EE 192 Discussion 7 (2/29-3/1)

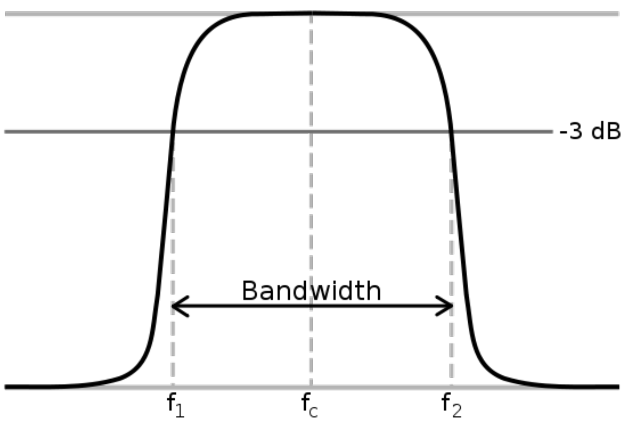
Magnetic Sensing, Part 2

Materials

- Inductor coil
- Inductor coil with bandpass filter (RLC circuit)
- Magnetic test track
- LM324 and LM6144 op amps
- Breadboard
- Various resistors and breadboard wire

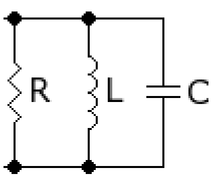
1. *Frequency response*. Hold the inductor coil at a fixed height perpendicular to the magnetic test track. With the oscilloscope hooked up to the inductor, sweep the frequency from 10kHz to 1MHz.

   Find the natural resonant frequency (f_c, at the maximum Vpp), and the -3dB cutoff frequencies (f_1 and f_2 where Vpp is 0.707*max Vpp).



   Example value: 200kHz with a bandwidth of 8kHz (-3dB frequencies of 196, 204kHz). The values found by different teams varied but were all within the same decade (x100kHz).

2. *Frequency response of RLC resonator.* Now repeat the process with the RLC circuit (C=560pF, R=100kOhm), finding the resonant frequency and -3dB cutoff frequencies. What is the bandwidth of this sensor?



   Example values: 71kHz with a bandwidth of 4kHz (-3dB frequencies of 69, 73kHz).

   Give a reason why the resonant frequency is not exactly 75kHz.

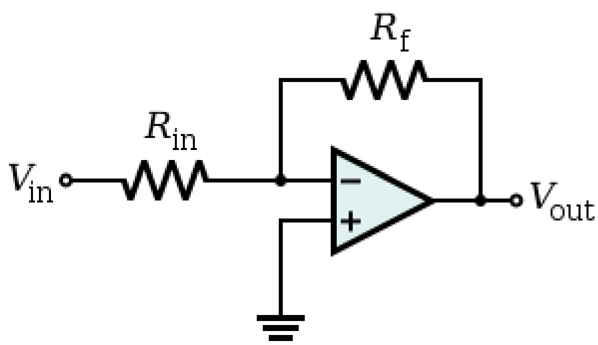
   Capacitor and inductor values are not exact; both have ~10kHz. (Instructor Note: Watch out! Some capacitors may have +80/-20% tolerances.)

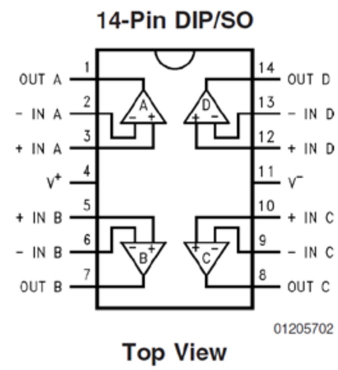
   The Q factor (sharpness of the frequency response) is given by $Q = R\sqrt{\frac{C}{L}}$, and empirically by $Q = \frac{f_0}{\Delta f}$ (where Δf is the bandwidth and f_0 is the resonant frequency). Calculate the Q factor using both methods. Do they differ, and if so, why? (Hint: Q factor is defined as the ratio of Energy Stored / Energy Dissipated by the resonator.)

   The calculated value is 26.1, and the empirical value is about 16 (may vary). This discrepancy is probably because of unmodeled parasitics (i.e. series resistance in the inductor) which causes more energy to be dissipated.

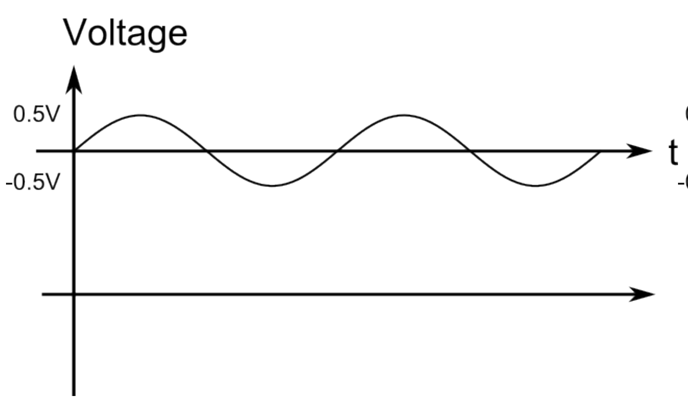
Op Amp Non-idealities

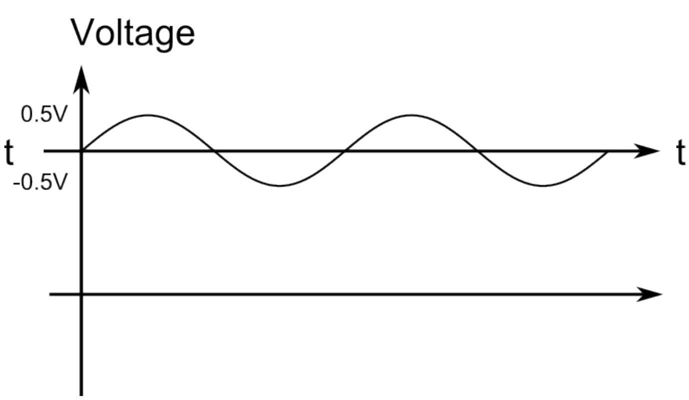
Build the following inverting amplifier on a breadboard. Use $R_f = 39k\Omega$ and $R_{in} = 10k\Omega$ to get a gain of approx. 4. (Both the LM324 and LM6144 have the same pinout.) Use $V^+ = 5V$ and $V^- = -5V$.





3. *Slew rate limit*. Using the LM324 (a cheap op amp), hook up the function generator to Vin using a 75kHz sine wave at 0.5Vpp and record the waveform. Using the oscilloscope axes to estimate, what is the slew rate limit?
   This should look like a triangle wave; the LM324 is unable to output an amplified 75kHz signal.
   Next replace it with the LM6144 (a high-quality op amp) and record the waveform. Note the difference.





4. *Bias current*. Still using the LM6144, replace the resistors with $3.9M\Omega$ and $1M\Omega$ resistors. Record the waveform. Why does this happen? (The input bias current is ~180nA.)
   When the input signal is .5V, the current that flows through the resistors is on the order of 100 nA. Therefore the ideal op amp assumption (that input bias current = 0) breaks down.
5. *Output saturation.* Replace the resistors with 3.9Ω and 1Ω resistors. Record the waveform. Why does this happen?
   The op amp output saturates at ~4mA. Therefore it is unable to raise the voltage at the output by much. Also, the function generator is probably not able to drive that much current through the tiny resistors.