Signal Processing Topic: Design Tasks 4-5

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 last 2 of 5 design tasks within this topic.

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 4

For this task you will need to build a small electret microphone amplifier on your breadboard. Following the datasheet provided on the course web-site, you can do this by tying the B- terminal of the microphone to ground, and attaching a 1kΩ resistor between the B+ terminal and VCC=6V (or anywhere around there). Pass the B+ terminal through a bypass capacitor to a simple opamp summing amplifier, with 10kΩ input impedance. The other input to the summing amplifier will go to the signal generator for this design task. The output from the summing amplifier should pass to the sound-card input protection circuit you built for Task 2. Please note that you will need to solder wires to the electret microphones provided. This should be done using the soldering workstations in your laboratory. Take care not to leave the soldering iron in contact with the terminals of the microphone for more than a couple of seconds, so as to avoid destroying the device.

Use the CRO to measure the output from your summing amplifier before attaching it to the sound card of the computer. Adjust the gain of the summing amplifier so that you get a decent strength signal when speaking close up to the microphone. Next, connect the signal generator to the other terminal of the summing amplifier and adjust it to produce a sinusoid of around 1kHz at around 0.2Vpp at the output of the summing amplifier. Connect your setup to the sound-card of the computer via the breakout boxes in the lab. Then make sure you can record and play back the microphone recording with the additive sinusoidal interference.

For this task, you are to design a digital signal processing system to remove a single frequency sinusoid of frequency f from the audio signal you record using Matlab's "audiorecorder" function. The key requirement is to suppress the sinusoidal interference to the point where it is "inaudible." The value of the frequency $f=f_0$ will be given to you at the start of the laboratory session. This will be the frequency of the interference signal that will be set up on the signal generator to test your solution.

You are strongly encouraged to discuss the design requirements and possible solutions in your tutorial group.

The principle soft objective here is to design a solution which maximizes the quality of the interference-free audio signal. A secondary soft objective is to develop a solution which can meet the key interference suppression requirement over as wide a range of frequencies as possible, rather than just the single frequency f_0. As often happens in design, you might find these soft objectives to be in conflict with one another.

As with all the design tasks, it is your responsibility to translate the design requirements and objectives stated above into technical requirements and objectives, so that you can develop solutions using methods known to you.

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

Analog IC's: LM324, LM348, LM741
Diodes: 1n4148
Microphones: AM4010 electret, or equivalent
Resistors and capacitors, as found in the laboratories

Assessment for this task:

Marks for this task are as follows:

- Achievement of requirements: (____/6)
- Works for *f* in [$0.7f_0$, $1.3f_0$] or as much of this range as possible: (____/4)
- Audio quality preservation: (____/4)
- Understanding: (____/8)

Weeks in which this task may be completed:

You may complete this task in any of Weeks 5 or 6. However, the value of *f* may vary from week to week.

Signal Processing Design Task 5

The setup for this task is the same as Task 4, except that you will need two microphones, each with its own opamp amplifier. Simple inverting amplifiers will do – i.e., there is no need for summing amplifiers. You will also need two input protection circuits, since you will be feeding two signals to the sound-card of the computer via the breakout boxes provided in the lab. You are free to augment these rudimentary circuits with additional analog front-end processing if you feel that it will help you to meet the design requirements and/or optimize the soft objectives.

The design objective for this task is to locate an audio source (the "target") which is emitting a tone at approximately 1kHz. You should be aware of the fact that the frequency of the sound source varies somewhat between physical targets and there are not enough targets for each student to have their own individual one. As a result, you may find yourself testing with different targets during the course of this design effort and so you will need to ensure that your solution is not overly sensitive to the exact frequency of the sound source. Your design is to be implemented in Matlab using digital signal processing. Specifically, your solution should print estimates of the direction of the sound source (over the range -90 to +90 degrees) at intervals of approximately 1 second.

It should be apparent that you will need to carefully select the spacing between your microphones, taking into account physical properties of the propagation of sound waves. You are strongly encouraged to discuss this design problem in your tutorial groups. If you are not already familiar with the concept of correlation, you would do well to *revise this important signal processing concept before coming to the tutorial*.

For this design task, there are two soft objectives. The first soft objective is to maximize the accuracy with which you determine the angle of the incident sound source. The second soft objective is to be able to robustly detect the location of the target sound source even when the target is at some distance and in the presence of other interfering sources of sound – e.g., other students talking in the laboratory.

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

Analog IC's: LM324, LM348, LM741
Diodes: 1n4148
Microphones: AM4010 electret, or equivalent
Resistors and capacitors, as found in the laboratories

Assessment for this task:

Marks for this task are as follows:

- Distinguishes left of centre from right of centre: (____/8)
- Accuracy (full marks for ±10 degrees or better): (____/4)
- Reliability (full marks for 2m with background chatter): (____/4)
- Understanding: (____/10)

Weeks in which this task may be completed:

You may be marked for this task **only in Week 6**.