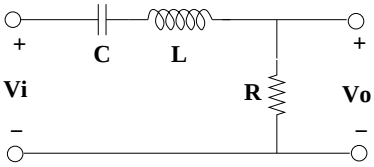
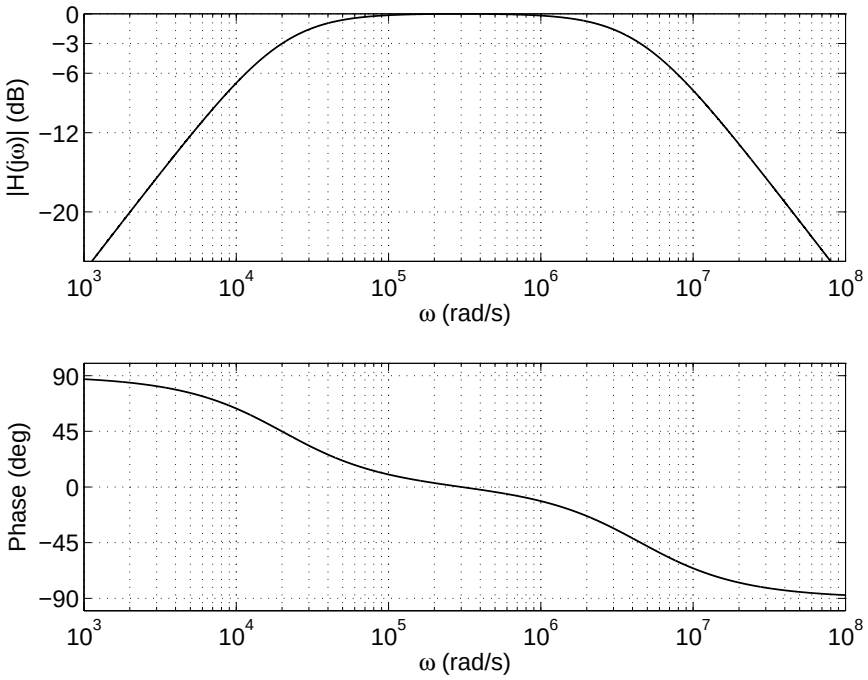
Problem Set #3: Review of Phasors and Filters

DUE: Friday, 2015-01-30 at 5:00 PM in the grader box

1 Filter Fun

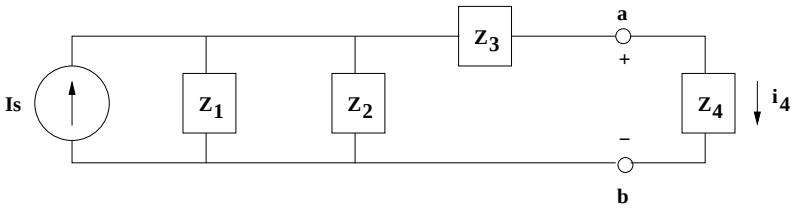
You're given the following filter, and you measure the magnitude and phase of its transfer function ($H(j\omega) = \frac{V_o(j\omega)}{V_i(j\omega)}$) in the lab, as shown in the following plots:





1. What type of filter is this (specify whether it is first- or second-order)? What is/are this filter's cutoff frequency/frequencies (reasonable estimates are okay)?
2. If $V_i(t) = 0.5\cos(2000t)$ V, then what is $V_o(t)$ (again, reasonable estimates are okay)?
3. Solve for the values of R & L needed to achieve this transfer function, assuming that C = 5.55 nF and the quality factor for this circuit can be expressed as $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$.

2 Equivalent Circuits

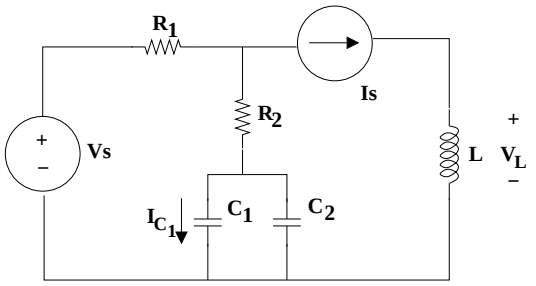


$I_s(t) = 10\cos(1000t)$ mA
Z_1 = 20 Ω
Z_2 = 30 Ω
Z_3 = ?
Z_4 = variable load

$Z_{1..4}$ represent discrete components in the circuit (i.e., resistors, capacitors, and inductors). When $Z_4 = \infty$ (open circuit across terminals a & b), $v_{ab} = 120\cos(1000t)$ mV, and when $Z_4 = 0$ (short circuit across terminals a to b), $i_4 = 9.86\cos(1000t + 9.46°)$ mA.

1. What is the Norton impedance (Z_N) for the circuit as seen from Z_4 (i.e., Z_4 acts as the load)?
2. Given Z_N, what is Z_3?
3. Is Z_3 a resistor, a capacitor, or an inductor? What is the value of this component?
4. Solve for $i_4(t)$ if Z_4 is a 5 mH inductor.
5. Solve for $v_{ab}(t)$ if Z_4 is a 5 mH inductor (same as (d)).

3 Multiple Sources



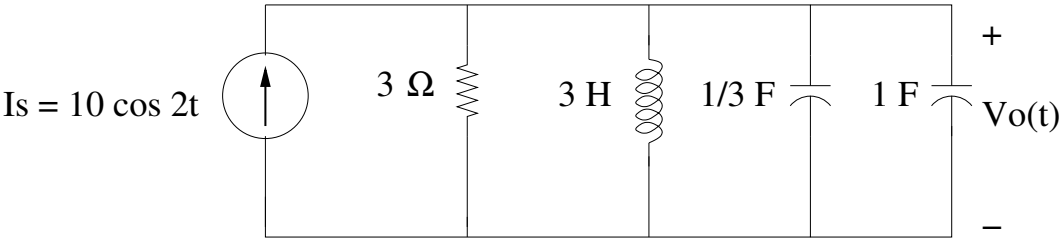
$V_s(t) = 20\cos(100t)$ V
$I_s(t) = 10\cos(1000t + 20°)$ mA
R_1 = 100 Ω
R_2 = 500 Ω
C_1 = 250 μF
C_2 = 750 μF
L = 5 mH

Assume that all of the sources have been on for a long time (i.e., the circuit is in a steady-state condition).

1. Solve for an expression for $V_L(t)$.
2. Solve for an expression for $I_{C_1}(t)$.

4 Phasor Practice:

For the circuit below, use phasor techniques to solve for Vo(t):



5 Filter Design and Bode Plots:

Design a passive RC highpass filter that will attenuate signals with frequencies of 600 rad/sec by 20 dB.

- Draw your circuit.
- Derive its transfer function.
- What is your desired cutoff frequency?
- What component values (R, C?) will you use?
- Draw the Bode plot (both magnitude and phase) for your circuit.
- Now design a passive RL highpass filter with the same cutoff frequency and draw your circuit.
- What component values will you use?
- Describe the differences (if any) you would expect in the Bode plots between your RL and RC filters.

6 Practical Issues- Batteries:

Rechargeable, battery-powered devices are becoming more ubiquitous in the medical setting. Compare/contrast these four types of rechargeable batteries in terms of energy density, output voltage, battery life, recharge time, and weight: (1) lead acid, (2) NiCad, (3) NIMH, and (4) Li-ion.

Li-ion batteries have become very common in cell phones, digital cameras, laptop computers, and many other portable electronic devices. Unfortunately, there is also a non-negligible fire risk associated with these devices. What is responsible for this fire risk, and what safeguards do modern versions of these batteries utilize?