Digital Filter

Lab 5

Readings:

Lecture Notes

- **Lecture 14: Digital Filtering and Control**

Lab Description:

For this lab students will implement two digital filters a 1st order low pass filter and a 2nd order notch filter. To do this students will need to use the SAMD20's ADC and DAC as well as an external frequency generator. Students will attach the frequency generator so that the ADC on PA11 can read the sine waveform. Then process the read waveform. Then output the result from the DAC on PA02.

hint: when using the external frequency generator adjust the DC offset, and output level on it so that a full waveform can be seen on an Oscilloscope when attached to the board.

First Order Low Pass Filter:

The following transfer function is a 1st order low pass filter with a bandwidth of b.

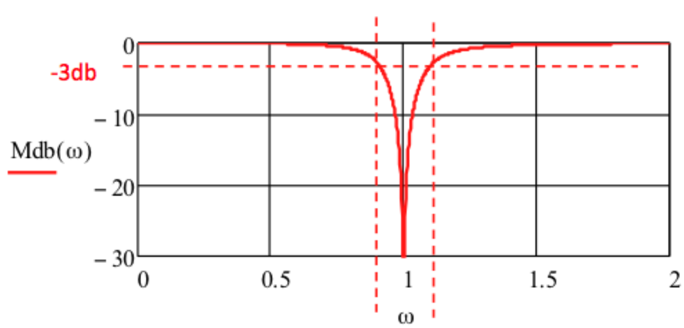
$$H(s) = \frac{a}{s+b} \qquad \Rightarrow \qquad H(z) = \frac{a}{\dfrac{z-1}{T_s}+b} = \frac{aT_s}{z-1+bT_s}$$

Second Order Notch Filter:

The following transfer function is a 2nd order notch filter (a.k.a. band reject filter).

$$H(s) = \frac{s^2+\omega_n^2}{s^2+\dfrac{\omega_n}{Q}s+\omega_n^2}$$

The frequency w_n (in rad/sec) is the center of the rejecting band, Q is the quality factor, and w_n/Q is the bandwidth of the rejection band. The following figure shows this transfer function's magnitude response plot with w_n=1 and Q=5. The bandwidth of this transfer function is 1/5. The x-axis of the plot is in rad/sec and is shown in linear scale. The vertical axis is in dB scale.



Matlab:

The following steps should be taken in matlab to get the proper transfer function to implement in the SAMD20 code.

The following sample transfer function is a second-order low pass filter with w_n = 5Hz

$$H(s) = \frac{(10\pi)^2}{s^2 + 5\pi s + (10\pi)^2}$$

1) Hc = tf ([(10pi)^2] , [1, 5pi, (10pi)^2]) //This will create Hc as the continuous time transfer function
2) bode(Hc)   //To observe the Bode diagram of Hc
3) Hd = c2d(Hc, 0.002)   // This will create Hd as the discrete time transfer function with a sampling frequency of 500Hz or a Ts of 0.002. Ts in the c2d() function is in seconds.

After obtaining the discrete transfer function follow the steps from Lecture 14 page 4 and 5. Keep in mind that the Ts used in the c2d() function must match that of the TC interrupt frequency. If the TC interrupt frequency does not match the Ts the filter will not work as intended.

Required Tasks: ***<u>please comment your code</u>**

Task 1: Implement a digital 1st order low pass filter with a rejection frequency of your choosing with a sampling frequency of 1,000Hz.

Task 2: Implement a digital 2nd order notch filter that rejects a 60Hz frequency component with a bandwidth of 10Hz and a sampling frequency of 1,000Hz.

<u>For Task 1 and 2 do the following:</u>

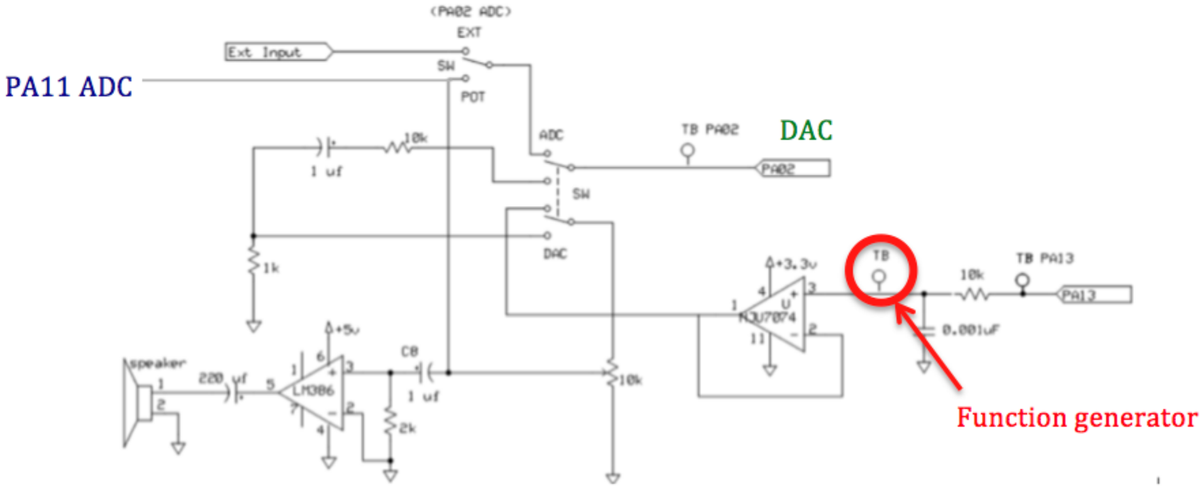
- Work through Matlab to create the proper transfer functions
    - Observe and get screenshots of the bode diagram for the transfer functions

- Observe and get Oscilloscope screenshots of
    - The bandwidth
    - Rejection frequency
    - The aliasing effect

- Compare the bandwidth from the Matlab bode diagram to the observed bandwidth on the Oscilloscope.

- Determine the time it takes for the calculations to process. Measure time for these lines with respect to the entire ISR timing.
    - Filter equation
    - ADC
    - DAC
    - Any else in your ISR

hint: outset and outclr to measure the time on an oscilloscope. Dont comment out the lines just change the locations of outset and outclr.



Attach the external function generator to the test point after the low pass filter circled in red.