PHYS-COIS 2250H – Electronics

Final Examination : Tuesday 14th April 2009.

Allowed: 3 hours. Calculator.
Answer <u>question 1</u> and <u>three</u> of the remaining four questions.
Question 1 is worth 40% of the marks, and the rest 20% each.

1.a) Sketch a two-port network that includes a Zener diode and a resistor, that will act as a *voltage regulator*. Briefly (in approximately two sentences) describe how it works, and what happens if the resistor within the network takes too small, and too large, a value.

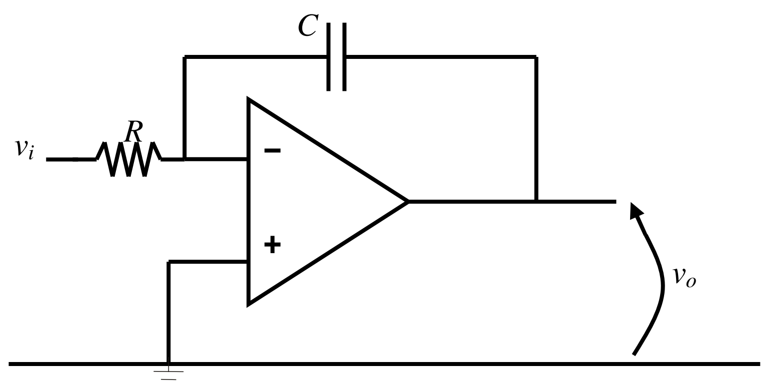
b) Use a truth table to verify one of DeMorgan's theorems, given below:

$$\overline{A \bullet B} = \overline{A} + \overline{B}$$

Represent each side of this equation in terms of a circuit diagram containing logic gates.

c) What are the basic assumptions used in solving negative-feedback operational amplifier circuits?

d) Show that the circuit shown below acts as an integrator.



e) A lab interface card contains a 12-bit DAC that produces a DC voltage between 0 and 5 V. What binary numbers (and equivalent decimal numbers) should represent i) the high byte, and ii) the low byte, to output a voltage of 1.35 V?

2. A box contains ideal resistances, copper wires and voltage sources connected in an unspecified way, and has two output terminals A and B. If a resistance of 10 Ω is connected between A and B it is found to dissipate 2.5 W. If a resistance of 90 Ω is connected between A and B, it is found to dissipate 0.9 W.
a) What power will be dissipated in a 30 Ω resistor connected between A and B?
b) What power will be dissipated in a resistance of $R_L = 10\,\Omega$, if connected to a 5 V battery, and this series combination connected between A and B?
c) Is your answer to (b) unique? Explain.

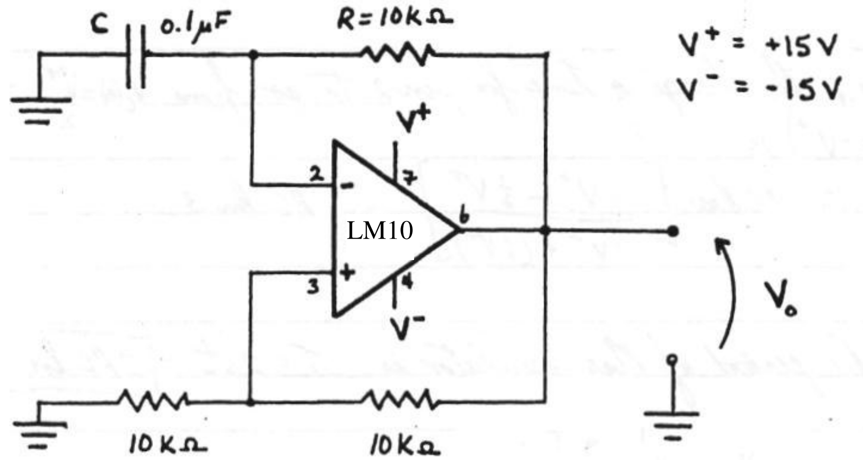
3. The circuit shown below is a *relaxation oscillator* built from an ideal (infinite open-loop gain, infinite input impedance and zero output impedance) operational amplifier.

a) **First** consider simply a series RC circuit, with capacitor initially uncharged, and DC input voltage V_0. Show that the voltage across the capacitor as a function of time is given by:

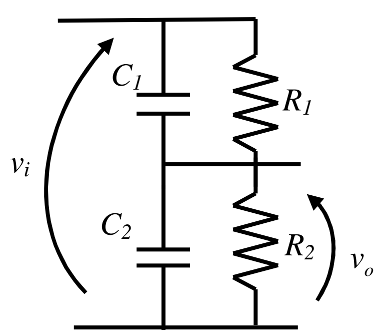
$$V_C(t) = V_0\left(1 - e^{-t/RC}\right)$$

b) Now explain, with diagrams showing the waveforms at the two inputs and the output, how the relaxation oscillator works.

c) By considering the steps in your solution to part (a) explain how one would derive that the period of a relaxation oscillation is $2RC\ln 3$, and calculate the frequency of oscillation for the circuit shown.



4. Consider the circuit shown below, in which $v_i(t) = V_0 \cos(\omega t)$.



a) Describe what is meant by the *impedance* of a capacitor, and why it is a useful concept in circuit analysis.

b) (most marks) Using a complex representation for voltages and currents, define all necessary currents in the circuit above, and then carefully write down all equations required to find $\tilde{v}_o$ as a function of $\tilde{v}_i$.

c) (fewer marks) Show that the complex *transfer function* of this circuit is given by:

$$\frac{\tilde{v}_o}{\tilde{v}_i} = \frac{\omega R_1 R_2 C_1 - jR_2}{\omega R_1 R_2 (C_1 + C_2) - j(R_1 + R_2)}$$

Hand this in if you do question 5

5. a) Choose values for all the labelled resistors for the emitter-biased AC voltage amplifier, shown below, for a voltage gain $v_o/v_i = -(R_L/R_E) = -6$, and as large a voltage swing as reasonable. Include the collector characteristics below as part of your answer.

b) What function do C_1 and C_2 serve?

c) Describe, without full calculations, how you would select the values for C_1 and C_2.