Filters, Sensors and Signal Processing

1. An audio song has frequencies in the range of 100-2000Hz. It is corrupted with a high frequency noise of 13kHz. You need to design a low pass filter to filter out the 13kHz by reducing the power of the 13kHz noise by 18dB. What should be the cut-off frequency of the low-pass filter? (**Ans: $f_{cut\text{-}off}$ =1649.73 Hz**)
2. George is a frequent flyer with Singapore Airlines. He loves music, but is annoyed by the low frequency humming (30 – 60 Hz) from the airplane engine when he is flying. He decided to design a high pass filter to tackle this problem. He primarily listens to electronic dance music (generally in the frequency range of 800 to 3000 Hz). Help him design a filter to suppress the humming by atleast 21 dB. (**Ans: $f_{cut\text{-}off}$ =670.53 Hz**)
3. Design a band pass filter to allow only frequencies in the 6th octave to pass through. To ensure all the frequencies of the 6th octave are allowed to pass, choose cut-off frequencies at-least 200 Hz away from the 6th octave frequencies. (Hint: Verify this by calculating the **gain in dB** for your highest and lowest 6th octave frequencies. The gain for these frequencies and the whole octave should be 0dB).
4. Design an active band pass filter with a pass band gain of 6 dB to amplify a frequency range of 150 – 850 Hz. (Hint: Use the gain in dB formula to find the values for R_1 and R_f in non-inverting configuraiton.)
5. The REV Robotics Analog Pressure Sensor is a 5V (V_{cc}) sensor that can measure pressures up to 200 PSI. It outputs an analog voltage that is proportional to the measured pressure. Given the output voltage (V_{out}), pressure (p) can be calculated as follows:

   $$p = 250\ (V_{out}/V_{cc}) - 25$$

   This sensor is connected to a setup with a maximum pressure of 10 PSI. How would you extend the setup range to make it work with an Arduino with an ADC range of 0 – 3.3 V?
6. HIH-4030 is a commonly used humidity sensor IC chip. It operates at 5 volts and the output of the sensor varies as 30.680 mV/Relative Humidity percentage. V_{out} at 0% Relative Humidity is 0.958V. Design a humidity sensing circuit using HIH-4030 to obtain the relative humidity percentage. Provide details of your design such as resistors, operational amplifier configuration, if any. How can the sensing system be designed with the help of an Arduino?
7. A sound signal, X(t) in the audible frequency range is passed through a low pass filter with cut-off frequency of 3000 Hz to obtain the signal Y(t). What is the maximum sampling period that can be used to sample Y(t) without degrading its quality? (**Ans: 166.67µs**)
8. A microphone is recording an audio song with a frequency range of the 2nd to the 5th octave. The song is corrupted by a 15 kHz noise. This recording needs to be sampled by an Arduino Uno for controlling the loudness of the speaker connected to the audio system.

   a) Design an analog low pass filter to suppress the 15 kHz noise by at least 20 dB. (**Ans: $f_{cut\text{-}off}$ =1.5 kHz**)

   b) What is the minimum sampling rate required for processing the audio song? (**Ans =1975.6 Hz**)

c) If we need to design a digital low pass filter, what is the minimum sampling rate required to suppress the 15 kHz noise? (**Ans: 30 kHz**)