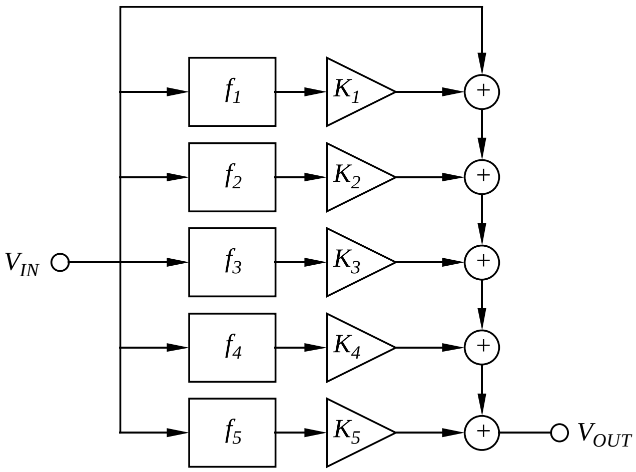
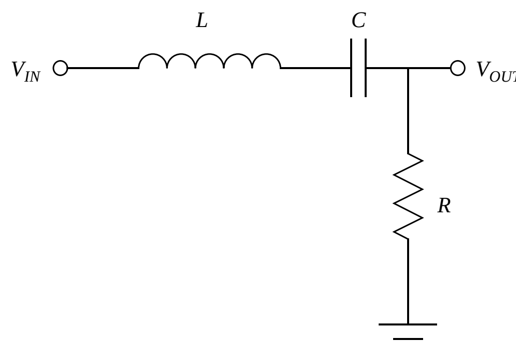
EE 381K **DIGITAL SIGNAL PROCESSING** Spring 1998

COMPUTER HOMEWORK THREE

Due: Wedenesday, April 22, 1998

This assignment concerns the design and implementation of a digital graphic equalizer for audio. An equalizer allows certain fixed bands to be boosted (gain > 1) or cut (gain < 1) according to user settings. The 'graphic' term refers to the fact that analog versions are usually equipped with sliding potentiometers to set the gain of each band, and a look at the positions of the sliders indicates graphically the frequency response of the sytem. Well, that's how the story goes. The equalizer system is shown below at the left.





The five filters, labeled f_1 through f_5, are bandpass filters with unity gain and zero phase at their respective center frequencies. When all the gains K are set to zero, the system has a flat frequency response with unity gain. If, for instance, $K_1 = 1$, frequencies around f_1 are subject to a gain of 2 (6 dB). If $K_2 = -0.5$, frequencies around f_2 are subject to a gain of 1/2 (–6 dB), and so on. Thus we have individual control over different bands by varying the values of K.

We will use a second-order analog prototype for the filters, shown above at the right. **Compute** the s-plane transfer function of this filter, and **show** that it has unity gain and zero phase at the center frequency. **Show** that the Q of the filter (ratio of center frequency to 3 dB bandwidth) is given approximately by $(1/2R)\sqrt{(L/C)}$ (do not solve the quadratic for this; assume Q is large).

We will use the bilinear transformation to construct these five filters digitally, for analog center frequencies of 50, 200, 800, 3200 and 12,800 Hz, assuming a sampling frequency of 44,100 Hz and a Q of 2. Assume that $\alpha = 2/T_s$ and pre-warp the analog frequencies so the digital frequencies are exact. On one graph, with a logarithmic frequency scale and linear magnitude scale, **plot** the frequency responses of all five filters from 20 to 20,000 Hz. Use 8192 points in `freqz`. You should see five overlapping peaked functions.

Now **implement** the equalizer according to the diagram above. You may use `for` loops; the function `filter` will be useful. Have a five-element vector which contains the desired boost or cut of each band in dB. Set this vector to [–3 12 6 –12 6], and apply the equalizer to a chirp signal (one with a frequency that changes linearly with time from DC to the Nyquist frequency) of length 16384 points. **Compute** the transfer function of the equalizer by finding the absolute value of the ratio of the `fft` of the output to the `fft` of the input. **Plot** this on a dB scale with a logarithmic frequency axis, and show that the equalizer is indeed approximately 'graphic'.