The University Of Sheffield.

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

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2009 - 2010 (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 **(i)** Sketch the waveshapes you would expect to observe for V_S, V_O and I_C in the circuit of figure 1a. Why is this type of power supply unattractive from the electricity supply industry's point of view? **{*5*}**

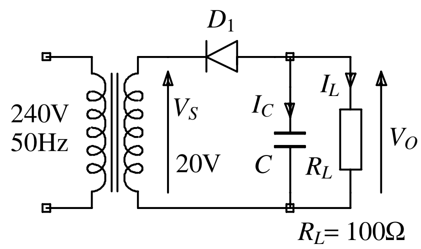

Figure 1

(ii) Using a suitable model, estimate the minimum value of C that can be used to give a ripple voltage of less than 2V peak to peak. You should state any assumptions or approximations that you use and formulae should be justified by appropriate reference to the model. **{*5*}**

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 **(ii)**. The load for the 9V supply may draw a current anywhere between 5mA and 15mA and the zener diode specifications recommend a minimum current through the diode of 5mA.

(iii) What is the largest value of series resistance that can be used in the regulator circuit? You should state any assumptions or approximations used in arriving at your answer. **{*5*}**

(iv) 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*}**

(v) What power rating should the resistor have if it must survive a worst case condition of the regulator output being short circuited to ground? **{*2*}**

Assume in all parts of the question that the transformer and the 50Hz main supply are perfect and that the diode has zero series resistance.

2 **(a)** **(i)** For the circuit of figure 2a, find the value of V that will put the diode on the point of conduction. (ie, $V_D = 0.7$ V and $I_D = 0$) **{*2*}**

(ii) Work out I_D and V_D for $V = +5$ and $V = -5$. **{*4*}**

(iii) With the help of the results of parts **2 (a) (i)** and **(ii)** or by other means, sketch a graph of I_R as a function of V for $V = +5$ to $V = -5$. Label all the main features of your graph. **{*4*}**

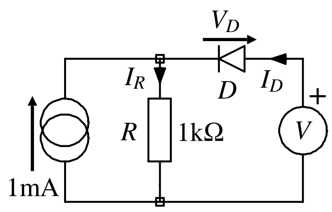

Figure 2a

(b) **(i)** For the circuit of figure 2b 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*}**

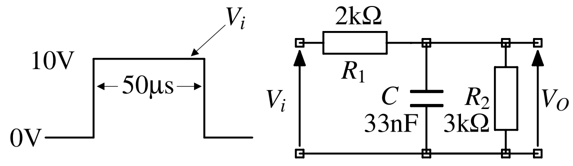

Figure 2b

(ii) An ideal diode D and resistor R_3 are now added to the circuit as shown in figure 2c. Sketch the I_C that you would expect to observe from figure 2c in response to the input shown in figure 2b. Label your sketch with peak values and time constants. **{*6*}**

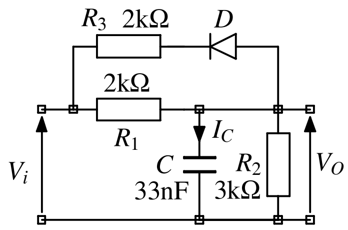

Figure 2c

3 **(a)** Figure 3a shows a MOSFET switching circuit. The switch is controlled by VGS which is 10 V for an "on" state and 0 V for an "off" state. The "off" state drain current is approximately zero and $r_{DS(ON)}$ is 0.1 Ω.

(i) Calculate the "on" state I_D . **{*1*}**

(ii) What is the "on" state power dissipation in the MOSFET? **{*3*}**

(iii) Explain briefly how any inductance in the load would affect the switch. Draw a circuit diagram to show how a diode can be used to prevent damage to the switch under inductive load conditions. **{*4*}**

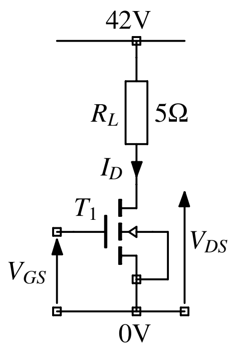

Figure 3a

(b) **(i)** Work out the dc conditions V_B, V_C and I_C for the circuit of figure 3b. Assume that $V_{BE} = 0.7$V and that β for T_1 is 400. **{*4*}**

(ii) Redraw the circuit to include the coupling and decoupling capacitors that would be necessary to achieve a high voltage gain. Indicate which capacitors are for decoupling. **{*4*}**

(iii) Draw a small signal equivalent circuit of figure 3b assuming that the capacitors of part **(b)(ii)** have been added and that the source is a voltage source with a series resistance R_S. **{*4*}**

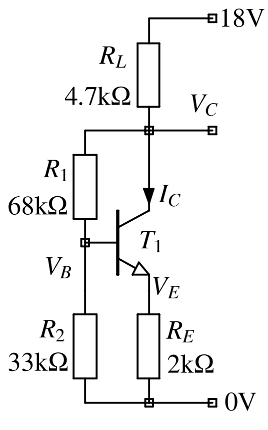

Figure 3b

4 **(a)** **(i)** In the amplifier circuit of figure 4a, V_1 is a voltage source and V_O is the resulting output voltage. Write down the gain, V_O/V_1 of the amplifier assuming that $A_v \Rightarrow \infty$. Suggest resistor values that would be suitable to get a gain magnitude of 10 using a typical op-amp. **{*3*}**

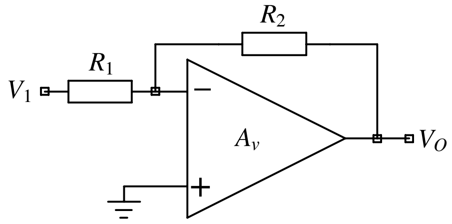

Figure 4a

(ii) If A_v is finite, show that

$$\frac{V_O}{V_1} = -\frac{\dfrac{R_2}{R_1+R_2}}{\dfrac{1}{A_v}+\dfrac{R_1}{R_1+R_2}} \qquad \{6\}$$

(b) For the circuit of figure 4b

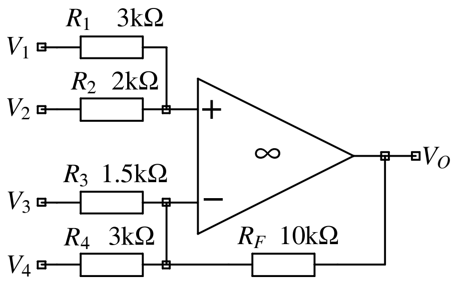

Figure 4b

(i) Find V_O/V_1 when V_2, V_3 and $V_4 = 0$. **{*1.5*}**

(ii) Find V_O/V_2 when V_1, V_3 and $V_4 = 0$. **{*1.5*}**

(iii) Find V_O/V_3 when V_1, V_2 and $V_4 = 0$. **{*1.5*}**

(iv) Find VO/V_4 when V_1, V_2 and $V_3 = 0$. **{*1.5*}**

(v) If $V_1 = 3$ V, $V_2 = 2 \sin \omega t$ V, $V_4 = (5 - 3 \sin \omega t)$ V and V_3 is of the form $(a + b \sin \omega t)$, by using the results of **(b)** **(i)** to **(iv)** or by other means find the values of a and b necessary to make $V_O = 0$ V. **{*5*}**

4RCT/DAS

END OF PAPER

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

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

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

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

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

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