The University of Sheffield
Department of Electronic and Electrical Engineering

EEE103/EEE121/EEE141 Problem Sheet

Transistors as Switches and Amplifiers

Q1 Why is it important to ensure that a transistor switch is driven on an off properly?

The transistor in the circuit of figure 1 has a large signal static current gain, h_{FE}, of between 70 and 250. When V_i is 10V, the switch must be "on" and when V_i is 0V the switch must be "off". Find,

(i) The "on" state I_C through the switch. (1.25A)

(ii) The worst case (largest) I_B in the "on" state. (17.86mA)

(iii) The value of R_B that will ensure proper switching for all possible values of h_{FE}. You can assume here that the "on" state V_{BE} is 0.7V. (521Ω)

(iv) The power loss in the on state if $V_{CE\ SAT}$ = 250mV. (313mW)

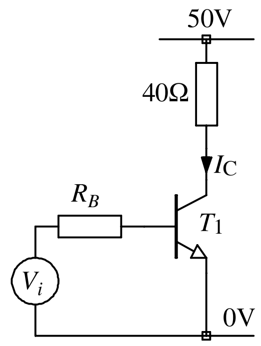

Figure 1

Q2 In addition to the bipolar transistor of figure 1, you have some MOSFETs with an on-state resistance, $r_{DS\ ON}$, of 0.25Ω. Work out the on-state power loss for one of these MOSFETS if it was substituted for T_1 in the circuit of figure 1 and hence decide whether or not it would be a better choice than the BJT in figure 1 from an efficiency point of view. Assume that when V_i = 10V, the MOSFET is switched on properly. (390mW, no)

Q3 The 40Ω load in figure 1 has associated with it a series inductance of 100mH as shown in figure 2.

(i) What is the energy stored in the inductive part of the load if S has been on for a long time? (78mJ)

(ii) What is the purpose of D and R?

(iii) What is the value of I_D immediately after S opens? (1.25A)

(iv) What is the decay time constant of I_D if R = 0Ω? (2.5ms)

AND FOR EXPERTS

(v) What is the maximum R that can be used if S has a maximum voltage rating of 200V? (120Ω)

(vi) If R = 100Ω and the switch switches fifty times per second, what is the power dissipation in R? (2.8W)

Assume that D is ideal and that there is no capacitance associated with the circuit.

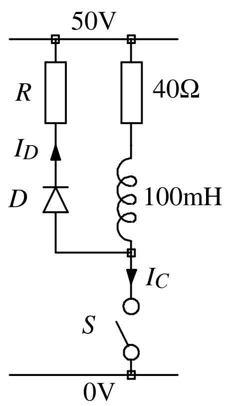

Figure 3

Q4 In the circuit of figure 4, the motor rotates in a clockwise direction when the current through it is in the direction shown.

(i) Which two switches must be on to cause clockwise rotation?

(ii) Which two switches must be on to cause anticlockwise rotation.

(iii) Sketch out the circuit to show where idling diodes could be placed to prevent excessive switch voltages due to motor winding inductance. Indicate which diodes would conduct if the motor had just been switched off from a clockwise rotation state.

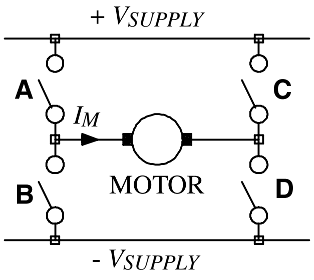

Figure 4

Q5 The manufacturers data for the BC183 transistor states that the current gain, h_{FE} (= I_C/I_B), may lie anywhere in the range 100 to 850.

(i) Evaluate I_B in figure 5. (2.35μA)

(ii) Within what range of voltage will the collector voltage, V_{CE}, fall if a BC183 is used in the circuit of figure 5? (5V to 18.2V)

(iii) Why is the circuit of figure 5 a poor bias circuit?

AND FOR EXPERTS

(iv) If the temperature coefficient of h_{FE} is 0.5% per ^{o}C, what is the temperature coefficient of collector voltage for a particular BC183 with h_{FE} = 450? (-40mV^{o}C^{-1})

You should assume that a forward biassed p-n junction has 0.7V across its terminals.

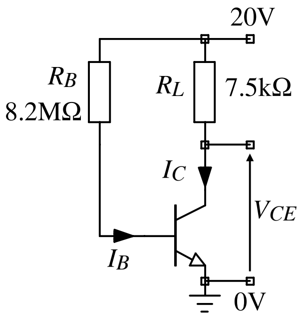

Figure 5

Q6 For the circuit of figure 6, V_{BE} = 0.7V and all voltages are measured with respect to 0V.

(i) Work out the d.c. conditions, V_C, V_E and I_C using the assumption that I_B is negligible. (12.3V, 3.22V and 3.22mA)

(ii) Work out r_{be} and g_m for the transistor of figure 6 if β = 500. (4.04kΩ, 0.124A/V)

(iii) Draw a small signal equivalent circuit of the circuit of figure 6.

AND FOR EXPERTS

(iv) Estimate the small signal voltage gain, v_o/v_s, of the circuit. (-78.7)

AND FOR REAL EXPERTS

(v) Work out the temperature coefficient of I_C assuming that the transistor of question 5 is used and that h_{FE} is the only temperature dependence in the circuit. (1.16μA ^{o}C^{-1})

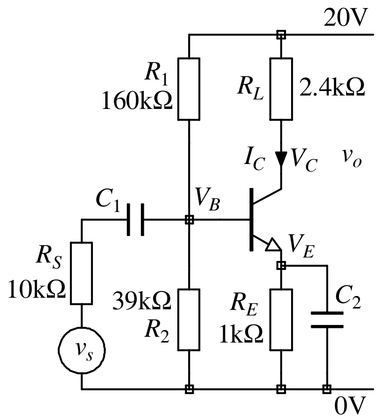

Figure 6

Q7 For the circuit of figure 7,

(i) Work out the d.c. conditions, V_C, V_E, I_C and I_F using the assumption that I_B is negligible. (13.5V, 2.55V, 946μA and 108μA)

(ii) Evaluate the small signal transistor parameters g_m and r_{be}. (36.4mA/V, 13.7kΩ)

(iii) Draw the small signal equivalent circuit of figure 7 assuming that all capacitors are small signal short circuits.

AND FOR EXPERTS

(iv) Work out the small signal voltage gain, v_o/v_s, of the circuit for:

a) $R_S = 0$ (-300)
b) $R_S = 10\text{k}\Omega$ (-132)

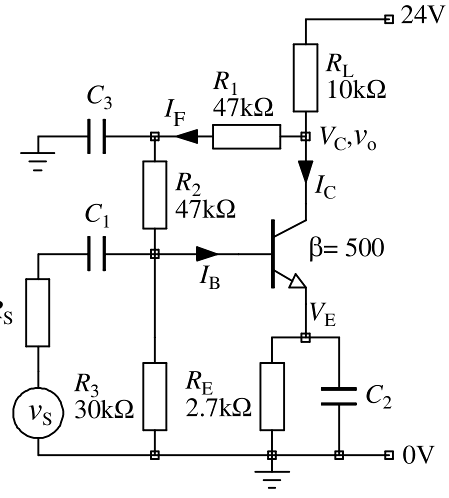

Figure 7

AND FOR REAL EXPERTS

(v) What would the small signal voltage gain be if C_3 was omitted from the circuit and $R_S = 10\text{k}\Omega$? (-8.85)

You should assume that a forward biassed p-n junction has a forward voltage drop of 0.7V across its terminals.

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

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

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

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