# COLLEGE OF ENGINEERING
# PUTRAJAYA CAMPUS
# FINAL EXAMINATION

## SEMESTER 2 2013 / 2014

| | |
|---|---|
| PROGRAMME | : **Bachelor of Electrical & Electronics Engineering (Honours)**<br>**Bachelor of Electrical Power Engineering (Honours)** |
| SUBJECT CODE | : **EEEB273** |
| SUBJECT | : **ELECTRONIC ANALYSIS AND DESIGN II** |
| DATE | : **January 2014** |
| TIME | : **3 hours** |

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**INSTRUCTIONS TO CANDIDATES:**

1. This paper contains **Six** (6) questions in **Ten** (10) pages.
2. Answer **ALL** questions.
3. Write **all** answers in the answer booklet provided.
4. Write answer to different question on **a new page**.
5. For all calculations, assume that $V_T$ = **26 mV**.
6. Use at least **4 significant numbers** in all calculations.

# MODEL ANSWERS

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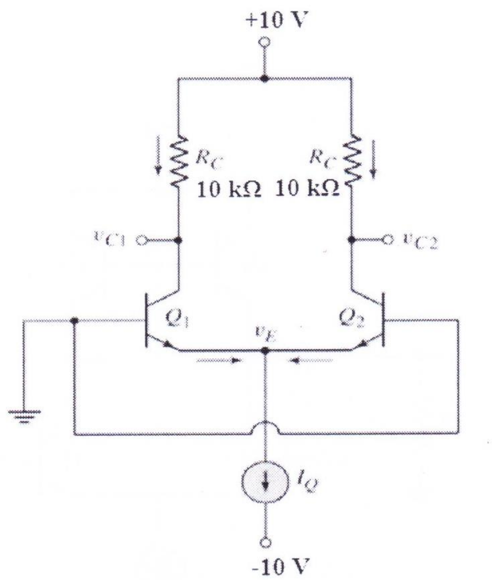
***THIS QUESTION PAPER CONSISTS OF TEN* (10) *PRINTED PAGES INCLUDING THIS COVER PAGE.***

**Question 1 [20 marks]**




Sketch and label of complete figure [5 marks]

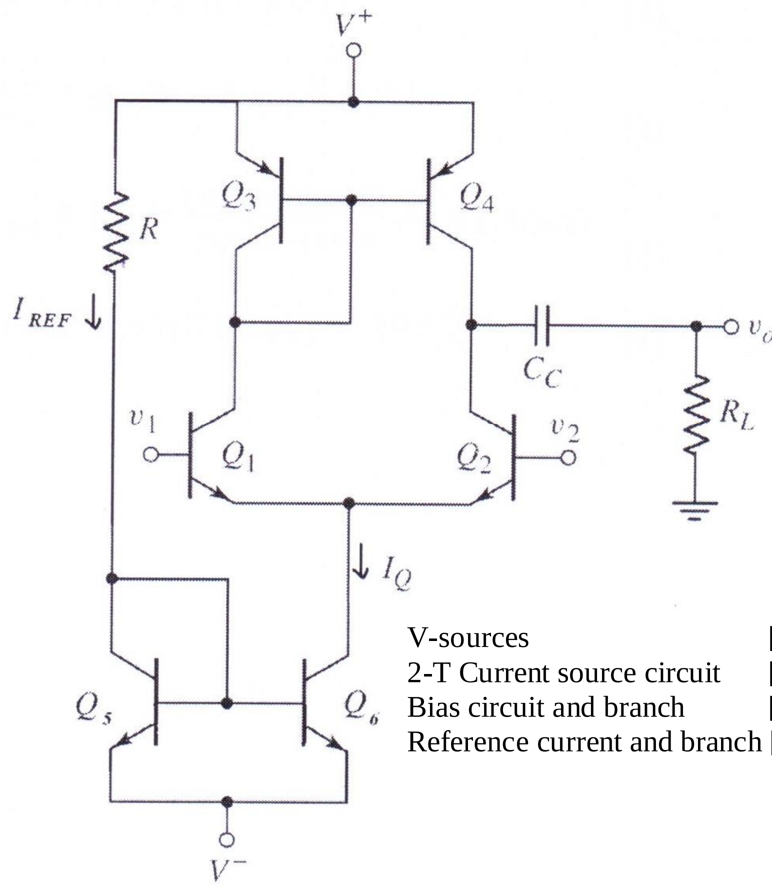
As $V_{C1} = V_{C2} = 4$ V, and $I_Q = 1.2$ mA,
Using KVL rule, $V^+ - I_{C1}R_C = V_{C1} = 4$ V [4]
$I_Q = I_{C1} + I_{C2} = 1.2$ mA [2]
$\Rightarrow I_{C1} = I_{C2} = 1.2\text{m}/2 = 0.6$ mA [2]
Substituting $I_{C1}$, $(10)-(0.6)R_C = 4 \Rightarrow R_C = 10$ kΩ [2]

Assuming that $v_{B1} = v_{B2} = 0$ V [1]
$v_{cm} = (v_{B1} + v_{B2})/2 = 0$ V [1]
$v_d = v_{B1} - v_{B2} = 0$ V [1]

$V_E = v_{B1}$ ï $V_{BE}$(on) $= 0 - 0.7 = -0.7$ V [2]

**Question 2 [15 marks]**

(a)




| | |
|---|---|
| V-sources | [1 mark] |
| 2-T Current source circuit | [2 marks] |
| Bias circuit and branch | [1 mark] |
| Reference current and branch | [1 mark] |

(b) *The equation used is* $v_o = g_m v_d (r_{O2} || r_{O4})$

$$A_d = \frac{v_O}{v_d} = g_m (r_{O2} || r_{O4})$$ [1 mark]

$$g_m = \frac{I_Q/2}{V_T} = \frac{0.25m/2}{0.026} = 4.808\ mA/V$$ [1 mark]

$$r_{O2} = \frac{V_{AN}}{I_Q/2} = \frac{120}{0.125m} = 960\ k\Omega$$ [1 mark]

$$r_{O4} = \frac{V_{AP}}{I_Q/2} = \frac{100}{0.125m} = 800\ k\Omega$$ [1 mark]

$$(r_{O2} || r_{O4}) \Rightarrow \frac{(960k)(800k)}{(960 + 860)k} \Rightarrow 436.4\ k\Omega$$ [1 mark]

∴ Substituting for the terms,

$$A_d = \frac{v_O}{v_d} = (4.808\ m)(436.4\ k) = 2098$$

[1 mark]

(c) $v_O = g_m v_d (r_{O2}||r_{O4}||R_L)$ is used. [1 mark]

$$A_d = \frac{v_O}{v_d} = g_m (r_{O2}||r_{O4}||R_L)$$ [1 mark]

$$(r_{O2}||r_{O4}||R_L) \Rightarrow \frac{(436.4k)(100)k}{(436.4 + 100)k} = 81.36\ k\Omega$$ [1 mark]

$$A_d = (4.808m)(81.36k) = 391.2$$ [1 mark]

**Question 3 [10 marks]**

(a) From voltage transfer characteristics of complementary push-pull output stage in Class B, both transistors are cut off and $v_O$ is 0 in the dead band portion. [1.5marks]

A not perfect sinusoidal signal means that ñcrossover distortionò is produced by the dead band region. [1.5marks]

(b) (i) [1 mark]

$$i_{Cn} = I_S \exp\left(\frac{V_{BE}}{V_T}\right) \Rightarrow V_{BE} = V_T \ln\left(\frac{i_{Cn}}{I_S}\right) = (0.026)\ln\left(\frac{10^{-3}}{2\times10^{-15}}\right) = 0.7004\text{ V}$$

$$V_{BB} = 2V_{BE} = 1.40077\text{ V}$$ [1 mark]

(ii) For $\upsilon_o = -3.5\text{V}$, $i_{Cp} \cong \frac{3.5}{1} = 3.5\text{ mA} \cong i_L$ [0.5 mark]

$$\upsilon_{EB} = (0.026)\ln\left(\frac{3.5\times10^{-3}}{2\times10^{-15}}\right) = 0.732957\text{ V}$$ [0.5 mark]

$$\upsilon_{BE} = 1.40077 - 0.732957 = 0.66781\text{ V}$$ [0.5 mark]

$$i_{Cn} = (2\times10^{-15})\exp\left(\frac{0.66781}{0.026}\right) \Rightarrow i_{Cn} = 0.2857\text{ mA}$$ [0.5 mark]

Then $i_{Cp} \cong 0.2857 + 3.5 = 3.7857\text{ mA}$

$$\upsilon_{EB} = (0.026)\ln\left(\frac{3.7857\times10^{-3}}{2\times10^{-15}}\right) = 0.734997\text{ V}$$

$$\upsilon_{BE} = 1.40077 - 0.734997 = 0.66577\text{ V}$$ [0.5 mark]

$$i_{Cn} = (2\times10^{-15})\exp\left(\frac{0.66577}{0.026}\right) \Rightarrow i_{Cn} = 0.2642\text{ mA}$$

$$i_{Cp} = 3.5 + 0.2642 = 3.764\text{ mA}$$

$$\upsilon_I = \upsilon_o - \upsilon_{EB} + \frac{V_{BB}}{2} = -3.5 - 0.735 + 0.7004 = -3.535\text{ V}$$ [0.5 mark]

(iii) The power dissipated in $R_L$,

$P_{RL} = i_L^2 R_L = (3.5)^2(1\text{k}) = 12.25\text{ mW}$ [2 marks]

**<u>Question 4 [20 marks]</u>**

(i)

| | | | |
|---|---|---|---|
| $I_{D3}$ | $= (k'_p/2)(W/L)_3(V_{SG3} + V_{TP})^2$ | | |
| $150\mu$ | $= (40\mu/2)(50)(V_{SG3} - \mathbf{0.4})^2$ | | [1] |
| $V_{SG3}$ | $= \mathbf{0.7873\ V}$ | | [0.5] |
| $R_{D1}$ | $= V_{SG3} / I_{D1} \quad = V_{SG3} / (I_Q/2)$ | | [1] |
| | $= 0.7873 / (200\mu/2)$ | $= \mathbf{7.87\ k\Omega}$ | [0.5] |
| $I_{D4}$ | $= (k'_n/2)(W/L)_4(V_{GS4} - V_{TN})^2$ | | |
| $200\mu$ | $= (100\mu/2)(40)(V_{GS4} - \mathbf{0.4})^2$ | | [1] |
| $V_{GS4}$ | $= \mathbf{0.7162\ V}$ | | [0.5] |
| $V_{G4}$ | $= V_O + V_{GS4} = 0 + 0.7162$ | $= \mathbf{0.7162\ V}$ | [1] |
| $R_{D2}$ | $= (V_{G4} - (V^-)) / I_{D3}$ | | [1] |
| | = (0.7162 ï (**-3.5**))/(150µ) | $= \mathbf{28.108\ k\Omega}$ | [0.5] |
| $R_S$ | $= (V_O - (V^-)) / I_{D4}$ | | [1] |
| | $= (0 - (\mathbf{-3.5}))/(200\mu)$ | $= \mathbf{17.5\ k\Omega}$ | [1] |

(ii)

| | | | |
|---|---|---|---|
| $A_{d1}$ | $= (g_{m1} R_{D1})/2$ | | [1] |
| $g_{m1}$ | $= 2\ \text{SQRT}[(k'_n/2)(W/L)_1(I_Q/2)]$ | | [1] |
| | $= 2\ \text{SQRT}[(100\mu/2)(20)(200\mu/2)]$ | $= \mathbf{0.6325\ mA/V}$ | [1] |
| $A_{d1}$ | $= ((0.6325m)(7.87k))/2$ | $= \mathbf{2.49\ V/V}$ | [1] |

(iii)

| | | | |
|---|---|---|---|
| $A_2$ | $= -g_{m3} R_{D2}$ | | [0.5] |
| $g_{m3}$ | $= 2\ \text{SQRT}[(k'_p/2)(W/L)_3(I_{D3})]$ | | [1] |
| | $= 2\ \text{SQRT}[(40\mu/2)(50)(150\mu)]$ | $= \mathbf{0.7746\ mA/V}$ | [0.5] |
| $A_2$ | $= -(0.7746m)(28.108k)$ | $= \mathbf{-21.772\ V/V}$ | [1] |

(iv)

| | | | |
|---|---|---|---|
| $A_3$ | $= \mathbf{1}$ (assume) | | [1] |
| $A_v$ | $= A_{d1} \times A_2 \times A_3$ | | [2] |
| | $= (2.49) \times (-21.772) \times (1)$ | $= \mathbf{-47.8\ V/V}$ | [1] |

**Question 5 [15 marks]**

$$R_{i2} = r_{\pi 16} + (1+\beta_n)R_E^{'}$$ [1]

$$R_E^{'} = R_9 \| [r_{\pi 17} + (1+\beta_n)R_8]$$ [1]

$$r_{\pi 17} = \frac{\beta_n V_T}{I_{C17}} = \frac{(200)(0.026)}{0.54\text{m}} = 9.63\,\text{k}\Omega$$ [1]

$$\Rightarrow R_E^{'} = 50\text{k} \| [9.63\text{k} + (1+200)(0.1\text{k})] = 18.6\,\text{k}\Omega$$ [0.5]

$$r_{\pi 16} = \frac{\beta_n V_T}{I_{C16}} = \frac{(200)(0.026)}{15.8\varepsilon} = 329\,\text{k}\Omega$$ [1]

$$\Rightarrow R_{i2} = 329\text{k} + (201)(18.6\text{k}) = 4.07\,\text{M}\Omega$$ [0.5]

$$R_{i3} = r_{\pi 22} + (1+\beta_p)[R_{19} \| R_{20}]$$

$$r_{\pi 22} = \frac{\beta_p V_T}{I_{C13A}} = \frac{(50)(0.026)}{0.18\text{m}} = 7.22\,\text{k}\Omega$$ [1]

$$r_{\pi 20} = \frac{\beta_p V_T}{I_{C20}} = \frac{(50)(0.026)}{0.138\text{m}} = 9.42\,\text{k}\Omega$$ [1]

$$R_{20} = r_{\pi 20} + (1+\beta_p)R_L$$

$$R_{20} = 9.42\text{k} + (51)(2\text{k}) \cong 111\,\text{k}\Omega$$ [1]

$$R_{19} = r_{o13A} = \frac{V_A}{I_{C13A}} = \frac{50}{0.18\text{m}} = 278\,\text{k}\Omega$$ [1]

$$\Rightarrow R_{i3} = 7.22\text{k} + (51)[278\text{k} \| 111\text{k}] = 4.05\,\text{M}\Omega$$ [1]

$$R_{o17} \cong r_{o17} = \frac{V_A}{I_{C17}} = \frac{50}{0.54\text{m}} = 92.6\,\text{k}\Omega$$ [1]

$$R_{act2} = r_{o13B} = \frac{V_A}{I_{C13B}} = \frac{50}{0.54\text{m}} = 92.6\,\text{k}\Omega$$ [1]

$$A_{v2} = \frac{-\beta_n(1+\beta_n)R_9(R_{act2} \| R_{i3} \| R_{o17})}{R_{i2}\{R_9 + [r_{\pi 17} + (1+\beta_n)R_8]\}}$$

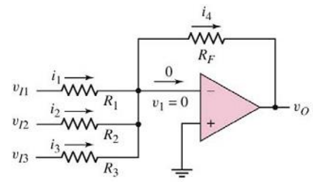
$$A_{v2} = \frac{-(200)(201)(50\text{k})(92.6\text{k} \| 4.05\text{M} \| 92.6\text{k})}{4.07\text{M}\{50\text{k} + [9.63\text{k} + (201)(0.1\text{k})]\}}$$ [2]

$$A_{v2} = -285$$ [1]

**<u>Question 6 [20 marks]</u>**

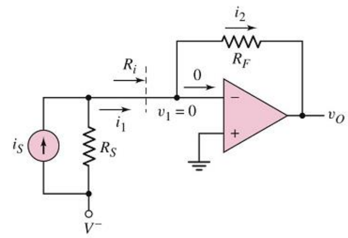
(a) Can state and draw 3 of the following applications:

Summing amplifier [1]



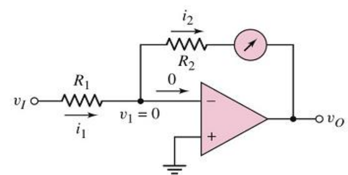

[1]

Current to voltage converter [1]



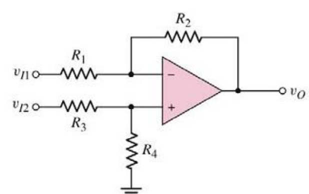

[1]

Voltage to current converter [1]



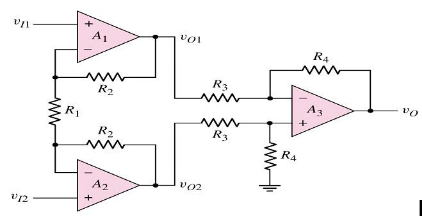

[1]

Difference amplifier [1]



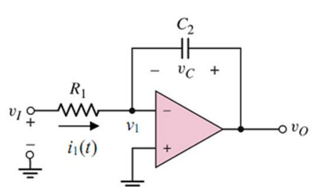

[1]

Instrumentation amplifier [1]



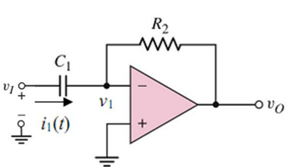

[1]

Integrator [1]



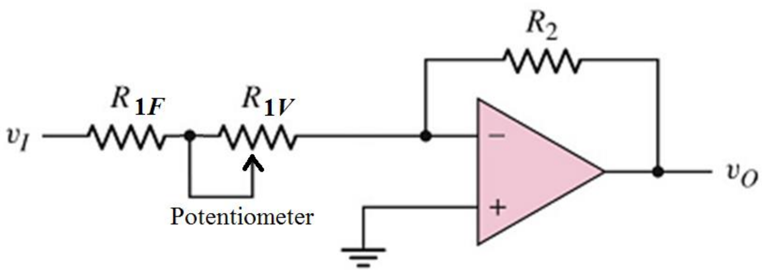

[1]

Differentiator [1]




[1]

(b)




[2]

| | | | |
|---|---|---|---|
| $A_v$ | $= -R_2/(R_{1F} + R_{1V})$ | | [1] |
| $R_2$ | $= 200$ kΩ. | $R_{1F}$ is a constant value resistor. | |

$R_{1V}$ is a potentiometer. Gain is maximum, i.e. -25, when $R_{1V} = 0$ Ω.

| | | | | |
|---|---|---|---|---|
| $A_{v1}$ | $= -25$ | $= -R_2/(R_{1F} + R_{1V})$ | $= -200\text{k}/(R_{1F} + 0)$ | [2] |
| $R_{1F}$ | $= 8$ kΩ | | | [0.5] |
| $A_{v2}$ | $= -10$ | $= -R_2/(R_{1F} + R_{1V})$ | $= -200\text{k}/(8\text{k} + R_{1V})$ | [2] |
| $R_{1V}$ | $= 12$ kΩ | | | [0.5] |

(c)

$$i_1 = \frac{v_{I1} - v_{I2}}{R_1} = \frac{(0.60 - 0.30 \sin \omega t) - (0.60 + 0.30 \sin \omega t)}{20k} \text{ [1]}$$

$$\Rightarrow i_1 = \frac{-0.60 \sin \omega t}{20k} = -0.030 \sin \omega t \text{ (mA) [0.5]}$$

$$v_{O1} = i_1 R_2 + v_{I1} = (-0.030 \sin \omega t \text{ (mA)})(115k) + (0.60 - 0.30 \sin \omega t \text{ (V)}) \text{ [1]}$$
$$\Rightarrow v_{O1} = 0.60 - 3.75 \sin \omega t \text{ (V) [0.5]}$$

$$v_{O2} = -i_1 R_2 + v_{I2} = -(-0.0030 \sin \omega t \text{ (mA)})(115k) + (0.60 + 0.30 \sin \omega t \text{ (V)}) \text{ [1]}$$
$$\Rightarrow v_{O2} = 0.60 + 3.75 \sin \omega t \text{ (V) [0.5]}$$

$$v_O = (R_4 / R_3)(v_{O2} - v_{O1}) = (200k / 50k)[(0.60 + 3.75 \sin \omega t) - (0.60 - 3.75 \sin \omega t)] \text{ [1]}$$
$$\Rightarrow v_O = (200k / 50k)(7.5 \sin \omega t) = 30 \sin \omega t \text{ (V) [0.5]}$$

Other solution :

$$v_{O1} = (1 + R_2 / R_1) v_{I1} - (R_2 / R_1) v_{I2} = 0.60 - 3.75 \sin \omega t \text{ (V) [2]}$$
$$v_{O2} = (1 + R_2 / R_1) v_{I2} - (R_2 / R_1) v_{I1} = 0.60 + 3.75 \sin \omega t \text{ (V) [2]}$$
$$v_O = (R_4 / R_3)(1 + 2R_2 / R_1)(v_{I2} - v_{I1}) = 30 \sin \omega t \text{ (V) [2]}$$