University of California, Davis  
Society of Manufacturing Engineers at UC Davis  
ENG 17*  
Circuits I  
Unofficial  
Assorted Comprehensive Practice

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1) Mesh Analysis, Nodal Analysis, and Source Transformation

For the circuit below,

a) Using nodal analysis, write an equation that relates $I_A$, $V_A$, $V_B$, the node voltage at node 1, and the node voltage at node 2. Label the latter two as $V_1$ and $V_2$, respectively.

b) Assume $I_A = 1^V$ and $V_A = 4^V$, use source transformation and mesh analysis, and find the numerical value of $V_B$. Explain how you would use $V_B$ to find $V_1$.

2) KCLs and KVLs with Dependent Sources

For the circuit below,

Using a combination of KVL and KCL, set up a set of equations or a matrix system that can simultaneously solve the numerical values of

a) The current through the 10 $\Omega$ resistor (label this $I_A$)

b) The current through the 7 $\Omega$ resistor (label this $I_B$)

c) The voltage across the independent current source

Bonus: find the numerical values of a), b), and c).
3) Operational Amplifiers, Nonlinear Diodes, and DC Power

For the circuit below, the operational amplifier is ideal. $D_1$’s I-V relationship is $I_{D1} = \frac{V_{D1}}{17000}$ and $D_2$’s relationship is $I_{D2} = I_S e^{\frac{V_{D2}}{V_T}}$, where $I_S = 7 \times 10^{-20}$ and $V_T = 0.025$ (i.e. $I_{D2} = 7 \times 10^{-20} e^{\frac{V_{D2}}{0.025}}$), $V_2 = 10^V$, $I_1 = 0.1^A$.

![Circuit Diagram]

a) What kind of feedback is this?

b) Find the operational point of $D_1$ (i.e. find its current and voltage drop). First, estimate the point graphically and then analytically verify these values to two significant figures.

c) Using your values in part b), repeat part b) for $D_2$.

d) Calculate the DC power dissipated by $R_i$ if it is 100 $\Omega$.

e) Redraw the circuit by replacing the ideal opamp with a non-ideal model. It should have an input resistance of $R_{IN}$, output resistance of $R_{OUT}$, and gain of $A$. Label those components accordingly. Assume that the diodes have the same operational points as in part b) and c) and replace both diodes with an equivalent resistor. Also, remove $I_1$ from the circuit, rewire the circuitry so $V_2$ can be used to power the 100 $\Omega$ at the positive terminal and $D_1$ without changing the operational points of those two components from $I_1$’s effects.

f) From your circuit you drew in part e), numerically find the value of the Thevenin resistance looking into the circuit after the independent source if $R_{IN}$ is infinite and $R_i = R_{OUT} = 100$ $\Omega$.

4) RLC Circuits

For the RLC circuit here, write the second order differential equation for $V_L(t)$ as a function of $V_{IN}(t)$ in terms of $C_1$, $C_2$, $R$, and $L$. The coefficient of one of the two highest order derivatives should be unity. (One of the $d^2/dt^2$ terms should have a coefficient of 1).

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5) A Broken Buck Converter

A rough model of a simple Buck Converter is shown below, with one input voltage source, two resistors, one inductor, one capacitor, and two switches. Usually, the switch on top, $S_1$, switches on and off very fast to trigger conversion of voltage (and $S_2$ is modeled here as a diode - read more about it!). However, in this circuit, the Buck converter is broken and cannot function like it usually does. Instead, we model this as having $S_1$ being closed for a very long time, and $S_2$ being open for a very long time. At $t = 0$, both switches are toggled. $S_1$ will stay permanently open and $S_2$ stay permanently closed. $C = \frac{1}{8} \text{ F}$, $L = 2 \text{ H}$, $R_3 = 2 \text{ \Omega}$, and $R_1 = 2 \text{ \Omega}$. $V_s = 2 \text{ V}$. (underlined text is background materials and is for fun/extra purposes only! Not needed to solve this problem)

a) Completely derive an expression of L's current.
b) Completely derive the expression of $V_o(t)$.

Both part a) and b) must have numerical values with $t$ as the variable.

6) Operational Amplifiers and RL Circuits

The switch is open for a very long time and at $t = 0$, the switch is flipped on. The opamp is ideal.

a) Find the minimum value of $V_{cc}$ such that the output will be in the linear region for $t > 0$.
b) In seconds, how long does it take for the response to reach 97% of the final value?
c) Derive an expression for the current through the opamp’s output. Is it going out of the output? Or in?
d) The same opamp is used to implement an ideal difference amplifier with absolute gain of 60. What is its common mode rejection ratio? What is its $A_{dm}$?

7) Voltage Controlled Current Source Implementation

A nonlinear device is to be powered with a current.

a) The voltage drop across the NLD given the current $I$ through it is $V(I) = 50I + \ln(50I)$ for if $V$ is at least 0, and otherwise $V = 0$. At what current does the NLD turn on?
b) Using an ideal opamp, a 4V DC source, and one resistor with a value of your choice, implement a current source that supplies 40mA to the NLD. Draw the full schematic. You may neglect the power supply of the opamp. Mark the voltage drop polarity of the NLD.
c) Due to temperature variations, your voltage source actually fluctuates between 3.95V and 4.05V. Find the range of voltages at the output of the opamp based on your schematic of b).
8) Second Order Differential Equations

The differential equation of the 2H inductor in an RLC circuit is

\[ \frac{d^2}{dt^2} i(t) + 12 \frac{d}{dt} i(t) + 100i(t) = 408 \sin(2t) \]

At \( t = 0 \), \( i(t) = 2 \) A and the voltage across the inductor is 12 V. Completely solve for \( i(t) \).

9) Passive Component Power

A circuit is known to be a capacitor and a \( \frac{1}{4} \) H inductor in parallel. The voltage (in green) across the circuit and the current (in blue) going into the circuit is plotted.

(a) Write the expression for the instantaneous power and use it to find the average power.

(b) At what frequency, in Hertz, would this circuit resonate?

10) Transformers

The primary inductor of the transformer is 5H, the secondary is 6H, and the mutual inductance is 3H. Assume sinusoidal steady state and derive the relationship \( V_2/i_1 \) and \( V_2/V_1 \) in phasor form in terms of operational angular frequency \( \omega \).

11) Impedance Matching

The operational frequency is \( 5/\pi \) Hz

(a) Using one resistor of any value and either a capacitor or an inductor of any value, draw the matching network with the components’ values so that maximum power is transferred to the load under these constraints. What percentage of power dissipated by the load is from the power supplied?

(b) Write the phasors of the impedance of the source, matching network, and the load.

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