Electronic Circuits and Systems (EEE211)

Course Work: Assignment–2

Deadline: 08-November-2024, 23:59 hours @ LMO

Q1 – Differential amplifiers (Total: 25 marks)

For the differential amplifier depicted in Fig. 1, the circuit parameters: $V^+ = 5\,V$, $V^- = -5\,V$, $I_Q = 0.8\,mA$, and $R_C = 25\,kOhm$. The transistor parameters are $\beta = \infty$, $V_A = \infty$, $V_{BE}(on) = 0.7\,V$, and $V_T = 26\,mV$. For the input voltages $v_{B1} = 1.001\,V$ and $v_{B2} = 0.999\,V$:

i. Determine quiescent collector currents i_{CQ1} and i_{CQ2}, common emitter voltage v_E, and collector-emitter voltages v_{CE1} and v_{CE2} (*hint: find everything for the common mode input voltage* v_{cm}). **(5 marks)**

ii. Considering the exponential relationship between collector current i_C and base-emitter voltage v_{BE} of a BJT $\left(i_C = I_S \exp\left(\frac{v_{BE}}{V_T}\right)\right)$, find the collector voltages v_{C1} and v_{C2}. **(9 marks)**

iii. Considering two-sided output $v_O = v_{C2} - v_{C1}$, determine the differential-mode gain and, assuming that the common-mode gain of the amplifier $A_{cm} = -0.01$, calculate the common mode rejection ratio (CMRR) in absolute values and in decibels. **(11 marks)**

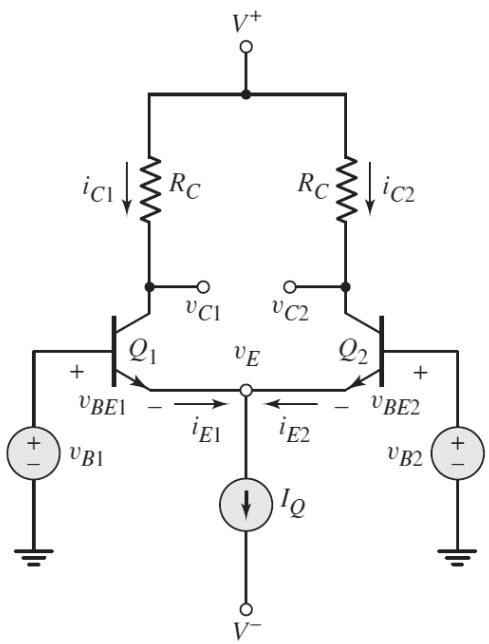

Fig. 1 – Basic BJT differential-pair configuration

Q2 – Current mirrors and Widlar current source (Total: 25 marks)

a. For the two-transistor current source depicted in Fig. 2.a, the circuit parameters: $V^+ = 10\ V$, $V^- = 0\ V$, and $R_1 = 50\ kOhm$. The transistor parameters are $\beta = 80$ and $V_{BE}(on) = 0.7\ V$.

i. Neglecting the Early effect ($V_A = \infty$), determine the reference current I_{REF}, the output current I_O, and the base currents I_{B1} and I_{B2}. **(7 marks)**

ii. Accounting for the Early effect, the ratio of load current to reference current is given by

$$\frac{I_O}{I_{REF}} = \frac{1}{\left(1 + \frac{2}{\beta}\right)} \times \frac{\left(1 + \frac{V_{CE2}}{V_A}\right)}{\left(1 + \frac{V_{CE1}}{V_A}\right)}$$

For Early voltage $V_A = 100\ V$, determine the small-signal output resistance r_O looking into the collector of transistor Q2. **(7 marks)**

b. Consider the Widlar current source shown in Fig. 2.b. The voltage source is provided with $V^+ = 3\ V$ and $V^- = -3\ V$, $V_{BE1}(on) = 0.7\ V$ and thermal voltage $V_T = 26\ mV$.

i. Neglecting the base currents and considering the exponential relationship between collector current I_C and base-emitter voltage V_{BE} ($I_C = I_S \exp(V_{BE}/V_T)$), determine the required values of the reference current resistor R_1 and emitter resistor R_E to set the reference current to $I_{REF} = 2\ mA$ and the output current to $I_O = 10\ \mu A$. **(8 marks)**

ii. Determine the base-emitter voltage V_{BE2} of transistor Q2. **(3 marks)**

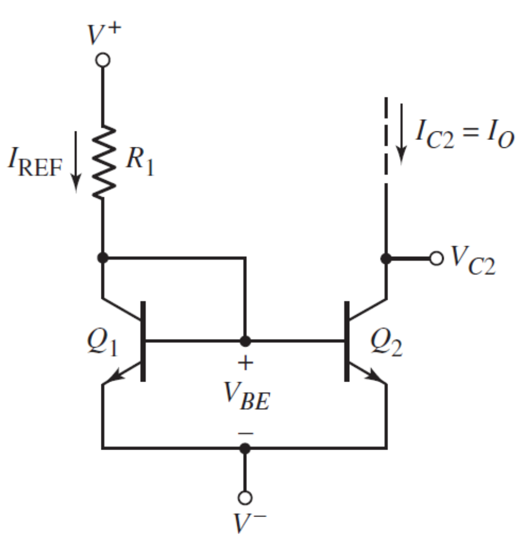

Fig. 2.a – Two-transistor current source

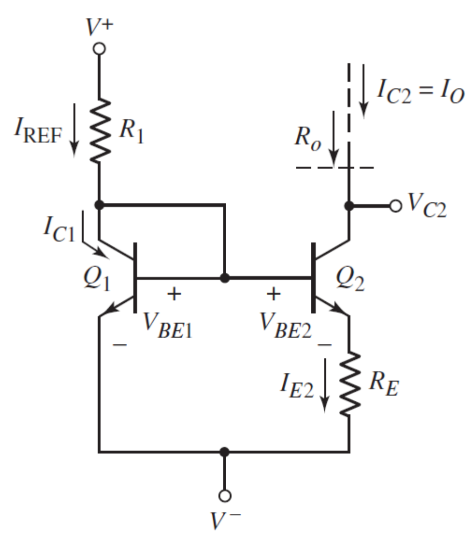

Fig. 2.b – Widlar current source

Q3 – Basic feedback concepts (Total: 25 marks)

For the basic configuration of a feedback amplifier depicted in Fig. 3, where input signal $S_i = 1\ mV$, output signal $S_o = 99.9\ mV$, and feedback signal $S_{fb} = 0.999\ mV$.

i. Determine the closed-loop gain A_f, feedback transfer function β, and open loop gain A. (**4 marks**)

ii. Determine the required value of feedback transfer function β to obtain the closed-loop gain of $A_f = 200$. (**4 marks**)

iii. For $\beta = 0.005$ and $A = 100\,000$ (*hint: these are not exactly equal to the solution of ii.*) and assuming that the open loop gain A can vary by $\pm 50\%$, estimate the variation of the closed-loop gain A_f in percentage value. **(8 marks)**

iv. Assuming that the feedback transfer function β does not depend on frequency and the frequency response of a basic amplifier follows the transfer function $A(s)$:

$$A(s) = \frac{A_0}{1 + \frac{s}{\omega_H}}$$

Derive the closed-loop gain transfer function $A_f(s)$, and determine closed-loop low frequency gain A_{f0} and closed-loop corner frequency ω_{fH} if the open loop corner frequency $\omega_H = 10\ rad/s$, low-frequency gain $A_0 = 10^5$, and feedback transfer function $\beta = 10^{-3}$. (**9 marks**)

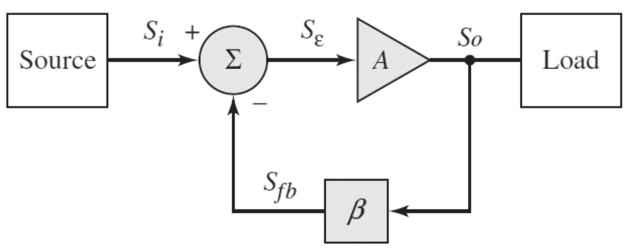

Fig. 3 – Basic configuration of a feedback amplifier

Q4 – Ideal feedback topologies (Total: 25 marks)

a. Consider the ideal feedback amplifier depicted in Fig. 4.a:

i. Determine the feedback connection type of the amplifier and justify your choice. **(2 marks)**

ii. Determine the open loop gain A_i if the source resistance $R_S = \infty$, input current $I_i = 1\,mA$, output current $I_o = 500\,mA$, and feedback current is $I_{fb} = 0.99\,mA$. **(2 marks)**

iii. For the same signal conditions ($I_i = 1\,mA$, $I_o = 500\,mA$, and $I_{fb} = 0.99\,mA$), determine the input resistance of the feedback amplifier R_{if} if the input resistance of a basic amplifier $R_i = 5\,kOhm$. **(6 marks)**

b. Consider the ideal feedback amplifier depicted in Fig. 4.b:

i. Determine the feedback connection type of the amplifier and justify your choice. **(2 marks)**

ii. Derive the closed-loop gain function A_{gf} of the amplifier. **(5 marks)**

iii. Given input and output resistances of the basic amplifier (R_i and R_o, respectively), derive the input and output resistances of the feedback amplifier (R_{if} and R_{of}, respectively). **(8 marks)**

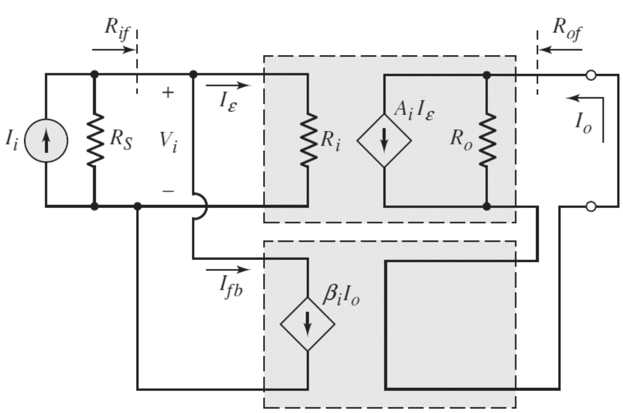

Fig. 4.a – An ideal feedback amplifier

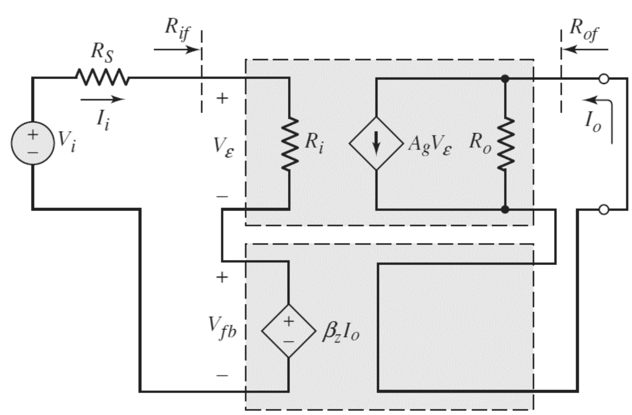

Fig. 4.b – An ideal feedback amplifier