Control Systems Lab
Experiment 4: Noise Cancellation in Headphones

Group 18-Tuesday Batch
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1 Objectives

The primary aim of the experiment was to **design and implement an analog circuit for noise cancellation in headphones**. The objectives of the experiment were as follows:

(a) To achieve an attenuation of **20dB** when noise of frequency **100Hz** is applied.

(b) To design an **analog compensator** to stabilize the system, i.e. loop shaping of the loop transfer function.

2 Description of the Setup

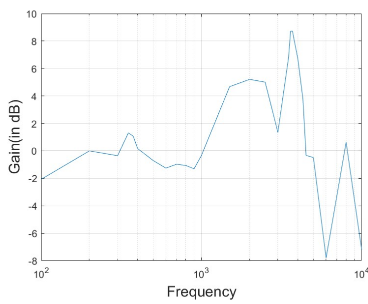
1. The set-up consists of a plastic box, having standard headphones that take an input signal($x(t)$) and provide the output($y(t)$) which is basically the input + noise($n(t)$).
$$y(t) = x(t) + n(t)$$

2. We had to connect the above described set-up to a compensator circuit in order to achieve noise cancellation.

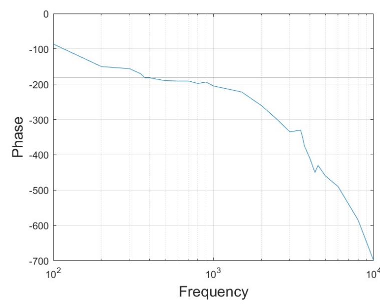
3 Procedure

3.1 Characterizing the system

We connected the **Signal Generator** and the **DSO** to the input and output of the set-up respectively to measure the variation in **gain** and **phase** of the system from **100Hz to 10kHz**. Using this data, we plotted the **bode plots** of the system.



(a) Gain Bode Plot of uncompensated system



(b) Phase Bode Plot of uncompensated system

From these plots we obtain the following values:

- Gain at 100Hz= **-2.07dB**
- Phase at 100Hz= **-86 degrees**
- Phase crossover frequency= **371 Hz**

3.2 Compensator Design

We followed the following steps to design the compensator:

1. We need to achieve a gain of **20dB** at a frequency of **100Hz** and a **negative gain** at the phase crossover frequency i.e. 371 Hz. We are designing a second order **lag compensator** to achieve the same.
2. We get the compensated bode plot response by superimposing the lag compensator response with the bode plot of the system. It is worth observing that the **gain** and **phase** can be directly added due to the gain being on a logarithmic scale and the phase of complex numbers being additive in nature.
3. We then tune the gain(K), zeroes(z_1, z_2) and poles(p_1, p_2) to achieve the required specifications.
4. The compensator is of the form:

$$C(s) = K\frac{(s+z_1)(s+z_2)}{(s+p_1)(s+p_2)}$$

5. After fixing the values of the parameters, we calculate the values of the resistances and capacitances required to make the circuit.
6. We then connected the circuit in **cascaded open loop configuration** and **closed loop configuration** and observed the output.

4 Hardware Implementation

Following is the circuit used for the compensator with the values of all components:

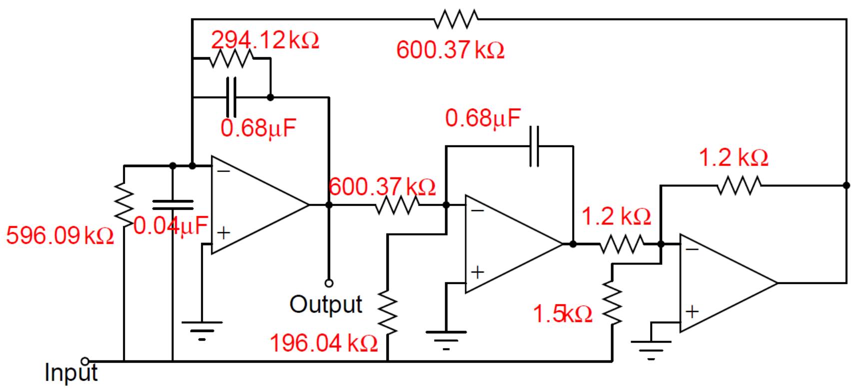
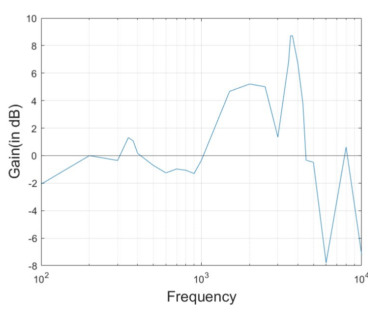


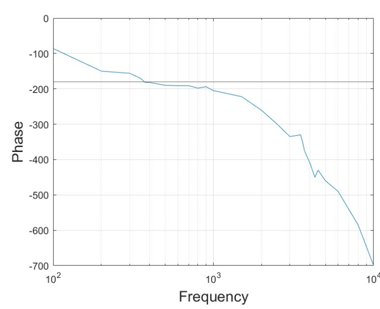
Figure 2: Compensator Circuit

5 Plots

Following are the bode plots for the uncompensated system:

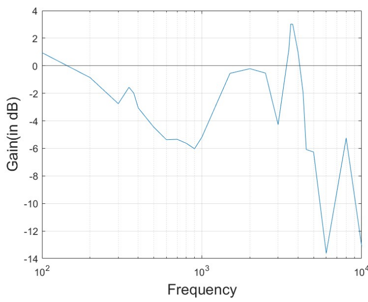


(a) Gain Bode Plot of uncompensated system

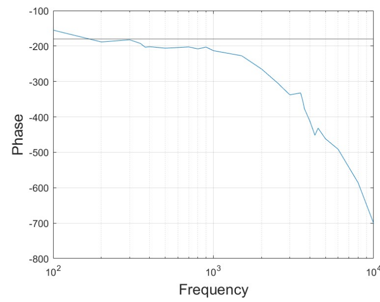


(b) Phase Bode Plot of uncompensated system

Following are the bode plots of the open loop cascaded system:



(a) Gain Bode Plot of open loop cascaded system



(b) Phase Bode Plot of open loop cascaded system

6 Challenges Faced

- We faced a lot of difficulties in characterizing the system since, there was a lot of external disturbance and the variation of gain and phase values with time.
- The phase crossover frequency for the apparatus given to us was very low(370Hz), so it was very difficult to design the compensator with the given specifications. Therefore, we had to modify our target i.e. achieve a **positive gain** for **100Hz** and a **positive gain margin** for stability of the system.
- There was a difference between the theoretical and practical results since we could not find exact values for resistors and capacitors.

7 Results

We obtained the following transfer function:

$$C(s) = 0.5\frac{(s+439.6)(s+471)}{(s+12.56)(s+18.84)}$$

- Gain at 100Hz=**1.5dB**
- Phase Margin=**10 degrees**
- Gain Margin=**2dB**

We observe that our system is stable as gain margin and phase margin are both positive. We obtained a much lower gain at 100Hz because of an extremely low value of the phase crossover frequency in the uncompensated system.

8 Learnings from this experiment

- The experiment provided us with insight into the practical applications of lag and lead compensators and enabled us to implement the hands-on circuit for a second-order lag compensator.
- The experiment provided us with an idea of the working of noise-cancelling headphones which are very commonly used today.