Laboratory 7

Electronics Engineering 3210

System Realization and Frequency Response

Purpose:

In this lab exercise the student will design a circuit using operational amplifiers that will realize a given a transfer function. The student will then compare the frequency response of that system to the theoretical response of the system.

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.

Consider a system with the following transfer function:

$$H(s) = \frac{Y(s)}{F(s)} = \frac{10^{15}}{(s^2 + 10^5 s + 10^{10})(s + 10^5)}$$

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, to plot the frequency response of

$$G(s) = \frac{4s + 28}{s^2 + 6s + 5}$$

You might type:

```
>> G = tf([4 28],[1 6 5]);
>> bode(G);
```

Note that in a Bode plot, the magnitude part is a log-log plot because the frequency scale is logarithmic and the magnitude is given in decibels, which is also logarithmic.

Comment: The <u>power</u> ratio of two signals may be measured in Bels, where

$$\text{power ratio (in Bels)} = \log_{10}\left(\frac{P_{out}}{P_{in}}\right)$$

The Bel turns out to be too course a measure of power ratio, so the decibel (dB), which equals one tenth of a Bel, is used instead:

$$\text{power ratio (in deciBels)} = 10\log_{10}\left(\frac{P_{out}}{P_{in}}\right)$$

Often, we have a ratio of voltage (or current) rather than a ratio of power. But it is easy to show that the signal power is proportional to the square of signal voltage (current), or

$$\frac{P_{out}}{P_{in}} = \left(\frac{V_{out}}{V_{in}}\right)^2$$

So if a ratio of voltage is known, the power ratio in dB can be computed by:

$$\text{power ratio (in deciBels)} = 10\log_{10}\left(\frac{P_{out}}{P_{in}}\right) = 20\log_{10}\left(\frac{V_{out}}{V_{in}}\right)$$

End of comment.

Design a circuit using operational amplifiers to realize the transfer function, *H*(*s*). You may use any technique you wish, but if you cascade the transfer functions shown in Figure 1, the system can be implemented with just two operational amplifiers.

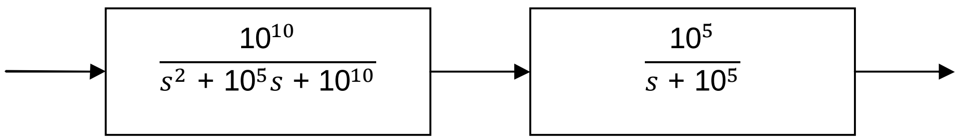

Figure 1. Cascade Realization.

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. Find its online datasheet and print the pin diagram. Affix the pin diagram to your lab book. 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 5kHz 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 10kHz, 15kHz, 20kHz, 25kHz, 30kHz, 40kHz and 50kHz.

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.)

Connect a second scope probe to the input, f(t), of your circuit and measure the phase delay for each of the frequencies listed above. (Measure the time lag, divide by the period, then multiply by 2π or 360°). Compare the phase delays you observed with the phase plot of the frequency response you computed earlier. Record your findings.

Configure the function generator to produce a15kHz square wave. Sketch the output waveform y(t) in your lab book. Using your knowledge of the frequency spectrum of the square wave and the frequency response of this system, form a hypothesis that explains your observations.

Based on your hypothesis, predict (in general terms) what you will observe if the input is a triangle wave. Record your prediction then configure the function generator to produce a triangle wave and see if you were correct.

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