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

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2007 - 2008 (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 and the secondary voltage is as shown.

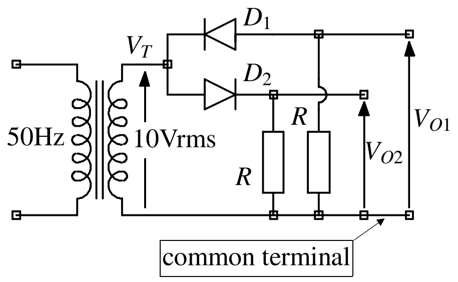

Figure 1

(i) Sketch the waveforms you would expect to see at V_T, V_{O1} and V_{O2}. Label times and amplitudes and take care to ensure the correct relative timings of your sketched waveforms. State any assumptions you have made about the diodes in the circuit. {*6*}

(ii) What are the average values of the three waveforms of part (**i**)? {*3*}

The resistors, R, are removed from figure 1 and replaced by loads that draw an approximately constant current of 100mA from V_{O1} and V_{O2}. These loads, however, require a supply with a ripple voltage no larger than 1V peak to peak, so smoothing capacitors must be added between each output line and the common terminal.

(iii) Estimate a suitable value of smoothing capacitor for the V_{O1} and V_{O2} outputs. {*3*}

(iv) Sketch the waveshape of the voltage you would expect to observe at V_{O1} after the capacitors have been added to figure 1, labelling peak values and ripple voltage. Assume that ideal components are used. {*2*}

(v) One quarter of the 100mA load current is drawn by a zener diode regulator circuit designed around a 9V zener diode with a zener slope resistance r_z of 6Ω. Calculate the value of resistor that must be between V_{O1} and the zener diode and estimate the ripple voltage superimposed on the regulated output. {*6*}

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

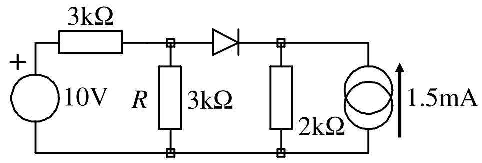

Figure 2a

(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 10V 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 0V to +20V. Label the cordinates of the point where the diode changes state and label the slopes of straight line sections of your sketch. **{*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 any time constants. **{*4*}**

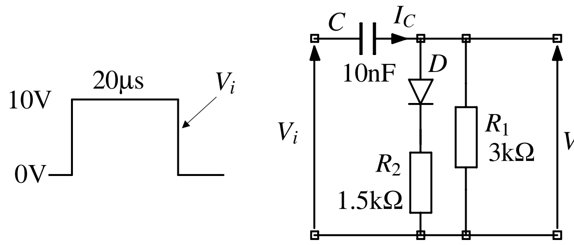

Figure 2b

(ii) R_2 and ideal diode D are now added to the circuit. 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 MOSFET in figure 3a has an "on" state resistance of 4Ω. The load for the switch is an actuator with resistive and inductive components, R_L and L. Assume that D has a forward voltage drop of 0.7V.

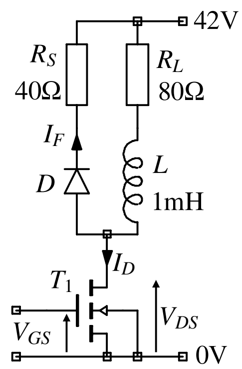

Figure 3a

(i) what is the purpose of D? **{*2*}**

(ii) Calculate I_D assuming T_1 has been "on" for a long time. **{*3*}**

(iii) Calculate the on-state power loss in T_1. **{*2*}**

(iv) What is the peak value of V_{DS} that will occur during the turn-off process? **{*4*}**

(b) **(i)** Work out the dc conditions V_C and I_C and the small signal parameters g_m and r_{be} for the circuit of figure 3b. Make sure you state any assumptions and approximations that you use. Assume that $V_{BE} = 0.7$V and the b for T_1 is 400. **{5}**

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

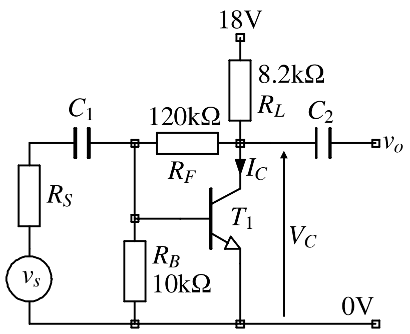

Figure 3b

4 **(a)** Assuming that an ideal operational amplifier is available, sketch two circuit diagrams, one of a practically useful inverting amplifier circuit and one of a practically useful non-inverting amplifier circuit that each use the operational amplifier and two resistors. Be sure to indicate which circuit is which. Write down the voltage gain of each circuit in terms of the components you have used. **{*8*}**

(b) **(i)** Find v_o/v_i for the circuit of figure 4a. **{*5*}**

(ii) Draw a circuit diagram of a simpler circuit that will achieve the same voltage gain. **{*2*}**

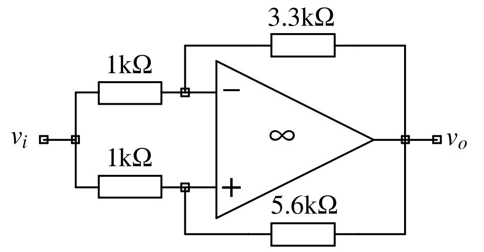

Figure 4a

(c) For the circuit of figure 4b, calculate the value of a that will make the sinusoidal component of v_o equal to zero. **{*5*}**

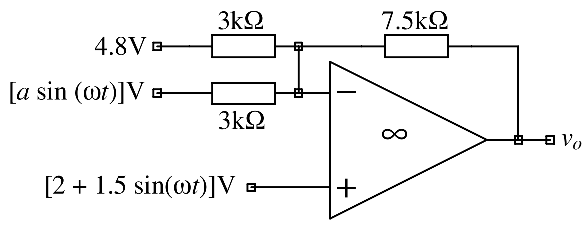

Figure 4b

4RCT/DAS
END OF PAPER

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

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

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

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

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

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