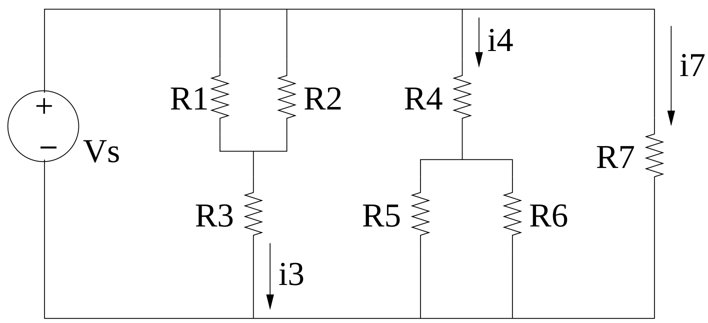
Problem Set #1: Review of Analog Circuit Analysis

DUE: Friday, 2013-01-24 at 5:00 PM in the grader box

1 Where do the electrons flow?

1. Solve for the currents in each of the branches (i_3, i_4, i_7) shown in the following circuit shown in Figure 1.

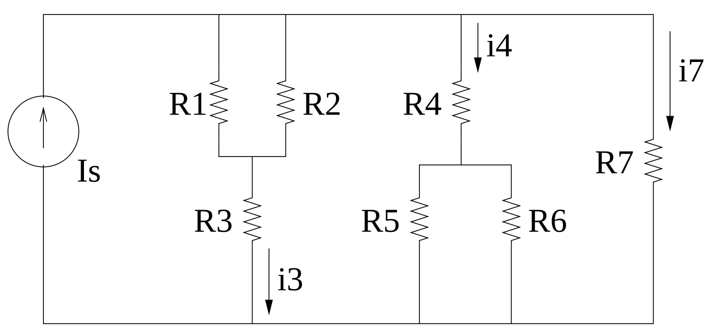


Component	Value
V_s	9 V
R_1	10 Ω
R_2	10 Ω
R_3	5 Ω
R_4	10 Ω
R_5	20 Ω
R_6	20 Ω
R_7	30 Ω

Figure 1: Voltage Source Circuit

2. How much power is supplied by the voltage source (magnitude only)?

3. Solve for the new branch currents (i_3, i_4, i_7) when a current source is substituted for the voltage source:



Component	Value
I_s	11 A
R_1	10 Ω
R_2	10 Ω
R_3	5 Ω
R_4	10 Ω
R_5	20 Ω
R_6	20 Ω
R_7	30 Ω

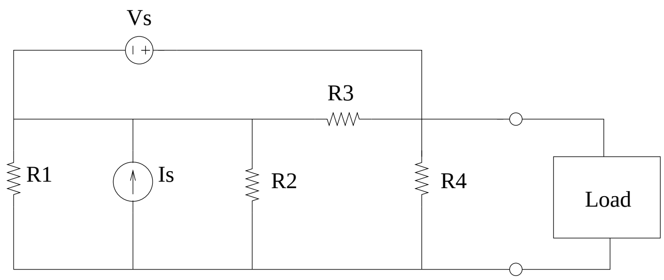
Figure 2: Current Source Circuit

4. How much power is supplied by the current source (magnitude only)?

2 If I only had a voltage source...

It is the night before a big senior design project is due, and you need to build the following circuit that can be attached to an arbitrary load across the output terminals:

Unfortunately the other members of your group dropped the ball and only bought a single ideal current source. At first you panic, but then you realize that you learned some tricks in ECE110L that will save the day.



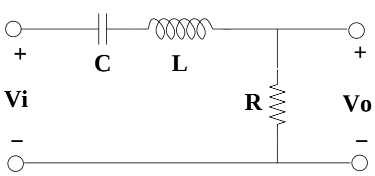
Component	Value
V_s	5 V
I_s	1 A
R_1	5 Ω
R_2	10 Ω
R_3	10 Ω
R_4	20 Ω

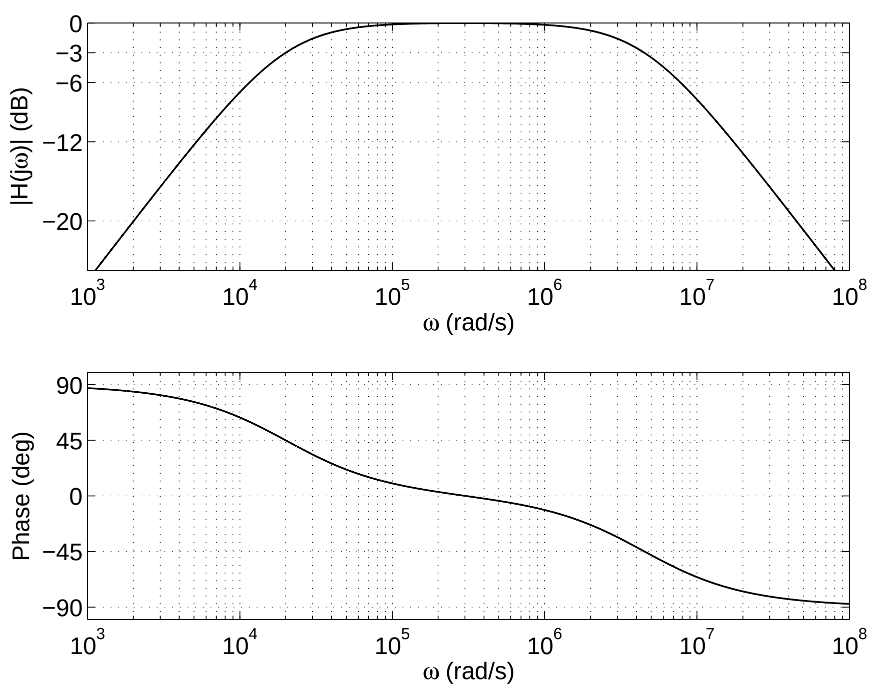
Figure 3: Big senior project circuit

1. Construct the Norton equivalent circuit for the circuit shown in Figure 3. Clearly solve for, draw and label the Norton equivalent circuit. How much current does the current source need to provide, and what value resistor do you need for your circuit?
2. After building your Norton equivalent circuit, you realize that the current source that your group ordered is a dud. Just as you make this realization, a friend walks by the lab and offers you an ideal voltage source that you can use for your project. Clearly solve for, draw and label the Thévenin equivalent circuit for the circuit shown in Figure 3. How much voltage does the voltage source need to provide, and what value resistor do you need for your circuit?

3 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:



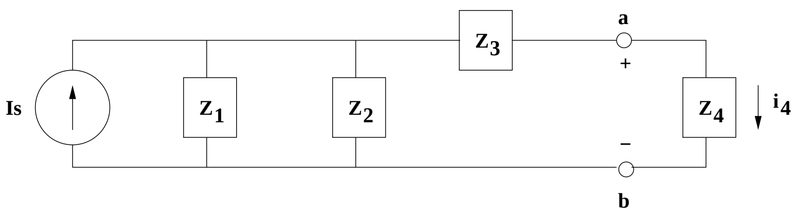


1. What type of filter is this (specify whether it is first- or second-order)? What is/are this filter's cutoff

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 $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$.

4 Equivalent Circuits

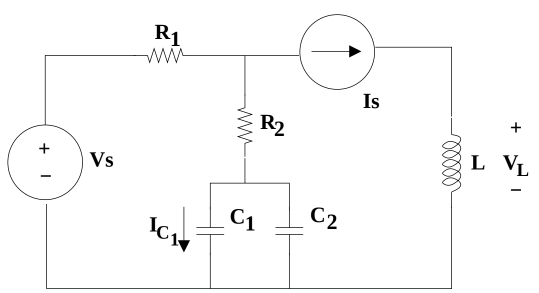


$I_s(t) = 10\cos(1000t)$ mA
Z_1 = 20 Ω
Z_2 = 30 Ω
Z_3 = ?
Z_4 = variable load

$Z_{1..4}$ 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)).

5 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 $I_{C_1}(t)$.

6 Practical Engineering: Outlets and Plugs

1. Describe the difference between a "hot" and "neutral" wires with respect to an electrical outlet.
2. What purpose does the round, centered prong serve on a typical three-pronged plug / outlet? As part of your answer, sketch a simple circuit diagram showing how this would be connected (1) to the device, and (2) to the "hot" and/or "neutral" connections. What role does this center prong play in patient / operator safety in the context of a medical device?
3. One of the two "flat" prongs on an electrical plug tends to wider than the other prong, forcing you to plug it into an outlet in a certain orientation. Describe why this is done and how that relates to the safety of the user of that device.
4. Describe how a Ground-Fault Circuit Interrupter (GFCI) outlet works. Where do you typically find this type of outlet in your home / apartment, and why are they more commonly found there compared to other rooms in your home?
5. Describe how a circuit breaker works. Compare/contrast circuit breakers with fuses. Describe how an Arc Fault Circuit Interrupter (AFCI) circuit breaker works compared to non-AFCI breakers.