K. J. SOMAIYA COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
Darlington Amplifier

Q1. Calculate DC voltages at each mode and DC currents in the give circuit.

Given: $R_1 = 82k\Omega$, $R_2 = 39k\Omega$, $R_E = 820\Omega$, $C_{C1} = 10\mu F$, $C_{C2} = 10\mu F$, $V_{CC} = 10V$, $\beta = 100$.

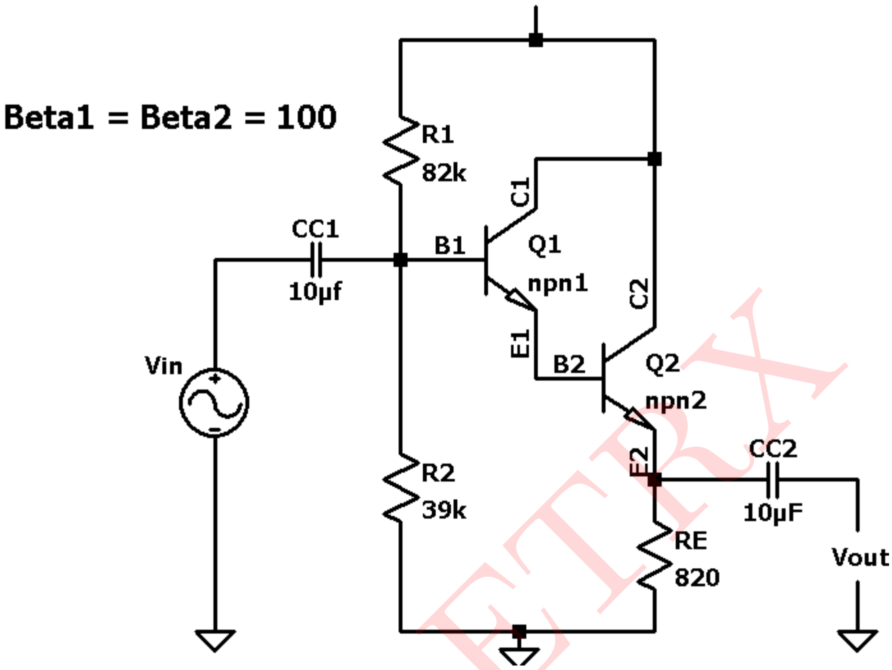

Figure 1: Circuit 1

Solution:

DC Analysis:

$V_{BE} = V_{BE1} + V_{BE2} = 0.7 + 0.7 = 1.4V$

$V_{TH} = \left(\dfrac{R_2}{R_1 + R_2}\right) \times V_{CC} = \left(\dfrac{39k}{82k + 39k}\right) 10 = \mathbf{3.223V}$

$R_{TH} = R_1 \mid\mid R_2 = 82\text{k} \mid\mid 39\text{k} = \mathbf{26.429k\Omega}$

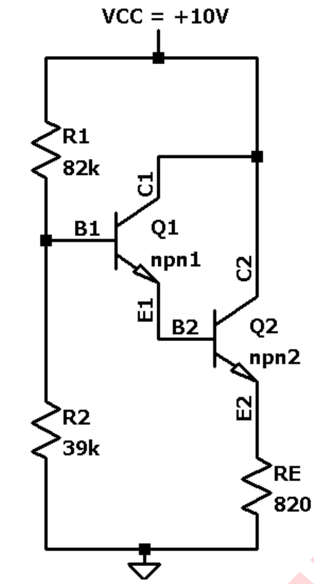

Figure 2: DC equivalent circuit

By thevenins equivalent circuit

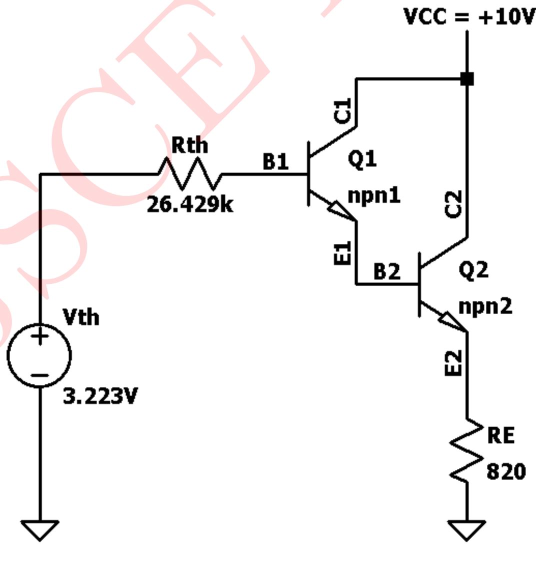

Figure 3: Thevenins equivalent circuit

$I_{BQ} = \dfrac{V_{TH} - V_{BE}}{R_{TH} + (1+\beta)^2 R_E} = \dfrac{3.223 - 1.4}{26.429k + (101)^2 \times 820} = \mathbf{0.18149\mu A}$

$I_{C1} = \beta I_{B1} = \mathbf{0.018149mA}$

$I_{E1} = I_{B1} + I_{C1} = \mathbf{0.01833mA}$

Now, $I_{E1} = I_{B2} = \mathbf{0.01833mA}$

$I_{C2} = \beta I_{B2} = \mathbf{1.83304mA}$

$I_{E2} = I_{C2} + I_{B2} = 1.83304 + 0.01833 = \mathbf{1.85137mA}$

$V_{E2} = I_{E2} R_E = 1.85137mA \times 820\Omega = \mathbf{1.5181V}$

V_{C2}= **10V**

$V_{CE2} = V_{C2} - V_{E2} = 10 - 1.5181 =$ **8.4819V**

Q point = (I_C, V_{CE})= **(1.83304mA , 8.4819V)**

Small signal parameters:

$$r_{\pi 1} = \frac{\beta V_T}{I_{C1}} = \frac{100 \times 26mV}{0.018149mA} = \mathbf{143.258k\Omega}$$

$$r_{\pi 2} = \frac{\beta V_T}{I_{C2}} = \frac{100 \times 26mV}{1.83305mA} = \mathbf{1.418k\Omega}$$

Mid frequency equivalent circuit:

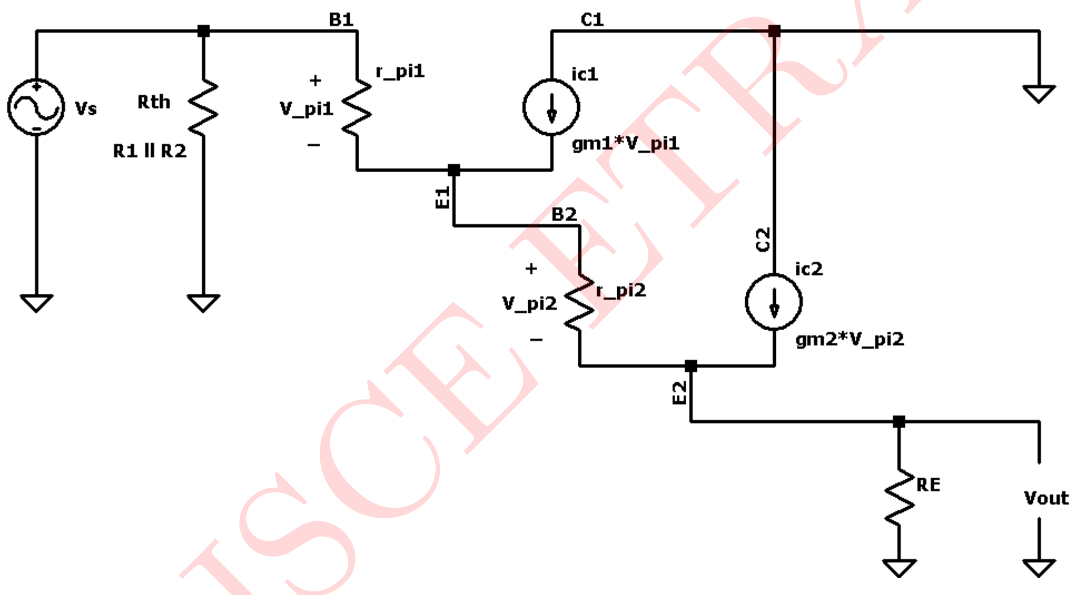

Figure 4: Mid frequency equivalent circuit

$Z_{i2} = r_\pi + (1+\beta)R_E = 1.418k + (101) \times 820 =$ **82.238kΩ**

$Z_{i1} = r_\pi + (1+\beta)Z_{i2} = 143.258k + (101) \times 82.238k =$ **8.449MΩ** (very high)

$Z_i = R_1 \mid\mid R_2 \mid\mid Z_{i1}$ = 82k || 39k || 8.449M = **26.3465kΩ** (R_1 and R_2 decreases input impedence)

$$Z_{o2} = \frac{Z_{o1} + r_{\pi 2}}{1+\beta}$$

$$Z_{o1} = \frac{(R1||R_2) + r_\pi}{1+\beta} = \frac{26.429k + 143.258k}{101} = \mathbf{1.680\ k\Omega}$$

$$Z_{o2} = \frac{1.680k + 1.418K}{101} = \mathbf{30.6732}\ \Omega \text{ (Very low)}$$

$Z_o = Z_{o2}||R_E = 30.6732||820 =$ **29.5671** Ω (very low)

A_i Current gain:

$$A_{i_1} = \frac{I_{E1}}{I_{B1}} = (1+\beta) = \mathbf{101}$$

$$A_{i_2} = \frac{I_{E2}}{I_{B2}} = (1+\beta)= \mathbf{101}$$

$$A_{i_t} = A_{i2} \times A_{i1} = 101 \times 101 = \mathbf{10201} \text{ (very high)}$$

$$A_{i_s} = \frac{I_o}{I_i} = \frac{I_o}{I_{B2}} \times \frac{I_{B2}}{I_{B1}} \times \frac{I_{B1}}{I_i}$$

$$\frac{I_{B1}}{I_i} = \frac{R_{TH}}{R_{TH}+Z_i} = \frac{26.429k}{26.429k+8.449M} = \mathbf{3.1183mA}$$

$$A_{i_s} = 101.118mA = \mathbf{31.8097} \text{ (Presence of } R_{TH} \text{ reduces current gain)}$$

A_v Voltage Gain:

$$A_{V_2} = \frac{V_o}{V_1} = \frac{R_E}{Z_{i2}} \times A_{i_2} = 101 \times \frac{820}{82.238k} = \mathbf{1.007}$$

$$A_{V_1} = \frac{V_1}{V_i} = \frac{Z_{i1}}{Z_{i2}} \times A_{i_1} = 101 \times \frac{82.238k}{8.449M} = \mathbf{0.98307}$$

$$A_{V_T} = A_{V_2} \times A_{V_1} = 1.0070 \times 0.98307 = \mathbf{0.98995}$$

$$A_{V_{T_s}} = A_{V_T} \times \frac{Z_i}{Z_i + R_{sig}} = \mathbf{0.98997} \ (\because R_{sig}= 0)$$

$$A_{V_{T_s}} indB = 20\log_{10}(0.98995)= -\mathbf{0.08775dB}$$

SIMULATED RESULTS:

Above circuit was simulated in LTSpice and results are presented below:

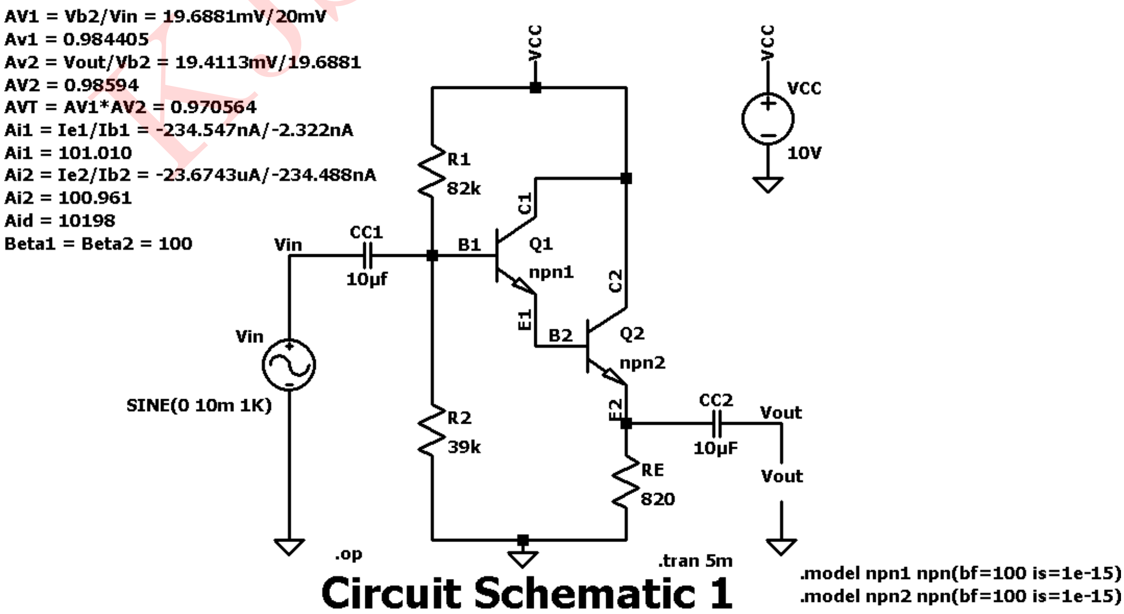

Figure 5: Circuit Schematic

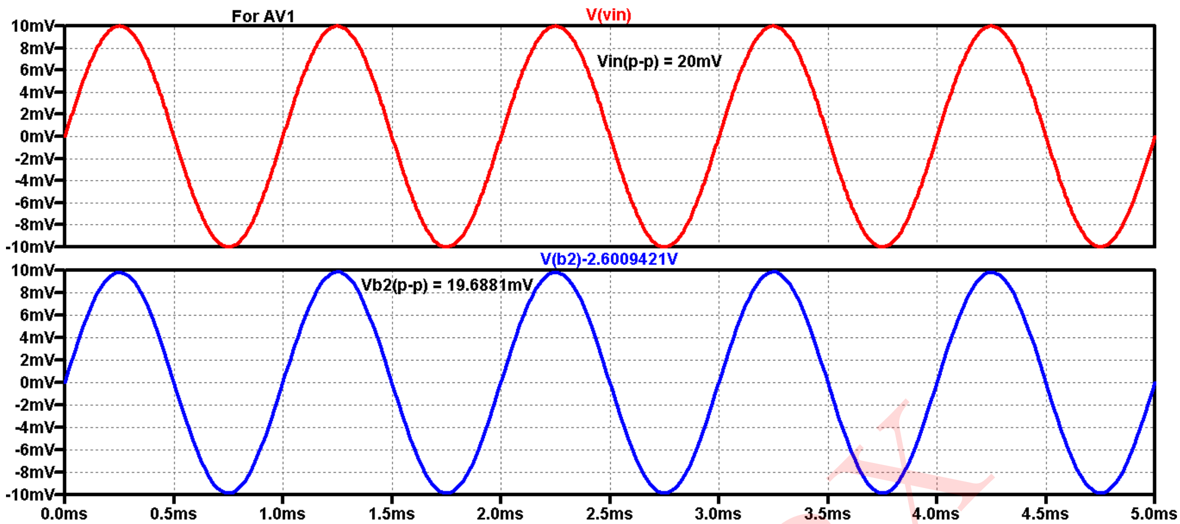

Figure 6: Input output waveform for A_{V_1}

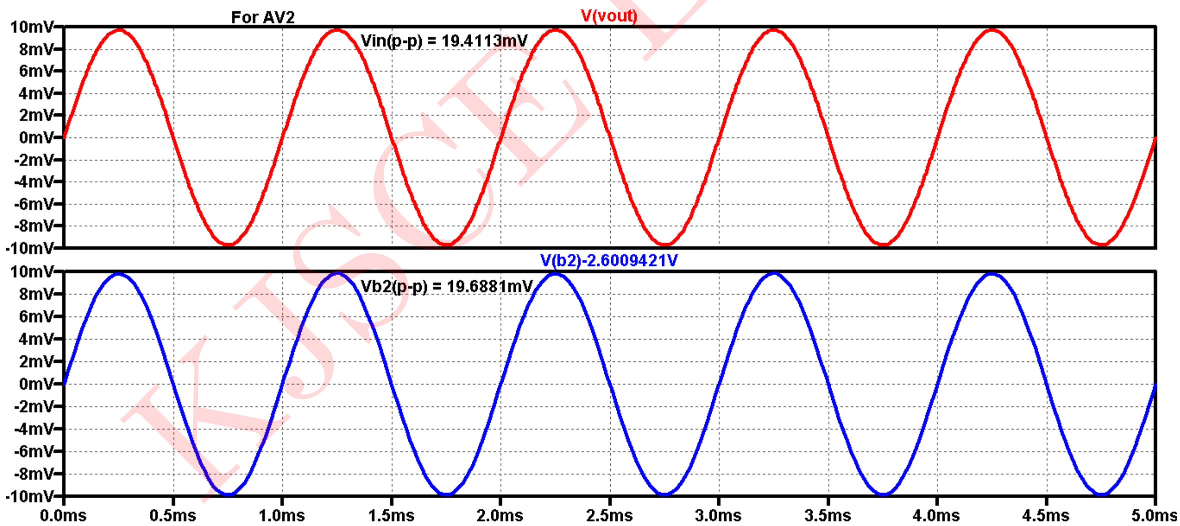

Figure 7: Input output waveform for A_{V_2}

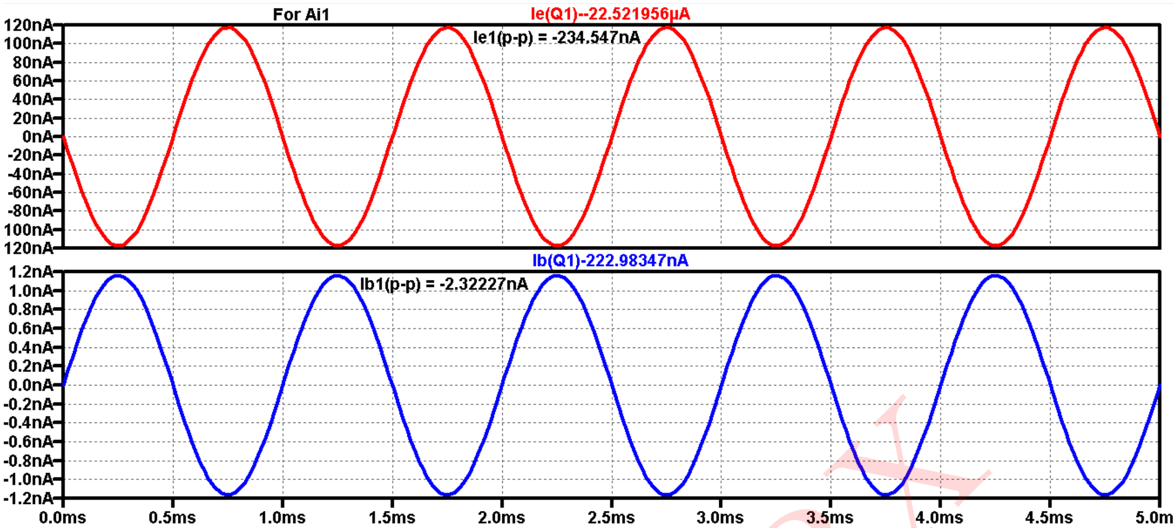

Figure 8: Input output waveform for A_{i_1}

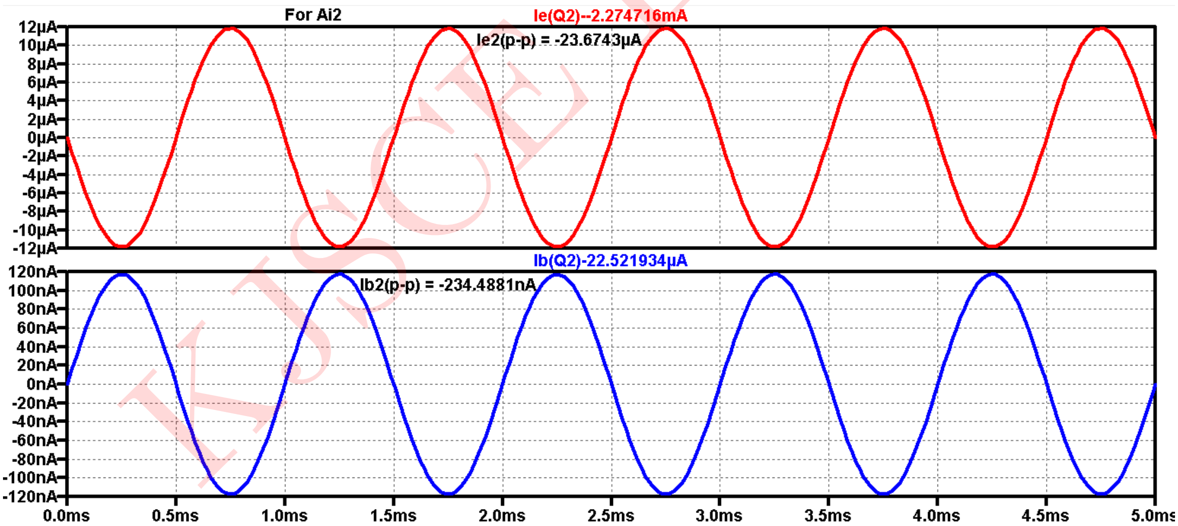

Figure 9: Input output waveform for A_{i_2}

Comparison of Theoretical and Simulated Values:

Parameters	Simulated	Theoretical
Stage 1:		
I_{B1}, I_{C1}	0.2229μA, 0.0222mA	0.18149μA, 0.018149mA
I_{E1}	0.02252mA	0.01833mA
Stage 2:		
I_{B2}, I_{C2}	0.02252mA, 2.225mA	0.01833mA, 1.83304mA
I_{E2},V_{E2}	2.274mA, 1.865V	1.85137mA, 1.5181V
V_{C2}, V_{CE2}	10V, 8.135V	10V, 8.4819V
A_{V_1}	0.984404	0.98307
A_{V_2}	0.98594	1.0070
A_{V_T}	0.97056	0.98995
A_{i_1}	101.010	101
A_{i_2}	100.961	101
A_{i_T}	10198	10201
Z_i	–	26.3456kΩ
Z_o	–	29.5671Ω

Table 1: Numerical 1

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