EE133 - Lab 4.5
IF Amplification and Filtering

1 Objectives

- To demonstrate the ease of creating passive analog filters
- To enhance the reception circuit with some intermediary frequency amplification and filtering

2 IF Amplification and Filtering

For the rest of the quarter, we will not hand out explicit prelabs and labs; we will rather give you a circuit to build and some suggested steps to make it work. You are free to simulate and test the circuits as you please, and we will only make sure you have done what’s absolutely necessary (i.e. that you have a working circuit). However, we hope that you will continue to be thorough in your analysis and design.

One of the major problems with your receiver is that it relies on a large input power so that the PLL has a large enough input signal to lock. We simply need to add some amplification in the signal path in order to get more range. We could do this at the input, but that would require an amplifier to work at 24 MHz and we don’t want to bother with those high frequencies (yet). In the early days of radio, Armstrong had this same problem getting gain at high frequencies and therefore invented the ‘super-heterodyne’ receiver. This receiver mixes the high-frequency input signal, say 24.3 MHz, down to a lower ‘intermediate frequency (IF)’ (300 kHz) and then amplifies this lower frequency signal. Hopefully, this system sounds familiar as you have spent the first part of the quarter building it.

Our next task is to build an IF Amplifier to work at 300 kHz with a gain of around 10,000 (or 80 dB). We will use the Elantec 2211, dual op-amp for the building block. Since this amp has a gain-bandwidth product of 400 MHz and is stable for gains greater than 2, it should be perfect for our 300 kHz amplifier.

One other major problem that we haven’t yet addressed is filtering. Imagine if your neighbor was transmitting a large signal at 24.5 MHz while you were working at 24.3 MHz. If this signal got into your system and was mixed down to 500 kHz, it could potentially mess with your PLL. We will therefore build a bandpass filter to make sure these unwanted signals don’t interfere with our receiver.

![IF Amplification and Filtering Circuit Diagram](image)

Figure 1: IF Amplification and Filtering

For your prelab this week, design and build the circuit shown in Figure 1. Notice that the incoming signal is ac coupled, amplified by the non-inverting amplifier, band-pass filtered by the $L_1, C_1, L_2, C_2$ combination, and finally amplified again by the second op-amp.

- Design your amplifiers to each have gains of around 100 and use a potentiometer on the second amplifier in order to have a variable gain stage.
- The goal is to design a 4 pole Butterworth Filter (AKA Maximally Flat). We want a bandwidth of 100 kHz and a rolloff of 40 dB to either side. Please refer to Tom’s lecture last Thursday or this week’s handout on filters (forthcoming)
### Element Values for Maximally Flat Low-Pass Filter Prototype

<table>
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<tr>
<th>N</th>
<th>g1</th>
<th>g2</th>
<th>g3</th>
<th>g4</th>
<th>g5</th>
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</table>

Table 1: \( g_o = 1 \), \( \omega_c = 1 \) \( N = 1605 \)

- Design a low-pass filter with the correct \( w_o \). Then convert this prototype into a bandpass filter. (Hint: The low-pass prototype is not going to be \( N=4 \).)

- Simulate, using either MATLAB or HSPICE, the frequency response of this filter (with standard component values). Please refer to the parts sheet to see what components we have in the lab.

- Simulate the frequency response of the entire circuit using HSPICE. (You’ll have to write most of the SPICE deck, a shell with the EL2211 model is given on the web page.)

- Build and test the IF amplifier/filter. (Notice that only one chip is necessary because the EL2211 is a dual op-amp.) How does it compare with your simulated results? How quickly does your filter roll-off (in dB/decade)?

- Hook up the entire receiver with the IF amp in place and find the new range of your transmitter/receiver pair.