Signal Processing Topic: Design Tasks 1-3

Preliminary Notes

The Signal Processing Design topic in this subject is spread over 3 weeks, with laboratories in Weeks 4, 5 and 6. This handout introduces the first 3 of 5 design tasks within this topic. The remaining design tasks will be released according to the schedule that appears on the course web-page at http://subjects.ee.unsw.edu.au/~elec4123.

Your performance in these design tasks will be assessed in the laboratory, although your participation in tutorial discussions will be separately assessed (worth a total of 20% over the duration of the course). The laboratory component of your assessment for the Signal Processing design tasks as a whole is worth 17% of the marks for the course. As indicated in the course overview, this is composed of 10% for design outcomes and 7% for understanding. To simplify the awarding of marks, these percentages are multiplied by a factor of 5. This means that there are a total of 50 marks for design outcomes in Signal Processing and 35 marks for design understanding in Signal Processing. An individual breakdown of the maximum marks available for each task is provided in the following. However, these individual figures may add up to more than a total of 85 marks. Where this happens, your overall mark in the Signal Processing design topic will be capped at 85.

Some of the Signal Processing design tasks involve analog circuits, and hence require the use of a breadboard. Other design tasks involve digital signal processing, for which the laboratory computers will play a major role, although you are permitted to bring your own laptop to the lab for these later tasks.

As with the Electronics design topic, the Signal Processing tasks described here, your breadboard **may not be populated prior** to the laboratory session – demonstrators will insist upon this. Again, all of your design notes must be recorded in your **laboratory notebook. Your lab notebook may not consist of loose leaf paper. It must have a cover, which must be labelled with your name and the course title or code.**

You are **permitted to take your populated breadboard** and any electronic components which you have used out of the laboratory, for your own independent experimentation. However, components must be signed off by the demonstrator and you must bring these same components back to the laboratory the following week, together with an unpopulated breadboard.

Please remember to bring a breadboard with **sufficient size** to accommodate the solutions to multiple tasks at once, since this will obviously help you to be assessed efficiently.

Sharing Equipment and Communication in the Lab

Due to current resource constraints, you will generally share a work bench in the laboratory with a lab partner. Despite this, your design, implementation and assessment for these tasks are all individual. Naturally, you cannot expect to have your design permanently tethered to the power supply, oscilloscope, signal generator, laboratory computer, or other laboratory equipment. You should, therefore, communicate with your lab partner and establish a good working relationship for sharing the equipment.

Although assessment is individual, you can communicate freely with your lab partner regarding the design problem. There is no expectation that your partner should help you with the construction or preliminary testing of your design, but this is permitted so long as you both agree.

Apart from communication with your lab partner and the lab demonstrators, you should avoid any significant communication with other students in the lab. **Demonstrators have full authority to clamp down on unnecessary communication**, including by moving troublesome students to the end of the assessment list, which may delay assessment until a following week – you will find that being assessed early is very important for success, especially since you are not permitted to bring assembled solutions into the laboratory.

Assessment Procedure

Demonstrators will maintain an ordered assessment list. You may not add your name to the list until you have a solution you are prepared to have assessed. Students who have already been assessed for a task may have the opportunity to be re-assessed, during the same or a later laboratory session, but students who have not yet been assessed will be given priority over those seeking re-assessment.

Demonstrators may ask you to move to a separate area for assessment, so that your lab partner need not be disturbed. With this in mind, you should ensure that your implementation is as portable as possible, so that you can easily connect it to a separate power supply, signal generator, or oscilloscope, as appropriate. The same thing applies to tasks that require the lab computer; in this case, you should ensure that your software is on a USB stick that can readily be moved and run on a different computer.

Signal Processing Design Task 1

In this design task, you are to design, build and test and analog band-pass filter (an electronic circuit) whose gain is within ±1.5dB of unity within the passband, which extends from f_L to f_H and is at most -17dB at frequencies smaller than $f_L/10$ or larger than $10f_H$. The values of f_L and f_H will be given to you at the start of the laboratory.

It is important that you make sure you understand the requirements for this simple design task very well before you get to the laboratory.

For this particular design task, your soft objective is to design a solution which is as robust as possible to manufacturing variations associated with the electronic components you use. You should be able to comment on the impact of variations in capacitor and resistor values, within their respective tolerances, and why your design should meet the requirements in spite of these variations.

Available Electronic Components (on hand with your lab demonstrator):

Transistors: BC549, BC559
Analog IC's: LM324, LM348, LM741
Resistors and capacitors, as found in the laboratories

Assessment for this task:

Marks for this task are as follows:

- Achievement of requirements: (____/6)
- Able to meet requirements with reasonable component tolerances: (____/4)
- Understanding: (____/7)

Weeks in which this task may be completed:

You may complete this task in any of Weeks 4, 5 or 6. However, the parameters f_L and f_H will generally change from week to week, which may possibly require you to modify your design.

Signal Processing Design Task 2

In this design task, you are to design and implement a digital sampling and interpolation system. You will use the sound-card of the computer, together with Matlab, to record 10 seconds or more of an external analog signal, sampling it at a sampling rate of R samples/second and playing it back. You can use the Matlab functions "audiorecorder" and "audioplayer" to record and playback waveforms using the computer's sound-card. The input signal will be provided via the laboratory signal generators, while the output signal will be played back and viewed on the oscilloscope. The waveform shape and frequency (or range of frequencies) f to be set up on the signal generator will be given to you at the start of the laboratory, along with the value R.

To help you perform this task, the electronics workshop have prepared a breakout box which can be (or is) connected to the computer's audio-in and audio-out jacks and also to your breadboard. While this breakout box provides significant protection to the computer's sound card, in this task you will supplement this mechanism with your own protection circuit. This will prove valuable if you wish to perform some of the tasks on your own computer, where the laboratory breakout box might not be available.

The protection circuit which you need to construct uses 4 diodes and a 1kΩ resistor to limit the voltage which can be passed to the computer's audio-in jack to around ±1.3V in the worst case. Make sure you know how to do this. You must draw a schematic of the appropriate circuit in your lab notebook and you must then lay out the components very neatly on your breadboard and **get it checked by the laboratory demonstrator before proceeding** to pass any signals to the computer.

It should be apparent to you that the sample rate R might require some explicit sub-sampling in some Matlab code, because the "audiorecorder" function generally supports only a small set of possible sampling rates. It should also be apparent that aliasing might be an issue – you should endeavour to discover whether the "audiorecorder" function provides sufficient anti-aliasing when used at low sampling rates. Finally, it should be apparent to you that some interpolation of the sampled signal might be required, again depending on the value of R. In general, you may need to implement a low-pass filter of some form.

For this task, there is no explicitly stated requirement for a particular degree of aliasing suppression, so you should take it as a soft design objective to minimize the aliasing power, subject to reasonable computational complexity. It is very important that you know how to determine whether a sampled signal contains aliasing.

Available Electronic Components (on hand with your lab demonstrator):

Diodes: 1n4148
Resistors and capacitors, as found in the laboratories

Assessment for this task:

Marks for this task are as follows:

- Achievement of requirements: (____/6)
- Minimization of aliasing: (____/4)
- Understanding: (____/7)

Weeks in which this task may be completed:

You may complete this task in any of Weeks 4, 5 or 6. However, the sampling rate R and the frequency (or range of frequencies) f and the waveform shape may change from week to week, which may possibly require you to modify your approach.

Signal Processing Design Task 3

In this design task, you are to design and implement an analog filter which is able to extract the third harmonic from a waveform whose frequency *f* and shape (square or triangular) will be given to you at the start of the laboratory session. Your design is intended to produce a sinusoid whose frequency is 3*f* and whose total harmonic distortion (THD) is smaller than *X* dB, where the value of *X* will be given to you at the start of the laboratory session. The amplitude of the output signal from your filter should vary by no more than ±50% as the frequency *f* varies by ±10% of its stated value. You can assume ahead of time that *f* will be no smaller than 1kHz and no larger than 10kHz.

It should be apparent to you that both the shape of the waveform and the value of *X* are parameters which may affect the fundamental structure of the design. You should make sure you understand what exactly is meant by THD and you should also think about how you might confirm that your design meets the requirements. You are strongly encouraged to discuss such matters during your tutorial session, but be sure to do your own research and thinking beforehand and be sure also to research any ideas which come up during tutorials before going to the laboratory.

For this task, your soft design objective is to come up with a simpler solution, wherever this is possible. By simple, we mean that fewer electronic components are preferred.

Available Electronic Components (on hand with your lab demonstrator):

Transistors: BC549, BC559
Analog IC's: LM324, LM348, LM741
Resistors and capacitors, as found in the laboratories

Assessment for this task:

Marks for this task are as follows:

- Achievement of requirements: (____/9)
- Simplicity of the design: (____/3)
- Understanding and neatness of the breadboard layout: (____/8)

Weeks in which this task may be completed:

You may complete this task in any of Weeks 4, 5 or 6. However, the parameters parameters *f* and *X* will generally change from week to week, as may the waveform shape; such changes may possibly alter your design decisions.