K. J. SOMAIYA COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
DC Biasing Circuits

1. Find the Q point for the following shown in circuit with given parameters:
$R_1 = 87.4\text{k}\Omega$, $R_2 = 12.6\text{K}\Omega$, $R_D = 0.5\text{K}\Omega$, $R_S = 0.5\text{K}\Omega$, $V_{DD} = 5\text{V}$, $V_{SS} = -5\text{V}$, $V_P = -3.5\text{V}$, $I_{DSS} = 12\text{mA}$

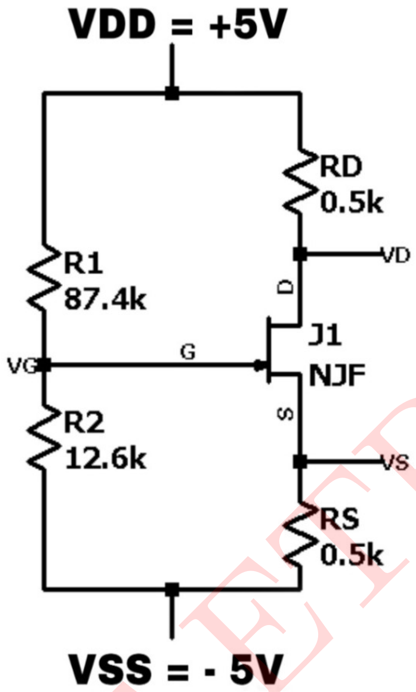

Figure 1: Circuit 1

Solution:

Assuming the transistor is baised in the saturation region, the DC drain current us given by:

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2$$

Next we find the Q point i.e V_{DSQ} and I_{DQ}

$$V_G = V_{TH} = \frac{R_2}{R_1 + R_2}(5 - (-5)) - 5$$

$$V_G = \frac{12.6k\Omega}{87.4k\Omega + 12.6k\Omega} \times 10 - 5$$

$$V_G = V_{TH} = -3.75\text{V}$$

$$V_{GS} = V_G - V_S$$

$$V_{GS} = -3.74 - I_D R_S$$

$$V_{GS} = -3.74 - 500 I_D \text{ ——— } (\ 1\ )$$

$$I_D = 12 \times 10^{-3}\left(1 - \frac{V_{GS}}{(-3.5)}\right)^2 \text{———} (\ 2\ )$$

Put (2) in (1)

$$V_{GS} = -3.74 - 6\left(1 + \frac{2V_{GS}}{3.5} + \frac{V_{GS}^2}{3.5^2}\right)$$

$$V_{GS} = -9.74 - \frac{12V_{GS}}{3.5} - \frac{6{V_{GS}}^2}{3.5^2}$$

$$\frac{(V_{GS})^2}{(3.5)^2} + \frac{31V_{GS}}{7} + 9.74 = 0$$

$$V_{GS} = -5.26V or - 1.24V$$

We choose -1.24V since $V_{GS} > V_P$

$$V_S = V_G - V_{GS}$$

$$V_S = -3.74 - (-1.24)$$

$$V_S = \mathbf{-2.5V}$$

$$I_D = 12 \times 10^{-3}\left(1 + \left(\frac{-1.24}{3.5}\right)\right)^2$$

$$I_D = \mathbf{5mA}$$

Applying KVL to the drain source loop:

$$V_{DS} = 5 - I_D R_D - I_D R_S - (-5)$$

$$V_{DS} = 5 - 5 \times 0.5 - 5 \times 0.5 + 5$$

$$V_{DS} = \mathbf{5V}$$

Q point $= (V_{DS}, I_D)$

Q point $=$ **(5V, 5mA)**

SIMULATED RESULTS:
Above circuit is simulated in LTspice and results are as follows

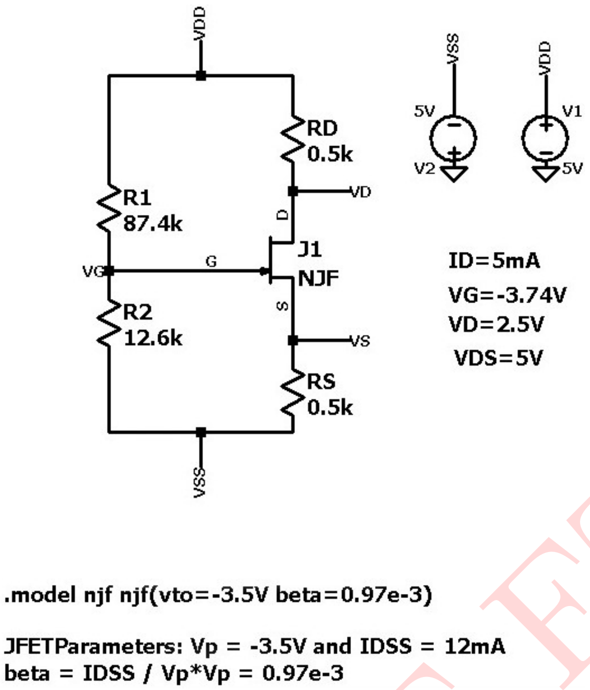

Figure 2: Circuit Schematic: Results

Comparsion between observed and theoretical values :

Parameters	Observed	Theoretical
V_D	2.5V	2.5V
V_G	−3.74V	−3.74V
I_D	4.9mA	5mA
V_{DS}	5V	5V
V_S	−2.5V	−2.5V

Table 1: Numerical 1

2. Find V_G, V_{GS}, I_D and V_D for the circuit below:

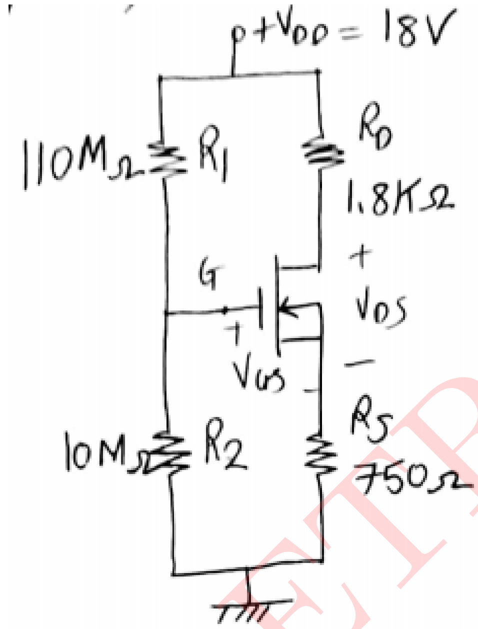

Figure 3: Circuit 2

Solution:

$$V_G = \frac{R_2}{R_1 + R_2} V_{DD} = 1.5V$$

$$V_S = I_D R_S$$

$$V_{GS} = V_G - V_S = V_G - I_D(750) \text{——— (1)}$$

$$V_{GS} = 1.5 - I_D(750)$$

We assume that given NMOS D device is working in saturation region

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = 6\left(1 + \frac{V_{GS}}{3}\right)^2 \text{——— (2)}$$

Put (2) in (1)

$$V_{GS} = 1.5 - 750 \times 6\left(1 + \frac{V_{GS}}{3}\right)^2$$

$$V_{GS} = 1.5 - 4.5\left(1 + \frac{2V_{GS}}{3} + \frac{{V_{GS}}^2}{9}\right)$$

$$V_{GS} = 1.5 - 4.5 - 3V_{GS} - 0.5{V_{GS}}^2$$

$$0.5{V_{GS}}^2 + 4V_{GS} - 3 = 0$$

Solving the above quadratic equation, we get

$V_{GS} = -0.8377V$ or $-7.16V$

$V_{GS} = \mathbf{-0.8377V} \qquad \because (\ V_{GS} > V_P)$

$$I_D = 6\left(1 - \frac{(-0.8377)}{(-3)}\right)^2 = 3.11mA$$

$I_D =$ **3.11 mA**

Applying KVL to D-S Loop:

$V_{DD} - I_D R_D - V_{DS} - I_D R_S = 0$

$V_{DS} = V_{DD} - I_D(R_D + R_S)$

$V_{DS} = 18 - 3.11 \times 10^{-3}(1.8k\Omega + 750\Omega)$

$V_{DS} =$ **10.07V**

3. Find the Q point, V_{DS} for the following shown in circuit with given parameter. Also find V_D, V_S and V_{DG}.
$R_1 = 2.1\text{M}\Omega$, $R_2 = 270\text{K}\Omega$, $R_D = 2.4\text{K}\Omega$, $R_S = 1.5\text{K}\Omega$, $V_{DD} = 16\text{V}$,
$V_P = -4\text{V}$, $I_{DSS} = 8\text{mA}$, $C_{C1} = 5\mu\text{F}$, $C_{C2} = 10\mu\text{F}$, $C_S = 20\mu\text{F}$.

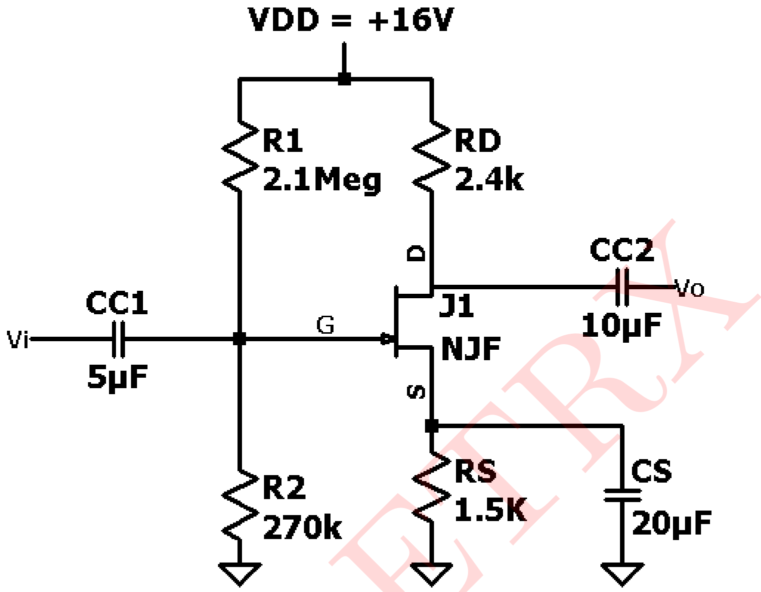

Figure 4: Circuit 3

Solution:

The above circuit is a voltage divider bais using a JFET.

For DC Analyisis

$$V_G = \frac{R_2}{R_1 + R_2} V_{DD}$$

$V_G = \mathbf{1.82V}$

$V_S = I_D R_S = (1.5k) I_D$ ——— (1)

$V_{GS} = V_G - V_S$

$V_{GS} = 1.82 - (1.5k) I_D$ ——— (2)

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2$$

$$I_D = 8mA\left(1 - \frac{V_{GS}}{4}\right)^2 \text{ ——— (3)}$$

Solving equations (3) and (2)

$$V_{GS} = 1.82 - (1.5K) \times 8mA \left(1 + \frac{V_{GS}}{2} + \frac{(V_{GS})^2}{4^2}\right)$$

$$V_{GS} = 1.82 - 12 \left(1 + \frac{V_{GS}}{2} + \frac{(V_{GS})^2}{16}\right)$$

$$V_{GS} = 1.82 - 12 - 6V_{GS} - 0.75(V_{GS})^2$$

$$0.75(V_{GS})^2 + 7V_{GS} + 10.18 = 0$$

$$V_{GS} = -1.8V or - 7.53V$$

$$V_{GS} = \mathbf{-1.8V} \qquad \because (V_{GS} > VP)$$

$$I_D = 8 \times 10^{-3} \left(1 - \frac{-1.8}{(-4)}\right)^2$$

$$I_{DQ} = \mathbf{2.42\ mA}$$

Q point =$(-1.82$V, 2.42mA)

Applying KVL to the drain source loop:

$$V_{DS} = V_{DD} - I_D R_D - I_D R_S$$

$$V_{DS} = 16 - 2.42 \times 10^{-3}(2.4K + 1.5k)$$

$$V_{DS} = \mathbf{6.56V}$$

$$V_D = V_{DD} - I_D R_D$$

$$V_D = 16 - 2.42 \times 10^{-3} \times 2.4k$$

$$V_D = \mathbf{10.19V}$$

$$V_S = I_{DQ} R_S$$

$$V_S = 2.42 \times 10^{-3} \times 1.5k$$

$$V_S = \mathbf{3.63V}$$

$$V_{DG} = V_D - V_G$$

$$V_{DG} = 10.19 - 1.82$$

$$V_{DG} = \mathbf{8.37V}$$

SIMULATED RESULTS:

Above circuit is simulated in LTspice and results are as follows

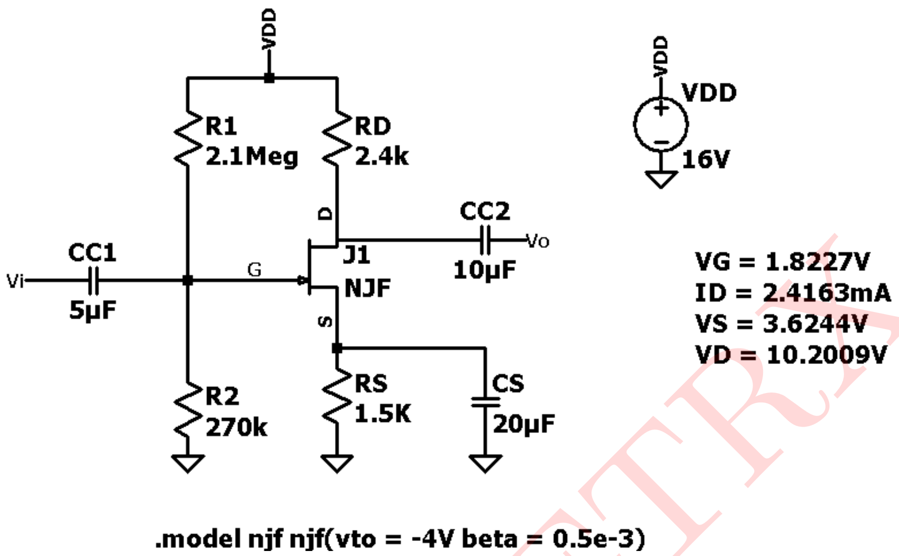

Figure 5: Circuit Schematic: Results

Comparsion between observed and theoretical values :

Parameters	Observed	Theoretical
V_G	1.8227 V	1.82V
I_D	2.4163mA	2.42mA
V_{DS}	6.66V	6.55V
V_S	3.6244V	3.63V

Table 2: Numerical 3

4. Find V_{DS} for the following shown in circuit with given parameter, Also find V_{GS} and I_D $R_D = 10\text{M}\Omega$, $R_G = 2\text{K}\Omega$, $V_{DD} = 12\text{V}$, $V_{GS(on)} = 8\text{V}$, $V_{GS(th)} = 3\text{V}$, $I_{D(on)} = 6\text{mA}$, $C_{C1} = 1\mu\text{F}$, $C_{C2} = 1\mu\text{F}$.

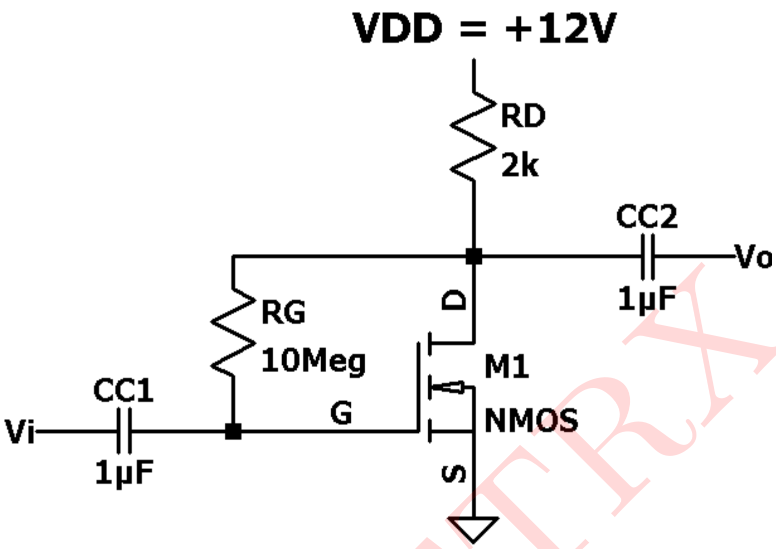

Figure 6: Circuit 4

Solution:

The above circuit is a drain feedback bais for E MOSFET.

$$k_n = \frac{I_{D(on)}}{(V_{GS(on)} - V_{GS(th)})^2} = \frac{6 \times 10^{-3}}{(8-3)^2}$$

$k_n = 0.24 \times 10^{-3} A/V^2$

Applying KVL to the input loop:

$V_{DD} - V_{GS} - I_D R_D - I_G R_G = 0$

$V_{GS} = V_{DD} - I_D R_D$

$V_{GS} = 12 - 2000 I_D \qquad \because I_G = 0$

$I_D = k_n (V_{GS} - V_{GS(th)})^2$

$I_D = 0.24 \times 10^{-3} (12 - 2000 I_D - 3)^2$

$I_D = 0.24 \times 10^{-3} (81 - 3600 I_D + 4 \times 10^6 (I_D)^2)$

$960 I_D^2 - 9.64 I_D + 19.44 \times 10^3 = 0$

$I_D = 2.8mA$ or $7.25mA$

For $I_D = 7.25\text{mA}$

$V_{DS} = V_{DD} - I_D R_D$

$V_{DS} = 12 - 7.25 \times 10^{-3} \times 2 \times 10^3$

$V_{DS} =$ **2.5V**

Practically value of V_{DS} must be positive, Hence I_D cannot be 7.25mA

For $I_D = 2.8$mA

$V_{DS} = V_{DD} - I_D R_D$

$V_{DS} = 12 - 2.8 \times 10^{-3} \times 2 \times 10^3$

$V_{DS} = 6.4$V

$V_{GS} = V_{DS} = 6.4$V $\quad\quad \because$ (Gate and Source terminals are connected)

SIMULATED RESULTS:

Above circuit is simulated in LTspice and results are as follows

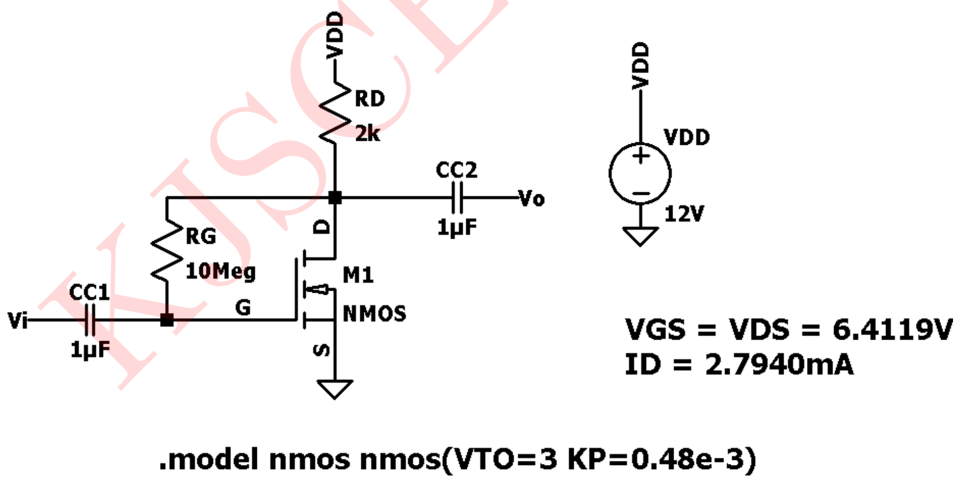

Figure 7: Circuit Schematic: Results

Comparsion between observed and theoretical values :

Parameters	Observed	Theoretical
V_{GS}	6.4119 V	6.4V
I_D	2.794mA	2.8mA
V_{DS}	6.4119V	6.4V

Table 3: Numerical 4

5. Find I_B, I_C, V_{CE}, V_C for the following shown in circuit with given parameter. R_B = 10kΩ, R_C = 4kΩ, R_E = 4kΩ, β = 75, V_{CC} = 8V, V_{EE} =−8V.

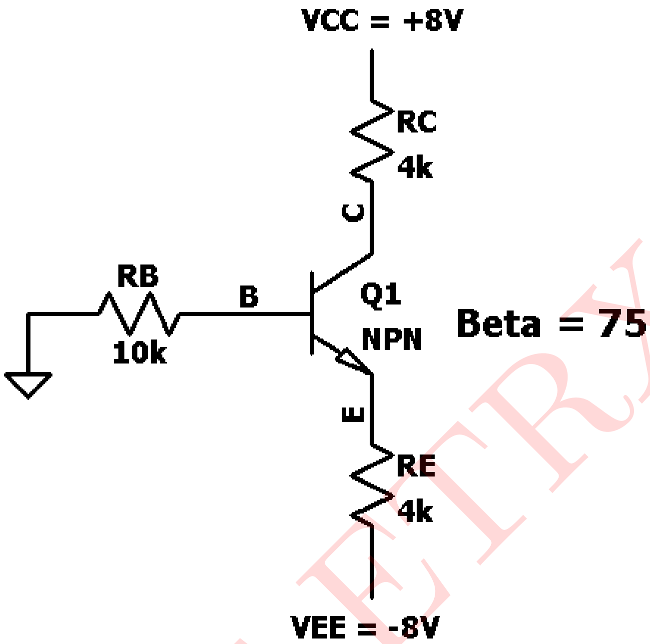

Figure 8: Circuit 5

Solution:

Applying KVL to the input loop.

$-I_B R_B - V_{BE} - I_E R_E - V_{EE} = 0$ ——— (1)

$I_E = I_B + I_C$

$I_E = I_B + \beta I_B$

$I_E = (1 + \beta)I_B$ ——— (2)

Substituting equation (2) in equation (1)

$0 = -I_B R_B - V_{BE} - (1 + \beta)I_B R_E - V_{EE}$

$$I_B = \frac{-V_{EE} - V_{BE}}{R_B + (1 + \beta)R_E}$$

$$I_B = \frac{8 - 0.7}{10 \times 10^3 + (76)4 \times 10^3}$$

$I_B = \mathbf{23.248\mu A}$

$I_C = \beta I_B$

$I_C = \mathbf{1.743mA}$

Applying KVL to the output loop

$-V_{CE} + V_{CC} - I_C R_C - I_E R_E - V_E E = 0$

$V_{CE} = V_{CC} - I_C R_C - I_E R_E - V_{EE}$

$V_{CE} = 8 - 1.743 \times 4 - (I_B + I_C)R_E = 8$

$V_{CE} = 16 - 6.972 - 6.9729$

$V_{CE} = \mathbf{2.055V}$

$V_C = I_C R_C + 8$

$V_C = -1.743 \times 4 \times 10^3 + V_{CC}$

$V_C = \mathbf{1.028V}$

SIMULATED RESULTS:

Above circuit is simulated in LTspice and results are as follows

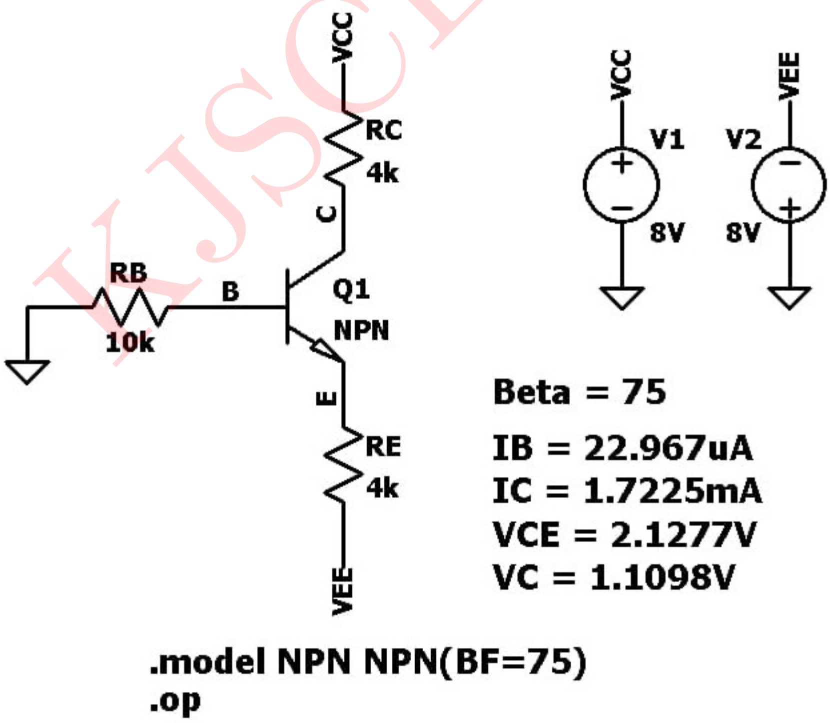

Figure 9: Circuit Schematic: Results

Comparsion between observed and theoretical values :

Parameters	Observed	Theoretical
I_B	22.96μA	23.24μA
I_C	1.7225mA	1.743mA
V_{CE}	2.1277V	2.055V
V_C	1.109V	1.028V

Table 4: Numerical 5

6. Find I_B, I_C, V_{CE}, V_C for the following shown in circuit with given parameter. $R_B = 20\text{k}\Omega$, $R_C = 10\text{k}\Omega$, $R_E = 2\text{K}\Omega$, $\beta = 75$, $V_{CC} = 5\text{V}$

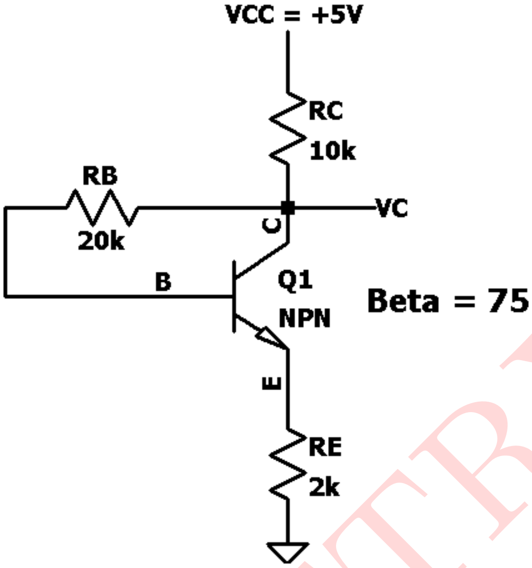

Figure 10: Circuit 6

Solution:

Applying KVL to the input feedback loop.

$V_{CC} - (I_B + I_C)R_C - I_B R_B - V_{BE} - I_E R_E$ ——— (1)

$I_E = I_B + I_C$

$I_E = I_B + \beta I_B$

$I_E = (1 + \beta)I_B$ ——— (2)

Substituting equation (2) in equation (1)

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (1+\beta)(R_E + R_C)}$$

$$I_B = \frac{5 - 0.7}{20k + (76)(4k + 10k}$$

$I_B = 4.6137\mu\text{A}$

$I_C = \beta I_B$

$I_C = \mathbf{1.3460mA}$

Applying KVL to the output loop

$V_{CE} = V_{CC} - (I_C + I_B)R_C - V_{CE} - (I_C + I_B)R_E = 0$

$V_{CE} = V_{CC} - (I_C + I_B) - (R_E + R_C) = 0$

$V_{CE} = 5 - (4.6137 \times 10^{-6} + 0.346 \times 10^{-3}) \times 12$

$V_{CE} = \mathbf{0.7056V}$

$V_C = 5 - (1 + \beta)I_B R_C$

$V_C = 5 - 76 \times 4.6137 \times 10^{-6} \times 10 \times 1000$

$V_C = \mathbf{1.4935V}$

SIMULATED RESULTS:

Above circuit is simulated in LTspice and results are as follows

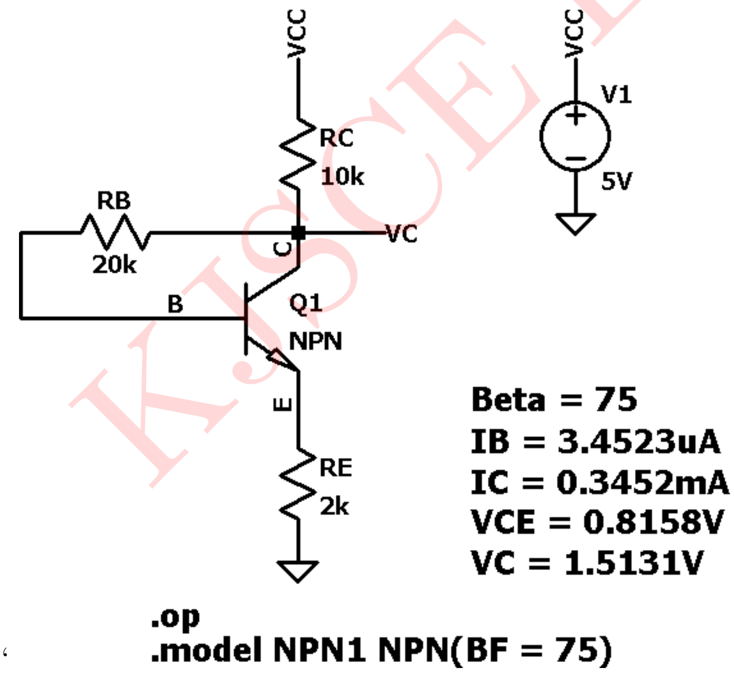

Figure 11: Circuit Schematic: Results

Comparsion between observed and theoretical values :

Parameters	Observed	Theoretical
I_B	3.4523μA	4.6137μA
I_C	0.3452mA	0.3460mA
V_{CE}	0.8158V	0.7926V
V_C	1.5131V	1.4935V

Table 5: Numerical 6

7. Find I_C, V_{CE} for the following shown in circuit 7 with given parameter $\beta = 120$, $R_B = 250\text{k}\Omega$, $R_C = 1.5\text{k}\Omega$, $V_{CC} = -5\text{V}$, $V_{EE} = 5$ V

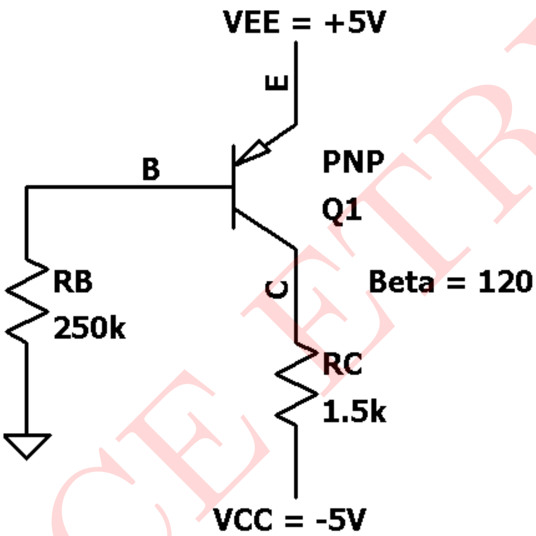

Figure 12: Circuit 7

Solution:

From circuit 7

$I_C = \beta I_B$

$$I_B = \frac{V_{EE} - V_{EB}}{R_B}$$

$$I_B = \frac{5 - 0.7}{250 \times 10^3}$$

$I_B = \mathbf{17.2\mu A}$

$I_C = \beta I_B$

$I_C = 2.064\text{mA}$ $V_C = I_C R_C + V_{CC}$

$V_C = (2.064 \times 10^{-3} \times 1.5 \times 10^3) - 5$

$V_C = \mathbf{-1.904V}$

$V_{EC} = V_E - V_C$ $V_{EC} = 5 - (-1.904)$ $V_{EC} = \mathbf{6.904V}$

SIMULATED RESULTS:

Above circuit is simulated in LTspice and results are as follows

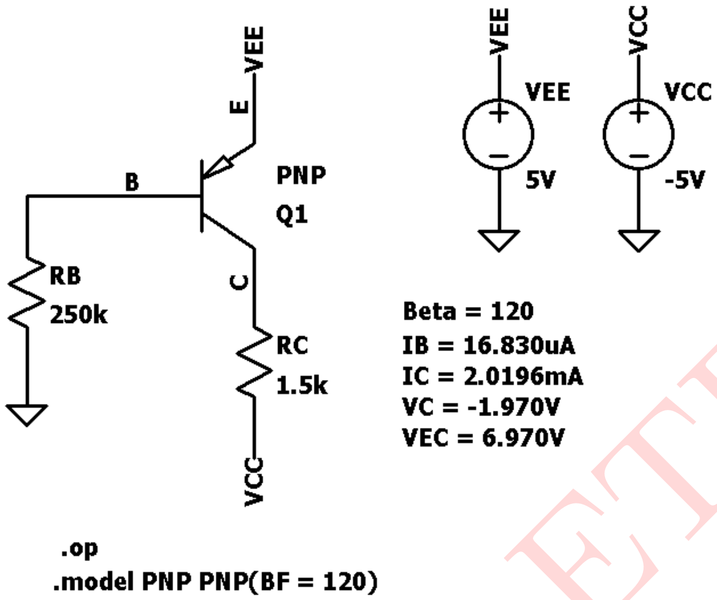

Figure 13: Circuit Schematic: Results

Comparsion between observed and theoretical values :

Parameters	Observed	Theoretical
I_B	16.830μA	17.2μA
I_C	2.0196mA	2.064mA
V_{CE}	6.970V	6.904V
V_C	-1.970V	-1.904V

Table 6: Numerical 7

8. Find I_C, V_{BC}, I_E for the following shown in circuit with given parameter.
$\alpha = 0.9920$, $R_C = 2.2\text{k}\Omega$, $R_E = 4\text{k}\Omega$, $V_{CC} = 9\text{V}$, $V_{EE} = 9\text{V}$

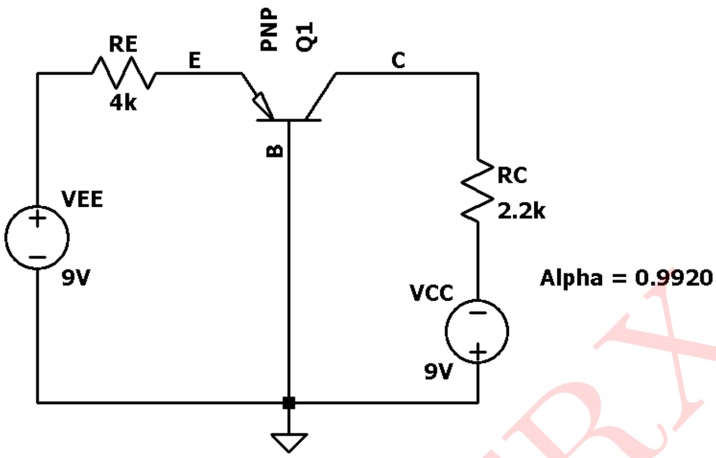

Figure 14: Circuit 8

Solution:

For circuit 8 applying KVL to emitter base loop

$$I_E = \frac{V_{EE} - V_{EB}}{R_E}$$

$$I_E = \frac{9 - 0.7}{4 \times 10^3}$$

$I_E = \mathbf{2.075mA}$

$I_C = \alpha I_E$

$I_C = \mathbf{2.0584mA}$

Applying KVL for circuit 8 to collecter base loop

$V_{BC} + I_C R_C = V_{CC}$

$V_{BC} = V_{CC} - I_C R_C$

$V_{BC} = 9 - (2.0584 \times 10^{-3} \times 2.2 \times 10^3)$

$V_{BC} = \mathbf{4.4715V}$

SIMULATED RESULTS:

Above circuit is simulated in LTspice and results are as follows

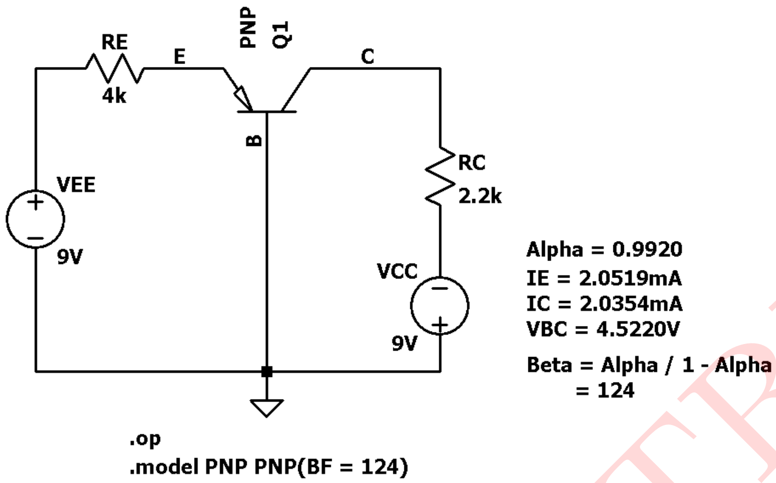

Figure 15: Circuit Schematic: Results

Comparsion between observed and theoretical values :

Parameters	Observed	Theoretical
I_E	2.0519mA	2.075mA
I_C	2.0354mA	2.0584mA
V_{BC}	4.5220V	4.4715V

Table 7: Numerical 8

9. Find I_C, I_B, I_E, V_{CE} for the following shown in below circuit with given parameters $\beta = 150$, $R_E = 1.5\text{k}\Omega$, $R_C = 1.5\text{k}\Omega$, $V_{EE} = -12\text{V}$, $V_{CC} = 12\text{V}$

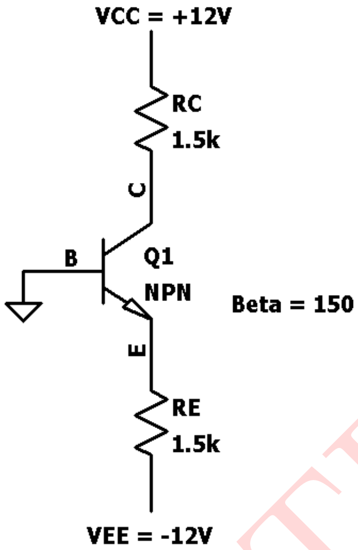

Figure 16: Circuit 9

Solution:

From circuit 9

$-V_{EE} - V_{BE} - I_E R_E = 0$

$I_E = I_B + I_C$

$I_C = \beta I_B$

$I_E - (1+\beta) I_B \; -V_{EE} - V_{BE} - (1+\beta) I_B R_E = 0$

$I_B = \dfrac{-V_{EE} - V_{BE}}{(1+\beta) R_E}$

$I_B = \dfrac{12 - 0.7}{1.5 \times 10^3 \times 151}$

$I_B = \mathbf{49.889 \mu A}$

$I_C = \beta I_B$

$I_C = \mathbf{7.4834mA}$

$I_E = I_B + I_C$

$I_E = \mathbf{7.533\ mA}$

For circuit 9 applying KVL to output loop

$V_{CE} = +V_{CC} - I_C R_C - I_C R_C - V_{EE}$

$V_{CE} = 12 - (7.4834 \times 1.5) - (7.533 \times 1.5) + 12$

$V_{CE} = \mathbf{1.4754V}$

SIMULATED RESULTS:

Above circuit is simulated in LTspice and results are as follows

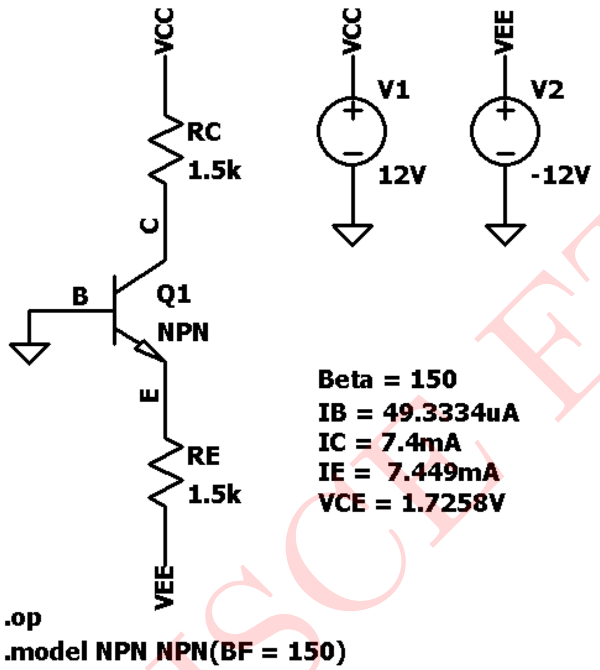

Figure 17: Circuit Schematic: Results

Comparsion between observed and theoretical values :

Parameters	Observed	Theoretical
I_B	49.3334μA	49.889μA
I_C	7.4mA	7.4834mA
I_E	7.449mA	7.533mA
V_{CE}	1.7258V	1.4754V

Table 8: Numerical 9

10. Find I_C, I_B, V_{CE} for the following shown in circuit 10 with given parameters $\beta = 100$, $R_B = 400\text{k}\Omega$, $R_C = 3.3\text{k}\Omega$, $V_{CC} = 12\text{V}$, $R_E = 1.5\text{k}\Omega$

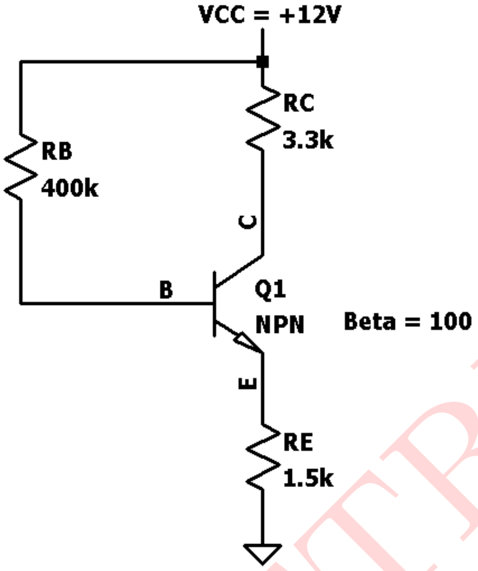

Figure 18: Circuit 10

Solution:

Applying KVL to the input loop of the above circuit

$V_{CC} - I_B R_B - V_{BC} - I_E R_E = 0$

$I_C = \beta I_B$

$I_E = I_C + I_B$

$I_E = (1+\beta) I_B$

$V_{CC} - I_B R_B - V_{BC} - (1+\beta) I_B R_E = 0$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (1+\beta) R_E}$$

$$I_B = \frac{12 - 0.7}{400 \times 10^3 + 101 \times 1.5 \times 10^3}$$

$I_B = \mathbf{20.4895\mu A}$

$I_C = \beta I_B$

$I_C = \mathbf{2.0489mA}$

Applying KVL to the output loop of the above circuit

$V_{CC} - V_{CE} - I_C R_C - I_E R_E$

$V_{CE} = V_{CC} - I_C R_C - (I_C + I_B) R_E$

$V_{CE} = 12 - (2.0489 \times 3.3) - (10 \times 20.4895 \times 10^{-6} \times 1.5 \times 10^{3})$

$V_{CE} = \mathbf{2.1344V}$

SIMULATED RESULTS:

Above circuit is simulated in LTspice and results are as follows

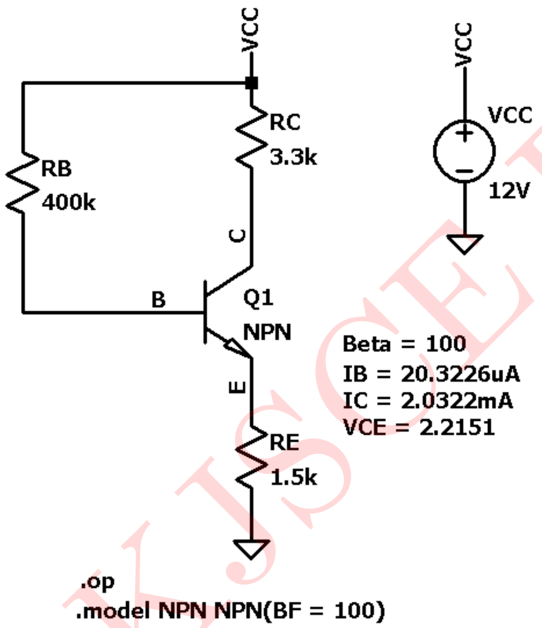

Figure 19: Circuit Schematic: Results

Comparsion between observed and theoretical values :

Parameters	Observed	Theoretical
I_B	20.3226μA	20.4895μA
I_C	2.0322mA	2.0489mA
V_{CE}	2.2151V	2.1344V

Table 9: Numerical 10

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