ENGG1300 Audio Filter Design Project (Internal students)

1. Task Description

Introduction:

In this activity, you will take on the role of an audio engineer who is in the middle of a crisis. Edgar Allen Poe's 213th birthday is this year, and the Brisbane City Council has organised a grand event to commemorate the occasion. As a crowning achievement, James Earl Jones (the voice of Mufasa and Darth Vader) has recorded a thirty second clip of him reading Poe's "The Raven", which will be broadcast over the loudspeakers at the beginning of the event; however, during a test run you realise that somehow the recording has been corrupted with high-frequency noise, apparently ruining it!

Fortunately, as a past student of ENGG1300, you realise that you may be able to use a filter to remove the noise from the recording before it is broadcast through the speakers. The fate of this prestigious event rests on your shoulders. Can you fix the problem in time, or will you be driven to madness like the subject of the poem?

The Task:

Your task is to design, implement and test a passive filter (using resistors and/or capacitors and/or inductors) to remove high-frequency noise from a provided audio recording while preserving the quality of the original signal. Your filter should be comprised of no more than two components (a resistor and a capacitor (RC) or a resistor and an inductor (RL)).

You must choose your components from the following values (which are available in the ENGG1300 Lab):

- Inductors: 22mH, 47mH with a tolerance of +/-20%
- Capacitors: 0.1uF, 0.22uF, 0.47uF with a tolerance of +/-20%
- Resistors: From the E24 series with values available from 10Ω to 100 kΩ, with a tolerance of +/-2%

While you have a wide range of resistors available, it is strongly recommended that you restrict your design to circuits that use resistors with values between 40Ω and 1 kΩ (this will minimise the impact of "loading effects".

The original signal is a voice recording containing frequencies predominantly below 1 kHz, and the noise is a single, constant tone at a frequency of 12.5 kHz.

On Blackboard, you have been provided with the audio files "noisy_1%.wav", "noisy_10%.wav", and "noisy_50%.wav", which contain the original recording plus noise with 1%, 10%, and 50% of the magnitude of the original signal respectively. For your reference, you have also been provided with the file "original_recording.wav", which contains the original audio recording without any noise.

Note that you are not expected to be able to design a filter that perfectly removes the noise without affecting the quality of the original signal. It is likely that the noise will still be audible after filtering, the quality of the recording will be degraded compared to the original, or both. The aim of this task is to instead give you experience with the process of designing and testing a solution to a specified problem, and we are more interested in how you follow this process.

Hints:

You may find the following hints to be useful for this task:

- Remember, the cut-off frequency is the frequency at which the filter has a gain of -3dB. This corresponds to the "half-power" level, but actually only represents a 23% change in how "loud" the signal sounds to your ears. Keep this in mind when choosing your cut-off frequency.
- When choosing component values, you will likely need to arbitrarily pick the value of one component and then use this to calculate the value of the other(s). Given that the range of capacitors and inductors available in the lab is much smaller than the range of resistors, it is usually easier to pick the value of the inductor or capacitor from the available selection first and then calculate the remaining component values.

Laboratory Access:

The second half of Practical Session 8B, and the whole of Practical Session 9B have been allocated for you to work on practical parts of this activity. No laboratory access will be available to work on this assessment outside of these scheduled class times.

It is strongly recommended that you complete your theory and design parts of this activity before Lab 9B session (and ideally before the Lab 8B session) so you can make the best use of this time to test and practice constructing your circuit; and to prepare for what you will be expected to do during the demonstration assessment.

Individual Work:

The work for this assessment should be completed individually. All students must complete the design and implementation of the circuit individually.

You are permitted to work together in the laboratory with 1-2 other students who share your lab station to test your respective circuits prior to the demonstration. However, each student is expected to construct the circuit on the breadboard from scratch and demonstrate it individually.

2. AUDIO FILTER DESIGN PROJECT DEMONSTRATION ASSESSMENT PROCESS

Your ENGG1300 Practical exam will be scheduled in one hour of one of your week 11 laboratory sessions. Your allocated session will be posted on the course blackboard website.

This assessment task is intended to assess two things:

- Your ability to design a simple filter circuit to address the design problem (most of this will be completed prior to the demonstration)
- Your ability to use the laboratory equipment to construct and test simple electronic circuits.

This assessment task is largely a “competency” assessment – we want everyone to get 100%! It is not designed to “rank” ability, but rather to determine whether you have developed an understanding of core course material related to filter design, and basic laboratory skills expected in an introductory electrical engineering course. As such, we will be as explicit as possible about the expectations, assessment structure, and the marking process for the demonstration assessment.

Pre-Demonstration:

Prior to your demonstration you should complete the calculation sheet on the marking template. This should include:

- The type of filter (i.e. low-pass, high-pass, band-pass, band-stop**)**
- Chosen cut-off frequency for your filter
- The schematic of your designed circuit (with input and output terminals clearly labelled)
- Calculations showing how you chose the component values for your filter, including a derivation of the transfer function and equation for the cut-off frequency
- A brief description of how well your filter design removes the noise from the signal of interest

These tasks should be completed in the lead up to and during Prac Classes 8B and 9B. As part of testing your circuit, you should follow the process used in Lab (XI) (i.e. generating both theoretical and experimental bode plots, and using the USB sound card and speakers to listen to the audio file with and without the filter connected).

This can be simply handwritten. If you complete electronically, you must print it out for the demonstration.

Conditions for Demonstration Assessment:

- 40 minutes for working
- You should bring:
  - Your UQ student ID
  - Your single page, pre-completed calculation sheet from the marking sheet
  - Writing materials (blue/black pen and/or lead pencil, ruler)
- Closed Book – No materials allowed (other than calculation sheet)
- Casio FX82 series or UQ approved (labelled) calculators allowed
- No computer access allowed.
- No electronic aids are permitted (e.g. laptops, phones).
- All answers must be written on the provided marking sheet.

Demonstration Procedure:

Bring your single page, pre-completed calculation sheet from the marking sheet.

Ensure you arrive at the lab on time, and quickly enter the room and sit at one of the nominated work benches when requested by the tutor. You may commence working when instructed by the lead-tutor in that session.

It is strongly recommended that you first reset the oscilloscope to factory defaults, modify settings for your setup (e.g. you will need to change probe ratios from factory default 10:1 to 1:1), and then connect both oscilloscope channels to a 2Vp-p 1000 Hz sinusoidal signal to ensure all multipliers, probes, connections, settings, etc. are working correctly. Once you have confirmed that this equipment is working correctly, you should proceed to carefully construct the circuit you have designed (this should be the one presented on your calculation sheet).

If you are having trouble constructing your circuit, or you believe that a piece of equipment is faulty, you can request assistance from a tutor. See final page for details.

Marking during the Demonstration:

When you have constructed your circuit (including double checking all the oscilloscope and function generator settings), and are ready to demonstrate, you should raise your hand to attract the attention of a tutor. *Note that as soon as the tutor commences marking, you will not have any further opportunity to fix any mistakes.*

If all tutors are busy with other students, then continue taking the measurements necessary to complete the results table and the Bode plot until the next tutor is available. The tutor to student ratio will be high enough that this delay should not be more than a few minutes in most cases. Note, that due to time constraints and the competency nature of this exam, no part marks are awarded. The trade-off for this fairly binary strict criteria is that if your circuit is incorrect in the first part of the marking process, your examiner will fix your circuit. This will allow you to potentially receive full marks for the remainder of the exam (obviously if you had an incorrect circuit setup, you would likely do poorly on the results table and Bode Plot).

When a tutor is available, they will examine you with the following steps.

Step 1: Mark "Circuit Construction and Setup"

These two criteria assess the physical construction of the circuit on the breadboard, basic oscilloscope setup, basic function generator setup, and ultimately the correct presentation of V_{in} and V_{out} on the oscilloscope.

Circuit Construction and Setup [Marked during demonstration]	
(1) Oscilloscope configured correctly for experiment in order to simultaneously show two input channels; probe ratio settings correct. Function generator correctly configured to generate a sinusoid at an appropriate amplitude (≈2VPk-Pk) at sensible frequency. Time/amplitude scale adjusted to make sense of input/output waveforms.	Yes: 2/2
	No: 0/2
(2) Circuit correctly constructed, with V_{out} and V_{in} terminals correctly identified; function-gen and scope leads connected correctly.	Yes: 2/2
	No: 0/2

In order to get marks for criteria (1) all of the following must be satisfied:

- Function generator must be set to provide a sinusoid with approximately 2V Pk-pk amplitude and a sensible frequency within the range of the experiment (i.e. greater than 10Hz, less than 20kHz, but recommended to be set at around 1KHz).
- Oscilloscope must be configured to simultaneously display the two measurement channels
- The probe ratios of both oscilloscope channels must be set to 1:1.
- The amplitude and time scales (and any other settings such as offset) must be set to sensibly view and verify the input and output waveforms *(although not necessarily set for accurate measurement)*.

In order to get marks for criteria (2), <u>all</u> of the following must be satisfied:

- Correct *type* of component (i.e. resistor, inductor, capacitor) must be selected and these must be placed on the bread board in the correct circuit configuration.
- Input and output terminals must be identified by you verbally
- Function generator lead correctly connected to the input terminal of the circuit.
- Oscilloscope leads should be correctly connected to the input and the output of the circuit.

The tutor will notify you of any errors as they proceed through the marking criteria. Any such errors will be penalised according to the appropriate marking criteria, and then fixed by the tutor to allow you to proceed (with a correct circuit) to the next part of the exam.

If a tutor had to fix your circuit during Step 1 of marking, they will give you the option of some more time before moving onto the next stage of marking.

<u>Step 2: Signal Measurement:</u>

The tutor will nominate a frequency and measurement method (either cursor function of MEAS function), and ask you to demonstrate your ability to measure the amplitude of V_{in} and V_{out}.

Signal Measurement <u>[Marked during demonstration]</u>	
Able to correctly and accurately measure V_{in} and V_{out} amplitudes at required frequency using the measurement method suggested by tutor. Time and amplitude scale must be adjusted appropriately.	3/3
Able to measure V_{in} and V_{out} amplitudes using ***some*** method without any assistance, even if this was not accurate, or not the method suggested by the tutor.	1.5/3
Not able to measure amplitude of V_{in} and V_{out} using any method	0/3

To achieve 3/3 for this criterion, you need to be able to competently use the suggested measurement methodology to make an accurate measurement in a timely manner. In addition to the mechanics of measurement the measurement function, you will need to:

- Adjust the function generator to supply the specified frequency
- Adjust the time scale such that you can see 1.5-4 periods of the sine wave on the screen
- Adjust the amplitude scale such that both the input and output voltages are simultaneously displayed, and that each occupies 40-60% of the vertical space.
- Apply the measurement method with both signals simultaneously displayed, and without physically re-connecting/adjusting/swapping oscilloscope leads.

You will have a fixed time-line to do this:

- If after 60 seconds you have not been able to demonstrate this method to you, you will be told that you have another 30 seconds to demonstrate this before you can no longer give them 3/3.
- After this time has elapsed, will no longer be able to receive 3/3 for this section but if you can now demonstrate *any method* for measuring a signal they will receive 1.5/3. You will have another 60 seconds to do this:
    - This could be manually measuring the signal amplitudes off the oscilloscope screen, using the cursor function, or the MEAS function.
- If after this time, you have still not shown an adequate method (including manual measurement off the screen), you will be awarded 0/3.

<u>Step 3: Technical Questions</u>

The marker will ask you 1-2 questions about the design, testing or performance of your filter circuit.

<u>Completing the demonstration task:</u>

After the in-demonstration marking, you should continue making the required measurements to complete the table and the Bode plot. It is essential that you label the correctly label X and Y axis and include X and Y titles (including specifying units); and that you clearly show your experimental measurements, and then a neat line through these values.

<u>Requesting Assistance:</u>

If you are having trouble constructing the circuit; or you believe that a piece of equipment is broken you can request assistance from a tutor. However, be aware, that as soon they commence assisting you, you will be penalised for any errors that they identify.

They will ensure your circuit is correct, setup the function generator with a 1kHz sinusoid as the input, and display V_{in} and V_{out} on the oscilloscope with the correct settings. You will be penalised up to 4 marks as per the “Circuit Construction and Setup” criteria. If you have entirely satisfied criteria (1) or criteria (2) you will still get marks for that component.

There will be no penalty if the equipment is faulty, and you will have the option of having the equipment replaced and continuing the exam; or re-sitting the exam later in the week. If you do choose to continue, you will not have the option of later deciding to re-sit the exam.

If your circuit isn’t working after 15 minutes, it is suggested you ask for help.