Data Provided: useful definitions and equations at end of paper (after Q4)

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2008 - 2009 (2 hours)

ANALOGUE CIRCUITS 1

Answer **THREE** questions. Solutions will be considered in the order in which they are presented in the answer book and **no marks will be awarded for an attempt at a fourth question.** Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1 The input to the transformer of figure 1 is a 50Hz sinusoid.

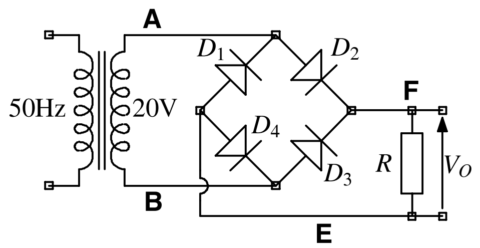

Figure 1

(i) The circuit of figure 1 has four nodes **A**, **B**, **E** and **F**. Write down the order of these nodes that describes the current path in the circuit when node **B** is positive with respect to node **A**. {*1*}

(ii) Sketch the waveform you would expect to see at V_O . Your sketch should contain at least one complete cycle of the input waveform. Label times and amplitudes. {*4*}

(iii) What is the average value of the waveform of part **(ii)**? {*2*}

(iv) If $R = 20\Omega$, what is the minimum value of capacitor that can be placed in parallel with R if the ripple voltage component of V_O must not exceed 2V peak to peak? {*5*} *(Some of these marks are given for the derivation of relationships used.)*

A zener diode regulator circuit is to be used to derive a 9V supply from the output of figure 1 which has been smoothed as described in part **(iv)**. The load for the 9V supply may draw a current anywhere between 5mA and 10mA and the zener diode specifications recommend a minimum current through the diode of 2mA.

(v) What is the largest value of series resistance that can be used in the regulator circuit? {*5*}

(vi) What ripple voltage would you expect to measure at the output of the regulator if $r_Z = 5\Omega$ and the input ripple to the regulator circuit is 2V peak to peak? {*3*}

Assume in all parts of the question that the transformer and 50Hz main supply are perfect and that the diodes D_1 to D_4 have zero series resistance.

2 **(a)** The diode in figure 2a has a forward voltage drop of 0.7V but is otherwise ideal.

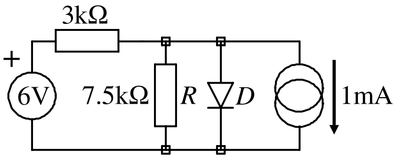

Figure 2a

(i) For the circuit of figure 2a, determine the conduction state of the diode and find either the forward conduction current through, or the reverse bias voltage across, the diode. **{*5*}**

(ii) If the 6V source is replaced by a variable source, V_1, sketch a graph of forward diode current, I_F, against V_1 as V_1 changes from −10V to +10V. Label the co-ordinates of the point where the diode changes state and define the straight line sections of your sketch either by their slopes or by the values of current at the extremes of V_1. **{*5*}**

(b) **(i)** The circuit of figure 2b consists initially of R_1 and C. Sketch the V_O you would expect to observe in response to the input shown. Include on your sketch both the leading and trailing edge responses of the input pulse and label peak values and time constants. **{*4*}**

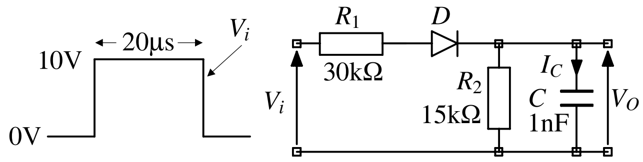

Figure 2b

(ii) R_2 and ideal diode D are now added to the circuit as shown in figure 2b. Sketch the I_C that you would expect to observe in response to the input shown in figure 2b. Label your sketch with peak values and time constants. **{*6*}**

3 **(a)** The BJT in figure 3a has a minimum dc current gain, h_{FE}, of 35, a $V_{BE(ON)}$ of 0.7V and a $V_{CE(SAT)}$ of 200mV. The load for the switch is an solenoid valve with resistive and inductive components.

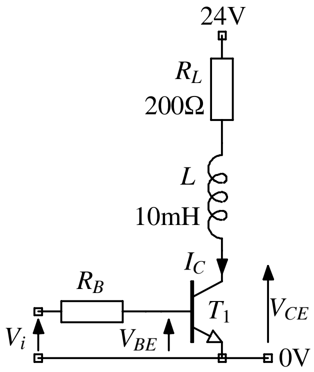

Figure 3a

(i) Calculate I_C assuming T_1 has been "on" for a long time. **{*1*}**

(ii) Find the largest value of R_B that can be used if $V_{i(ON)}$ is 5V and T_1 is required to switch properly. **{*4*}**

(iii) Explain briefly how L affects V_{CE} when the switch turns off. Show how the circuit can be modified by the addition of a diode to deal with the problems caused by L? **{*4*}**

(b) **(i)** Work out the dc conditions V_B,V_C and I_C and the small signal parameters g_m and r_{be} for the circuit of figure 3b. Assume that V_{BE} = 0.7V and that β for T_1 is 400. **{*5*}**

(ii) Draw a small signal equivalent circuit of figure 3b. **{*3*}**

(iii) What is the small signal gain, v_o/v_s, of the circuit assuming that all the capacitors are short circuits at the frequencies of interest? **{*3*}**

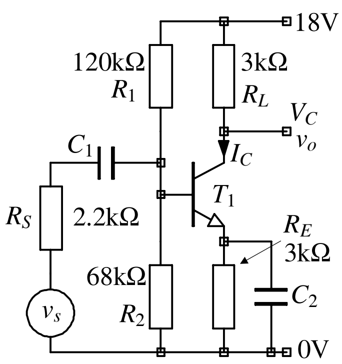

Figure 3b

4 (a) Draw a circuit diagram of a circuit that contains a virtual earth node. Define what is meant by the term "virtual earth" and explain briefly how your circuit maintains the virtual earth node. *{6}*

(b) Find $\dfrac{V_O}{V_2 - V_1}$ for the circuit of figure 4a.

{6}

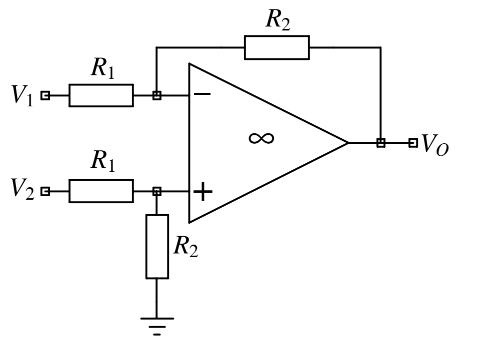

Figure 4a

(c) (i) What is the magnitude (ie, peak value) and phase (with respect to the input signals) of the sinusoidal component of v_o? *{4}*

(ii) What value of a will give a dc component of v_o of zero? *{4}*

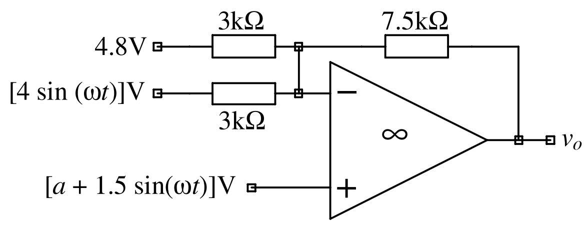

Figure 4b

4RCT/DAS
END OF PAPER

You may find some of the following relationships and definitions useful:

$$g_m = \frac{eI_C}{kT} \qquad r_{be} = \frac{\beta}{g_m} \qquad h_{FE} = \frac{I_C}{I_B} \qquad \beta = \frac{\Delta I_C}{\Delta I_B} = \frac{i_c}{i_b} \qquad \tau = RC$$

$$I = C\frac{dV}{dt} \qquad \omega = 2\pi f \qquad V(t) = (V_{START} - V_{FINISH})\exp\left(\frac{-t}{\tau}\right) + V_{FINISH}$$

$$V_{AVE} = \frac{V_P}{\pi} \text{ for a half wave rectified sinusoid} \qquad V_{rms} = \frac{V_P}{\sqrt{2}} \text{ for a sinusoid}$$

$$v_o = A_v\,(v^+ - v^-) \qquad \frac{kT}{e} = 0.026\text{V} \qquad V = IR$$

unit multipliers: p = x10^{-12}, n = x10^{-9}, μ = x10^{-6}, m = x10^{-3}, k = x10^{3}, M = x10^{6} G = x10^{9}

All the symbols have their usual meanings