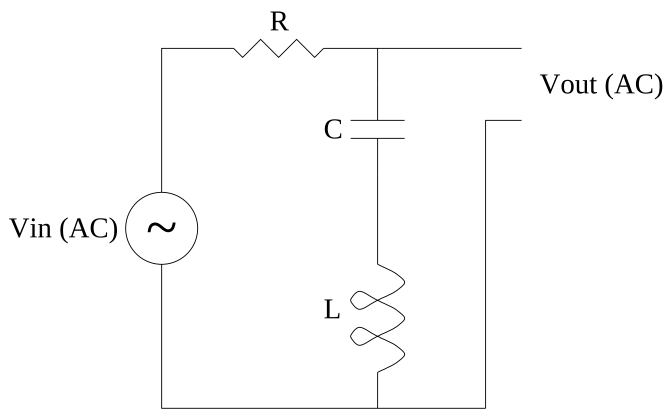
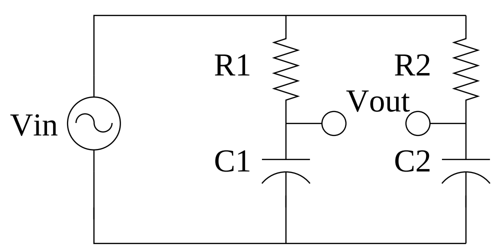
Problem Set #3: Detection Circuits and Filters

DUE: Monday, 2013-02-10 at 5:00 PM in the grader box

1. **Tuned RLC dividers**, as shown below, can be used to determine changes in capacitive transducers.
   (a) Generate plots of the magnitude and phase of the transfer function ($\bar{V}_{out}/\bar{V}_{in}$) for $\omega = 1000$ krad/s, R = 100 Ω and L = 1 mH for 0.5 $< C <$ 1.5 nF. Be sure to include your work to derive the transfer function, along with any code used to generate your plots (don't forget to label your axes with units!). [1]
   (b) Explain how the phase response of this divider is used to measure capacitive transducer changes.
   (c) What role does the resistor play in "tuning" this divider?
   (d) What is the maximum sensitivity of this circuit?



2. Consider the **reactance bridge circuit** below; derive an expression for C_2 in terms of C_1, R_1 and R_2 to balance this bridge (i.e., $V_{\text{out}} = 0$).



3. **First-Order Filter Design** Ultrasound scanners operate on signals that range from 1 - 10 MHz, but typically face significant noise $\leq$ 100 Hz.
   (a) Design a passive first-order filter using a capacitive element that:
      - Attenuates noise $\leq$ 100 Hz at least -40 dB relative to the desired passband of 1 - 10 MHz, and
      - does not distort the passband more than 15°.

      Make sure that you:
      - Draw the circuit diagram with specified component values.

[1]Self-check hint: make sure your plots agree with your analytic solution for the resonant frequency of this circuit.

- Explicitly state the magnitude and phase expressions for the transfer function.
- Draw the magnitude and phase Bode plots, and indicate the passband region and the region of noise being attenuated.
- What is the input impedance of your filter?

(b) Repeat the same design process as above for a passive first-order filter using an inductive element. Present the same circuit diagram, transfer functions, labeled Bode plots, and input impedance analysis.

(c) Comment on any differences between the behavior of the two passive filters. Most of the filters that we construct in lab use capacitive, instead of inductive, elements; why might this be?[2]

4. **Bandpass Filter Design** Electromyography (EMG) signals tend to have biopotential voltages ranging from 10^{-5} - 10^{-1} V over a frequency range of 50 - 5000 Hz. Assuming that you have a single op amp with a maximum output voltage of +10V, design a bandpass filter that will amplify the EMG to the maximum possible gain without exceeding the op amp's linear range of operation. Sketch the amplitude and phase Bode plots for this filter.

[2] This will require a literature search (which these days means an Internet search). Please cite all sources!