Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2012-13 (2.0 hours)

EEE340 Analogue and Switching Circuits 3

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. 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. **a.** Explain why hysteresis is usually necessary in comparator type circuits. **(2)**

b. Sketch the transfer characteristic, V_O against V_I, of the Schmitt trigger circuit shown in Figure 1a. Highlight the hysteresis band.

Determine the two input voltage values required at V_I to achieve Low-High and High-Low switching transitions on the output voltage V_O. You may assume that the voltage across the zener diode clamp is either V_{OH} or V_{OL} where $V_{OH} = -V_{OL}$.

Determine the circuit's hysteresis band in terms of V_{OH}, V_{OL}, R_1 and R_2. **(6)**

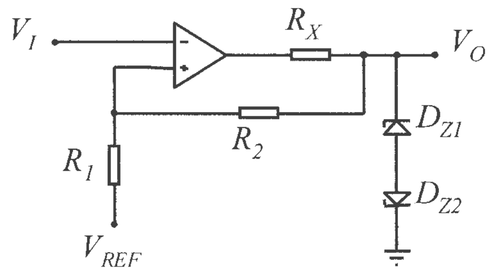

Figure 1a

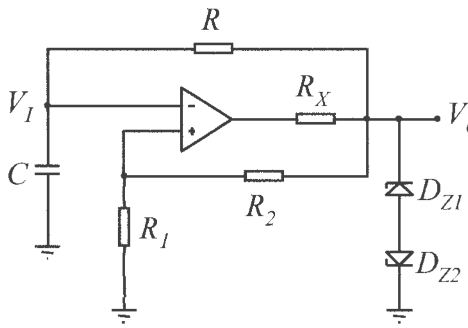

Figure 1b

c. Sketch and label the waveforms one would expect to observe at the inverting and non-inverting inputs of the operational amplifier and at node V_O of the astable oscillator circuit shown in Figure 1b. **(5)**

d. Show that the period of oscillation of the astable circuit of Figure 1b is given by,

$$T_{osc} = 2RCln\left(\frac{2R_1 + R_2}{R_2}\right)$$

You may assume that the voltage across the zener diode clamp is either V_{OH} or V_{OL} where $V_{OH} = -V_{OL}$. **(5)**

e. If $R_1 = 3R_2 = 1k\Omega$, what RC product is required to achieve an oscillation frequency of 2kHz. **(2)**

2. **a.** Sketch the I_c-V_{ce} output characteristic for a NPN transistor driving a resistive load which is connected to a supply voltage V_{cc} and the collector of the transistor, and where the emitter terminal of the transistor connected to 0V. On your sketch show the dependence of I_c & V_{ce} on the base current and label the off operating point, ideal and actual on-state operating points and V_{cesat}. **(6)**

b. Why is overdriving necessary in bipolar transistor switching applications?

State two effects of overdriving, one for the turn-on behaviour and one for the turn-off behaviour of the transistor and identify whether or not they are desirable or undesirable in a switching context. **(4)**

c. Determine the appropriate value of base resistor R_b required to achieve an overdrive factor $M = 6$ for the circuit shown in Figure 2 where $R_L = 15\Omega$, V_{cc}=300V, $h_{FEmin} = 50$, $V_{beON} = 1$V and V_I is the control voltage waveform, having a value of 9V when the transistor should be in its on-state, and -3V when the transistor should be in its off-state.

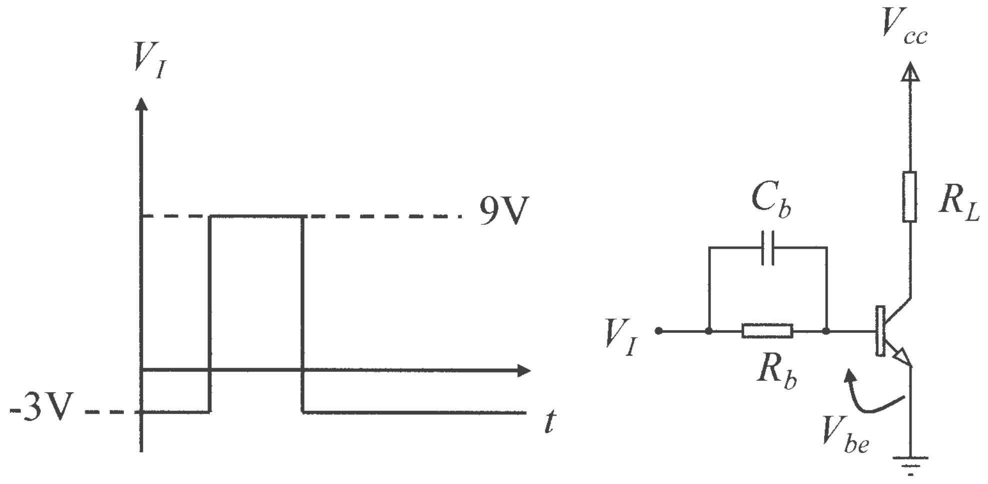

Figure 2 **(4)**

d. Given a storage time of t_s=450ns when the "off" control voltage V_I=-3V, what value of speed-up capacitor, C_b, is required to significantly reduce the turn-off time? You may assume the off-state base-emitter voltage V_{beOFF} = 0V. **(4)**

e. Sketch a circuit diagram showing how a Schottky diode may be used to limit the level of saturation attained in a transistor switch circuit. **(2)**

3. a. State the two simultaneous amplitude and phase conditions required to produce a linear oscillator circuit (i.e. the Barkhausen criterion). **(2)**

b. Show that the transfer function (v_2/v_1) of the Wien bridge network shown in Figure 3 is given by,

$$\frac{v_2}{v_1} = \frac{sCR}{s^2C^2R^2 + 3sCR + 1}$$

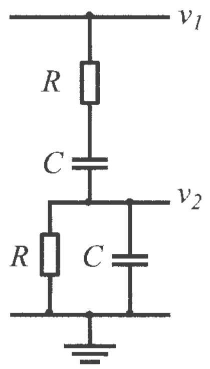

Figure 3 **(3)**

c. Derive an expression for the frequency at which the transfer function of part (b) is purely real. Determine the value of v_2/v_1 at this frequency. **(4)**

d. Draw a circuit diagram to show how the network of Figure 3 can be used with a suitably configured operational-amplifier to form a Wien bridge oscillator. Suggest suitable values for all the components in your circuit that are necessary to achieve an oscillation frequency of 1kHz. You do not have to use preferred values in your answer but the components value you choose should be practical. **(6)**

e. Why is it necessary to include a non-linear element somewhere in the circuit if the oscillator's output is to remain stable?

Describe how a negative temperature coefficient thermistor can be used to stabilise your oscillator circuit in part d and draw a circuit diagram showing how you would implement such a feature.

Hint: a negative temperature coefficient thermistor is a resistor with a value that decreases in proportion to an increase in its temperature. **(5)**

4. The circuit presented in Figure 4 is called a "buck converter" and it is used to "step-down" the DC input voltage (V_{dc}) to a lower level (V_{out}) suitable for a particular application. Since transistor T_1 is turned-on at a fixed interval (i.e. turned-on with constant switching frequency), the output voltage V_{out} is controlled by varying the on-time (conduction time) of T_1.

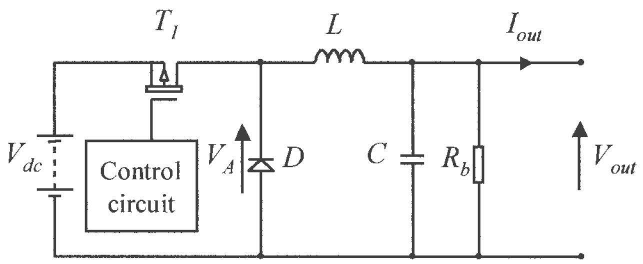

Figure 4

V_{dc}	36V
V_{out}	5V
Maximum I_{out}	3A
Diode D forward voltage drop	1V
Switching frequency	40kHz

Table 4

a. Draw the sub-circuits that represent the circuit behaviour when T_1 is turned "on" and when T_1 is turned "off". Indicate the path of current flow on your diagrams and describe the operation of the each sub-circuit. **(4)**

b. Determine the required "on" time for MOSFET T_1 if the buck converter is to produce the output voltage specified in Table 4.

Sketch the voltage V_A that you would expect to observe if this circuit is operated for the conditions listed in Table 4. Label peak values of the voltage levels and the time durations for the various parts of the waveform. Your waveform should show at least one complete switching period. **(5)**

c. Explain the purpose of resistor R_b.

If R_b=330Ω, what is the minimum value of L required to maintain correct choke input filter operation? **(5)**

d. Determine a suitable value for C if the output voltage is to have a maximum peak-to-peak ripple voltage of 50mV. **(4)**

e. If diode D is replaced with a MOSFET to improve conversion efficiency, describe how dead-time is used to ensure safe operation of both MOSFETs. **(2)**

MPF