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

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2006 - 2007 (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 circuit of figure 1 shows a full wave rectifier supplied by transformer with a centre tapped secondary winding. The voltage of each half of the centre tapped secondary is 15V rms.

(i) Sketch the form of V_O as a function of time assuming all the components used are ideal. Take care to label times and amplitudes on your sketch. What is the peak current through R_L? **{*4*}**

(ii) One of the diodes develops a fault which gives it a series resistance of 100Ω. Sketch the form of V_O as a function of time indicating on your sketch the effects of the faulty diode and labelling peak values and times. **{*4*}**

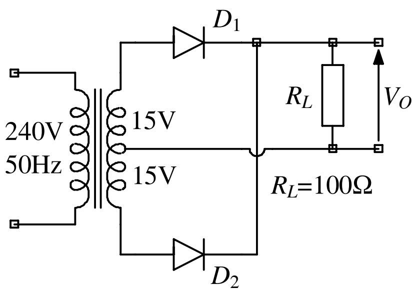


Figure 1

(iii) What is the average value of V_O over one complete input (50Hz) supply cycle for the conditions of the faulty diode described in part **(ii)**. **{*3*}**

The faulty diode is now replaced and the rectifier is to be used to provide a dc output with a superimposed ripple of 0.5V peak to peak or less.

(iv) Redraw the circuit of figure 1 to include a capacitor that could achieve the required smoothing. Calculate an appropriate value for the capacitor remembering to state any assumptions or approximations that you used in arriving at your result. **{*5*}**

(v) Explain briefly why this type of rectifier and smoothing arrangement causes large transient currents to flow in the transformer, the two diodes and the capacitor and comment on the problems that can be caused by such currents. **{*4*}**

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

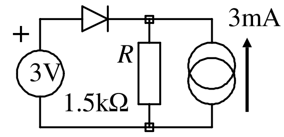


Figure 2a

(i) For the circuit of figure 2a, determine either the forward conduction current through, or the reverse bias voltage across, the diode. **{*4*}**

(ii) If the 3V source is replaced by a variable source, V_1, sketch a graph of $I_{FORWARD}$ against V_1 showing how the forward current varies as V_1 changes from -10V to +10V. **{*4*}**

(b) **(i)** The circuit of figure 2b consists initially of R_2 and C. Sketch the V_O you would expect to observe in response to a 0V to 10V input voltage pulse of 20µs duration. Be sure to sketch the responses to both the leading and trailing edges of the input pulse. Label your sketch with any time constants. Calculate the time for which V_O is above 7.5V. **{*6*}**

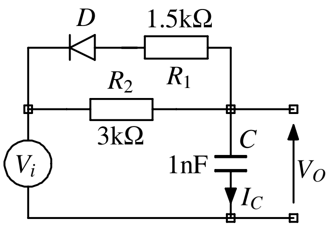


Figure 2b

(ii) R_1 and ideal diode D are now added to the circuit. Sketch the V_O and I_C that you would expect to observe in response to the input described in part **(b)** **(i)**. Label the I_C sketch with peak values and time constants. **{*6*}**

3 **(a)** In figure 3a T_1 is used to switch on a car headlamp, R_L. T_1 has a static current gain, h_{FE}, of 50 and the control inputV_i is 12V when the headlamp is required to be on and 0V when off. Assuming that T_1 switches properly,

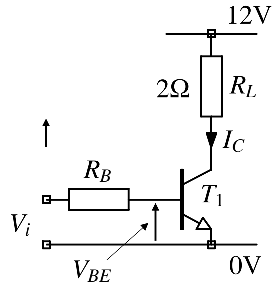


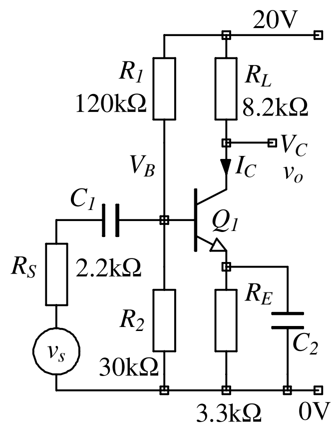
Figure 3a

(i) what is the on-state collector current of transistor T_1? **{*2*}**

(ii) calculate a suitable value for R_B assuming an on-state V_{BE} for T_1 of 0.7V. **{*4*}**

(iii) estimate the on-state power loss in T_1 assuming that T_1 has a $V_{CE\,SAT}$ specified as 300mV. **{*2*}**

(b) The transistor in figure 3b has a small signal current gain, β, of 400.



all voltages measured with respect to 0V

Figure 3b

(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 here that KT/e = 0.026V. **{*5*}**

(ii) Draw a small signal equivalent circuit of the circuit of figure 3b. **{*4*}**

(iii) Estimate the small signal gain v_o/v_s.. **{*3*}**

4 **(a)** Draw a diagram of an operational amplifier circuit that contains a virtual earth node and indicate where the virtual earth node is on your diagram. Explain briefly what is meant by the term "virtual earth" and explain how your circuit maintains a virtual earth at the node you have indicated. **{*7*}**

(b) Derive an expression for the gain v_o/v_i of figure 4a which includes the effects of A_v. **{*6*}**

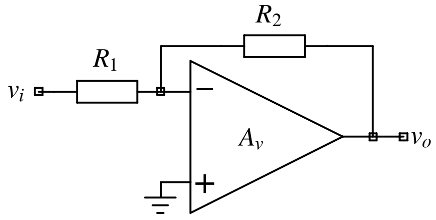


Figure 4a

(c) The output voltage, v_o, of the circuit of figure 4b will be of the form $v_o = a + b\sin\omega t$. Find a and b. **{*7*}**

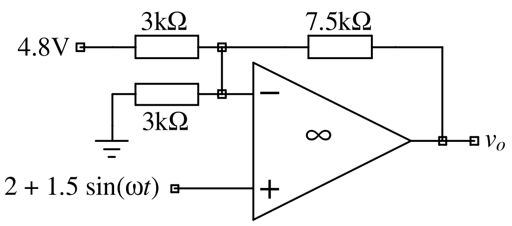


Figure 4b

4RCT/DAS
END OF PAPER

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

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

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

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

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

unit multipliers: p = $\times10^{-12}$, n = $\times10^{-9}$, μ = $\times10^{-6}$, m = $\times10^{-3}$, k = $\times10^{3}$, M = $\times10^{6}$ G = $\times10^{9}$

All the symbols have their usual meanings