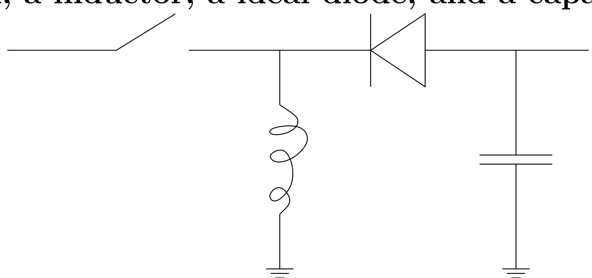
EE 322 Advanced Electronics, Spring 2012
Exam 2
solution
Friday March 30, 2012

Rules: This is a closed-book exam. You may use only your brain, a calculator and pen/paper. Each numbered question counts equally toward your grade.

Note: The questions are designed to test your conceptual understanding, not your ability to do many pages of math. If you find yourself doing long calculations there is a high probability that you are doing something wrong.

Switching regulator

1. **Draw a inverting switching regulator of the kind we studied in class, containing a switch, a inductor, a ideal diode, and a capacitor.**



2. **Derive an expression relating $V_{\text{out}}/V_{\text{in}}$ to T_C and T_O, the switch closed and open time.**

The increase in current when the switch is closed

$$\Delta I_C = T_C \frac{V_{\text{in}}}{L}$$

must equal the decrease in current when the switch is open

$$\Delta I_O = T_O \frac{V_{\text{out}}}{L}$$

$$\Delta I_C + \Delta I_O = 0$$

$$T_C V_{\text{in}} = -T_O V_{\text{out}}$$

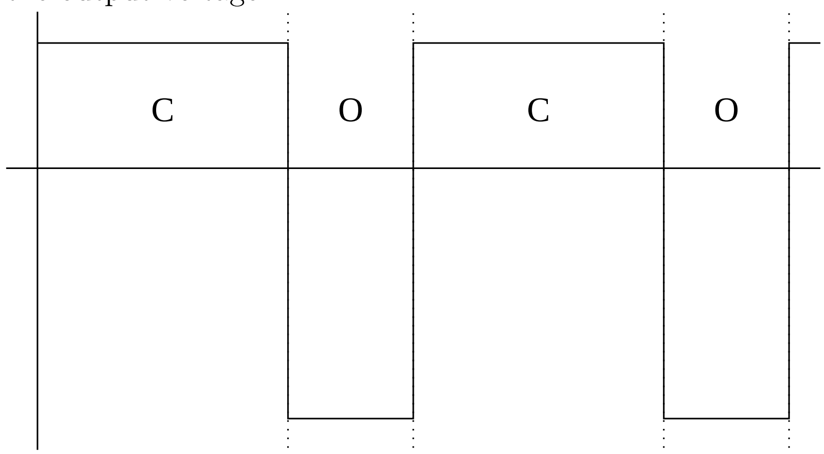
$$\frac{V_{\text{out}}}{V_{\text{in}}} = -\frac{T_C}{T_O}$$

3. **Assume $V_{\text{in}} = 5\,\text{V}$, and $V_{\text{out}} = -10\,\text{V}$. Plot, to scale, the voltage at the point where the inductor, diode, and switch meet, for continuous mode operation.**

In this case we have

$$\frac{T_C}{T_O} = \frac{10}{5} = 2$$

When the switch is closed the voltage at that point is the input voltage, when it is open it is the output voltage.



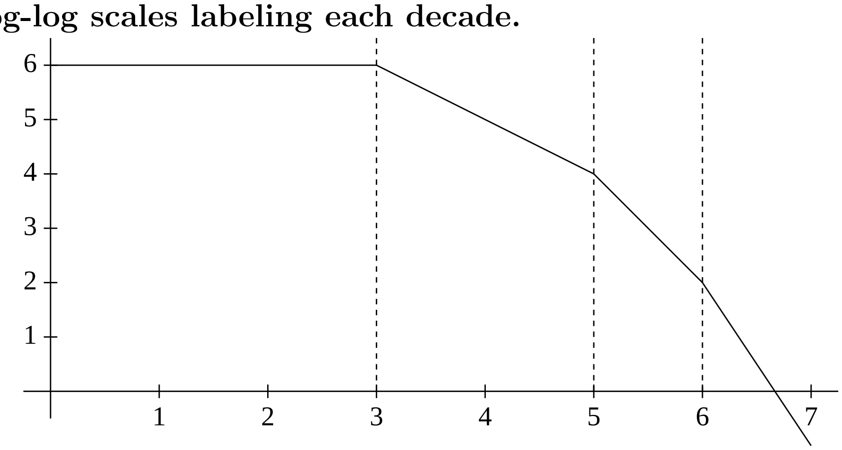
Feedback stability and compensation

(Questions 5-8 can be quickly solved graphically)

4. **Consider non-inverting amplifier made from an op-amp with open loop gain A, feedback resistor, R_2, and gain resistor $R_1 = 1\,\text{k}\Omega$. Write an expression for the feedback, β.**

$$\beta = \frac{R_1}{R_1 + R_2}$$

5. **A has DC gain 10^6 and poles at 1 kHz, 100 kHz, and 1 MHz. Plot, to scale, A on log-log scales labeling each decade.**

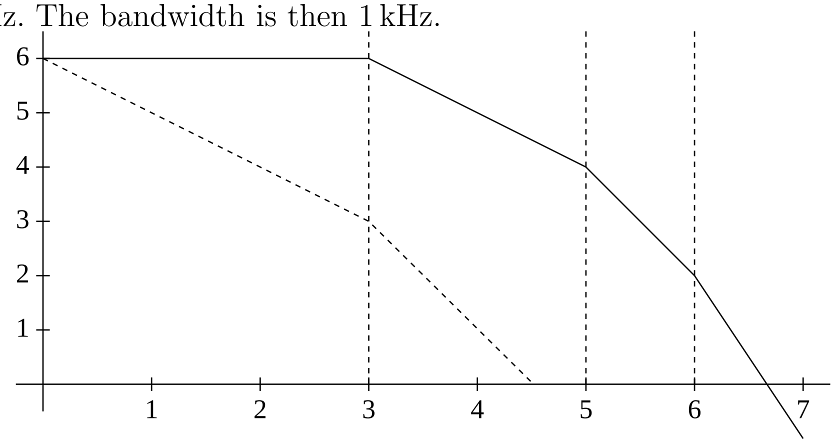


6. **What closed-loop gain will result in a 45° phase margin, and what value of R_2 will produce that gain?**

A 45° phase margin occurs at the second pole. The second pole corresponds to $1/\beta = 10^4$, which is the gain, and $\beta = 10^{-4}$. The value of R_2 should then be $R_2 = 10^4 R_1 = 10\,\mathrm{M\Omega}$.

7. **What should be the frequency of a new dominant pole which will result in a 45° phase margin at a closed loop gain of 10^3. What will be the corresponding bandwidth?**

When we do this the original first pole becomes the new second pole. It must be lowered to 10^3. We can do this graphically, and we can see that the new dominant pole must be at 1 Hz. The bandwidth is then 1 kHz.



8. **If instead you were able to introduce a zero at 100 kHz and a pole at 10 MHz, to what closed loop gain would the amplifier be stable, with 45° phase margin, and what would be its bandwidth?**

Answer is that the 1 MHz pole would be the second pole, and the gain at that frequency would be 10^3, and the bandwidth would be 1 MHz.