Credit Hours System

ELCN101

Electronics-1

Cairo University

Faculty of Engineering

Project 2: BJT Transistor and Amplifier

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Program: CCEE

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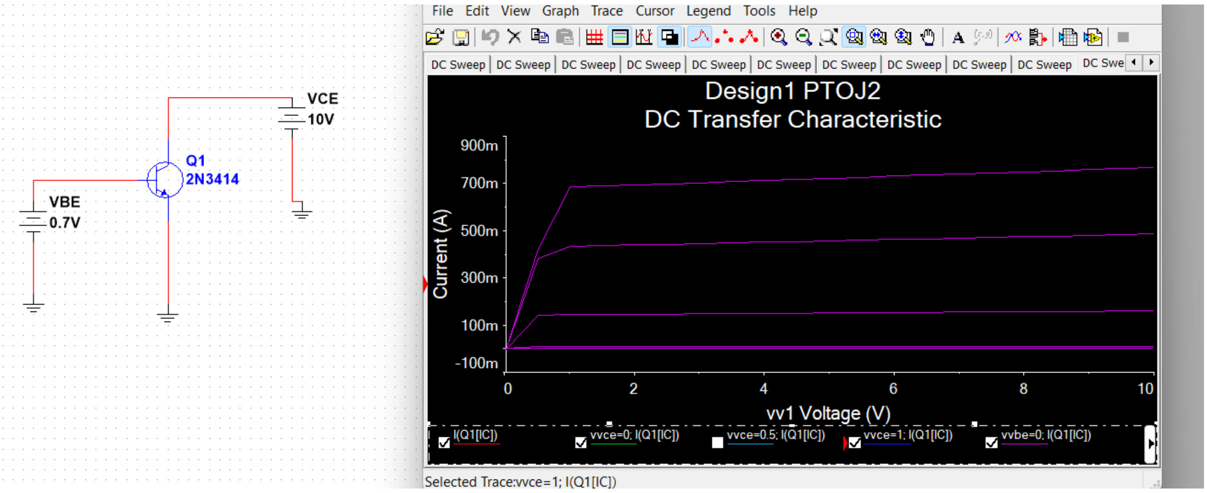
Part 1: I/V Characteristics:

NPN

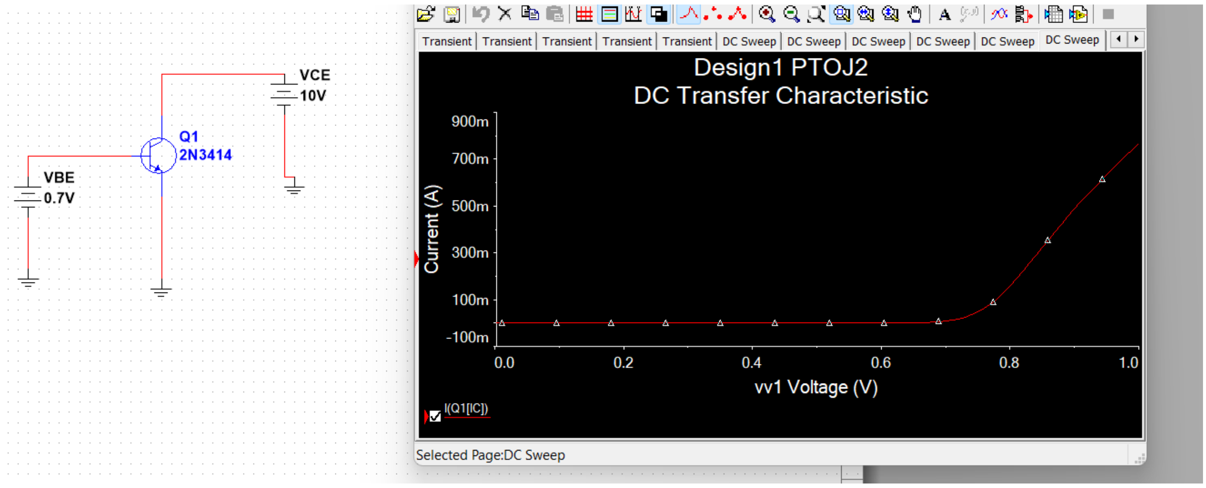
1)

a) I_C VS V_{CE} (for different V_{BE}'s)



Notice that I_C is not constant as V_{CE} changes; it is affected with the change in the collector-emitter voltage due to Early effect.

b) I_C VS V_{BE}



Notice That In the active region, the collector current I_C is exponentially related to the base-emitter voltage V_{BE}.

c) To get the value of Early voltage (V_A) for this transistor

<u>Using Hand Calculations</u>

→ get 2 points on the graph (I_C vs V_{CE})

$P_1(1.0264, 7.7479)$, $P_2(1.9972, 7.8491)$

$$\text{slope} = \frac{(7.8491 - 7.7479)m}{1.9972 - 1.0264} = 0.104244 \times 10^{-3}$$

∴ the eqn. of the straight line is given by $y = mx + c$

sub. P_1 in eqn with m = slope → get $C = 7.6409m \approx 7.641m$

to get V_A, it occurs at $y = 0$ ∴ $0 = (0.104244 \times 10^{-3})x + 7.641m$

∴ $x = -73.329$ ∴ $V_A = 73.329V$

V_A = 73.329 V

2)

<u>Bias Point</u>

AT V_{BE} = 0.7V

V_{CE}=10V

I_C=8.68*10^-3 A

<u>Analytical</u> <u>g_m</u>= (8.68*10^-3)/ (26*10^-3) =333.85m

g_m (from graph) =2.5284

Percentage error=86%

-Very large error

R_o

R_o=|-73.3|/ (8.68*10^-3) =8.4447k

R_o From Graph =9.593k

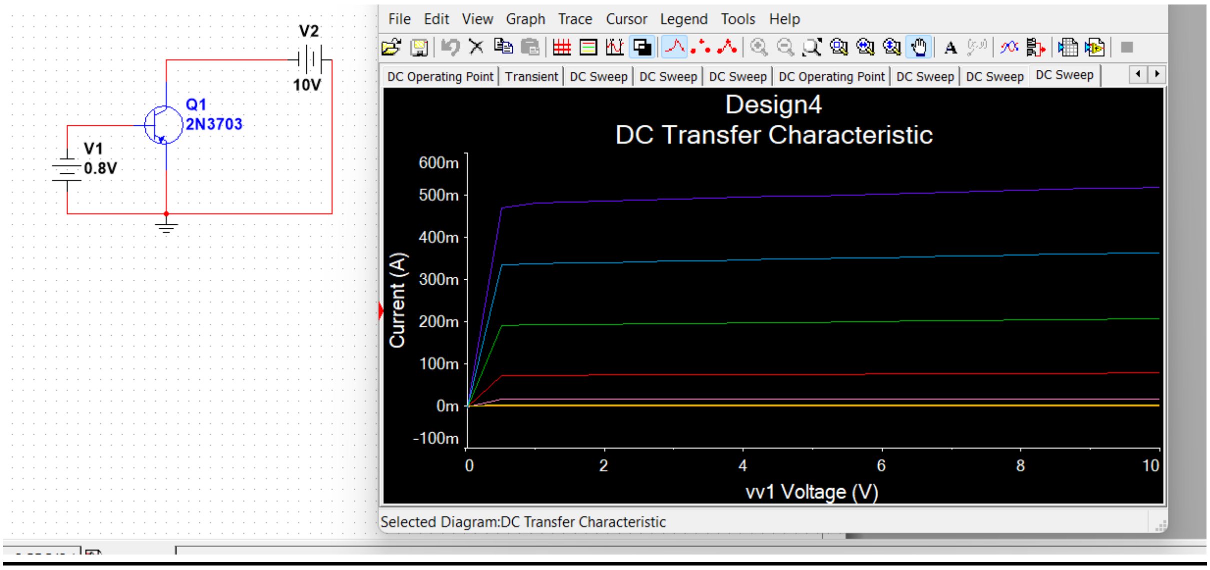
Percentage Error=11.95%

Notice that calculation of Ro from the graph by assuming a linear relation is valid only if the change in V_{CE} is minimal.

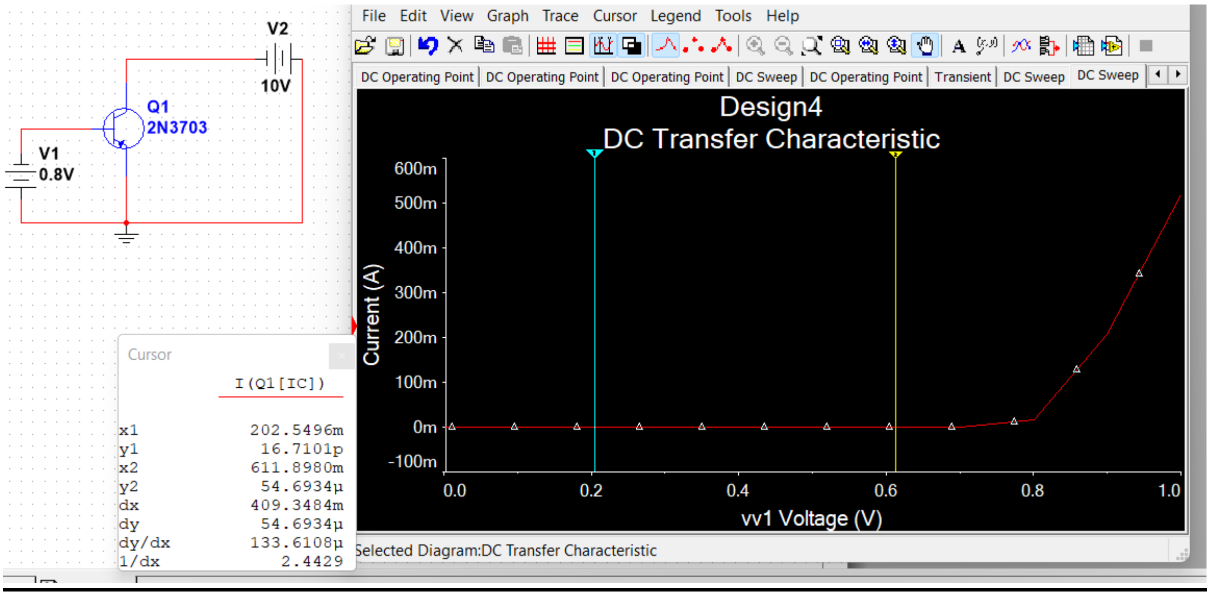
PNP

1)

a) I_C VS V_{EC} (for different V_{EB}'s)

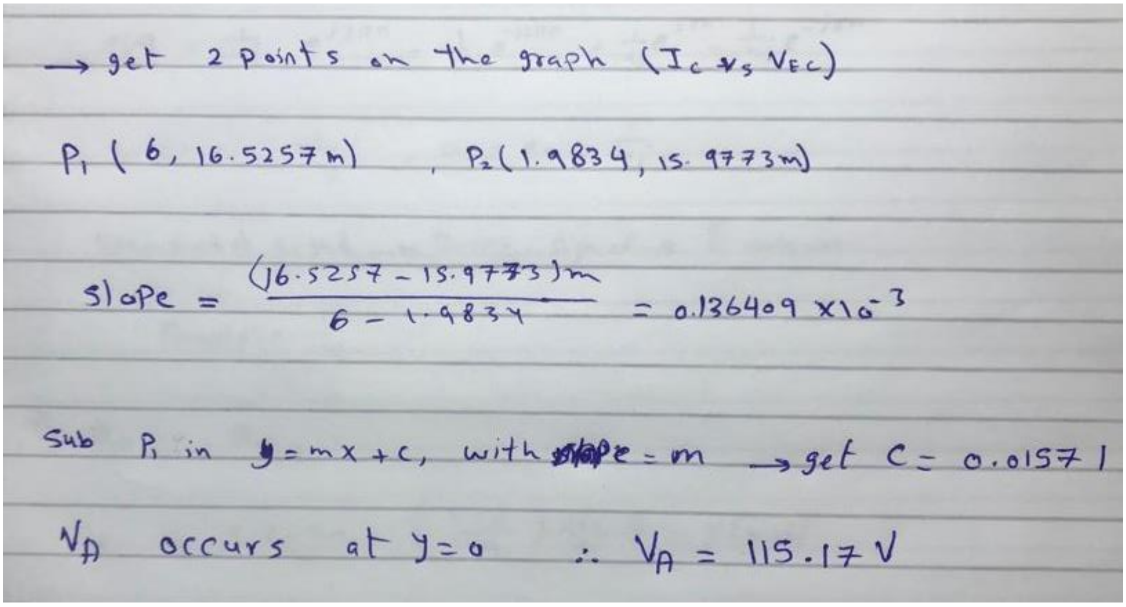


b) I_C VS V_{EB}



c) To get the value of Early voltage (V_A) for this transistor

Using Hand Calculations



→ get 2 points on the graph (I_C vs V_{EC})

$P_1(6, 16.5257m)$, $P_2(1.9834, 15.9773m)$

$$\text{slope} = \frac{(16.5257 - 15.9773)m}{6 - 1.9834} = 0.136409 \times 10^{-3}$$

Sub P_1 in $y = mx + c$, with slope = m → get $c = 0.01571$

V_A occurs at $y = 0$ ∴ $V_A = 115.17$ V

V_A = 115.17 V

It is noted that the Early voltage effect is higher for the PNP transistor as compared to the NPN transistor.

2)

Bias Point

AT V_{EB} = 0.8V

V_{EC} = 10V

I_C = 17.07365m

3	I(Q1[IC])	17.07365 m

Analytical g_m= (17.07*10^-3)/ (26*10^-3) = 656.67m

g_m (from graph) =388.7

Percentage error = 41%

-large error

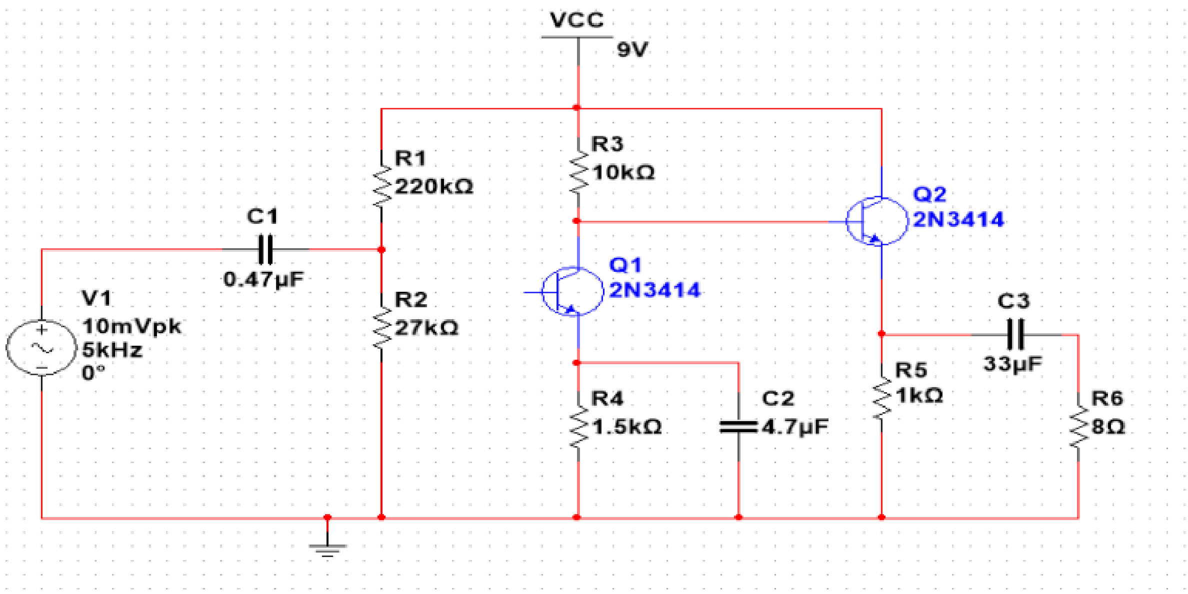
-R_o

R_o=|-127.14|/ (17.07*10^-3) =7.448k

R_o From Graph =6.993k

Percentage Error=6.1%

Part 2: Amplifier Simulation:



AT DC OPERATING POINTS

At Q1

$\beta 1 = (Ic / Ib) = 213.43 / 2.33 = 91.6$

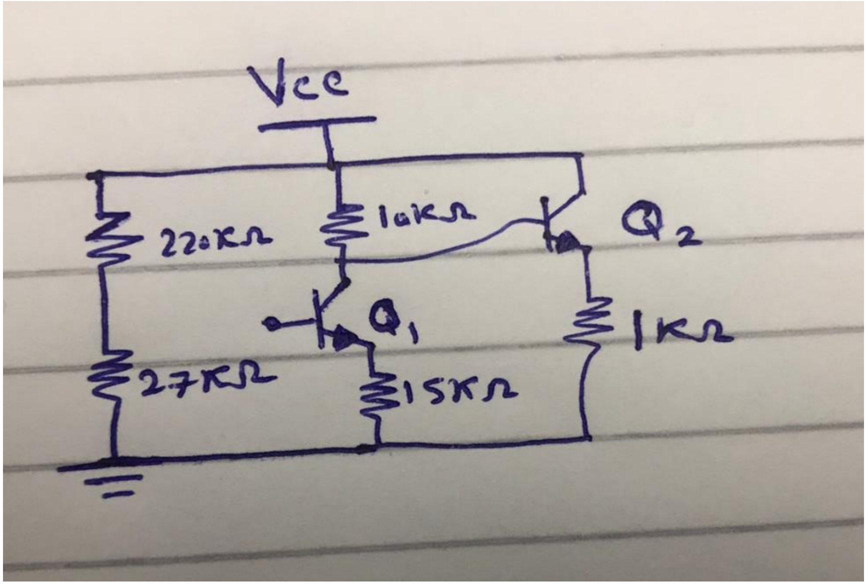
$V_{BE1} = 0.6V$

At Q2

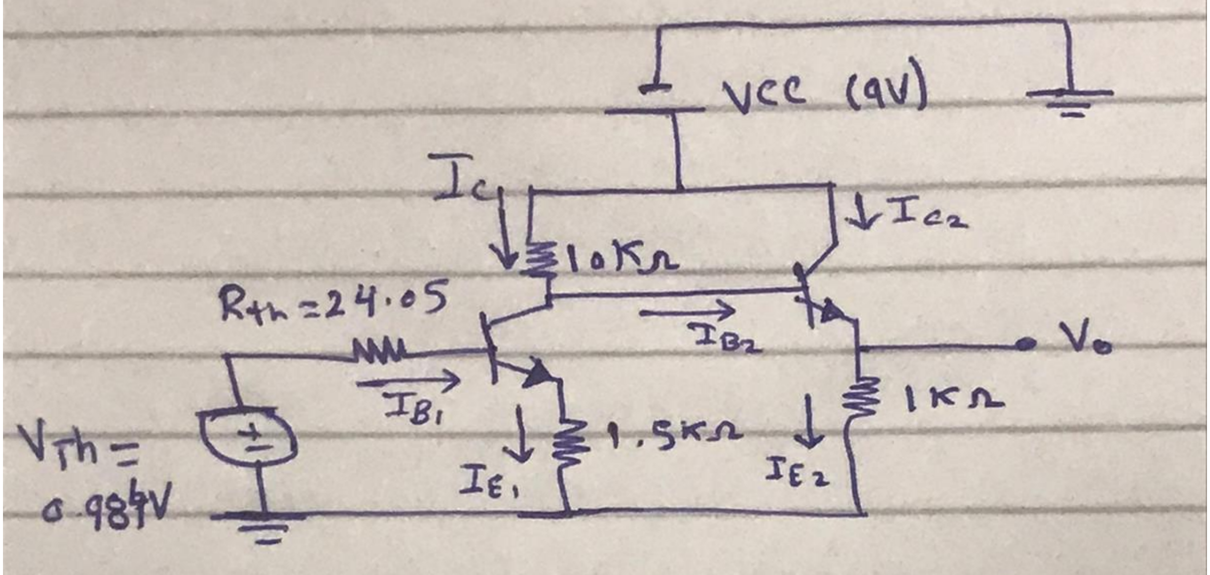
$\beta 2 = (Ic / Ib) = (5.65 / 0.047) = 120.21$

$V_{BE1} = 0.69V$

DC Analysis (Capacitors are O.C.)



Getting the equivalent circuit for the original circuit



$$V_{Th} = \left(\frac{27}{220+27}\right)9 = 0.984V$$

$$R_{Th} = 220K // 27K = 24.05K\Omega$$

V_{th} = 0.984V
R_{th} = 24.05 k$\boldsymbol{\Omega}$

KVL at loop 1:

$-V_{th} + I_{B1} * R_{th} + 0.6 + I_{E1} * 1.5 = 0, I_{E1}=(\beta+1)I_{B1}$
I_{B1}=2.35 µA
I_{C1}=214.9 µA
I_{E1}=217.25 µA

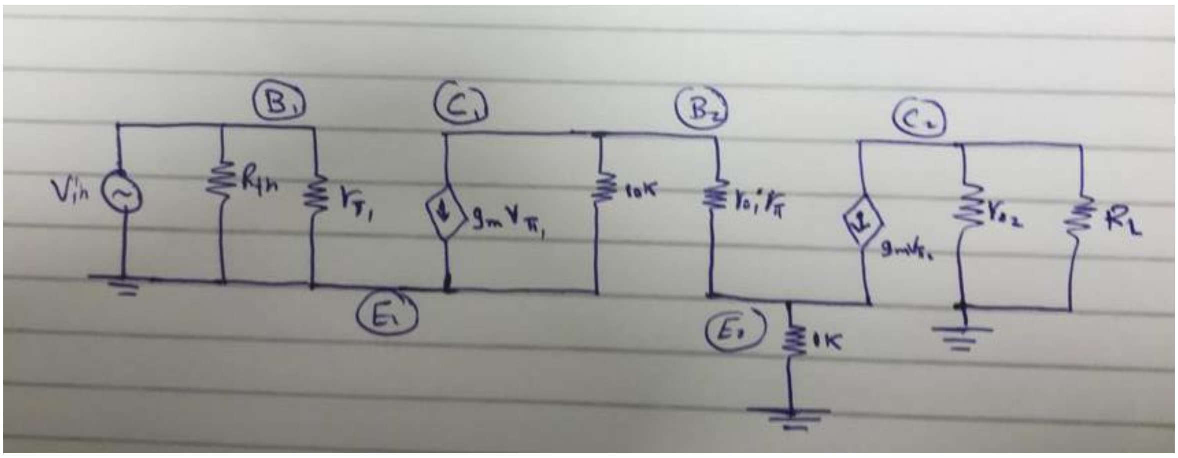
KVL at loop 2:

$-V_{CC} + 10(I_{C1} + I_{B2}) + 0.69 + I_{E2} * 1 = 0, \ I_E = (\beta_2 + 1) I_{B2}$
I_{B2} = 47.23 µA,
I_{C2} = 5.64 mA,
I_{E2} = 5.695 mA

<u>Model Parameters</u>

g_{m1}= I_{c1} / V_T = 8.26 micro Siemens
g_{m2}= I_{c1} / V_T = 0.216 Siemens
$r_{\pi1}$= β_1 / g_{m1} = 11.071k$\boldsymbol{\Omega}$
$r_{\pi2}$= β_2 / g_{m2} = 551.27$\boldsymbol{\Omega}$
r_{o1}= V_{A1} / I_{c1} = 342.48k$\boldsymbol{\Omega}$
r_{o2}= V_{A2} / I_{c2} = 13.0496k$\boldsymbol{\Omega}$

<u>The circuit reduces to the model shown:</u>

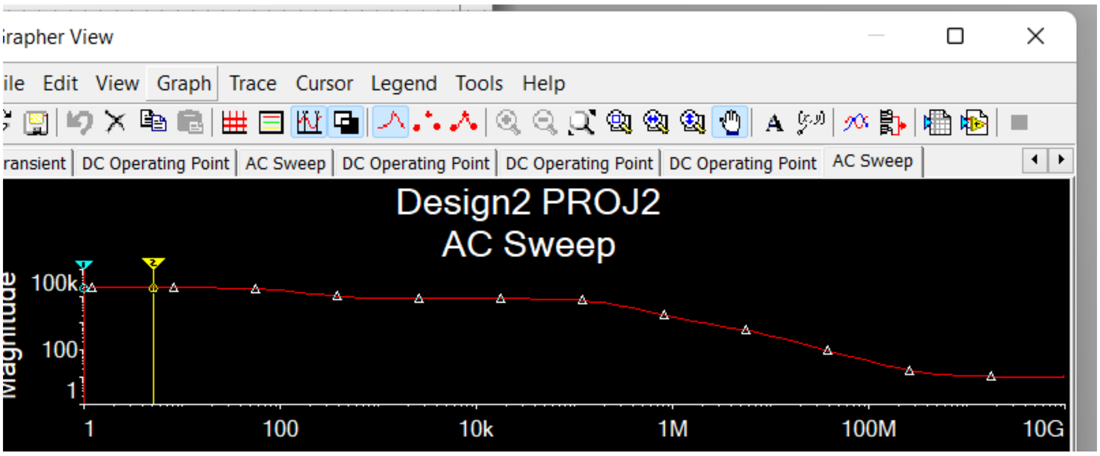


AC Analysis (Capacitors are Open-circuited)

To get R_{in}

$R_{in} = V_{in} / I_{in} = R_{th} // r_{\pi 1} = 7.54k\Omega$

Using Multisim (assuming the given parameters)

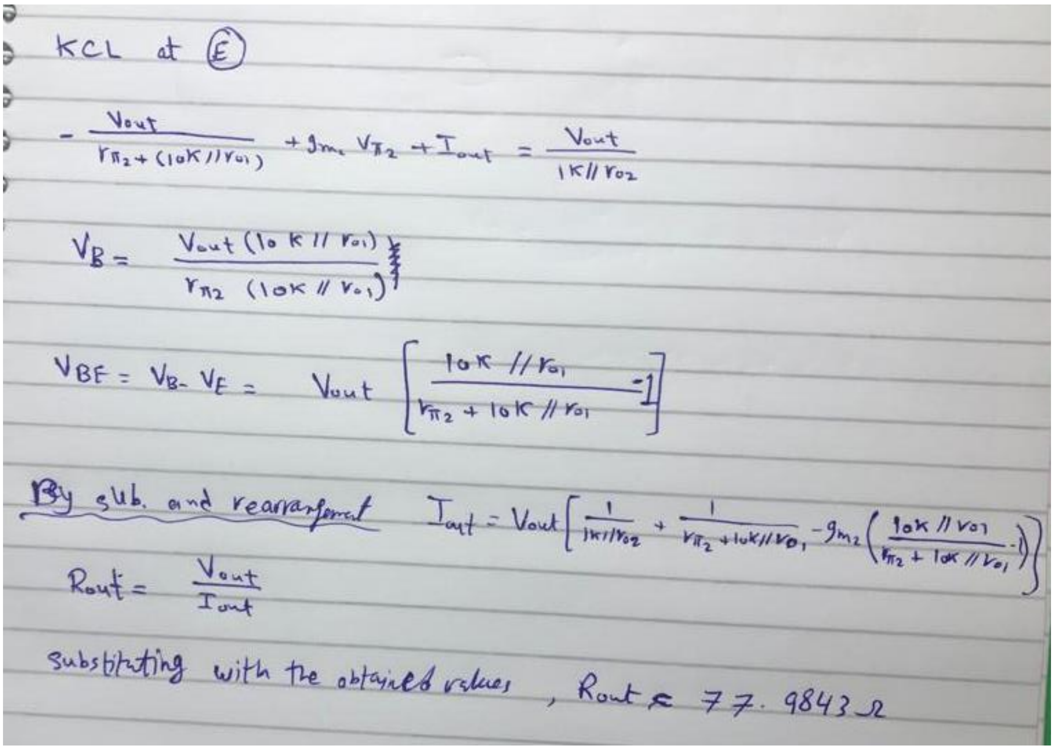


%error = ((7.54-8.26)/7.54)*100 = 9.55%

To get R_{out}

$V_{in} = 0$ and Remove R_L

Hand Analysis



KCL at E

$$-\frac{V_{out}}{r_{\pi_2}+(10K//r_{o1})} + g_{m_2} V_{\pi_2} + I_{out} = \frac{V_{out}}{1K//r_{o2}}$$

$$V_B = \frac{V_{out}(10K//r_{o1})}{r_{\pi_2}\ (10K//r_{o1})}$$

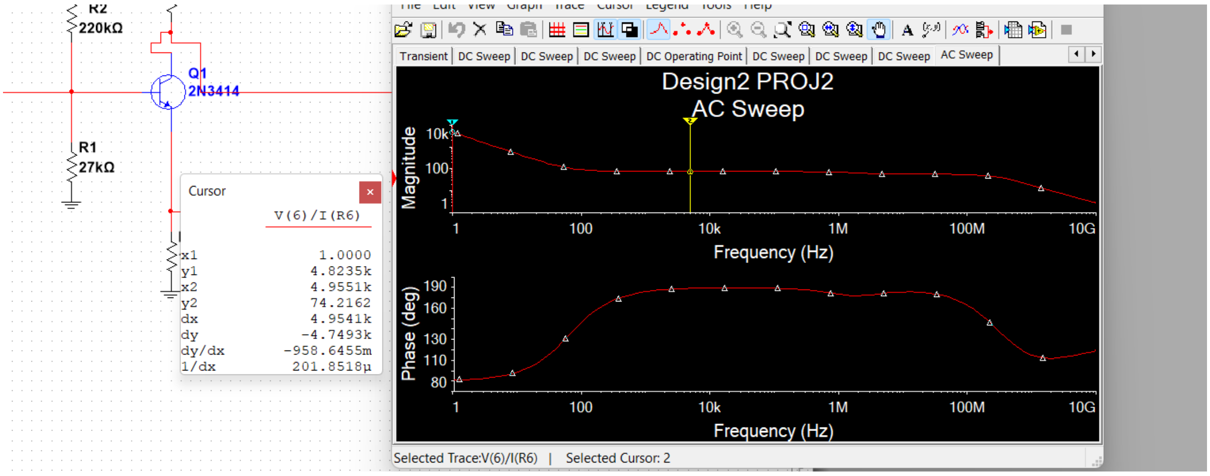
$$V_{BE} = V_B - V_E = V_{out}\left[\frac{10K//r_{o1}}{r_{\pi_2}+10K//r_{o1}} - 1\right]$$

By sub. and rearrangement $I_{out} = V_{out}\left[\frac{1}{1K//r_{o2}} + \frac{1}{r_{\pi_2}+10K//r_{o1}} - g_{m_2}\left(\frac{10K//r_{o1}}{r_{\pi_2}+10K//r_{o1}} - 1\right)\right]$

$$R_{out} = \frac{V_{out}}{I_{out}}$$

Substituting with the obtained values, $R_{out} \approx 77.9843\ \Omega$

On Multisim



%error=((77.9843-74.2162)/77.9843)*100=4.832%

Notice that:

- Rin is large (in kilos), contrary to Rout (7.54kohm vs 77ohm), which is what we seek in an amplifier circuit.

- An amplifier is ideal if it has infinite input resistance(Rin) and zero output impedance(Rout)
- Percentage errors in Rin, Rout, and Av are all small (< 10%) which make the results acceptable.

To Get A_v (Voltage Gain)

Using Hand Calculations

KCL @ E

$$g_{m2} V_{\pi 2} + \frac{V_{\pi 2}}{r_{\pi 2}} = \frac{V_{out}}{r_{o2} // \frac{1}{126}}$$

$$V_{\pi 2}\left(g_{m2} + \frac{1}{r_{\pi 2}}\right) = \frac{V_{out}}{r_{o2} // \frac{1}{126}}$$

$\therefore V_{\pi 2} = 0.554 V_{out}$

KCL @ B_2

$$\frac{V_{BC2}}{10} + \frac{V_{BC2}}{r_{\pi 2}} + g_m V_{\pi 1} + \frac{V_{BC2}}{r_{o1}} = 0$$

$\therefore V_{in} = V_{\pi 1}$

$V_{BC2} = V_{B2} - V_{C2} = V_{B2} - V_{out}$

$V_{B2} = 1.55 V_{out}$

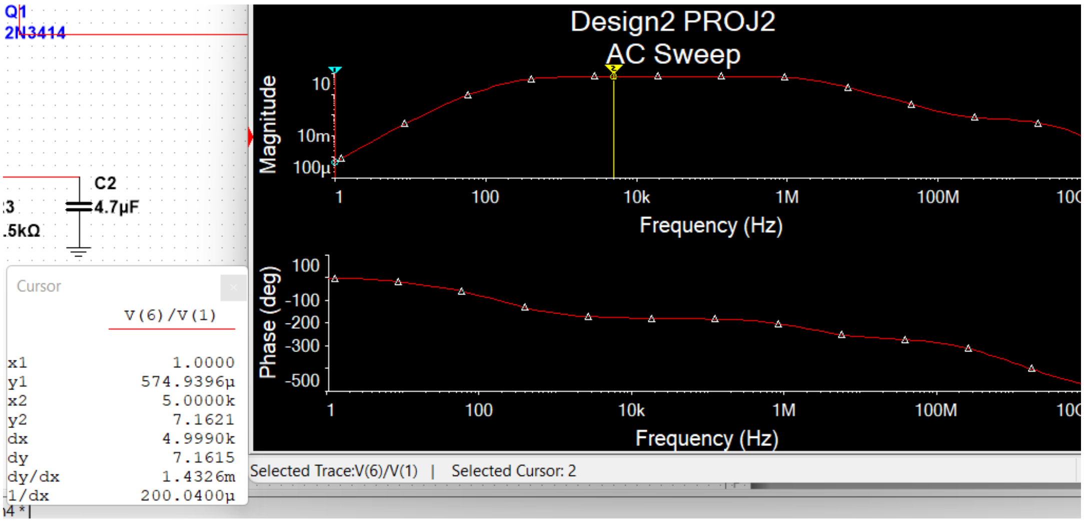
$\therefore$ By sub. and rearranging, we obtain

$$V_{out}\left[\frac{0.554}{r_{\pi 2}} + \frac{1.55}{r_{o1}} + \frac{0.554}{10}\right] = -g_{m1} V_{in}$$

$$\therefore A_V = \frac{V_{out}}{V_{in}} = -7.0818 \text{ V}$$

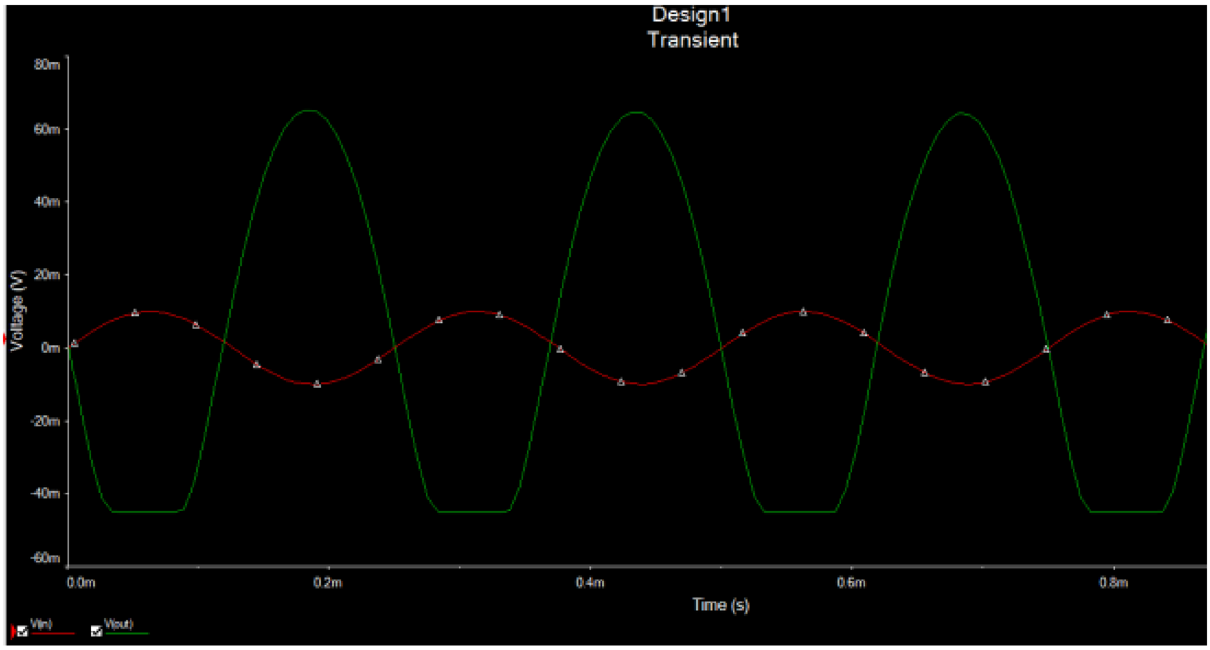
Notice That: The voltage gain is negative as the common emitter gain is negative and it is the dominant transistor here.

On Multisim



%error=((7.0818-7.1621)/7.0818)*100=1.14%

Simulation of Vin vs Vout using Transient analysis



Notice that Vout is > Vin which is the goal of an amplifier circuit.