Homework 3

Due Friday (5pm), Feb. 15, 2013

Please turn the homework in to the drop box located next to 125 Cory Hall (labeled EE 42/100). Make sure to clearly label your Name, Student ID, Class, and Discussion sections on the homework.

1) For the circuit below, use node voltage technique to find the thevenin equivalent circuit between nodes A & B. Hint: It is not necessary to use the supernode method. You can assume a current through the 4V source and then use the voltage relationship between nodes A and C.

![Circuit Diagram](image)

2) Op amps can be used as a buffer to prevent loading of a source circuit.
   (a) Supposed the source circuit has been reduced to it’s thevenin equivalent as shown below and the load circuit has been reduced to an equivalent resistance, $R_L$, as seen by the source.
   
   i) For the values given, what is the maximum current, $I_s$ that the source circuit would have to supply?
   
   ii) What is the output voltage, $V_{out}$ as a function of the load resistance?
(b) Now a buffer is added between the source circuit and the load.

i) For the circuit below, what is the current that the source circuit must supply?

ii) What is $V_{\text{out}}$ as a function of the load resistance?

![Diagram of a buffer circuit with $V_{\text{th}}=10\text{V}$, $R_{\text{th}}=200\ \Omega$, and load resistance $R_L$.]

3) It is common in electronics to convert a current signal into a voltage signal. One case where this is necessary, is when converting the photocurrent generated by a photodiode into a voltage signal for downstream processing electronics. A photodiode acts similar to a normal diode except it converts input optical power into a photocurrent. A photodiode must also be reverse biased for optimal operation.

As shown below, we can model a photodiode as an ideal current source with photocurrent given by $I_{\text{ph}} = R_i P_{\text{opt}}$ where $P_{\text{opt}}$ is the absorbed optical power [W] and $R_i$ is the current responsivity assumed to be 0.9 [Amps/Watt]. Note that $I_{\text{ph}}$ flows from the cathode to the anode since the diode is reverse biased. For this problem, we can ignore the diode leakage current.

![Diagram of a photodiode model with $I_{\text{ph}}=R_i P_{\text{opt}}$.]

(a) One way to both reverse bias the photodiode and convert the current into a voltage is with the circuit below in which the photocurrent is sent into a resistor. For this configuration calculate:

i) The voltage responsivity, $R_v = \frac{V_{\text{out}}}{P_{\text{opt}}}$

ii) A drawback of this configuration is that the diode bias is not constant. Find the input optical power at which the diode is no longer reverse biased.
A good way to convert the diode photocurrent into a voltage is with the following transimpedance amplifier (TIA). For this problem calculate:

i) The voltage across the diode. Does it depend on $P_{opt}$?

ii) The transimpedance gain, $G = \frac{V_{out}}{I_{ph}}$ and,

iii) The voltage responsivity, $R_v = \frac{V_{out}}{P_{opt}}$

Find $V_{out}$ as a function of $V_{in1}$ and $V_{in2}$. Assume that op-amp is ideal.
5.) Apply the source-superposition method to the circuit below to determine:
(a) \( I_{x}^{'} \), the component of \( I_{x} \) due to the voltage source alone.
(b) \( I_{x}^{''} \), the component of \( I_{x} \) due to the current source alone.
(c) The total current \( I_{x} = I_{x}^{'} + I_{x}^{''} \)
(d) \( P' \), the power dissipated in the 4-\( \Omega \) resistor due to \( I_{x}^{'} \)
(e) \( P'' \), the power dissipated in the 4-\( \Omega \) resistor due to \( I_{x}^{''} \)
(f) \( P \), the power dissipated in the 4-\( \Omega \) resistor due to the total current \( I \). Is \( P = P' + P'' \)? If not, why not?

![Circuit Diagram](image)

6.) Derive the expression for the output of the subtracting amplifier (\( V_{o} \)) using superposition principle. The circuit is shown below:

![Subtracting Amplifier Diagram](image)

7) For the following problem assume the diodes follow the idealized approximate behavior as shown in figure 2-34(d) of the text. The forward voltage is \( V_{F} = 0.7V \) for all diodes. You can also assume a diode is “on” if the voltage across it is greater than \( V_{F} \). For the following values of \( V_{s} \) determine (i) which diode (if any) is on and (ii) \( V_{o} \). Hint: Assume a particular on/off combination and check for self-consistency.

(a) \( V_{s} = 0.5V \)
(b) \( V_{s} = 3V \)
(c) \( V_{s} = 5V \)
(d) \( V_{s} = 7V \)