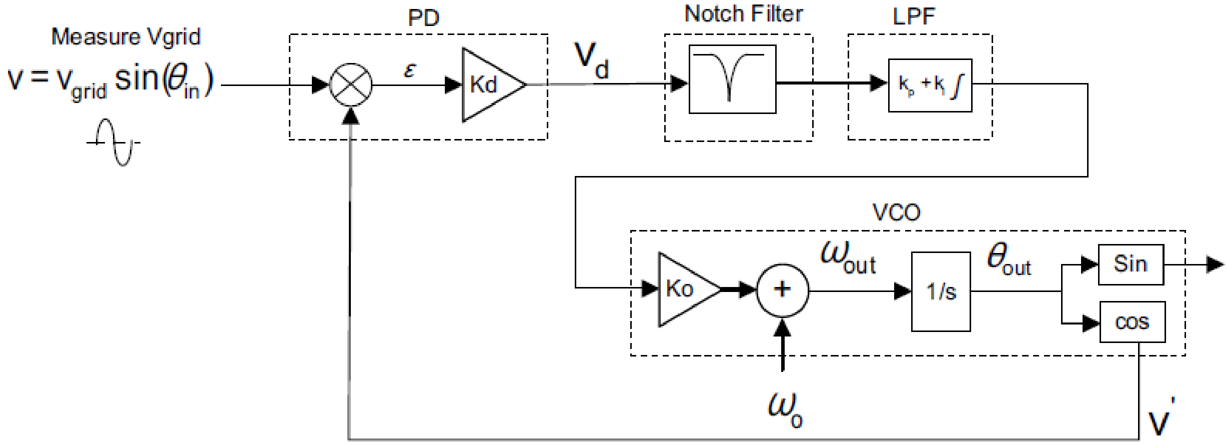
- To filter out high frequency that is at twice the frequency of the carrier and grid
- Control response of the PLL to step changes in the grid conditions, for example, phase leaps, magnitude swells, and so forth.

According to some analysis, it is clear that the LPF characteristic of the PI controller cannot be used to eliminate the twice to grid frequency component from the phase detect output in case of grid connected applications. Hence, alternative methods must be used that linearize the PD block.

Design Guide:

In this application report, one should a **lowpass filter** or **notch filter** to filter out twice the grid frequency component from the PD output

A notch filter can be used at the output of the phase detect block, which attenuates twice the grid frequency component very well. An **adaptive notch filter** can also be used to selectively notch the exact frequency in case there are variations in the grid frequency



Single Phase PLL With Notch Filter

Project-5: DSP application design originating from your research project

You may major in Electrical Engineering, Control Engineering, Mechanical Engineering, etc. Please choose a specific application from the project you are involved and solve it by using DSP technology. And then complete the research report.

Following are some possible topic listed for you to choose. Of course, you are allowed to select other any topic related to DSP.

(1) **Signal Extraction** from Noisy Input by using Signal Filtering

(2) **Vibration Spectrum Estimation** for Mechanical Fault Diagnosis

(3) **Power Load or Renewable Generation Forecasting** by using **Adaptive Signal Processing**

(4) ......