Second Semester Examinations 2015-16

ELECTRONIC CIRCUITS AND SYSTEMS

TIME ALLOWED: THREE HOURS

INSTRUCTIONS TO CANDIDATES

The numbers in the right hand margin represent an **approximate guide** to the marks available for that question (or part of a question). Total marks available are 100.

Question 1 carries 40 marks. All other questions carry 20 marks.

Answer ALL Questions.

Question 1

1 a) Consider the circuit of Fig Q1a). The transistor can be considered to be ideal and V_{BE} is a fixed value of about 0.6 V. (Assume the transistor always operates in the active regime.) 5

i) If the resistor R_C is doubled in value, do you expect I_C to increase, decrease or stay the same?

ii) What would happen to I_C if V_{CC} is doubled?

Briefly explain the reasons for your answers.

Part 1 notes Transistor models

(I_C stays the same in both cases; recall the equation for $I_C(V_{BE})$)

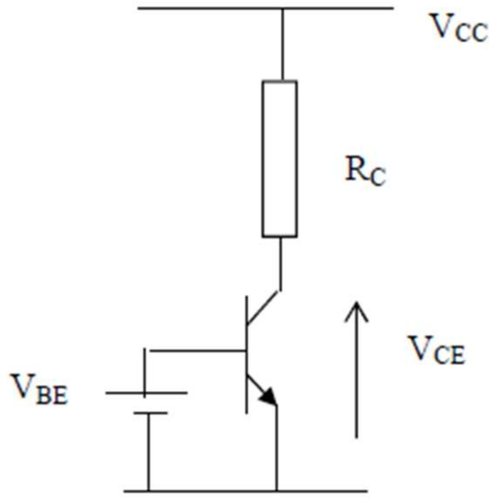


Figure Q1a

Question 1 (contd.)

b) Copy table Q1b) into your answer book. Complete the table with the words 'infinite' or 'zero', to specify the values of input and output resistances for the four generic types of amplifier. All amplifiers can be considered ideal. 5

Part 2 notes Amp. Properties

	voltage amplifier	current amplifier	transconductance amplifier	transresistance amplifier
Input Resistance				
Output resistance				

Table Q1b

c) Figure Q1c) shows an amplifier system. The source has low internal impedance and the load has a small resistance. Choose a suitable generic amplifier type to ensure good matching between source and load. Hence sketch a systems diagram with appropriate equivalent circuits for the source (Thevenin or Norton) and generic amplifier type. 5

Part 12 Generic amplifiers example in slides

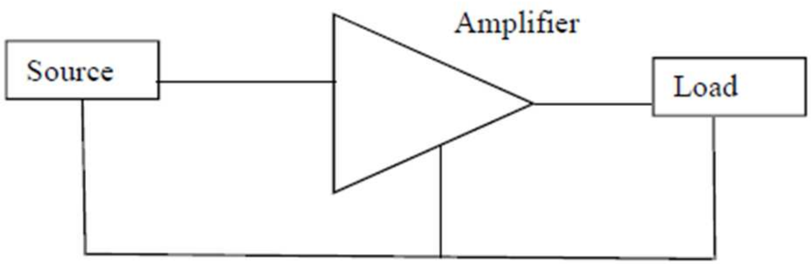


Figure Q1c

Question 1 (contd.)

d) An ideal transconductance amplifier is connected as shown in Fig. Q1d). The overall voltage gain of the circuit, v_o/v_g is 300 when R_L is 10 kΩ. Calculate the gain of the ideal transconductance amplifier. **5**

Part 12 notes Generic amplifiers example

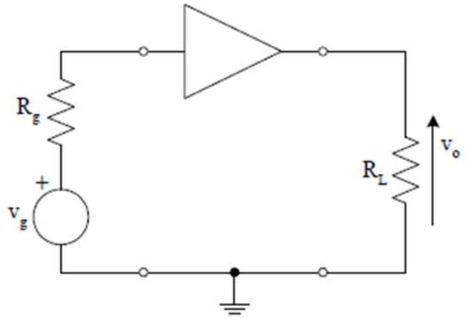


Figure Q1d

e) Use the given equation for the drain current of the MOSFET in saturation to show that the transconductance, g_m and output conductance, g_{ds} of the MOSFET are given by the following expressions: **5**

$$g_m \sim \sqrt{2\beta I_D} \qquad\qquad g_{ds} \sim I_D \lambda$$

Part 8 notes Field-effect transistors

Question 1 (contd.)

f) What is the function of the section of circuit shown in Figure Q1f). 5

Part 4 Notes
Current sources

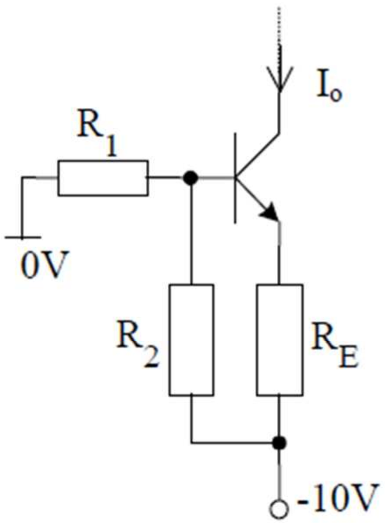


Figure Q1f

Calculate the value of I_o if $R_2 = 4R_1$ and $R_E = 7.3$ kΩ.

g) An operation amplifier with a slew-rate limit of 1V/μs is required to amplify a sinusoidal 100 kHz signal. Calculate the maximum amplitude of the output voltage that can be achieved without distortion. 5

Part 21 Notes
Op-amp limitations

Question 1 (contd.)

h) Figure Q1.h) shows a schematic diagram of a feedback amplifier with bias components and coupling capacitors removed. Identify the feedback topology and the amplifier type. Hence write down an expression for the feedback fraction, β. **5**

Part 14 notes Feedback applied to amplifiers

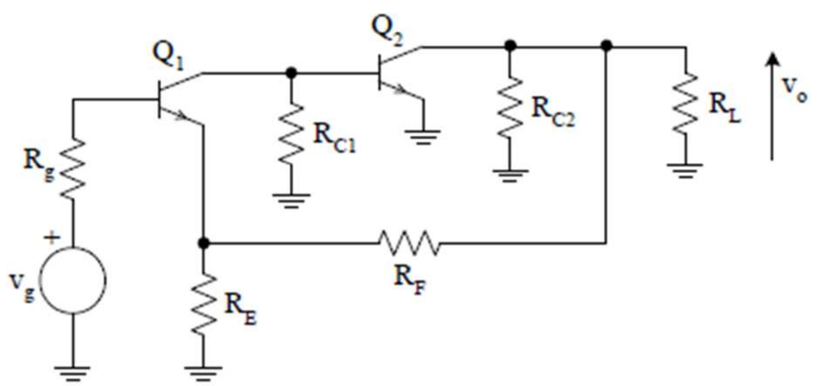


Figure Q1h

Question 2

Part 2 section Slides Design examples 1&2

2. a) You are required to design a 2-stage voltage amplifier (find values for R_E, R_{C1}, R_{C2}) to meet the following criteria: an input resistance of 400 kΩ and an overall voltage gain equal to or greater than 250, with a resistor output load, R_L. Use a common-emitter with emitter degradation (R_E) stage for the input, followed by a common-emitter amplifier with bias current equal to 0.5 mA.
($V_{CC} = 20$ V, $\beta_o = 200$ and the DC levels of the first and second stage outputs need to be set at half the supply voltage. Allow 10% of V_{CC} across R_E). Proceed as follows:

i) Draw a schematic circuit of your amplifier, omitting the bias resistors and coupling caacitors. **2**

ii) Work out the bias current and emitter resistor value to meet the input resistance specification. Hence find the value of the collector resistor of the first stage. **6** **8**

iii) Work out the gain of the first stage and hence find the required gain of the 2nd stage to meet the specification.

iv) Estimate the minimum value of load resistance, R_L to satisfy the specification of voltage gain.

b) Comment on the 'quality' of your voltage amplifier and suggest how it could be improved. **4**

Total

20

Question 3

Part 7
Freq. response of V-amplifiers

3. Figure Q3 shows an amplifier where the bias resistors and coupling capacitors are omitted for simplicity.

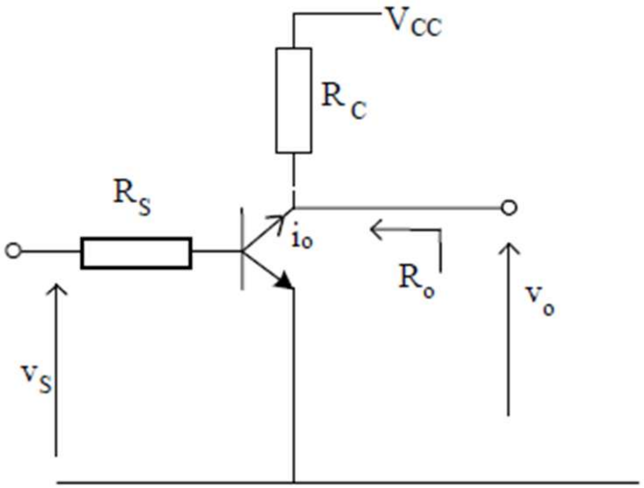


Figure Q3

The amplifier operates with a bias current of $I_C = 1$ mA and you may assume that $r_{bb'} = 0\ \Omega$. Other parameters are $\beta_o = 100$, $R_C = 2.5\ k\Omega$, $C_{bc} = 1$ pF, $R_S = 1\ k\Omega$ and

$C_{be} \sim \dfrac{g_m}{2\pi \times f_T}$ with $f_T = 200$ MHz,. (recall that $g_m = 40 \times I_C$).

a) Draw the ac equivalent circuit of the amplifier at high frequency. Apply Miller's theorem, and hence represent the circuit as two independent first order circuits. Estimate values for the input and output time constants (recall that $g_m \times r_{be} = \beta_o$). **8**

Question 3 (contd.)

b) Hence show that the voltage gain can be given by: **8**

$$\frac{v_o}{v_s} = -g_m R_C \frac{r_{be}}{r_{be} + R_S} \frac{1}{1 + j(f / f_H)}$$

where the bandwidth, f_H is given by $f_H \sim \dfrac{1}{2\pi \times RC}$ with $R = r_{be} // R_S$ and

$C \approx C_{be} + |g_m R_C| C_{bc}$

Calculate a value for the bandwidth.

[Ensure that you show all necessary circuit diagrams in your solutions]

Part 7
Freq. response
of V-amplifiers

c) The transistor is now loaded with a capacitor of value 1 nF (attached across the output terminal and ground). Estimate the new time constant for the output side of the circuit and hence the bandwidth. Comment on the result. **4**

Question 4

4 a) Draw the block diagram of a simple negative feedback system. Define the terms: open loop gain, $A_{o\ell}$, feedback fraction, β and closed loop gain, A_f. Hence derive the expression for the closed loop gain: **8**

$$A_f = \frac{A_{o\ell}}{1 + A_{o\ell}\beta}$$

Part 13 Feedback Theory

b) An amplifier with an open loop gain of 500 operates in an environment where a certain temperature rise causes the open loop gain to increase to 550. **6**
Treating the amplifier as a negative feedback system, find the necessary feedback fraction, β to ensure that that the closed loop gain does not change by more than 0.2%. Assume that β does not change with temperature.
Hence find the closed loop gain of the amplifier to satisfy this condition.

Question 4 (contd.)

c) A practical circuit to implement the amplifier is shown in Figure Q4c overleaf. **6**

Show that the voltage gain is given as

$$\frac{V_0}{V_i} = \frac{R_1 + R_2}{R_2}$$

and hence design the amplifier (choose suitable resistor values) to achieve the requirement found in part b). Justify any approximations used.

[If you were unable to complete part b), assume $A_f = 11$]

Part 16
Op-amp circuits

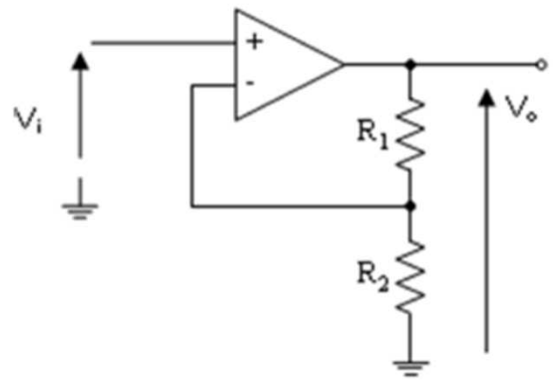
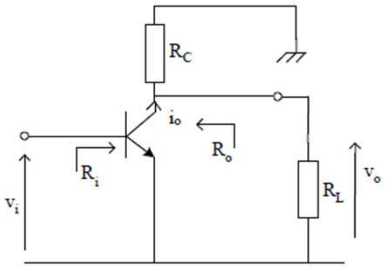


Figure Q4c

Attachment

ELEC271 / Amplifier properties

Common Emitter

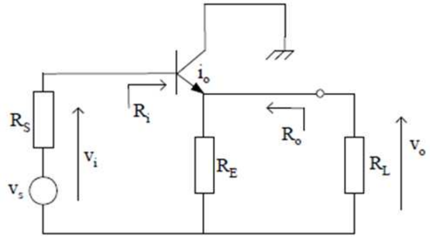


$R_i = r_{be}$

$R_o = R_C$

$$A_V = \frac{v_o}{v_i} = -g_m R_C \,//\, R_L$$

Common collector (Emitter follower)

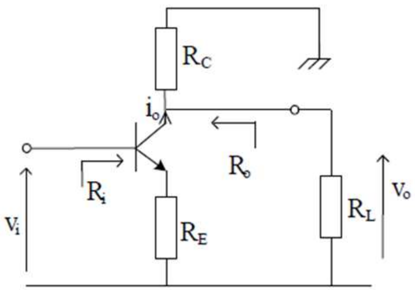


$$R_i = r_{be} + (1+\beta_o)R_E \,//\, R_L$$

$$R_o = \frac{r_{be} + R_S}{1+\beta_o} \,//\, R_E$$

$$A_V = \frac{g_m R_E \,//\, R_L}{1 + g_m R_E \,//\, R_L}$$

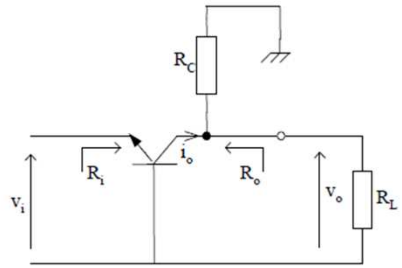
Common emitter with emitter degradation



$R_i = r_{be} + (1+\beta_o)R_E$ $\quad$ $R_o = R_C$

$$A_V = -\frac{g_m R_C \,//\, R_L}{1 + g_m R_E}$$

Common base



$R_i = \frac{r_{be}}{1+\beta_o} \approx 1/g_m = r_e$ $\quad$ $R_o = R_C$

$A_V = g_m R_C \,//\, R_L$