COLLEGE OF ENGINEERING
PUTRAJAYA CAMPUS
FINAL EXAMINATION

SEMESTER 2 2017 / 2018

PROGRAMME	**: Bachelor of Electrical & Electronics Engineering (Honours)** **Bachelor of Electrical Power Engineering (Honours)**
SUBJECT CODE	**: EEEB273**
SUBJECT	**: ELECTRONIC ANALYSIS AND DESIGN II**
DATE	**: January/February 2018**
TIME	**: 3 hours**

INSTRUCTIONS TO CANDIDATES:

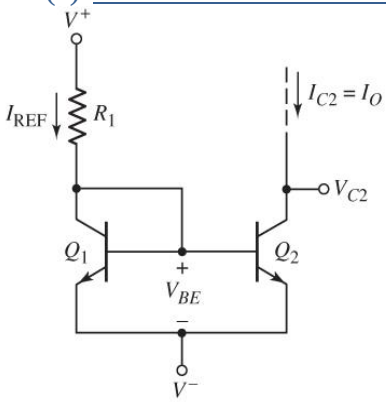
1. This paper contains **FIVE** (5) questions in **NINE** (9) pages.
2. Answer **ALL** questions.
3. Write **all** answers in the answer booklet provided. **Use pen** to write your answer.
4. Write answer to different question on **a new page**.

THIS QUESTION PAPER CONSISTS OF NINE* (9) *PRINTED PAGES INCLUDING THIS COVER PAGE.

Question 1 [20 marks]

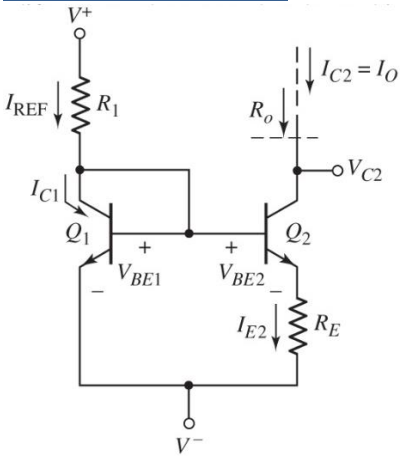
Answers to QUESTION 1

(a) *Two-transistor current source*



Total 5 marks
Placement of Q_1 and Q_2 [2 marks]
Resistors R_1 [1 marks]
I_{REF} and I_O labels [2 marks]

Widlar current source



Total 5 marks
Placement of Q_1 and Q_2 [2 marks]
Resistors R_1 and R_E [2 marks]
I_{REF} and I_O labels [1 mark]

(b) $I_{C1} = I_{REF} = I_S e(V_{BE1}/VT)$ …(1) **[1 mark]**

$I_{C2} = I_O = I_S e(V_{BE2}/VT)$ …(2) **[1 mark]**

$V_{BE1} - V_{BE2} = I_O R_E$ … (3) **[1 mark]**

$V_{BE1} = V_T \ln (I_{REF}/I_S)$ and $V_{BE2} = V_T \ln (I_O/I_S)$

$I_O R_E = V_T \ln (I_{REF}/I_S) - V_T \ln (I_O/I_S)$ **[1 mark]**

$= V_T \ln (I_{REF}/I_O)$ (proven) **[1 mark]**

(c) Using $I_c = I_S e^{\frac{V_{BE}}{V_T}}$;

$$I_S = \frac{I_{C1}}{e^{\frac{V_{BE}}{V_T}}} = \frac{1m}{e^{0.7/0.026}} = \mathbf{2.03 \times 10^{-15}\ A}$$

At I_{REF} = 3 mA, $V_{BE} = V_T \ln (I_{REF}/I_S)$

So V_{BE} = (0.026) ln(3m / 2.03 ×10^{-15}) = **0.7286 V**

Designing for R_1;

$V^+ - I_{REF}R_1 - V_{BE1} - V^- = 0$

$R_1 = (20 - 0.7286) / 3m$ = **6.423 kΩ**

Designing for R_E;

$I_O R_E = V_T \ln(I_{REF}/I_O)$

$R_E = (V_T/I_O) \ln(I_{REF}/I_O) = (0.026/50\mu) \ln(3m/50\mu)$ = **2.129 kΩ**

Question 2 [20 marks]

Answer to Q2(a):

I_{REF} = (V^+ - V_{BE5} - V_{BE3} - V^-) / (R_1) ≈ I_Q (β = 200) [2 marks]
= (10-0.7-0.7-(-10)) / (10k) = 1.86 mA [2 marks]
Ad = (g_m RC) / 2 = (I_Q R_C) / (4V_T) [2 marks]
g_m = I_Q / (2V_T) = (1.86m) / (2x26m) = 35.7692 mA/V [2 marks]
Ad = (35.7692m)(12.8k) / (2) = 228.923 V/V [2 marks]

Answer to Q2(b):

$Q2b(i)$

$A_d = g_{m2}\left(r_{o2} \parallel r_{o4}\right)$ [1]

$g_{m2} = \dfrac{I_{CQ}}{V_T} = \dfrac{0.5m/2}{26m} = 9.615\,\text{mA/V}$ [1]

$r_{o2} = \dfrac{V_{A2}}{I_{CQ}} = \dfrac{120}{0.5m/2} = 480\,\text{k}\Omega$ [1]

$r_{o4} = \dfrac{V_{A4}}{I_{CQ}} = \dfrac{80}{0.5m/2} = 320\,\text{k}\Omega$ [1]

$A_d = (9.615m)\left(480k \parallel 320k\right) = 1846.08$ [1]

$Q2b(ii)$

$R_O = r_{o2} \parallel r_{o4} = 480k \parallel 320k = 192\,\text{k}\Omega$ [2]

$Q2b(iii)$

$A_d = g_{m2}\left(r_{o2} \parallel r_{o4} \parallel R_L\right)$ [1]

$A_d = (0.75)(1846) = 1384.5 = (9.615m)\left(480k \parallel 320k \parallel R_L\right)$ [1]

$R_L = 1394.5\,\text{k}\Omega$ [1]

Question 3 [20 marks]

Answers:

Q3(a)

$I_1 = [V^+ - V^- - V_{BE}]/R_1 = (10-0.7)/18.6k = 0.5$ mA [1]

$I_Q R_2 = V_T \ln(I_1/I_Q)$

$I_Q(59.6) = (0.026)\ln(0.5m/I_Q)$ ➔ $I_Q = 0.27$ mA $= I_{C8}$ [2]

$I_{C2} = 0.135$ mA (*Neglect base current in Q1 and Q2*) [1]

$I_{R4} = [V^+ - I_{C2}R_C - V_{BE3} - V_{BE4}] / R_4$

$I_{R4} = [2.3 - 2(0.7)]/11.5k = 78.26$ uA $= I_{C4}$ (Neglect base current) [2]

$I_{C3} = I_{C4} / (1+\beta) = (78.26$ u $)/(151) = 0.5217$ uA [2]

$I_{C6} \cong I_{E6} = (v_o - V^-)/R_7 = (-0.1316+5)/5k = 0.9737$ mA [2]

Q3(b)

$A_d = v_O/v_d = (v_{O2}/v_d)(v_{O3}/v_{O2})(v_O/v_{O3}) = A_{d1}A_{v2}A_{v3}$ [1]

$A_{d1} = (g_{m2}/2)(R_C \,||\, R_{i2})$ [1]

$g_{m2} = I_{CQ2}/V_T = I_Q/(2V_T) = (0.27m)/(2 \times 0.026) = 5.912$ mA/V [0.5]

$r_{\pi 4} = \beta V_T / I_{C4} = (150 \times 26m) / (78.26$ u$) = 49.83$ kΩ [0.5]

$r_{\pi 3} = \beta V_T / I_{C3} = (150 \times 26m) / (0.5217$ u$) = 7.476$ MΩ [0.5]

$R_{i2} = r_{\pi 3} + (1 + \beta) r_{\pi 4} = 7.476M + (151)(49.83k) = 14.92$ MΩ [1.5]

$A_{d1} = (0.5)(5.912m)(20k \,\|\, 14.92M) = 59.04$ [0.5]

$A_{v2} = \frac{\beta(1+\beta)(R_5 \| R_{i3})}{R_{i2}} = \frac{(150)(151)(5k)}{14.92M} = 7.59$ [2.5]

$A_{v3} \approx 1$ [1]

$A_d = (59.04)(7.59)(1) = 448.1$ [1]

Question 4 [20 marks]

Answers:

Q4(a)

$P_L(ave)=10=(1/2)(V_p^2/R_L)$ [1]

$V_P = 0.8\ V_{CC} = (0.8)(24) = 19.2$ V [1]

$R_L = (1/2)[V_p^2/P_L(ave)] = \text{SQR}(19.2) / [(2)(10)] = 18.43\ \Omega$ [2]

$P_S(ave) = 2V_{CC}I = 2(24)(19.2/[(\pi)(18.43)]) = 15.92$ Watts [4]

$\eta = P_L(\text{ave}) / P_S(\text{ave}) = 10/15.92 = 0.628$ or 62.8% [2]

Q4b(i)

$$I_{D5} = K_{p5}\left(V_{SG5} + V_{TP}\right)^2 = (125\mu)\times(1.5-0.5)^2 = 125\,\mu\text{A} \quad [2]$$

$$I_Q = I_{D6} = I_{D7} = I_{D8} = I_{D5} = 125\,\mu\text{A} \quad [1]$$

$$I_{D1} = I_{D2} = I_{D3} = I_{D4} = I_Q / 2 = 62.5\mu\text{A} \quad [1]$$

Q4b(ii)

$$A_d = g_{m2}\left(r_{o2} \parallel r_{o4}\right) \quad [1]$$

$$g_{m2} = \sqrt{2K_pI_Q} = \sqrt{2(125\mu)(125\mu)} = 176.77\,\mu\text{A/V} \quad [0.5]$$

$$r_{o2} = \frac{1}{\lambda_p I_{D2}} = \frac{1}{0.02\times 62.5\mu} = 0.8\,\text{M}\Omega \quad [0.5]$$

$$r_{o4} = \frac{1}{\lambda_n I_{D4}} = \frac{1}{0.01\times 62.5\mu} = 1.6\,\text{M}\Omega \quad [0.5]$$

$$A_d = (176.77\mu)\left(0.8\text{M} \parallel 1.6\text{M}\right) = 94.277 \quad [0.5]$$

$$A_{v2} = -g_{m7}\left(r_{o7} \parallel r_{o8}\right)$$

$$g_{m7} = 2\sqrt{K_{n7}I_{D7}} = 2\sqrt{(100\mu)(125\mu)} = 223.6\,\mu\text{A/V} \quad [0.5]$$

$$r_{o7} = \frac{1}{\lambda_n I_{D7}} = \frac{1}{0.01\times 125\mu} = 0.8\,\text{M}\Omega \quad [0.5]$$

$$r_{o8} = \frac{1}{\lambda_p I_{D8}} = \frac{1}{0.02\times 125\mu} = 0.4\,\text{M}\Omega \quad [0.5]$$

$$A_{v2} = -(223.6\mu)\left(0.8\text{M} \parallel 0.4\text{M}\right) = -59.63 \quad [0.5]$$

$$A_v = A_d A_{v2} = 94.277\times(-59.63) = -5618.61 \quad [1]$$

Question 5 [20 marks]

Answers:

Q5(a)

$\boldsymbol{A_v = v_O / v_I = - (R_2 + R_{2V}) / (R_1 + R_{1V})}$ [2]

R_1 (min) = R_1 = 20 kΩ [1]
R_1 (max) = $R_1 + R_{1V}$ = 20 kΩ + 30 kΩ = 50 kΩ [1]
R_2 (min) = R_2 = 30 kΩ [1]
R_2 (max) = $R_2 + R_{2V}$ = 30 kΩ + 40 kΩ = 70 kΩ [1]

Absolute value of A_v is maximum when:
A_v(max) = **ABS**(- R_2(max) / R_1 (min)) [1]
⇨ A_v(max) = **ABS**(-70k/20k) = 3.5 V/V [1]

Absolute value of A_v is minimum when:
A_v(min) = **ABS**(- R_2(min) / R_1(max)) [1]
⇨ A_v(min) = **ABS**(-30k/50k) = 0.6 V/V [1]

Q5(b) $$v_O = -10v_{I1} - 5v_{I2} + 2v_{I3} + 5v_{I4}$$

$\boldsymbol{R_F / R_1 = 10}$ ➔ $\boldsymbol{R_F = 10\ R_1}$ **[1]**

and $\boldsymbol{R_F / R_2 = 5}$ ➔ $\boldsymbol{R_F = 5\ R_2}$ **[1]**

Given $\boldsymbol{R_1 = 50\ k\Omega}$,

➔ $\boldsymbol{R_F}$ = 10 R_1 = 10 x 50 kΩ **= 500 kΩ** **[1]**

and $\boldsymbol{R_2}$ = R_F / 5 = 500 kΩ / 5 **= 100 kΩ** **[1]**

$R_N = R_1 \parallel R_2$ = 50 kΩ || 100 kΩ = **33.333 kΩ**

$1 + R_F / R_N$ = 1 + 500k / (33.333k) = 16 **[0.5]**

$(1 + R_F / R_N)(R_P / R_A) = (16)\ (R_P / R_A) = 3$ **[1]**

and $(1 + R_F / R_N)(R_P / R_B) = (16)\ (R_P / R_B) = 5$ **[1]**

So, $(R_A / R_B) = 5/3$ **[1]**

Given $\boldsymbol{R_A = 240\ k\Omega}$,

then $\boldsymbol{R_B}$ = (3 R_A) / 5 = **144 kΩ** **[1]**

R_P = (5 R_B) / 16 = (3 R_A) / 16

➔ $\boldsymbol{R_P = 45\ k\Omega}$ **[0.5]**

$R_P = R_A \parallel R_B \parallel R_C$

➔ $\boldsymbol{R_C = 53.34\ k\Omega}$ **[1]**

APPENDIX:

A) BASIC FORMULA FOR TRANSISTOR

BJT

$$i_C = I_S e^{v_{BE}/V_T} \quad ;\text{NPN}$$

$$i_C = I_S e^{v_{EB}/V_T} \quad ;\text{PNP}$$

$$i_C = \beta i_B = \frac{\beta}{\beta+1} i_E$$

$$i_E = i_B + i_C$$

;Small signal

$$\beta = g_m r_\pi$$

$$g_m = \frac{I_{CQ}}{V_T}$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}}$$

$$r_o = \frac{V_A}{I_{CQ}}$$

$$V_T = 26\,\text{mV}$$

MOSFET

$$;\text{N}-\text{MOSFET}$$

$$v_{DS}(\text{sat}) = v_{GS} - V_{TN}$$

$$i_D = K_n[v_{GS} - V_{TN}]^2$$

$$K_n = \frac{\mu_n C_{ox} W}{2L} = \frac{k_n'}{2} \cdot \frac{W}{L}$$

$$;\text{P}-\text{MOSFET}$$

$$v_{SD}(\text{sat}) = v_{SG} + V_{TP}$$

$$i_D = K_p[v_{SG} + V_{TP}]^2$$

$$K_p = \frac{\mu_p C_{ox} W}{2L} = \frac{k_p'}{2} \cdot \frac{W}{L}$$

;Small signal

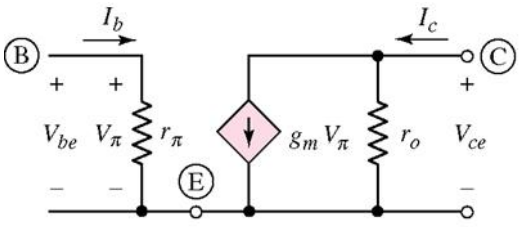
$$g_m = 2\sqrt{K_n I_{DQ}} \quad ;\text{N}-\text{MOSFET}$$

$$g_m = 2\sqrt{K_p I_{DQ}} \quad ;\text{P}-\text{MOSFET}$$

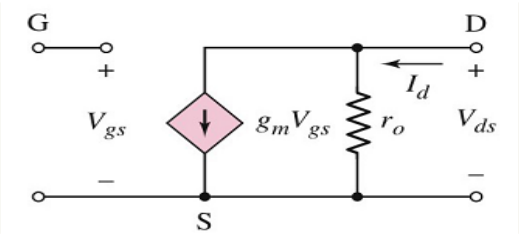
$$r_o \cong \frac{1}{\lambda I_{DQ}}$$

B) HYBRID-π EQUIVALENT CIRCUITS

BJT



MOSFET



C) QUADRATIC FORMULA

$$Ax^2 + Bx + C = 0 \qquad \rightarrow \quad x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$