Name:

Student ID Number:

Section Number: 01/02/03/04 A/B

Lecturer: Dr Jamaludin/Dr Fazrena Azlee

Table Number:

UNIVERSITI TENAGA NASIONAL

The National Energy University

College of Engineering

Department of Electronics and Communication Engineering

Test 1 – Model Answers

SEMESTER 2, ACADEMIC YEAR 2018/2019

Subject Code	:	**EEEB273/EEEB2014**
Course Title	:	**Electronics Analysis & Design II**
Date	:	**1 December 2018**
Time Allowed	:	**2 hours**

Instructions to the candidates:

1. Write your Name and Student ID Number. Indicate your Section Number and Lecturer's Name. Write also your Table Number.
2. **Write all your answers using pen**. **DO NOT USE PENCIL** except for the diagram.
3. **ANSWER ALL QUESTIONS. Show all calculations clearly**. Every value or parameter **must** be written with its correct **Unit**.
4. **WRITE YOUR ANSWER ON THIS QUESTION PAPER.**

NOTE: DO NOT OPEN THE QUESTION PAPER UNTIL INSTRUCTED TO DO SO.

☺ **GOOD LUCK!** ☺

Question Number	Q1 (a-d)	Q2 (a)	Q2 (b)	Q3 (a)	Q3 (b)	Q4 (a-b)	Total
Marks							

QUESTION 1 [30 marks]

Answers for Question 1

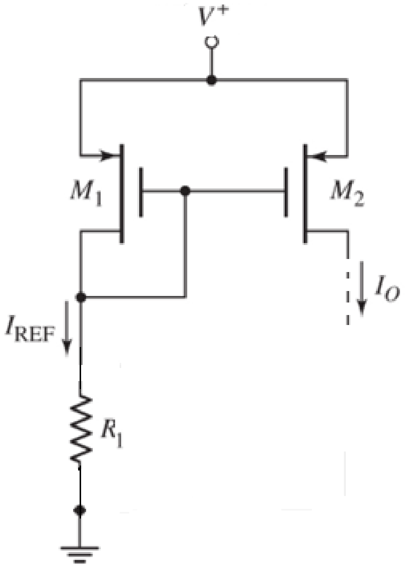
Two-transistor current source	Three-transistor current source	Wilson current source
Question 1(a) [2.5x3 marks] $R_1 = (V^+ - V_{BE} - V^-)/ I_{REF}$ [1] = (12 – 0.7 – (-12))/(1.2m) [1] = 19.417 kΩ [1/2]	$R_1 = (V^+ - 2\ V_{BE} - V^-)/ I_{REF}$ = (12 – 2x0.7 – (-12))/(1.2m) = 18.833 kΩ	$R_1 = (V^+ - 2\ V_{BE} - V^-)/ I_{REF}$ = (12 – 2x0.7 – (-12))/(1.2m) = 18.833 kΩ
Question 1(b) [4.5x3 marks] $I_O = I_{REF}/(1 + 2/(\beta))$ [1] = (1.2m)/(1+2/(40)) [1/2] = 1.1428 mA [1/2] $r_{O2} = V_A / I_O$ [1] = 120/(1.1428m) = 105 kΩ $R_O = r_{O2}$ [1] = 105 kΩ [1/2]	$I_O = I_{REF}/(1 + 2/(\beta(1+\beta)))$ = (1.2m)/(1+2/(40x41)) = 1.1985 mA $r_{O2} = V_A / I_O$ = 120/(1.1985m) = 100.12 kΩ $R_O = r_{O2}$ = 100.12 kΩ	$I_O = I_{REF}/(1 + 2/(\beta(2+\beta)))$ = (1.2m)/(1+2/(40x42)) = 1.1985 mA $r_{O3} = V_A / I_O$ = 120/(1.1985m) = 100.12 kΩ $R_O = (\beta\ r_{O3})/2$ = (40 x 100.12k)/2 = 2.002 MΩ
Question 1(c) [2x3 marks] $dI_O = dV_O / R_O$ [1] = 2.3 V / 105 kΩ [1/2] = 0.0219 mA [1/2]	$dI_O = dV_O / R_O$ = 2.3 V / 100.12 kΩ = 0.0229 mA	$dI_O = dV_O / R_O$ = 2.3 V / 2.002 MΩ = 0.0011 mA

Question 1(d) [3 marks]

Most stable: Wilson, medium stable: Three-transistor, least stable: Two-transistor.
Io for Wilson is approximately equal to Iref, Ro is the highest (dIo is the smallest).
Io for 3-transistor is approximately equal to Iref but bigger than Io for 2-transistor, Ro is the similar to 2-transistor (dIo is higher compared to Wilson).
Io for 2-transistor is lower than Iref compared to 3-transistor and Wilson, Ro is the similar to 3-transistor (dIo is higher compared to Wilson).

QUESTION 2 [30 marks]

Answers for Question 2(a)



(i) Sketch: [6 marks]

Correct connections for M1 & M2	[2 marks]
Correction connections for power supplies	[2 marks]
Correct direction and placement for IREF and IO	[2 marks]

(ii) Current relationships [4 marks]

$I_O = I_{D2} = ½ \; kn' \; (W/L)_2(VGS_2\text{-}VTN)^2$ [1 mark]

$I_{REF} = I_{D1} = ½ \; kn' \; (W/L)_1(VGS_1\text{-}VTN)^2$ [1 mark]

From circuit, $VGS_1=VGS_2=VGS$ [1 mark]

Divide Io with IREF, and common terms cancel out,
Left with current and aspect ratio terms only: [1 mark]

$$\frac{Io}{IREF} = \frac{(W/L)_2}{(W/L)_1}$$

Which is:

$$Io = \frac{(W/L)_2}{(W/L)_1}.IREF$$

Answers for Question 2(b)

(i) Calculate VGS [5 marks]

IREF = ID3 = ID1 = 2mA [1 mark]

$I_{D1} = K_{n1}(VGS_1\text{-}VTN)^2$

2mA = 25m(VGS1-0.9)^2

VGS1 = 1.1828V [1 mark]

VGS2=VGS1=1.1828V [0.5 mark]

VGS3=VGS1=1.1828V [0.5 mark]

Io = ID4 = ID2 = 40uA

$I_{D4} = K_{n4}(VGS4\text{-}VTN)^2$ [1 mark]

40uA = 25m(VGS4-0.9)^2

VGS4 = 0.94V [1 mark]

(ii) Calculate (W/L) [5 marks]

Kn1 = ½ kn' $(W/L)_1$ [1 mark]

25m =½ (0.5m) $(W/L)_1$

$(W/L)_1$ = 100 [1 mark]

$(W/L)_3 = (W/L)_1$ = 100 [0.5 mark]

$(W/L)_4 = (W/L)_2 = (W/L)_1$ = 100 [0.5 mark]

$(W/L)_2$ = [Io/IREF].$(W/L)_1$ [1 mark]

= [40u/2m].100 = 2 [1 mark]

(iii) Calculate Ro [4 marks]

For cascode, Ro = gm4ro4ro2 [1 mark]

gm4 = 2.sqrt(Kn4.ID4)

= 2.sqrt(25m)(40u) = 2mA/V [1 mark]

ro4 = ro2=1/λID4 = 1/(0.02)(40u) = 1.25MΩ [1 mark]

Ro = (2m)(1.25M)(1.25M) = 3.125 GΩ [1 mark]

(iv) Calculate percentage change in Io [4 marks]

% change in Io = dIo/Io x 100% [1 mark]

dIo = dVD4/Ro [1 mark]

= 2.5/3.125G = 8 x10^{-10} = 0.8 nA [1 mark]

% change in Io = 0.8n/40u x 100%

= 2x10^{-3} % [1 mark]

(v) Using 2T current source [2 marks]

The % change in Io shall increase [1 mark]

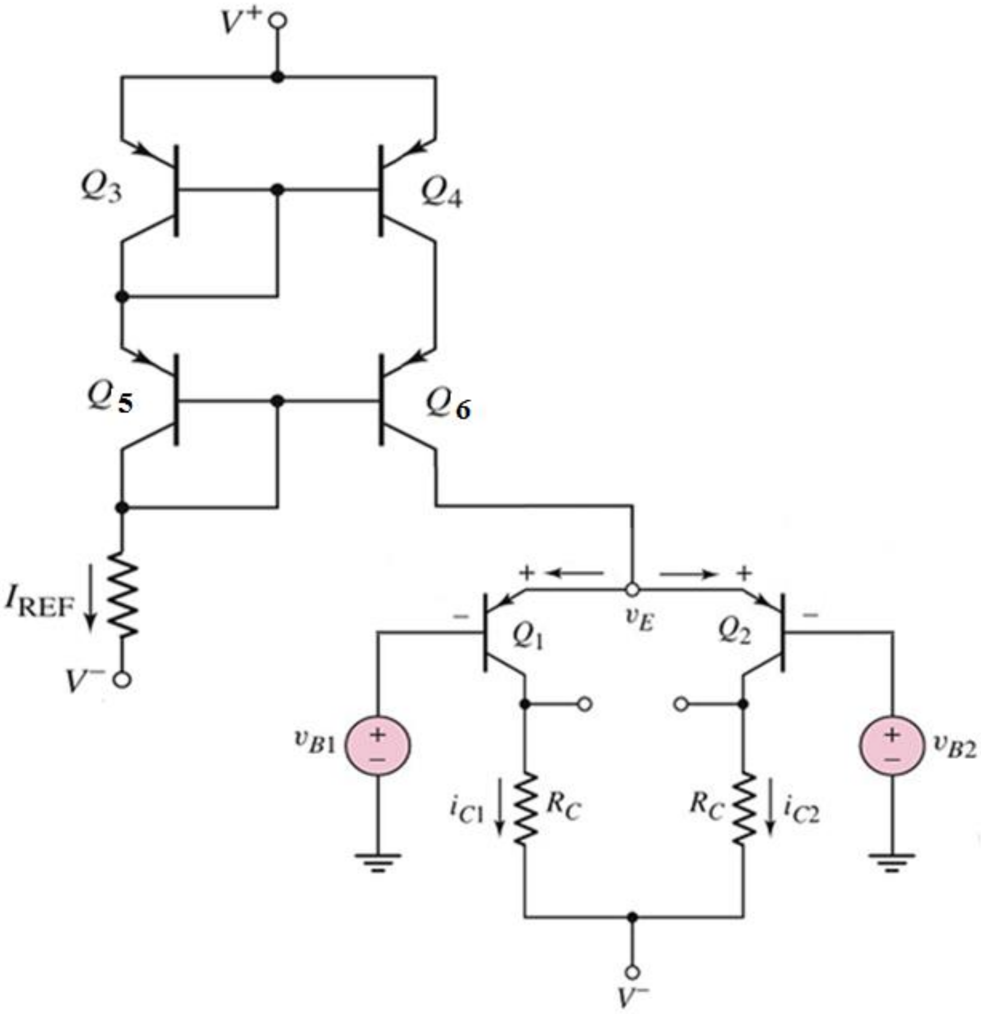
Because 2T has lower Ro, Ro=ro2=1.25M [0.5 mark]

dIo = 2.5/1.25M = 2 uA

% change in Io = 2u/40u x 100% = 5 % [0.5 mark]

QUESTION 3 [20 marks]

Answers for Question 3(a)



PNP Differential amp	[2]
PNP Cascode current source	[2]
Correct connections and power supplies	[1]

Total: 5 marks

Answers for Question 3(b)

Q3b(i) [5 marks]

$I_1 = \left(1 + \frac{2}{\beta}\right) I_Q = 4.067mA$ [1]

$I_1 = \left(1 + \frac{2}{\beta}\right)(4m) = 4.067mA$ [1.5]

$R_1 = \frac{V^+ - V_{BE} - V^-}{I_1} = 4.75k\Omega$ [1]

$R_1 = \frac{10 - 0.7 - (-10)}{4.067m} = 4.75k\Omega$ [1.5]

Q3b(ii) [5 marks]

$I_{E2} = \frac{I_Q}{2} = \frac{4m}{2} = 2\ mA$ [1]

$I_{C2} = \frac{\beta}{1+\beta} I_{E2} = 1.983mA$ [1.5]

$V_{O2} = V^+ - I_{C2}R_C$ [1.5]

$V_{O2} = 10 - (1.983m)(5k) = 0.085V$ [1]

Q3b(iii) [5 marks]

$V_{CE4} = V_{C4} - V_{E4} = (V_1 - V_{BE1}) - V^-$ [3]

$V_{CE4} = 0 - 0.7 - (-10) = 9.3V$ [2]

QUESTION 4 [20 marks]

Answers for Question 4

(a) **Calculate Ad, Acm and CMRR in dB [13 marks]**

IREF	= (V+-VBE-V-)/R1 = (10- 0.7)/37k	= 0.2514mA	[2 marks]
IQ	=IC4=IREF/[1+2/B] = 0.2514m/[1+2/250]	= 0.2494mA	[2 marks]
I1	= I2 = IQ/2 = 0.2494m/2	= 0.1247mA	[1 mark]
Gm	= I1/VT = 0.1247m/26m	= 4.796mA/V	[1 mark]
Rπ	= BVT/I1 = 250.26m/0.1247m	= 52.124kΩ	[1 mark]
Ad	= BRc/[2(rπ+RB)]		
	= 250.30k/2[52.124k+500]	= 71.2588V/V	[1.5 mark]
Ro of 2T	= ro4 = VA3/IQ = 100/0.2494m	= 400.96kΩ	[1 mark]
Acm	= -gm.Rc/[1+[2(1+B)Ro]/ (rπ+RB)]		
	= -4.796m(30k)/[1+[2(251)(400.96k)/(52.124k+500)]		[1.5 mark]
	= -0.0376 V/V		
CMRR in dB	= 20 log10[Ad/Acm] = 20 log10[71.2588/0.0376]		[1 mark]
	= 65.55dB		[1 mark]

(b) **Calculate output voltage [7 marks]**

Vd = v1 – v2
$=210x10^{-6}$sinwt V - $190x10^{-6}$sinwt V = $20x\ 10^{-6}$sinwt V [2 marks]
Vcm = [v1+v2]/2
= [$210x10^{-6}$sinwt V + $190x10^{-6}$sinwt V]/2 = $200x10^{-6}$sinwt V [2 marks]

Output voltage,
vo = AdVd + AcmVcm [2 marks]
= (71.2588)($20x\ 10^{-6}$sinwt V) +(-0.0376)($200x10^{-6}$sinwt V)
= $1.4177x10^{-3}$ sinwt V [1 mark]