Laboratory 8

Electronics Engineering 3210

Filter Design

Purpose:

In this lab exercise the student will design a filter that meets a set of given requirements, then will realize and test the design using operational amplifiers.

Preliminary:

Write a title and short description of this lab on a new page of your lab book. Make an entry in the table of contents for this lab.

You are to design a Chebyshev filter with a maximum of 1.5dB ripple in the pass band and a minimum of –24dB attenuation in the stop band. The pass band is 0Hz – 10kHz and the stop band is 20kHz – ∞Hz.

First, find the number of poles, n, required for your filter. You may use Equation 7.49b of the text or you may use the built-in MATLAB function cheb1ord(). Record all calculations in your lab notebook.

Once the number of poles has been determined, calculate ϵ (Equation 7.47 of the text) and x (Equation 7.50 of the text). Again, Record all calculations in your lab notebook.

Graph LHP (left half plane) semicircles of radius a and b in your notebook, where

$$a = \sinh(x) \text{ and } b = \cosh(x).$$

Locate the poles of the transfer function using n, a and b. Plot these poles on your graph. From these poles, determine the normalized transfer function for this filter.

Scale this function so the pass band will end at 10kHz by replacing s with s/(2π10kHz), then verify this function is correct by comparing it to the results of the built-in MATLAB function **cheby1()**.

Use MATLAB to find the frequency response of this system. This can be done using the built-in function **tf()** and the **bode()**. For example:

```
>> [num,den]=cheby1(n,r,Wp,'s');
>> T = tf(num,den);
>> bode(T);
```

Design a circuit using operational amplifiers to realize the transfer function of your filter just as you did in Lab 7. Choose capacitors and resistors from those available in the parts cabinet opposite room 416. A good operational amplifier is the LF353, which is also available in those part cabinets. It will be necessary to use a decoupling capacitor on the LF353. A 0.1μF capacitor between V^+ and V^- will do nicely. Draw the schematic of your circuit in your lab book and affix the Bode plot (frequency response) you computed earlier.

Procedure:

Build your circuit and connect its input f(t), to the function generator. Configure the power supply to produce both a positive and negative voltage. ±10 volts will do nicely. Connect the positive lead to the V^+ pin of the op-amp(s) and the negative lead to the V^- pin of the op-amp(s). Configure the function generator to produce a 1kHz sine wave with an amplitude of 5V. Measure the output of your circuit, y(t), with an oscilloscope and record its amplitude. Compute the power gain (or attenuation) in dB and record that as well. Repeat the procedure for frequencies of 2kHz, 5kHz, 10kHz, 20kHz, 50kHz and 100kHz.

Compare your results with the frequency response you computed earlier. Do the numbers agree? If they do not, check your circuit design and the connections and try again. (Small errors are normal due to the tolerances of the components.)

Record any additional observations you have made, and write a conclusion in your lab book that summarizes what you have observed or discovered.