LAB REPORT 6: BJT AMPLIFIER ANALYSIS

Name: Chanda Akshay Kumar
Roll No: 2024102014
Teammate: S. V. Santhosh
Roll No: 2024102054
Lab: Analog Electronics and Circuits (AEC)

3rrd question is after 4,5th questions

1. Objective

The objective of this experiment is to analyze a common emitter (CE) voltage amplifier circuit using BC547B transistor in LTSPICE. Theoretical calculations, simulations, and performance analysis will be conducted to verify various parameters.

2. Circuit Specifications

- Supply Voltage (VCC): 12 V
- R1 = 18.46 kΩ
- R2 = 2.24 kΩ
- RC = 30.3 kΩ
- RE = 2 kΩ
- RL = 1 kΩ
- CB = 10 μF
- CC = 10 μF
- CE = 100 μF

- **Input Signal:** vin = V_m*sin($2\pi f_0 t$) V with f_0 = 1 kHz
- **Transistor:** BC547B (NXP)

DC Analysis

(a) **Theoretical Calculations**
For DC analysis, AC sources are removed, and capacitors act as open circuits. The values of VC, VB, VE, IC, and IB are determined using:

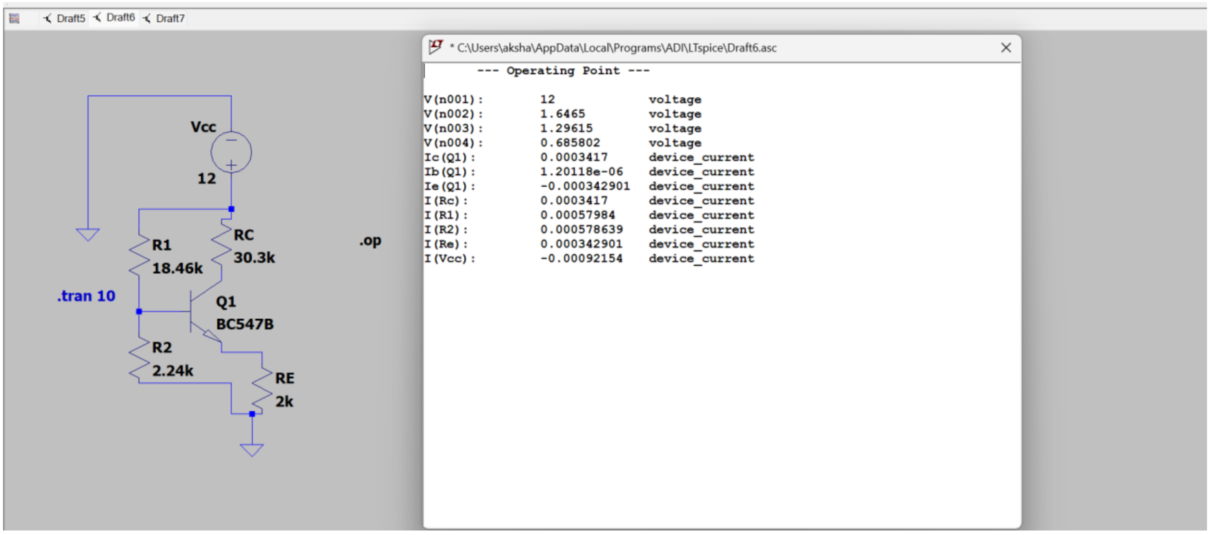
- VBE ≈ 0.7 V (for active mode)

- IC = β*IB (β avg Is taken as range of 260-280 according to Vcc and other factors in previous experiment)
- KVL and voltage divider rule to find node voltages.

The reason AC sources are replaced with its internal resistance and capacitors act as open During AC analysis is because,

As we are doing DC analysis after some time capacitors get fullty charged and act as open circuits and do not conduct DC current , but responds to AC currents and voltages

By constructing an amplifier that stays stable with respect to its operating point hence the change in the operating point due to the AC is neglected and it is replaced with its internal resistance



The values of bvoltages and currents from the plots (.op) and the values obtained theoretically are approximately the same

Values tabulated for theoretical and simulation obtained as per asked in the manual in the below written sheet

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4 Part-2(b) BJT amplifier analysis and design

(a)

$V_{CC} = 12\,V$ $R_1 = 18.46\,k\Omega$ $R_L = 1000\,\Omega$

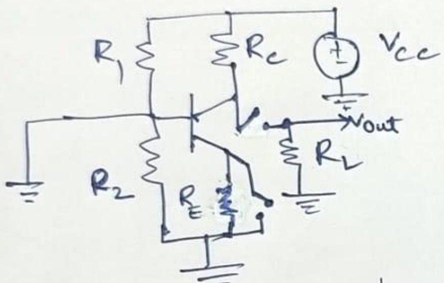
$C_B = 10\,\mu F$ $R_2 = 2.24\,k\Omega$ $v_{in} = V_m \sin(2\pi f_0 t)\,V$

$C_c = 10\,\mu F$ $R_E = 2\,k\Omega$ $f_0 = 1\,KHZ$

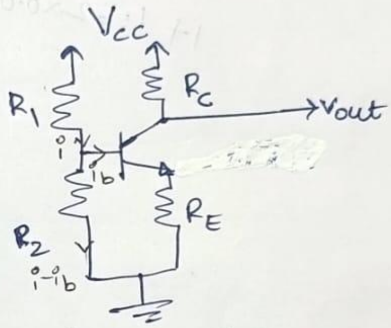
$C_E = 100\,\mu F$ $R_c = 30.3\,k\Omega$

BC547B NXP Npn Transistor

(a) DC analysis circuit becomes



$\Rightarrow$



V_{BE} fixed $\approx 0.7V$

β from previous experiment analysis.

$I_c = \beta I_B$

in forward active mode

In simulation LTspice

$V(n004) = V_e$

$V(n002) = V_c$

$V(n003) = V_B$.

$V(n001) = V_{CC} = 12\,V$

Practical Calculations

(# theoritical calculations)

$(i - i_b) R_2 = V_B$

$V_{CC} - V_B = (i)(R_1)$

$V_{CC} - (iR_2 - i_b R_2) = iR_1$

$\frac{V_{cc} + i_b R_2}{R_1 + R_2} = i$

$V_E = V_B - 0.7$

$V_B = R_2\left(\frac{V_{cc} - i_b R_1}{R_1 + R}\right)$

$I_E = \frac{V_B - 0.7}{R_E}$

$(\beta+1) i_b \cdot R_E = R_2\left(\frac{V_{cc} - i_b R_1}{R_1 + R_2}\right) - 0.7$

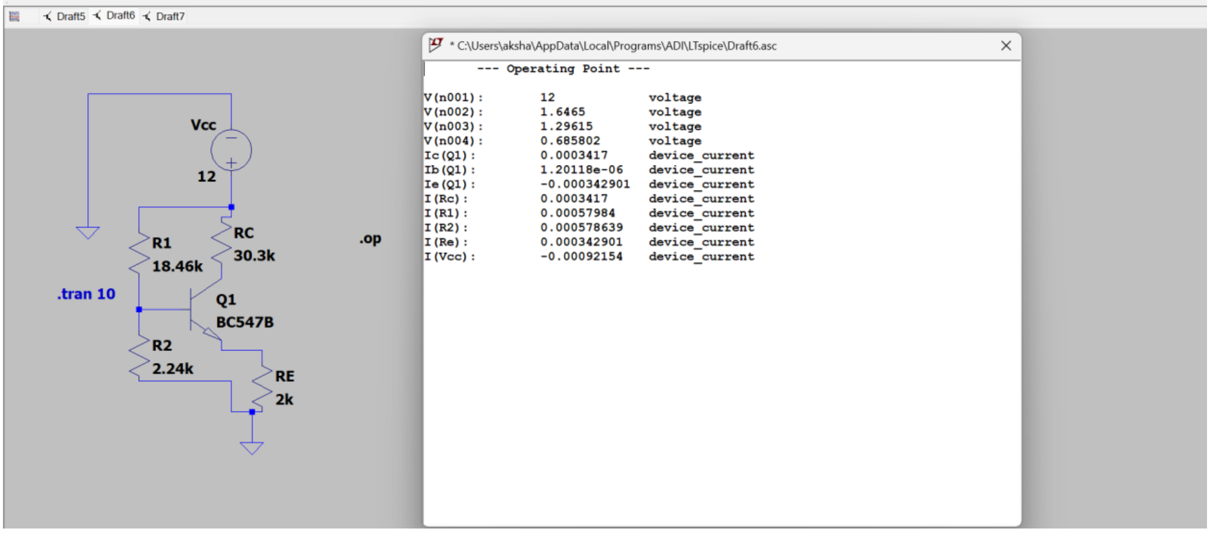
$i_b = \left(\frac{V_{cc} R_2}{R_1 + R_2} - 0.7\right) / \left(\frac{R_1 R_2}{R_1 + R_2} + (\beta+1) R_E\right) = 1.21\,\mu A$

$i_c = \beta i_b = 0.35\,mA$ $V_c = 1.9\,V$ $V_E = 0.599\,V$ $V_B = 1.294\,V$

Mode of Operation: .

(b) **Operating Point Simulation**

- Run **.op** simulation in LTSPICE.



- Compare theoretical and simulated values in a table.

4. Small Signal and Transient Analysis

(c) **Calculate Small Signal Parameters**

- gm = IC/VT = 13m/ohm
- rπ = β/gm = 21.8 kohm
- r0 = VA/IC = 181.4 kohm

(d) **Small Signal Equivalent Circuit**

- Replace capacitors with their impedance at f0 = 1 kHz.
- Draw the small signal equivalent model.

(e) **Derivation of Voltage Gain Expression**.

Use small signal model to derive Av = vout/vin

- Use small signal model to derive Av = vout/vin
- Calculated Av=12.23 approximately

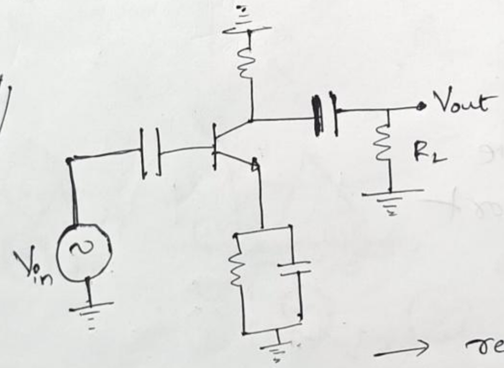
Simulated Values obtained in LTspice

experimental (LTspice)	Theoritical calculations
$V_{cc} = 12V$	$V_{cc} = 12V$
$V_c = 1.646\ V$	$V_c = 1.9V$
$V_B = 1.296\ V$	$V_B = 1.294V$
$V_e = 0.685\ V$	$V_e = 0.599mV$
$I_c = 0.341mA$	$I_C = 0.34mA$
$I_b = 1.2\times10^{-6}A = 1.2\mu A$	$I_b = 1.21\mu A$
$I_e = 0.342mA$	$I_e \approx i_c = 0.342mA$

* capacitors ~~to~~ act as open circuit for DC voltage after fully charged (charged immidiately) allow AC to pass

→ Small Signal parameters

Short all the constant voltage sources



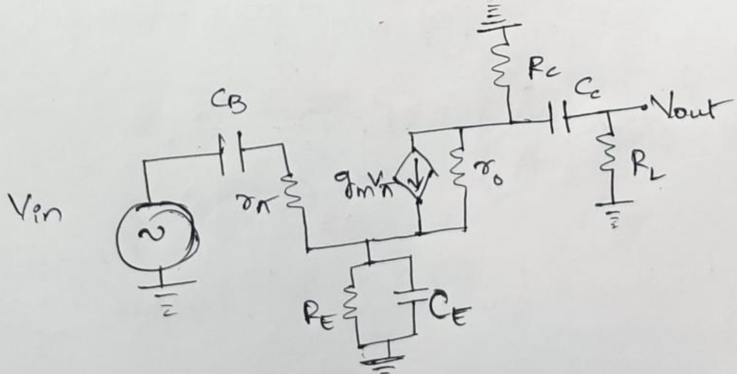
$$g_m = \frac{I_c}{V_T} \approx \frac{0.34mA}{26mV}$$

$$g_m = 13m\Omega^{-1}$$

$$r_\pi = \frac{\beta}{g_m} = 21.8K\Omega$$

$$r_o = \frac{V_A}{I_c} = 181.4K\Omega$$

→ replacing with model.



(f) **Transient Simulation**

- Run **.tran 50m** for Vm = 10 mV.
- Plot vin and vout.v

- Compare simulated gain with theoretical gain.
- In Ltspice simulation 11.15 and 13.89 for top-gain and bottom-gain of the signal respectively . images attached below
- i.e the range of gian is 11.15 to 13.90

$$A_v = \frac{-g_m \times (\text{collector load})}{1 + (g_m \times \text{emitter load})}$$

$$R_{ceff} = \left(\frac{1}{R_C} + \frac{1}{R_L + Z_{cc}} + \frac{1}{r_o} \right)^{-1} \approx 959\,\Omega$$

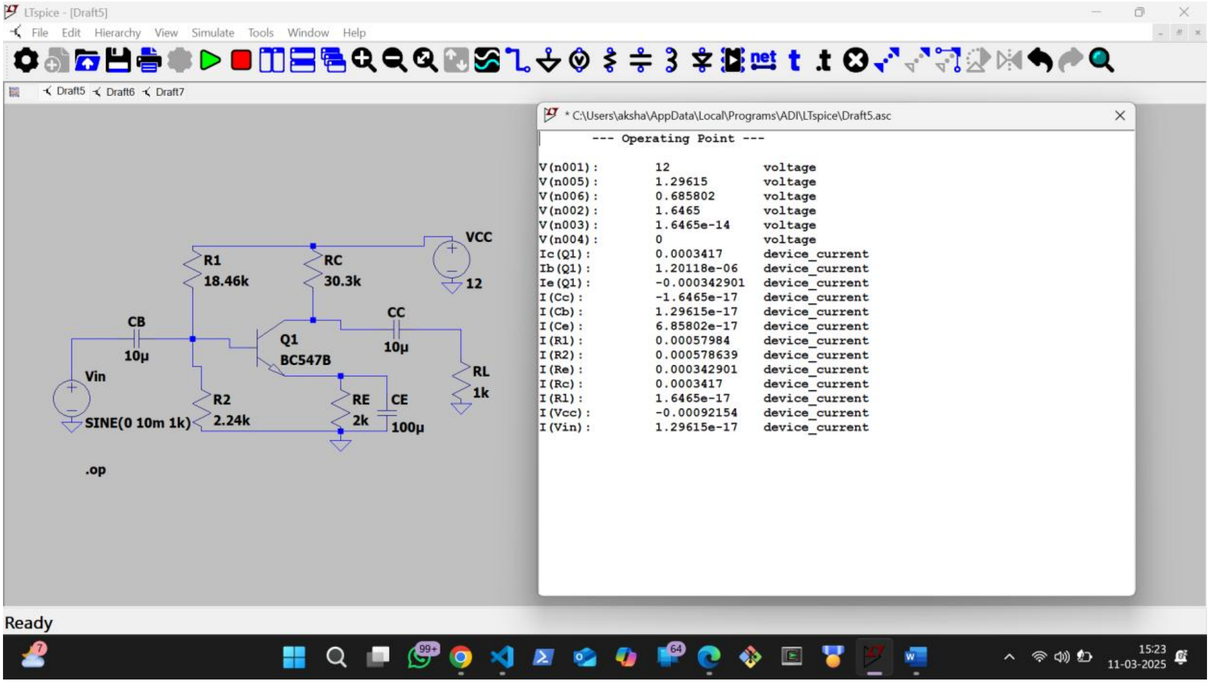
$$R_{Eeff} = \left(\frac{1}{R_E} + \frac{1}{Z_{CE}} \right)^{-1} \approx 1.62\,\Omega$$

$$A_v = -\frac{13m\Omega^{-1} \times 959}{1 + 1.62 \times 0.013} \approx 12.231$$

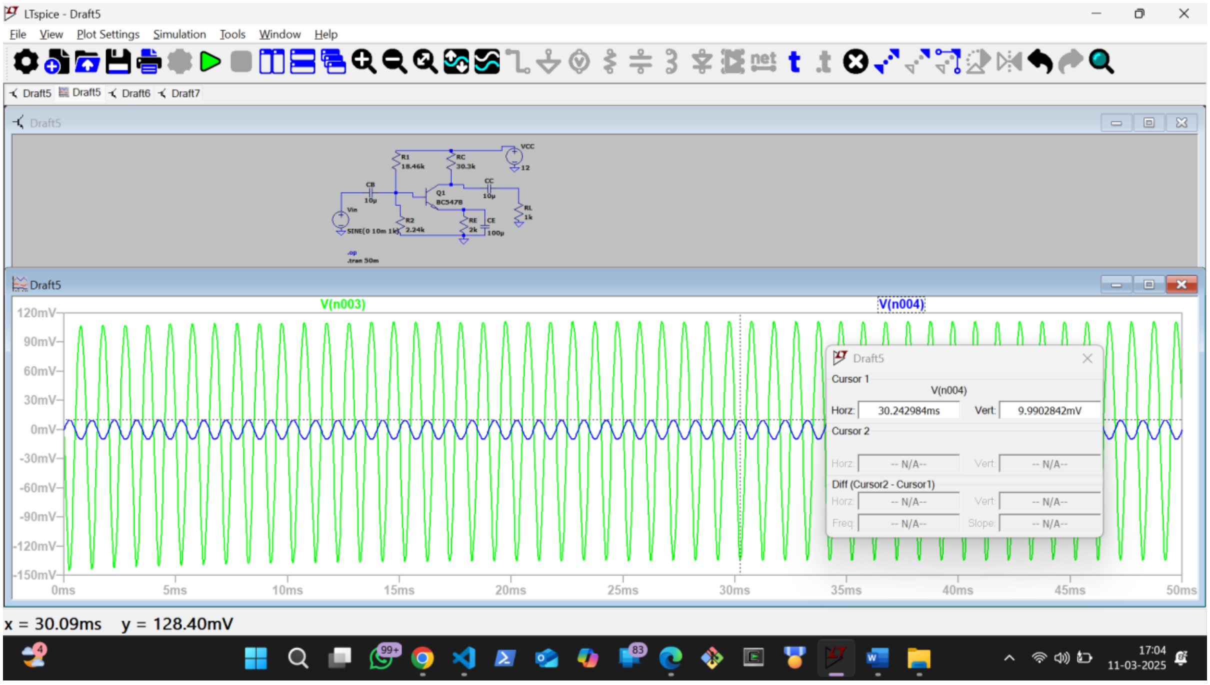
$$AV = \frac{V_{out}}{V_{in}} = \frac{138.7}{9.99} \approx 13.89 \quad [A_v \text{ bottom}]$$

$$= \frac{111.4}{9.99} \approx 11.15 \quad [A_v \text{ top}]$$

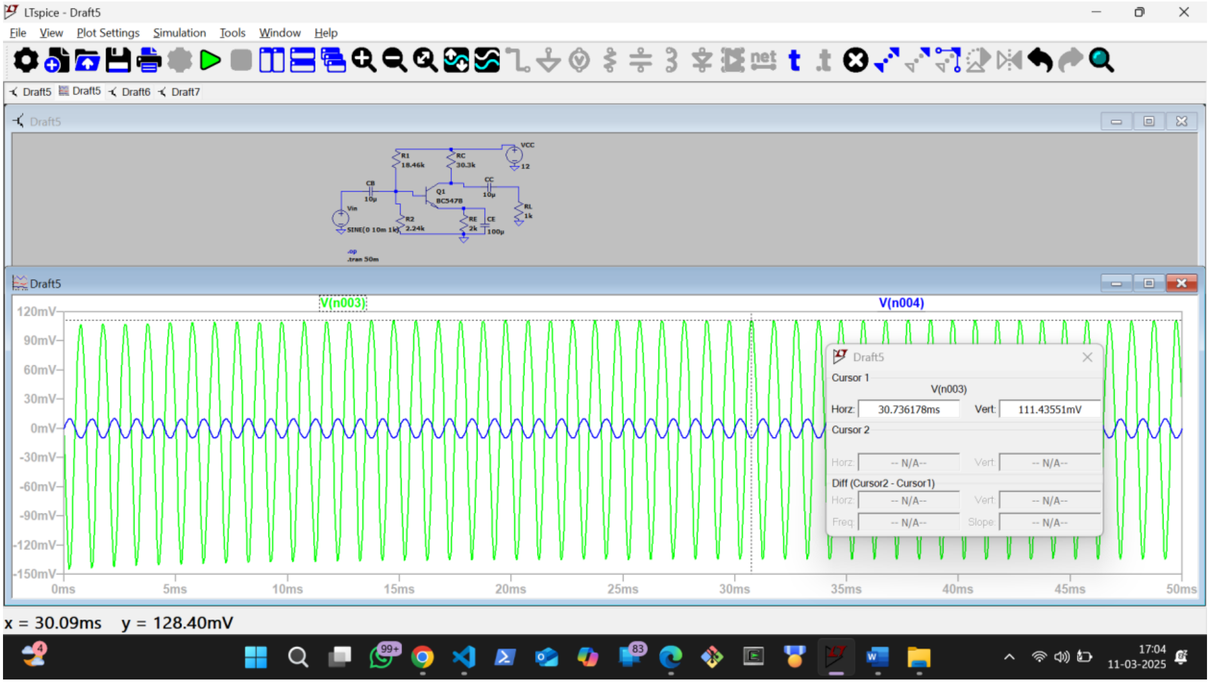
~~Av~~

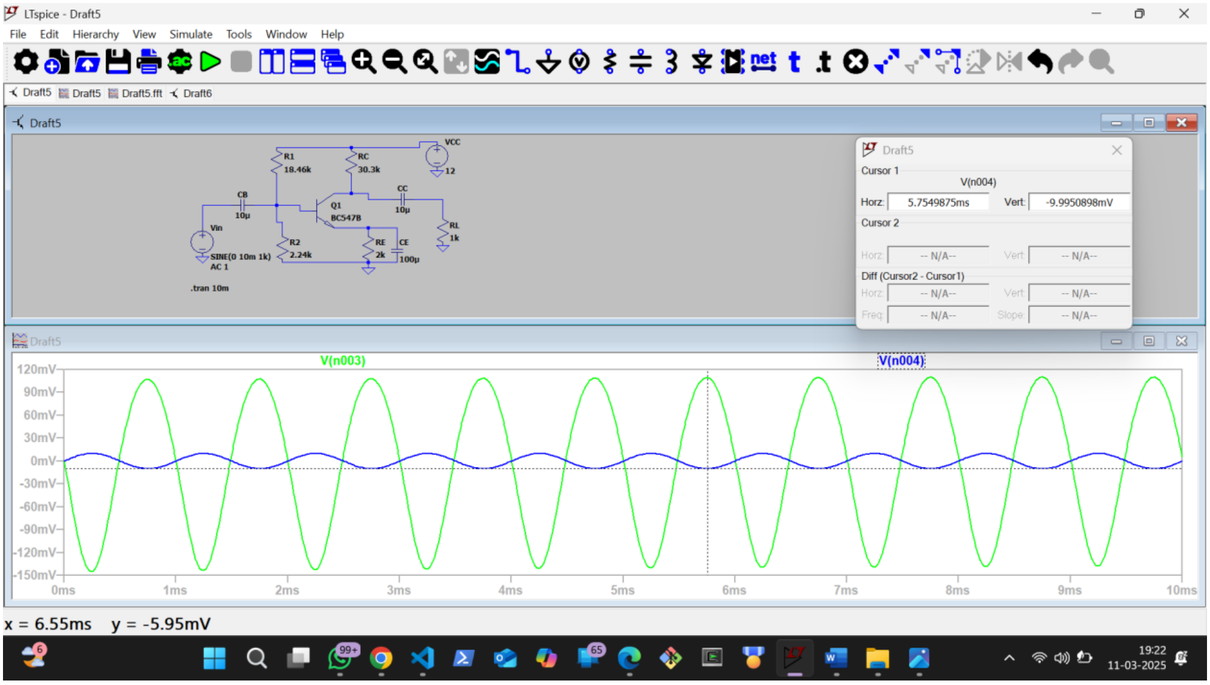


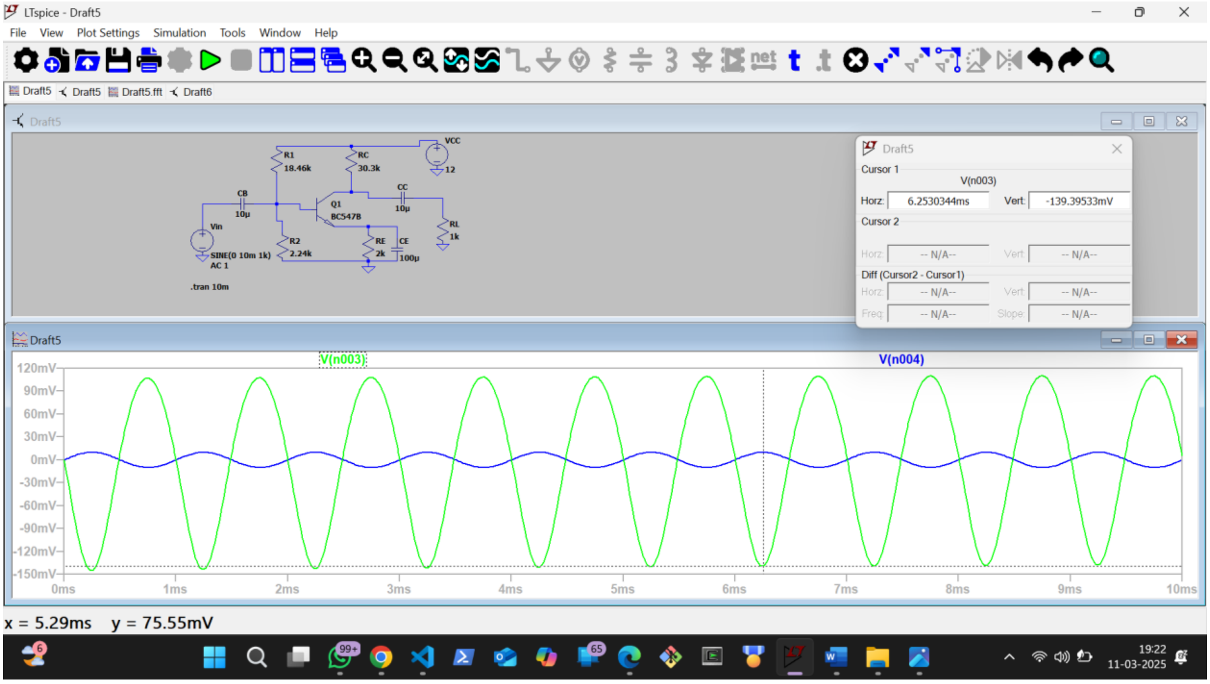
LTspice - [Draft5]
File Edit Hierarchy View Simulate Tools Window Help
Draft5 Draft6 Draft7
* C:\Users\aksha\AppData\Local\Programs\ADI\LTspice\Draft5.asc
--- Operating Point ---
V(n001): 12 voltage
V(n005): 1.29615 voltage
V(n006): 0.685802 voltage
V(n002): 1.6465 voltage
V(n003): 1.6465e-14 voltage
V(n004): 0 voltage
Ic(Q1): 0.0003417 device_current
Ib(Q1): 1.20118e-06 device_current
Ie(Q1): -0.000342901 device_current
I(Cc): -1.6465e-17 device_current
I(Cb): 1.29615e-17 device_current
I(Ce): 6.85802e-17 device_current
I(R1): 0.00057984 device_current
I(R2): 0.000578639 device_current
I(Re): 0.000342901 device_current
I(Rc): 0.0003417 device_current
I(Rl): 1.6465e-17 device_current
I(Vcc): -0.00092154 device_current
I(Vin): 1.29615e-17 device_current
VCC
12
R1
18.46k
RC
30.3k
CB
10µ
CC
10µ
Q1
BC547B
Vin
RL
1k
R2
2.24k
RE
2k
CE
100µ
SINE(0 10m 1k)
.op
Ready
15:23
11-03-2025



LTspice - Draft5
File View Plot Settings Simulation Tools Window Help
Draft5 Draft5 Draft6 Draft7
.tran 50m
V(n003)
V(n004)
120mV
90mV
60mV
30mV
0mV
-30mV
-60mV
-90mV
-120mV
-150mV
0ms
5ms
10ms
15ms
20ms
25ms
30ms
35ms
40ms
45ms
50ms
Cursor 1
V(n004)
Horz: 30.242984ms
Vert: 9.9902842mV
Cursor 2
Diff (Cursor2 - Cursor1)
x = 30.09ms y = 128.40mV
17:04
11-03-2025


LTspice - Draft5
File View Plot Settings Simulation Tools Window Help
Draft5 Draft5 Draft6 Draft7
R1 18.46k
RC 30.3k
VCC 12
CB 10µ
CC 10µ
Q1 BC547B
Vin
R2 2.24k
RE 2k
CE 100µ
RL 1k
SINE(0 10m 1k)
.tran 50m
V(n003)
V(n004)
Cursor 1
Horz: 30.736178ms
Vert: 111.43551mV
Cursor 2
Diff (Cursor2 - Cursor1)
120mV
90mV
60mV
30mV
0mV
-30mV
-60mV
-90mV
-120mV
-150mV
0ms
5ms
10ms
15ms
20ms
25ms
30ms
35ms
40ms
45ms
50ms
x = 30.09ms y = 128.40mV
17:04
11-03-2025

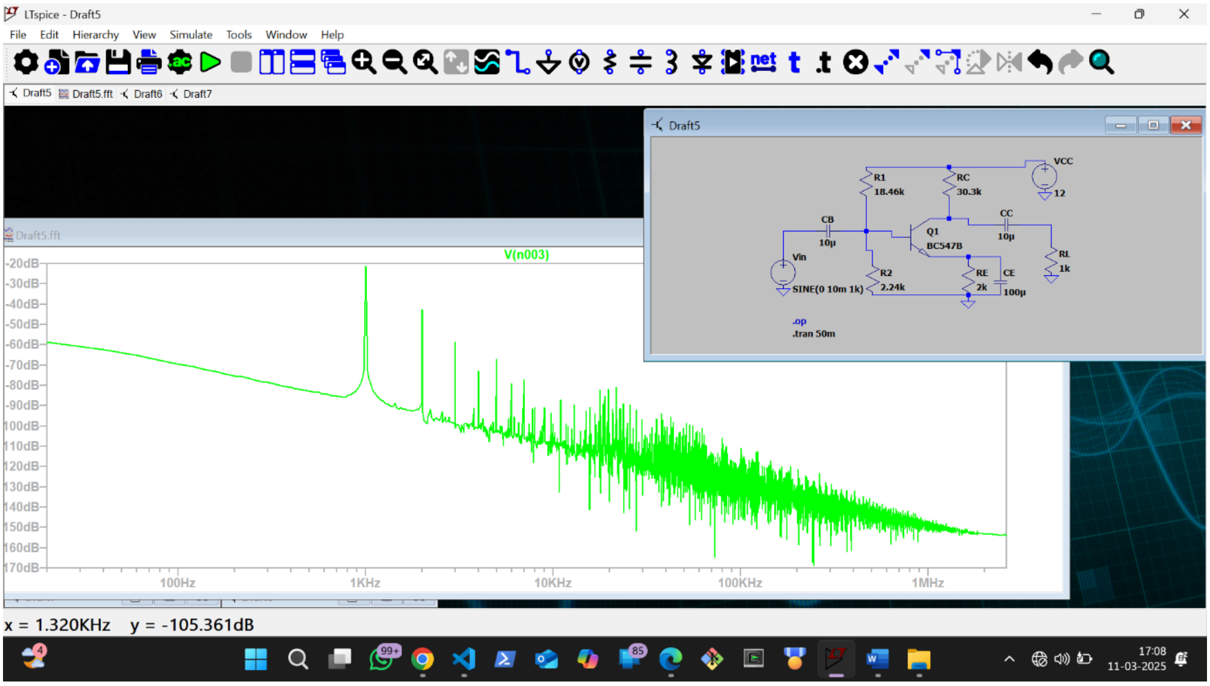

LTspice - Draft5
File Edit Hierarchy View Simulate Tools Window Help
Draft5 Draft5 Draft5.fft Draft6
R1 18.46k
RC 30.3k
VCC 12
CB 10µ
CC 10µ
Q1 BC547B
Vin
R2 2.24k
RE 2k
CE 100µ
RL 1k
SINE(0 10m 1k)
AC 1
.tran 10m
Cursor 1
V(n004)
Horz: 5.7549875ms
Vert: -9.9950898mV
Cursor 2
Diff (Cursor2 - Cursor1)
V(n003)
V(n004)
120mV
90mV
60mV
30mV
0mV
-30mV
-60mV
-90mV
-120mV
-150mV
0ms
1ms
2ms
3ms
4ms
5ms
6ms
7ms
8ms
9ms
10ms
x = 6.55ms y = -5.95mV
19:22
11-03-2025



Frequency Analysis

Fast fourier transform

Fundamental FFT 1st Harmonic at 1kHz frequencey

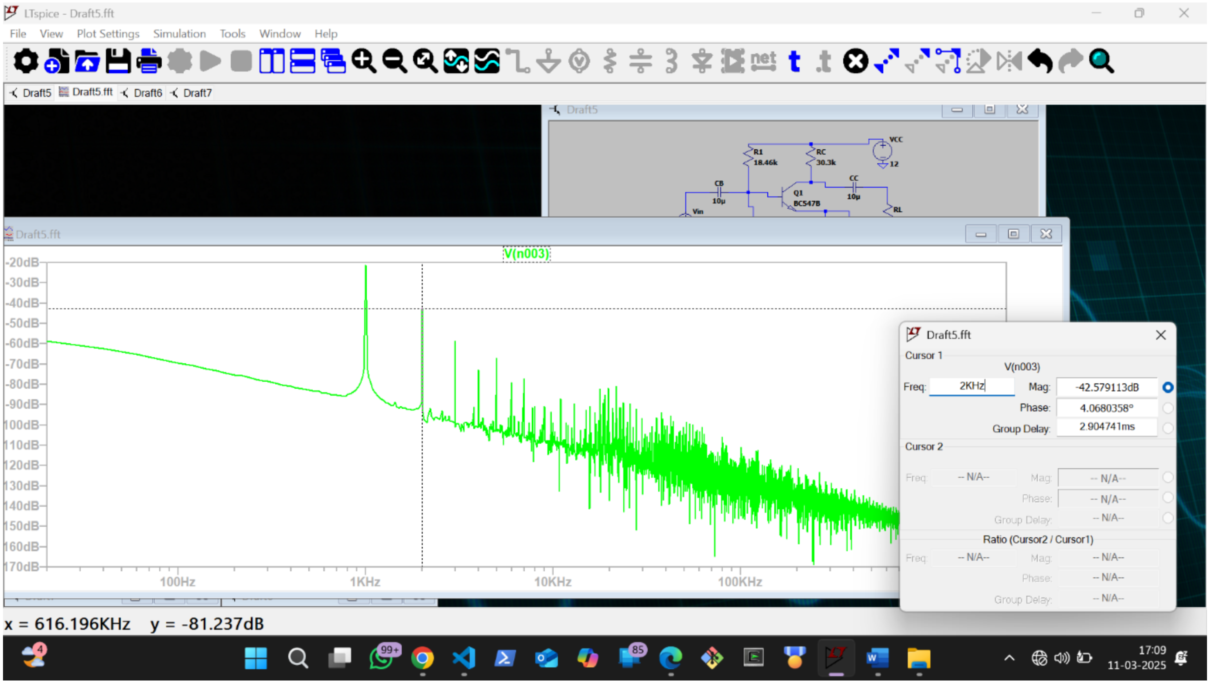


(g) **FFT Analysis**

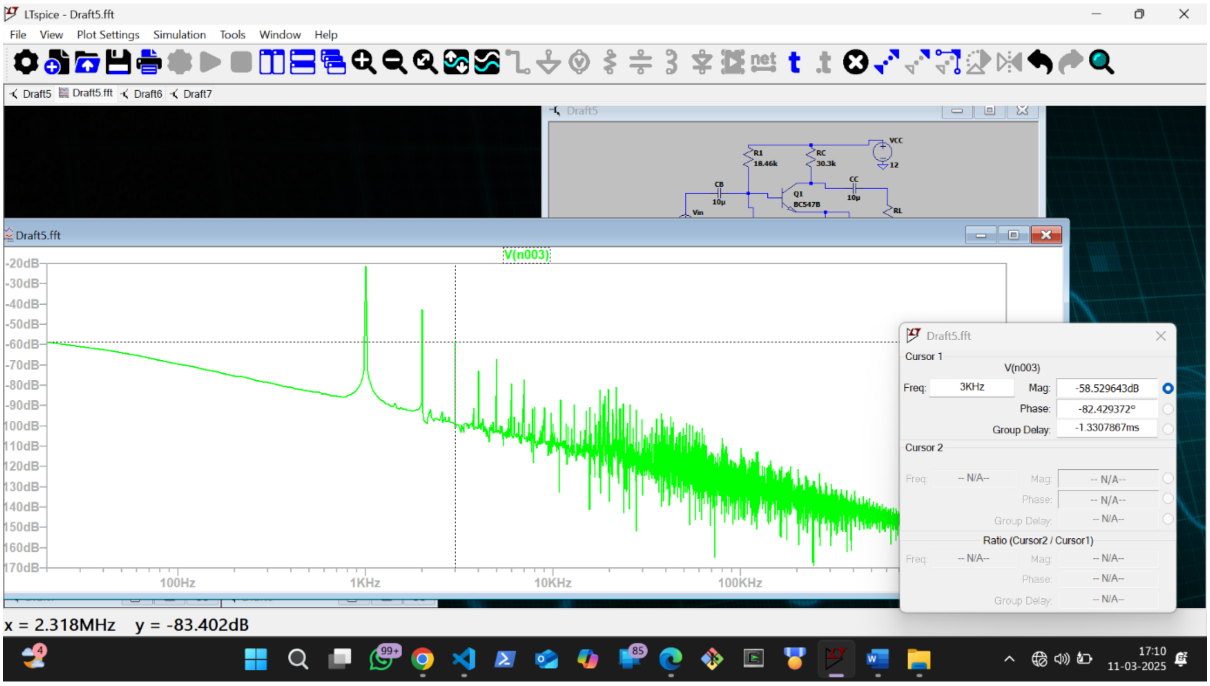
- Run FFT on vout.

- Compare 2nd, 3rd, and 4th harmonics with fundamental (1 kHz) component.

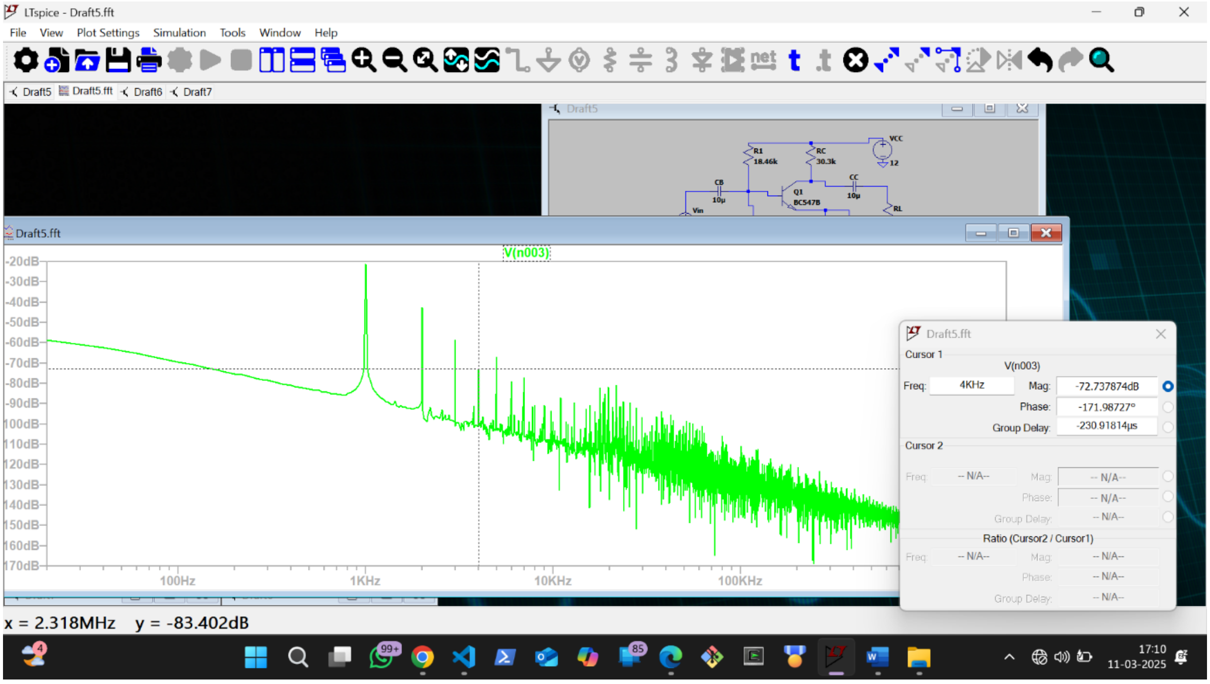
2nd Harmonic



3rd Harmonic



4th Harmonic



Differences for harmonic magnitudes

1KHz→-21.34 →0.34V

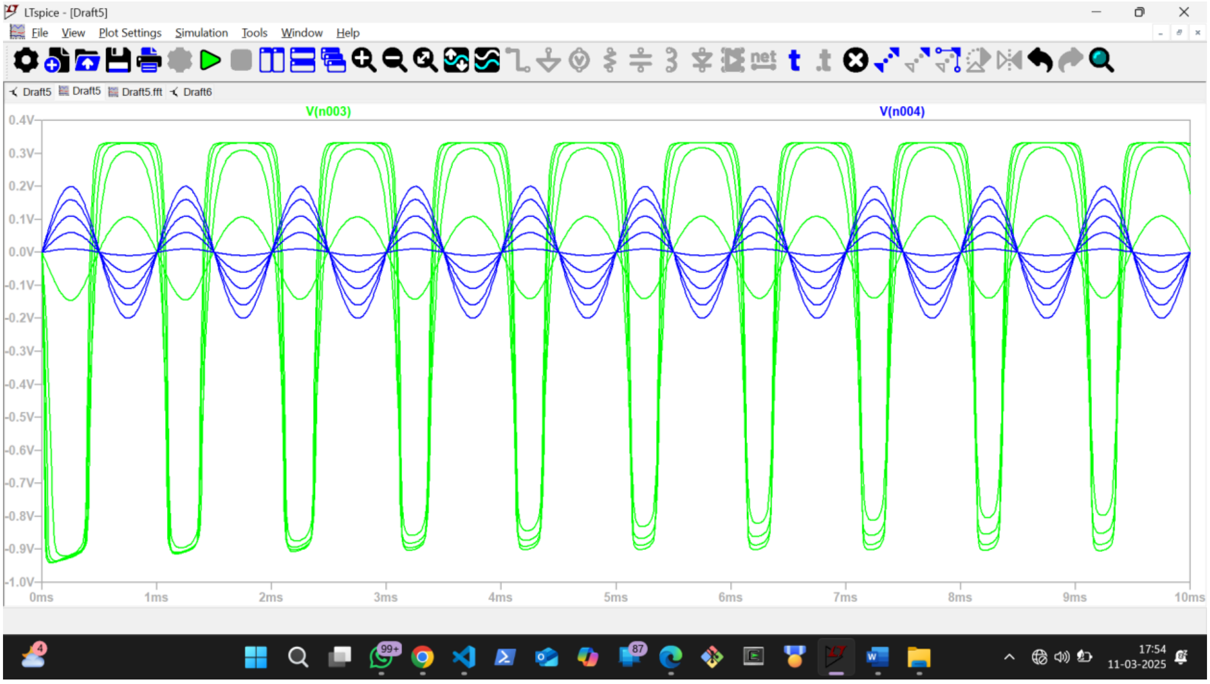
2KHz→ -42.579 →0.12V→1st - 2nd harmonic = 0.22V

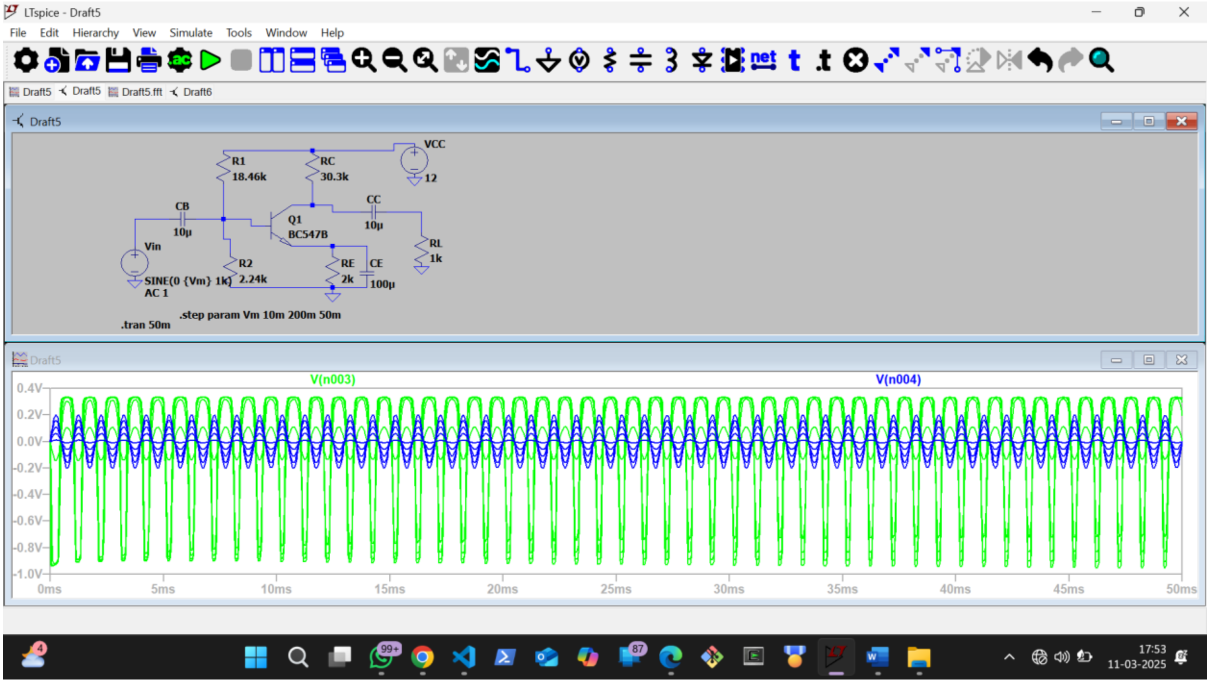
3KHz→ -58.52 →0.05V→1st - 3rd harmonic = 0.29V

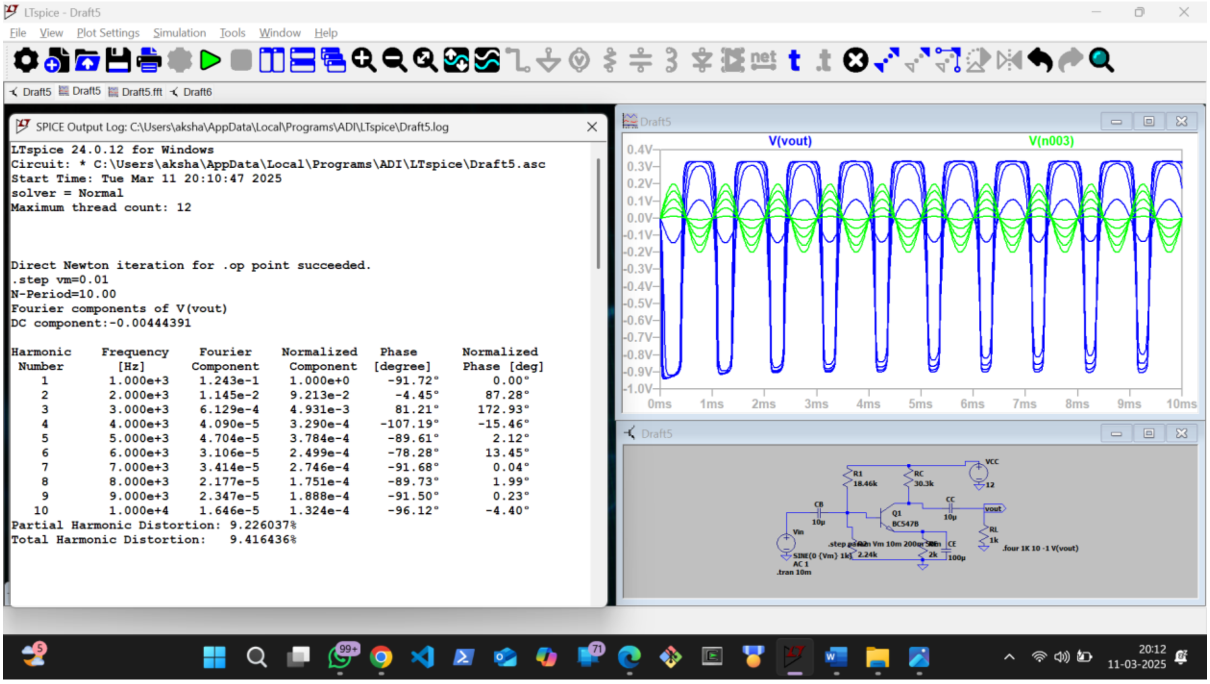
4KHz→ -72.73 →0.026V→1st - 4th harmonic = 0.314V

(h & i) **Total Harmonic Distortion (THD) Analysis and AC Analysis**

- Use parametric sweep: **.step param Vm 10m 200m 50m**.
- Extract THD from SPICE error log.
- Analyze THD increase with Vm and justify using calculations.
- Run **.ac dec 10 1m 1G**.
- Plot magnitude and phase of Av.
- Report DC gain (dB) and -3 dB bandwidth.


LTspice - [Draft5]
File View Plot Settings Simulation Tools Window Help
Draft5 Draft5 Draft5.fft Draft6
V(n003)
V(n004)
0.4V 0.3V 0.2V 0.1V 0.0V -0.1V -0.2V -0.3V -0.4V -0.5V -0.6V -0.7V -0.8V -0.9V -1.0V
0ms 1ms 2ms 3ms 4ms 5ms 6ms 7ms 8ms 9ms 10ms
17:54
11-03-2025


LTspice - Draft5
File Edit Hierarchy View Simulate Tools Window Help
Draft5 Draft5 Draft5.fft Draft6
Draft5
R1
18.46k
RC
30.3k
VCC
12
CB
10µ
CC
10µ
Q1
BC547B
Vin
SINE(0 {Vm} 1k)
AC 1
R2
2.24k
RE
2k
CE
100µ
RL
1k
.tran 50m
.step param Vm 10m 200m 50m
Draft5
V(n003)
V(n004)
0.4V 0.2V 0.0V -0.2V -0.4V -0.6V -0.8V -1.0V
0ms 5ms 10ms 15ms 20ms 25ms 30ms 35ms 40ms 45ms 50ms
17:53
11-03-2025



.step vm=0.06
N-Period=10.00
Fourier components of V(vout)
DC component:-0.097524

Harmonic Number	Frequency [Hz]	Fourier Component	Normalized Component	Phase [degree]	Normalized Phase [deg]
1	1.000e+3	5.993e-1	1.000e+0	-92.42°	0.00°
2	2.000e+3	2.192e-1	3.658e-1	-5.88°	86.54°
3	3.000e+3	1.295e-2	2.161e-2	69.09°	161.51°
4	4.000e+3	4.085e-2	6.817e-2	-10.36°	82.06°
5	5.000e+3	3.297e-2	5.501e-2	76.39°	168.81°
6	6.000e+3	1.604e-2	2.677e-2	167.88°	260.30°
7	7.000e+3	4.546e-3	7.586e-3	-96.95°	-4.53°
8	8.000e+3	1.896e-3	3.164e-3	164.40°	256.83°
9	9.000e+3	4.247e-3	7.088e-3	-109.39°	-16.96°
10	1.000e+4	3.289e-3	5.489e-3	-29.02°	63.40°

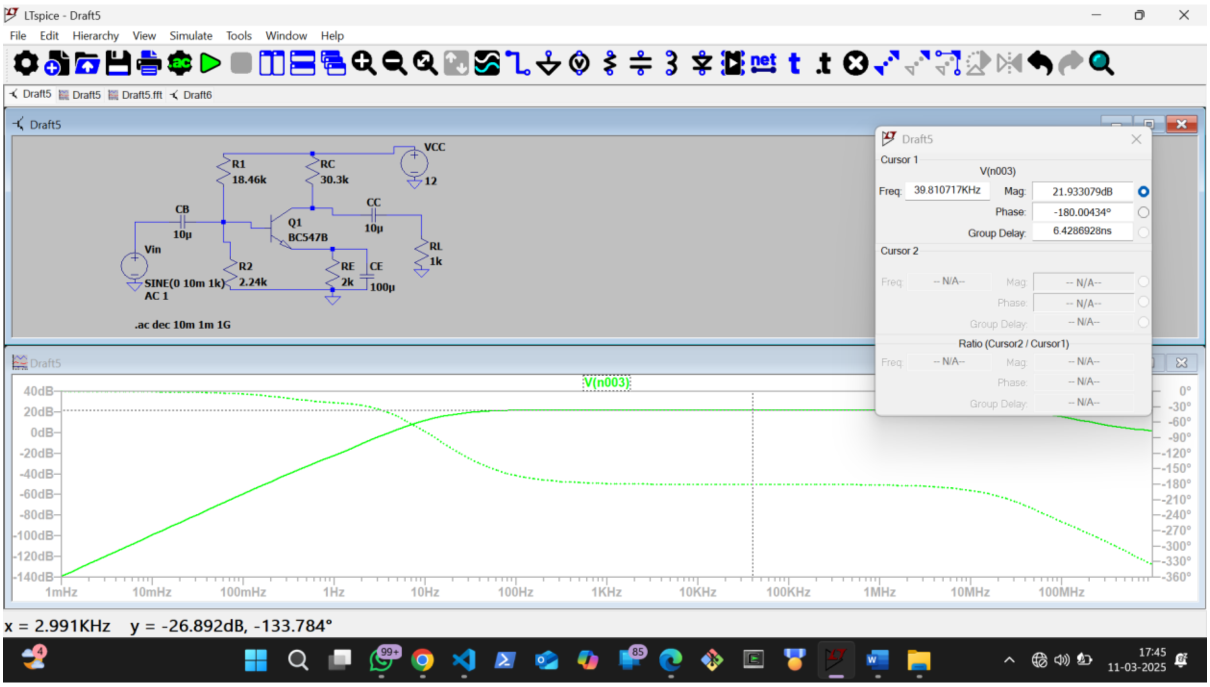
Partial Harmonic Distortion: 37.791268%
Total Harmonic Distortion: 40.993892%

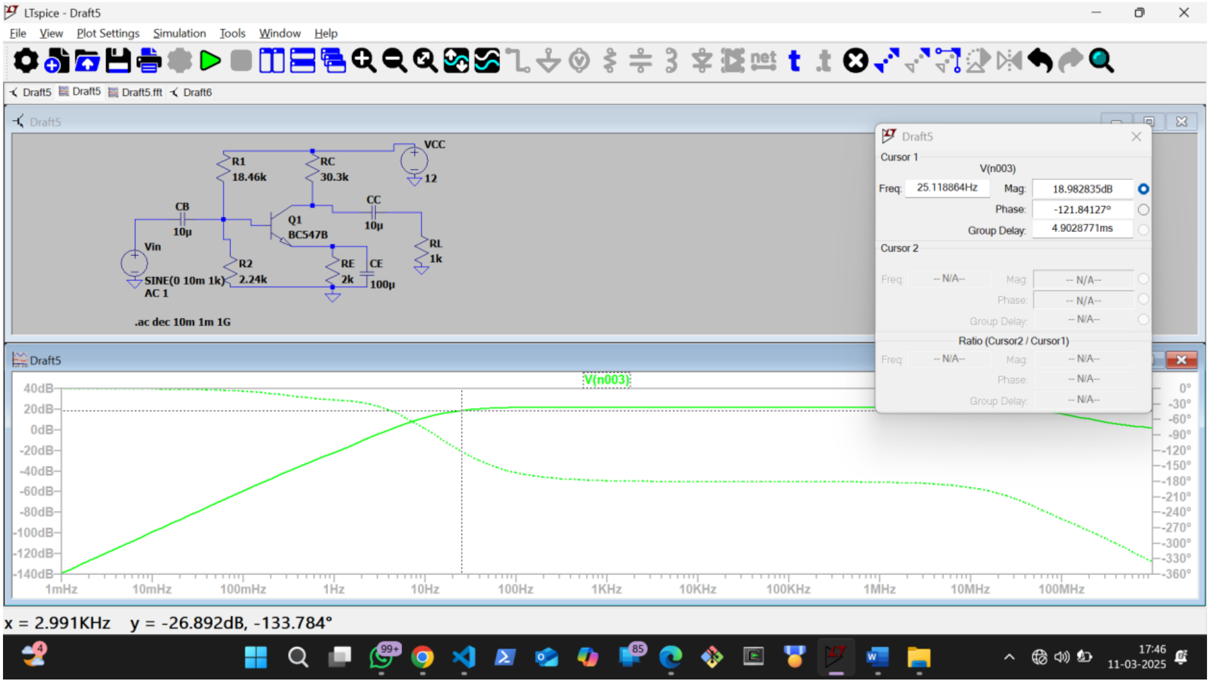
```
.step vm=0.11
N-Period=10.00
Fourier components of V(vout)
DC component:-0.065071

Harmonic     Frequency    Fourier     Normalized   Phase      Normalized
 Number        [Hz]      Component    Component   [degree]    Phase  [deg]
    1        1.000e+3    6.296e-1     1.000e+0     -93.17°       0.00°
    2        2.000e+3    2.892e-1     4.593e-1      -6.45°      86.72°
    3        3.000e+3    2.421e-2     3.845e-2      82.13°     175.30°
    4        4.000e+3    7.350e-2     1.167e-1     -13.62°      79.55°
    5        5.000e+3    6.177e-2     9.812e-2      76.50°     169.66°
    6        6.000e+3    2.458e-2     3.905e-2     174.89°     268.06°
    7        7.000e+3    3.392e-3     5.387e-3      -6.64°      86.52°
    8        8.000e+3    1.105e-2     1.755e-2     167.59°     260.76°
    9        9.000e+3    1.298e-2     2.061e-2     -98.29°      -5.13°
   10        1.000e+4    8.463e-3     1.344e-2     -18.68°      74.49°
Partial Harmonic Distortion: 48.803404%
Total Harmonic Distortion:   53.855299%
```

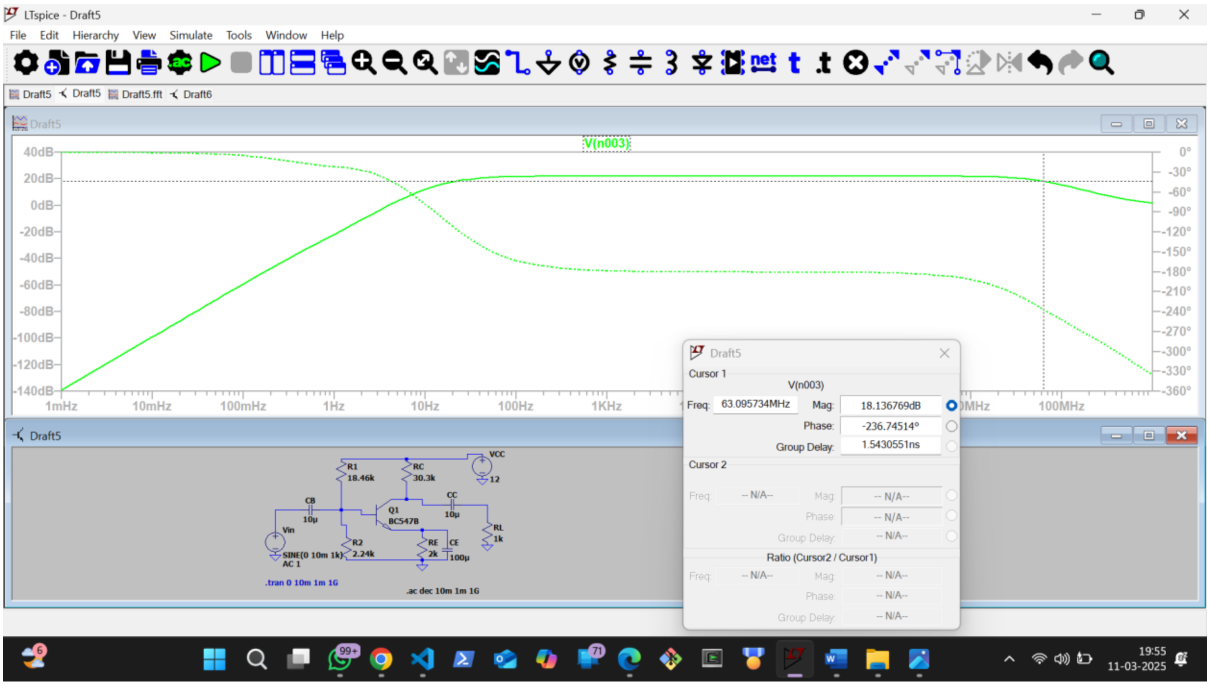
```
.step vm=0.16
N-Period=10.00
Fourier components of V(vout)
DC component:-0.0343598

Harmonic     Frequency    Fourier     Normalized   Phase      Normalized
 Number        [Hz]      Component    Component   [degree]    Phase  [deg]
    1        1.000e+3    6.101e-1     1.000e+0     -93.73°       0.00°
    2        2.000e+3    3.317e-1     5.438e-1      -6.72°      87.00°
    3        3.000e+3    7.422e-2     1.217e-1      85.07°     178.80°
    4        4.000e+3    5.861e-2     9.607e-2     -18.56°      75.16°
    5        5.000e+3    7.789e-2     1.277e-1      76.97°     170.70°
    6        6.000e+3    4.926e-2     8.075e-2     173.86°     267.59°
    7        7.000e+3    1.516e-2     2.485e-2     -87.83°       5.90°
    8        8.000e+3    1.098e-2     1.800e-2     174.25°     267.97°
    9        9.000e+3    2.212e-2     3.626e-2     -99.93°      -6.20°
   10        1.000e+4    1.764e-2     2.892e-2     -22.55°      71.18°
Partial Harmonic Distortion: 58.788415%
Total Harmonic Distortion:   64.638172%
```

```
tnom = 27
temp = 27
method = modified trap
.step vm=0.2
N-Period=10.00
Fourier components of V(vout)
DC component:-0.0151986

Harmonic     Frequency    Fourier      Normalized   Phase       Normalized
 Number        [Hz]       Component    Component    [degree]    Phase  [deg]
    1        1.000e+3     5.910e-1     1.000e+0     -94.09°       0.00°
    2        2.000e+3     3.498e-1     5.918e-1      -6.98°      87.11°
    3        3.000e+3     1.096e-1     1.855e-1      85.03°     179.12°
    4        4.000e+3     3.669e-2     6.209e-2     -27.98°      66.10°
    5        5.000e+3     7.923e-2     1.341e-1      76.64°     170.72°
    6        6.000e+3     6.654e-2     1.126e-1     172.86°     266.94°
    7        7.000e+3     3.222e-2     5.452e-2     -96.21°      -2.12°
    8        8.000e+3     4.434e-3     7.503e-3    -161.14°     -67.06°
    9        9.000e+3     2.524e-2     4.271e-2    -100.48°      -6.40°
   10        1.000e+4     2.497e-2     4.226e-2     -23.09°      70.99°
Partial Harmonic Distortion: 65.256930%
Total Harmonic Distortion:   71.503067%

Total elapsed time: 0.551 seconds.
```

THD increases with increasing input voltage because the BJT operates more nonlinearly at higher signal amplitudes, introducing harmonic distortion through gain variation, clipping, capacitance effects, and intermodulation.







Lower cutoff frequency is 25.11 Hz

Higher cutoff frequency is 63.09 MHz

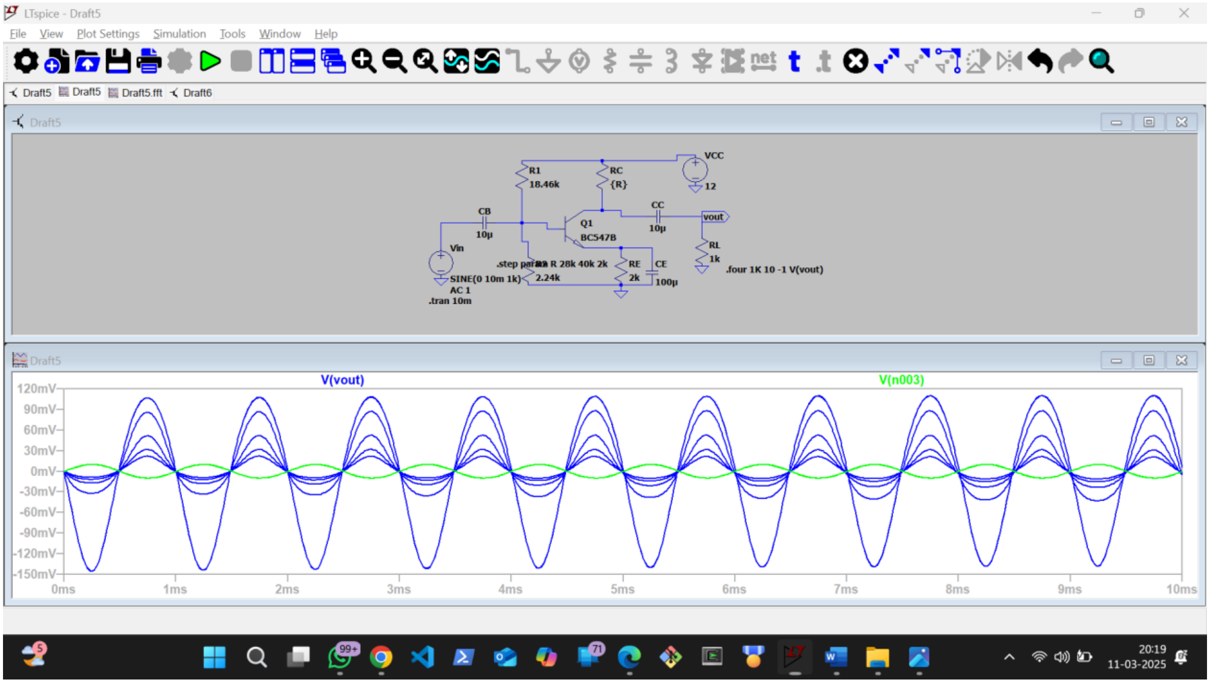
Band width is approx 63.09MHz

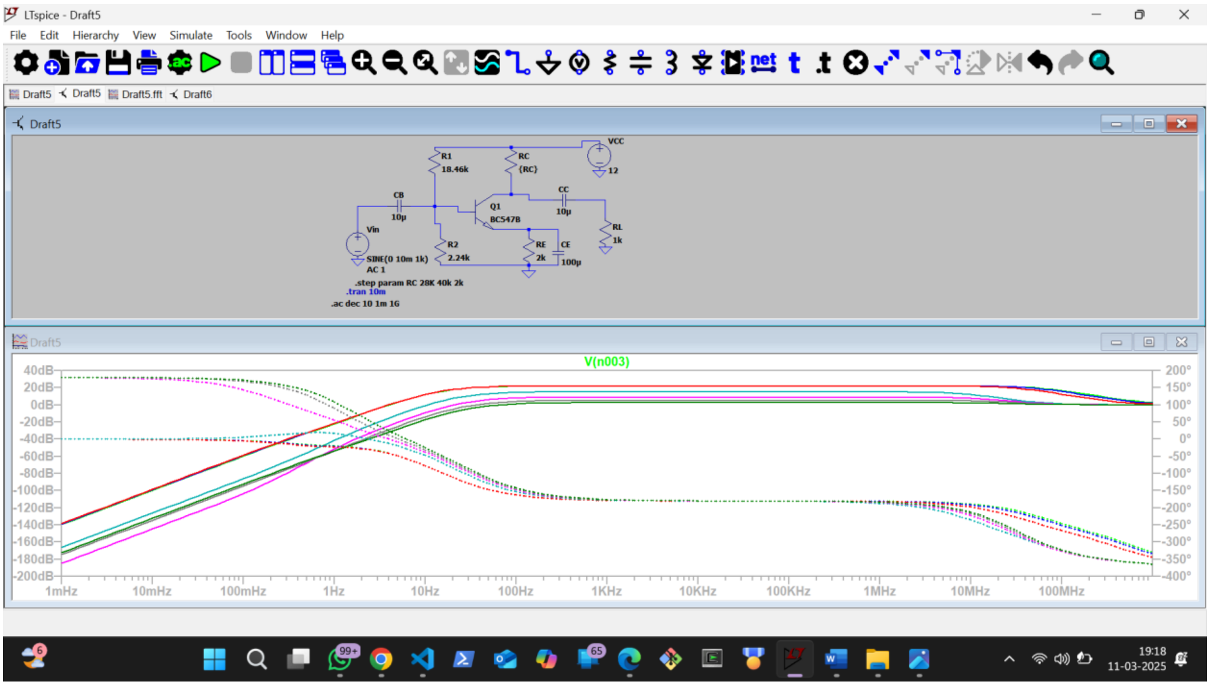
The max DC gain is 21.933 dB

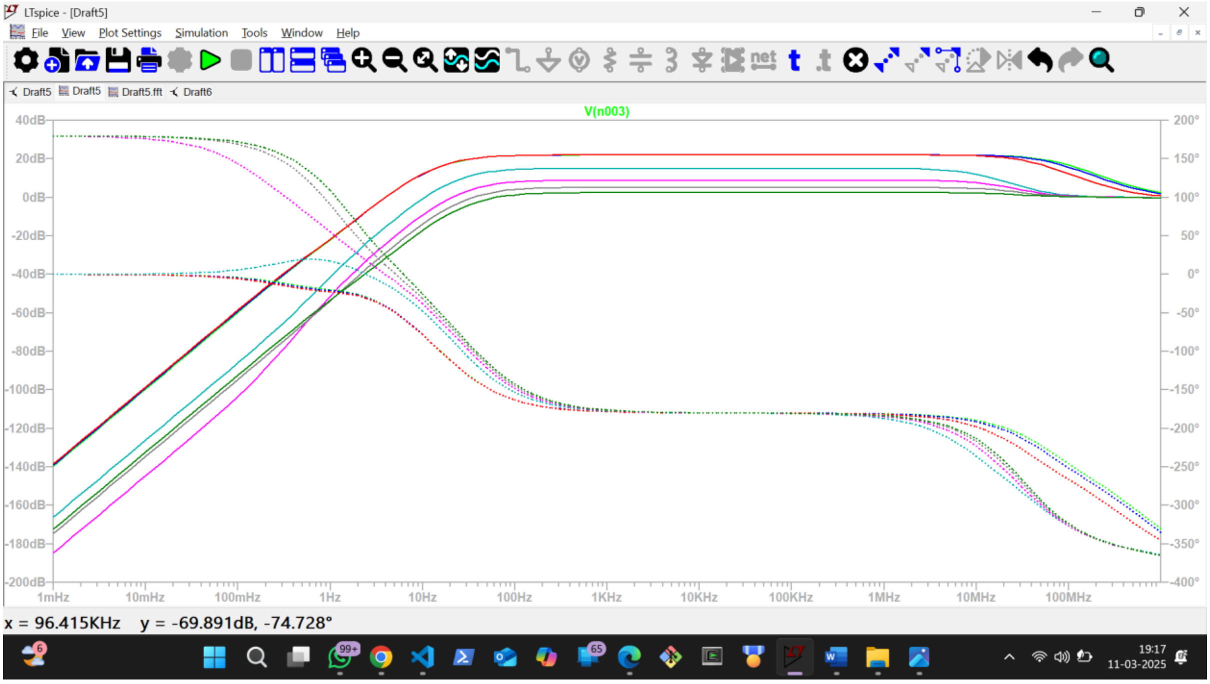
6. Change in gain by RC

(j) **Effect of RC on Gain**

- Parametrize RC from **28 kΩ to 40 kΩ** in steps of **2 kΩ**.
- Run **.ac** simulation and plot Av.
- Compare DC gain for different RC values.
- Justify gain variation quantitatively for RC = 30 kΩ and RC = 40 kΩ.







(j)

R_c	A_v
28	21.98
30	21.93
32	21.94
34	15.012
36	8.76
38	5.05
40	2.40

Yes, there is dependence of A_v on R_c

$A_v \propto R_c || R_k$ [from eq (1)]

$R_k \rightarrow$ net R_{eff} excluding R_c

A_c = max when $R_c = R_k$ (because parallel)

A_c decreases when different b/w increases.

5)

5) We require same bandwidth and same gain but Vcc changes from 12 Vcc to 5 Vcc

by prev calculations

$$V_C = 0.16\,V,\ I_C = 0.34\,mA \quad \text{at } V_{CC} = 5V$$

if and only if $R_C = 10k\Omega$

Similarly

$$V_{CC} R_2 = 1.3 (R_1 + R_2)$$

by Trial & error and some other calculations and theory

let, $R_1 = 30k\Omega$ $R_2 = 10.45k\Omega$

by considering these values such that V_B and i_B do not change as to be previous gain should be same

there's very little change in the bandwidth which can be adjusted by changing frequencey dependent Impedences silghty but not by huge Value.

In conclusion,

$R_1 = 30k\Omega$

$R_2 = 10.45k\Omega$

$R_C = 10k\Omega$

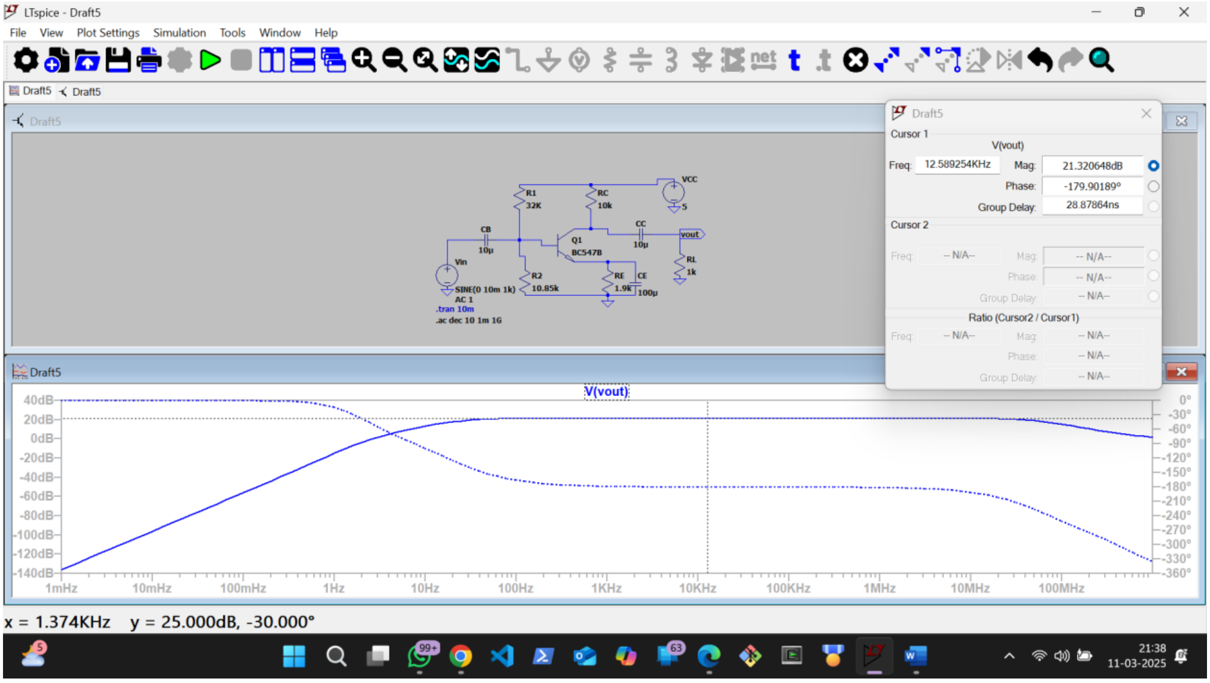
$R_L = 1k\Omega$

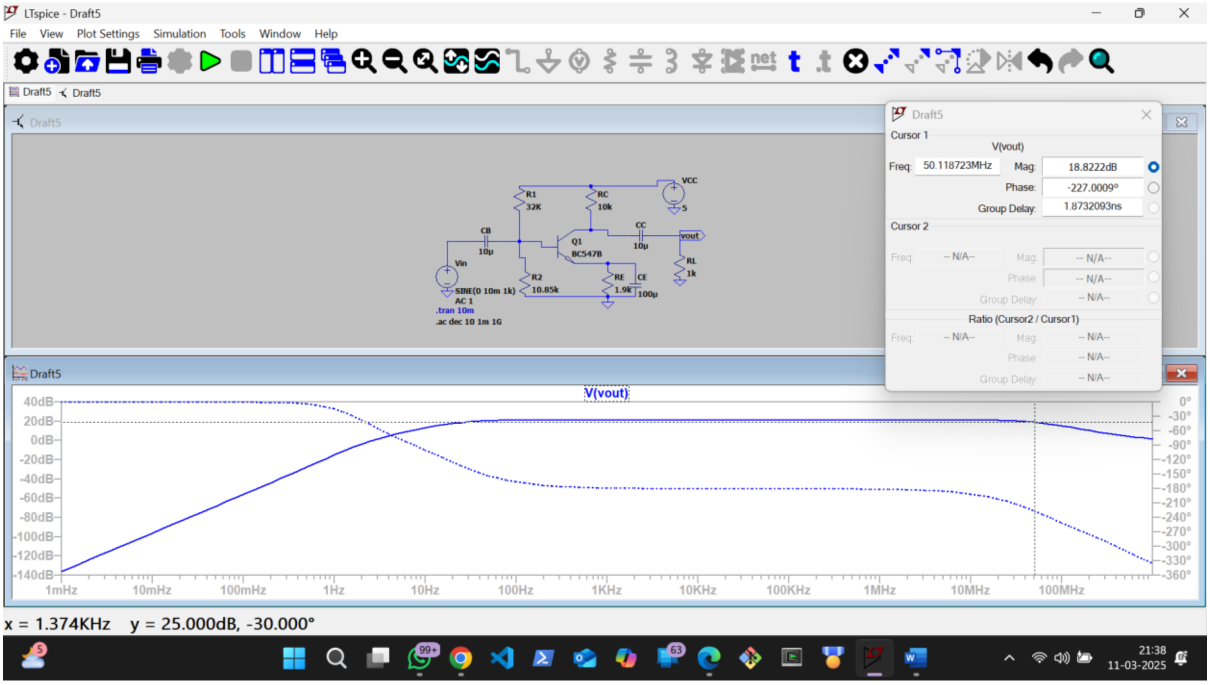
$R_E = 2k\Omega$

$C_E = 100\mu F$

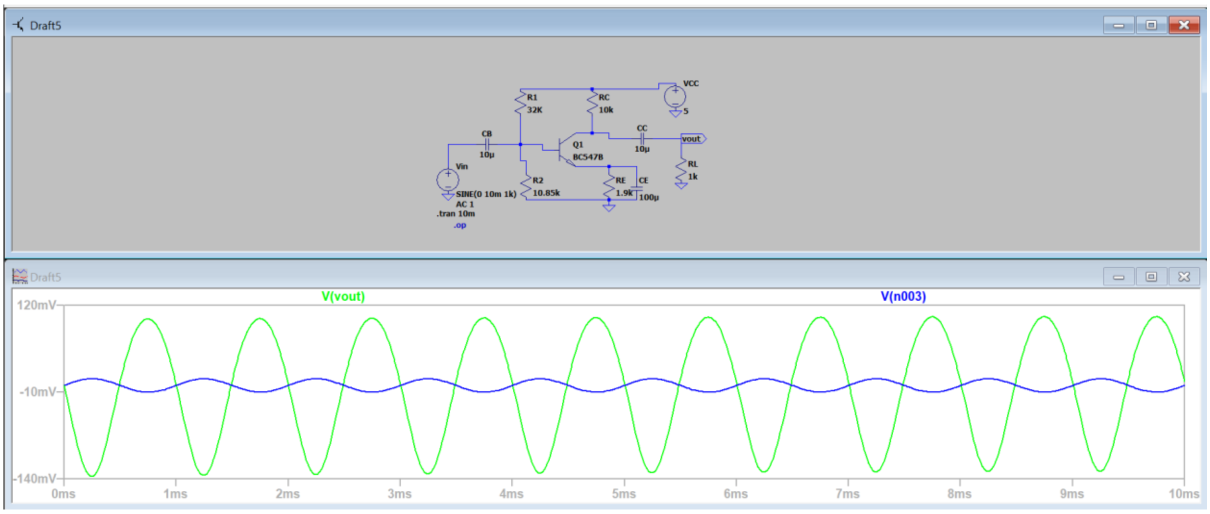
$C_B = 10\mu F$

$C_C = 10\mu F$


LTspice - Draft5
File View Plot Settings Simulation Tools Window Help
Draft5
Cursor 1
V(vout)
Freq: 12.589254KHz
Mag: 21.320648dB
Phase: -179.90189°
Group Delay: 28.87864ns
Cursor 2
Ratio (Cursor2 / Cursor1)
R1 32K
RC 10k
VCC 5
CB 10µ
CC 10µ
Q1 BC547B
vout
RL 1k
Vin
SINE(0 10m 1k)
AC 1
R2 10.85k
RE 1.9k
CE 100µ
.tran 10m
.ac dec 10 1m 1G
V(vout)
x = 1.374KHz y = 25.000dB, -30.000°
21:38
11-03-2025


LTspice - Draft5
File View Plot Settings Simulation Tools Window Help
Draft5
Cursor 1
V(vout)
Freq: 50.118723MHz
Mag: 18.8222dB
Phase: -227.0009°
Group Delay: 1.8732093ns
Cursor 2
Ratio (Cursor2 / Cursor1)
R1 32K
RC 10k
VCC 5
CB 10µ
CC 10µ
Q1 BC547B
vout
RL 1k
Vin
SINE(0 10m 1k)
AC 1
R2 10.85k
RE 1.9k
CE 100µ
.tran 10m
.ac dec 10 1m 1G
V(vout)
x = 1.374KHz y = 25.000dB, -30.000°
21:38
11-03-2025

V(n001):	5	voltage
V(n004):	1.25639	voltage
V(n005):	0.646256	voltage
V(n002):	1.61057	voltage
V(vout):	1.61057e-14	voltage
V(n003):	0	voltage
Ic(Q1):	0.000338943	device_current
Ib(Q1):	1.19143e-06	device_current
Ie(Q1):	-0.000340135	device_current
I(Cc):	-1.61057e-17	device_current
I(Cb):	1.25639e-17	device_current
I(Ce):	6.46256e-17	device_current
I(R1):	0.000116988	device_current
I(R2):	0.000115796	device_current
I(Re):	0.000340135	device_current
I(Rc):	0.000338943	device_current
I(Rl):	1.61057e-17	device_current
I(Vcc):	-0.000455931	device_current
I(Vin):	1.25639e-17	device_current



The DC power of the amplifier is

For VCC = 5V P_{DC}= Vcc*(Ic+(Vcc-Vb)*R1)=2.31mW

For VCC=12V P_{DC}= Vcc*(Ic+(Vcc-Vb)*R1)=11mW

The net effective current is taken from (.op) I(VCC):in both the pictures.

at

Let $I_{B_1} = 60\mu A$

Since slope is same

WKT, given

slope $= I_C / (V_A + V_{CE})$ equating slopes.

at 5V $\Rightarrow \frac{13.88}{V_A + 5V} = \frac{14.94}{V_A + 10V}$ at 10V

$14.94 V_A - 13.88 V_A + 5 \times 14.94 = 10 \times 13.88$

$1.06 V_A = 64.1$

$V_A = 60.47$ approx (60)

(3.2) from the graph.

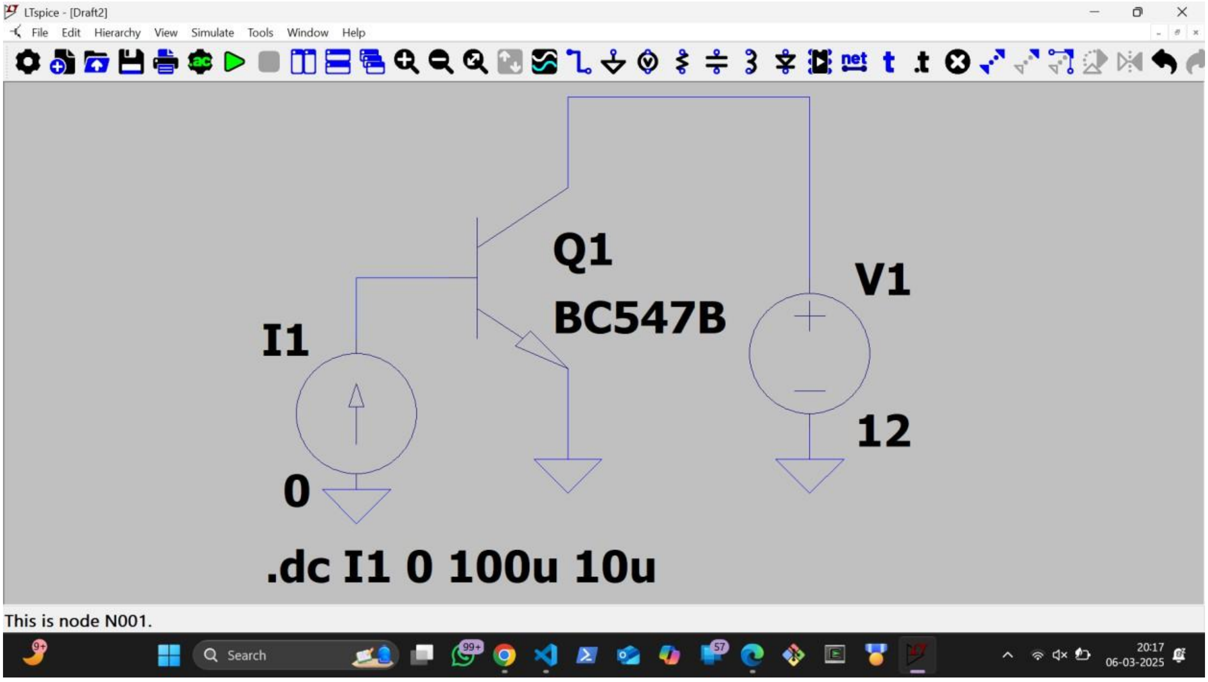
V_{BE} decreases -1.6 to $-2mV$ per °C is almost linear.

(3.1) from plot we get EBJ (Emitter base J^n)

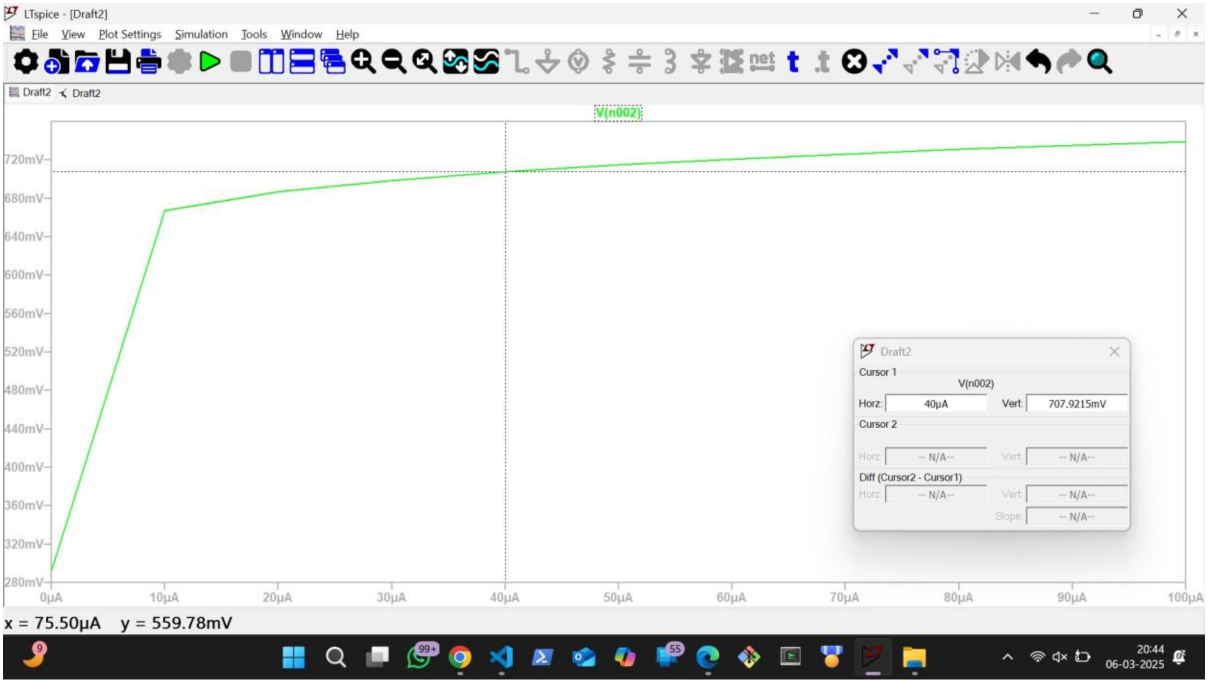
- voltage to be about 700-740 mV

from above plots for BJT in active/ saturation we need to have V_{BE} greater than the EBJ voltage

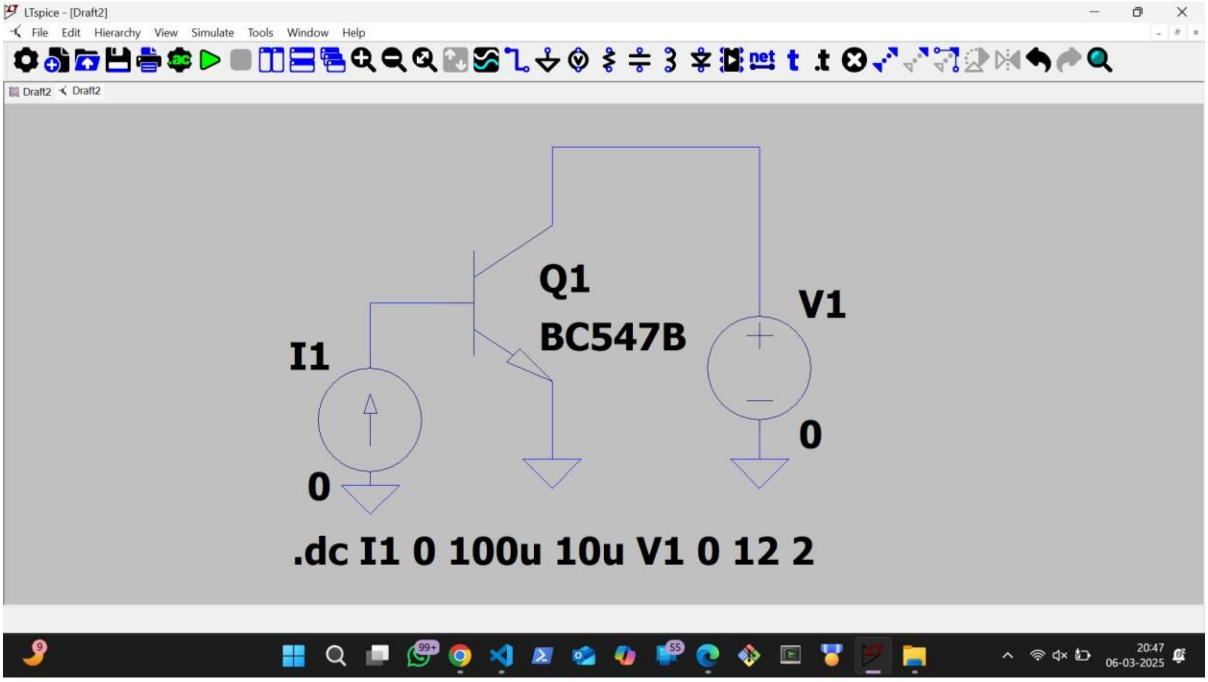
Q-3.1

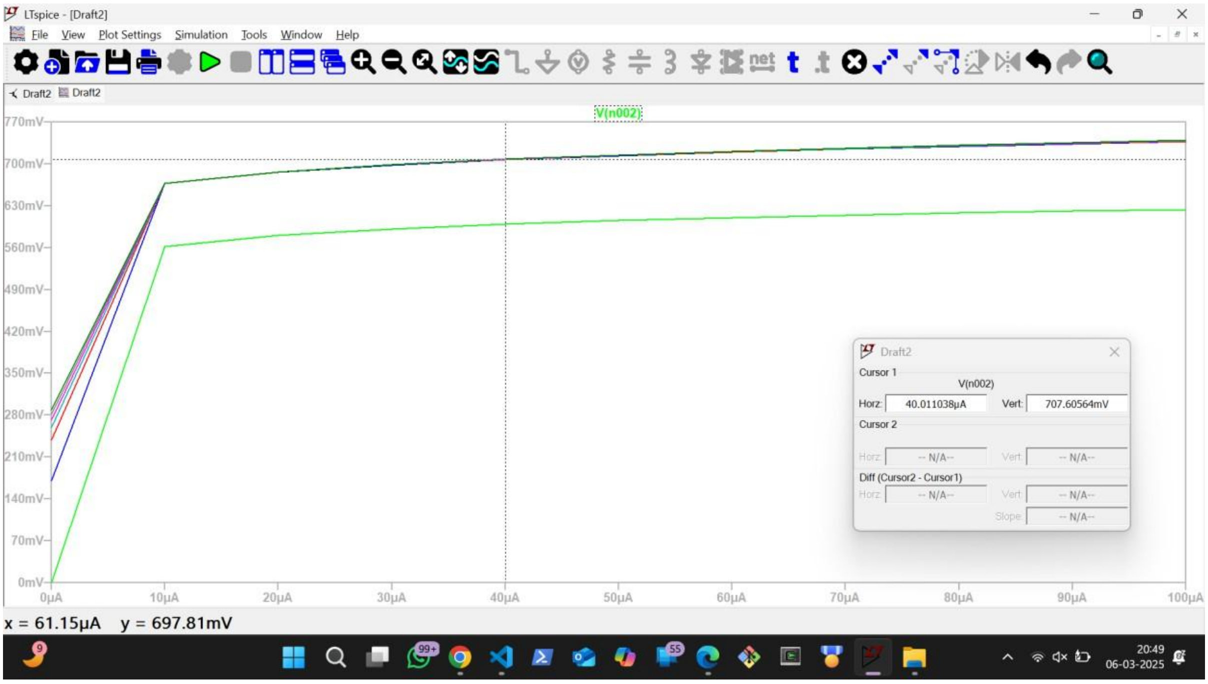


LTspice - [Draft2]
File Edit Hierarchy View Simulate Tools Window Help
Q1
BC547B
V1
I1
12
0
.dc I1 0 100u 10u
This is node N001.

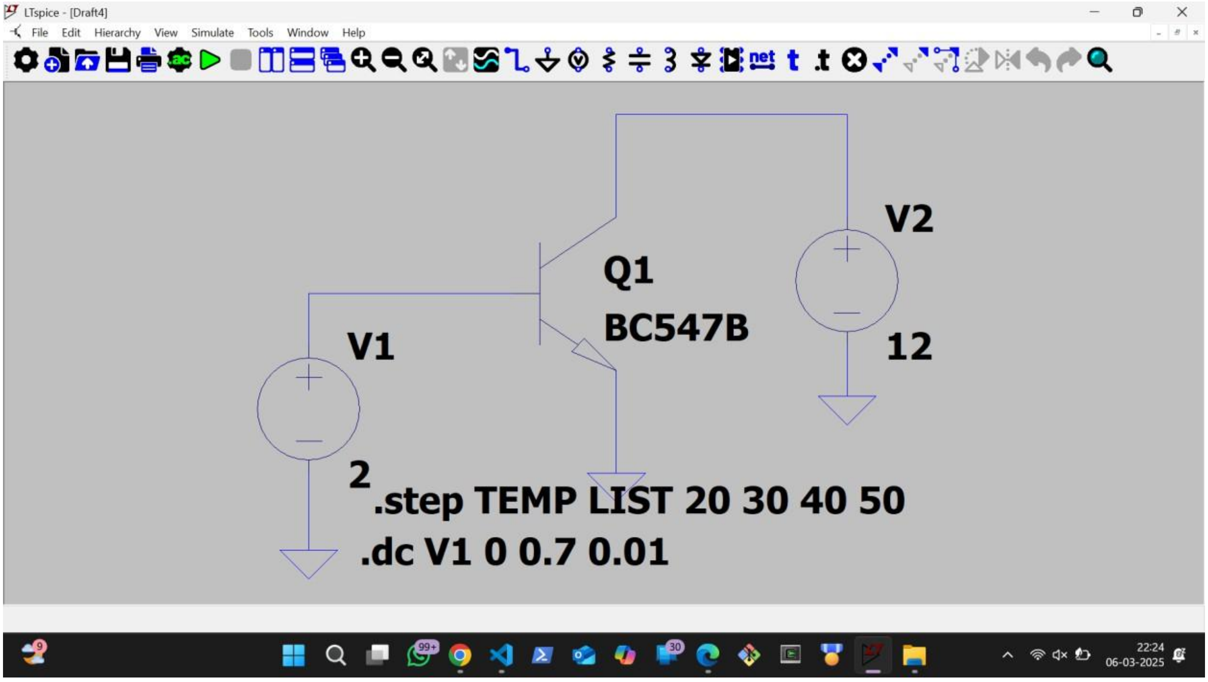


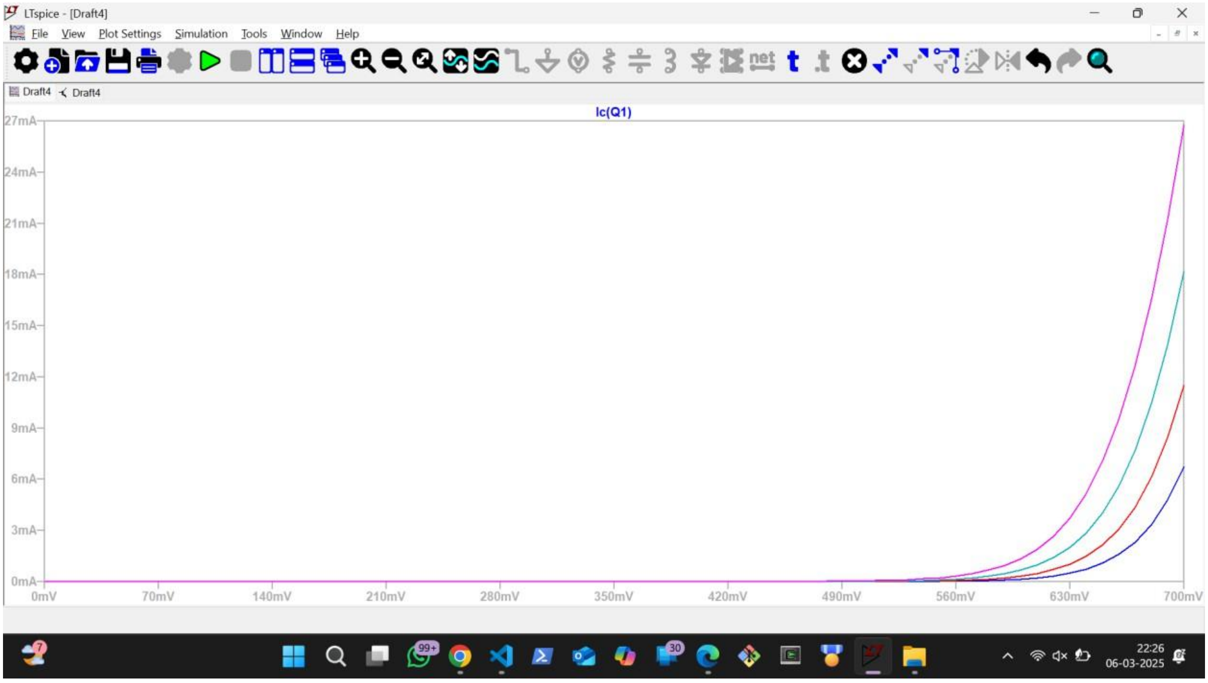
LTspice - [Draft2]
File View Plot Settings Simulation Tools Window Help
V(n002)
720mV
680mV
640mV
600mV
560mV
520mV
480mV
440mV
400mV
360mV
320mV
280mV
0µA
10µA
20µA
30µA
40µA
50µA
60µA
70µA
80µA
90µA
100µA
Draft2
Cursor 1
V(n002)
Horz: 40µA
Vert: 707.9215mV
Cursor 2
Diff (Cursor2 - Cursor1)
x = 75.50µA y = 559.78mV


LTspice - [Draft2]
Q1
BC547B
V1
I1
0
0
0
.dc I1 0 100u 10u V1 0 12 2


LTspice - [Draft2]
V(n002)
Cursor 1
Horz: 40.011038µA
Vert: 707.60564mV
Cursor 2
Diff (Cursor2 - Cursor1)
x = 61.15µA y = 697.81mV

Q-3.2


LTspice - [Draft4]
File Edit Hierarchy View Simulate Tools Window Help
V2
Q1
BC547B
V1
12
2
.step TEMP LIST 20 30 40 50
.dc V1 0 0.7 0.01
22:24
06-03-2025


LTspice - [Draft4]
File View Plot Settings Simulation Tools Window Help
Draft4 Draft4
Ic(Q1)
27mA
24mA
21mA
18mA
15mA
12mA
9mA
6mA
3mA
0mA
0mV
70mV
140mV
210mV
280mV
350mV
420mV
490mV
560mV
630mV
700mV
22:26
06-03-2025

(3.3) * below 0·24 is deep saturation $I_C \approx 0$ goes to cutoff

* forward active (0·65 – 0·71) * (0·25 – 0·26) saturation to 0·30

S.No	V_{CE}	$(I_{B_1})_1$	$(I_{B_1})_2$	$(I_{C_1})_1$	$(I_{C_2})_1$	ΔI_C	ΔI_B	β
1	100mV	50μA	60μA	5.34mA	6.21mA	0.87mA	10μA	87
2	600mV	50μA	60μA	12.95	15.29	2.34mA	10μA	234

β at saturation (100mV) 87

β at active (600mV) 234

Incremental.

Difference observed b/w β at different V_{CE} (sat to active) because collector goes into reversed bias while V_{CE} going from saturation to active mode

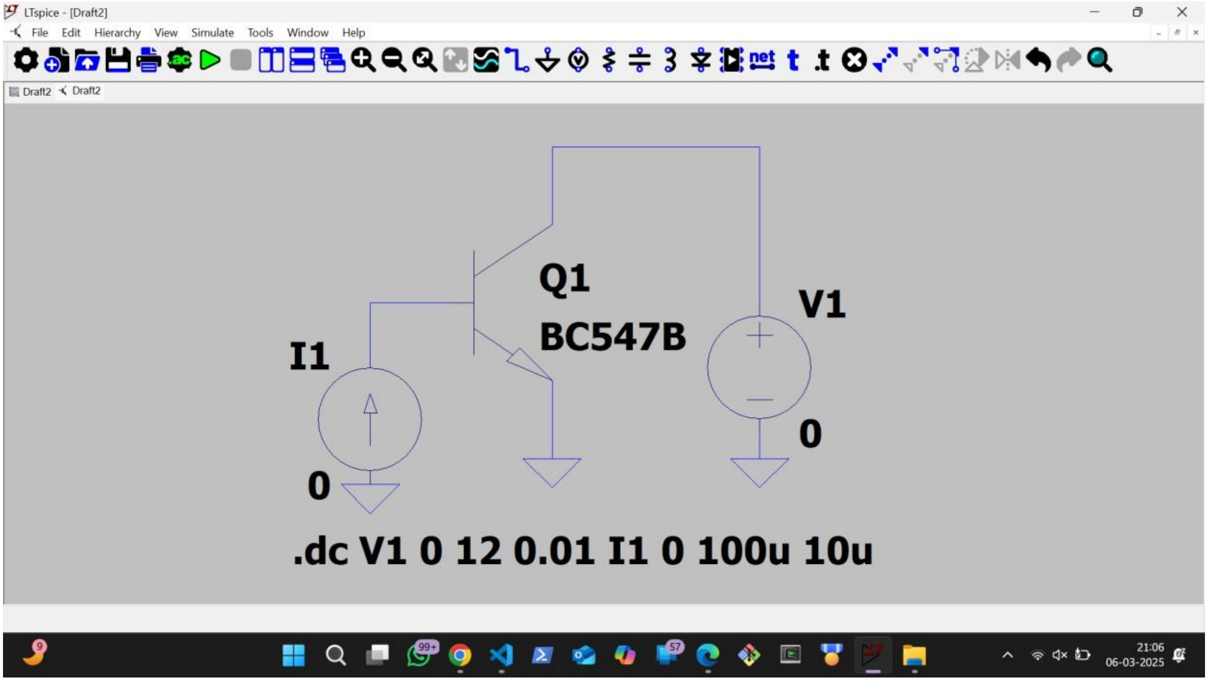
V_{CE}	I_C(mA)	I_B(μA)	$\beta = \frac{I_C}{I_B}$
1V	-178.68	0	—
1V	2.8	10	280
1V	5.5	20	275
1V	8.1	30	270
1V	10.61	40	265
1V	13.04	50	260
1V	15.39	60	256
1V	17.68	70	252
1V	19.91	80	248
1V	22.09	90	245
1V	24.2	100	242

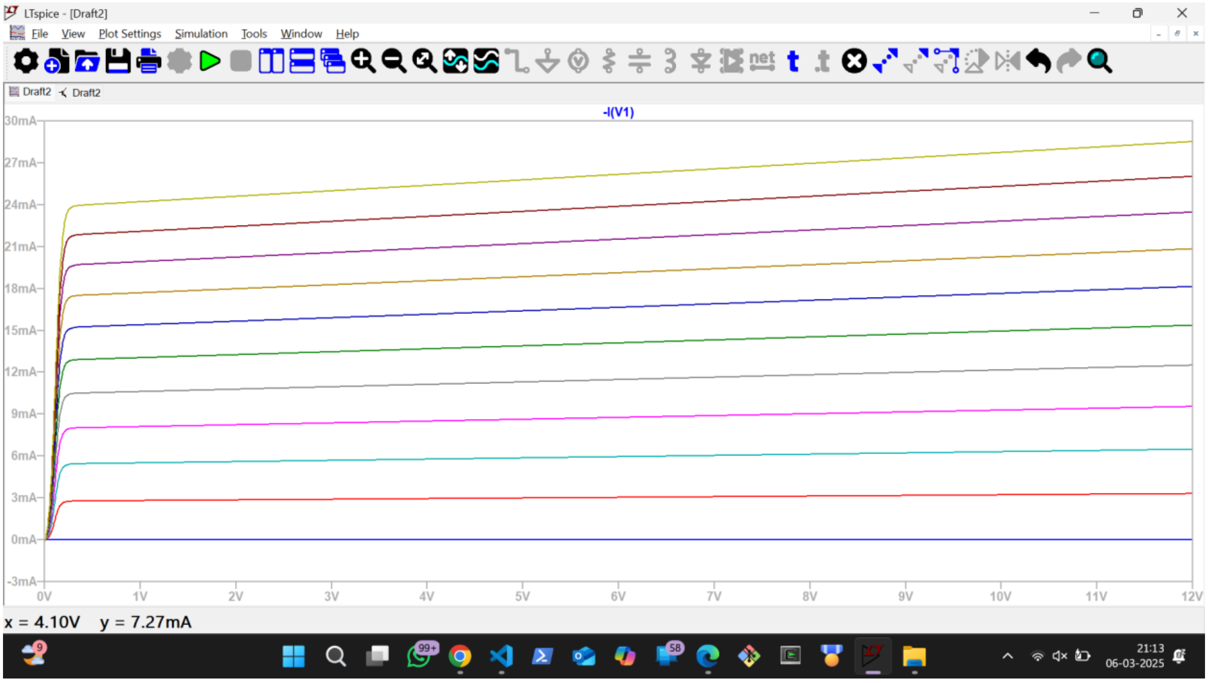
Then $I_B\downarrow$ and there by $\uparrow \beta = \frac{I_C}{I_B\downarrow}$

Hence β increases

Yes, Early effect is observed (Base-width modulation) causes β to increase as VCE $\uparrow$es as since higher VCE reduces the base width, so, IC increases in very small amount.

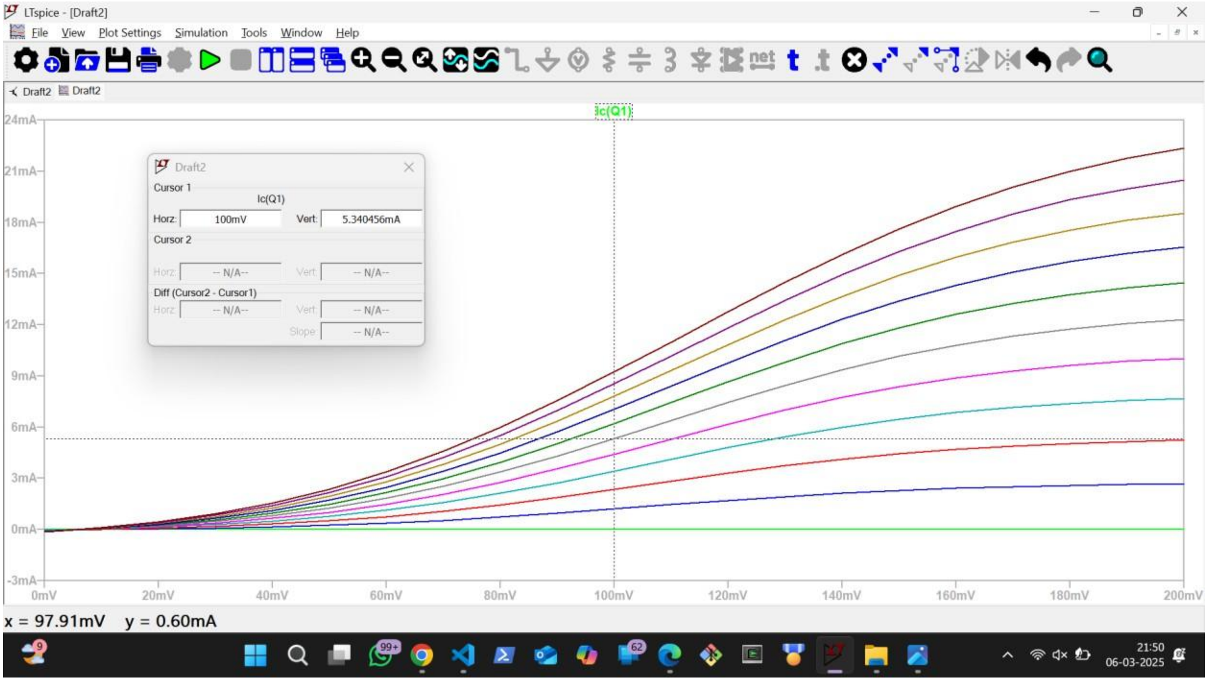
Q-3.3

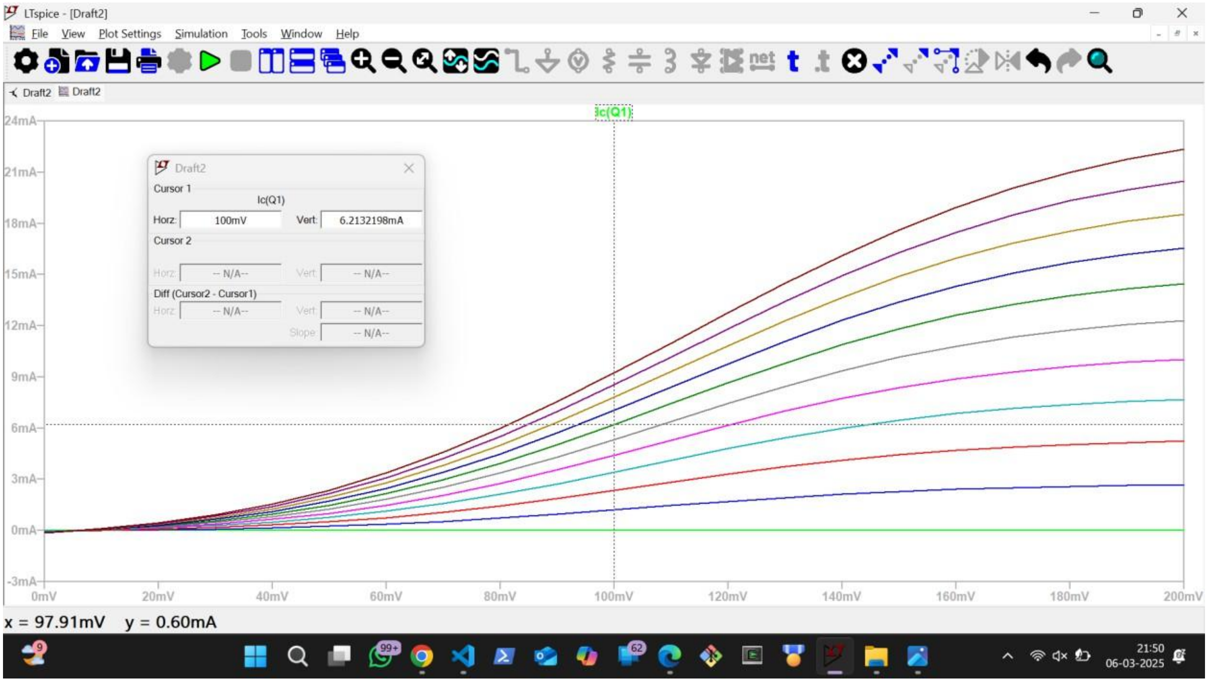

LTspice - [Draft2]
File Edit Hierarchy View Simulate Tools Window Help
Draft2 Draft2
Q1
BC547B
V1
I1
0
0
.dc V1 0 12 0.01 I1 0 100u 10u
21:06
06-03-2025


LTspice - [Draft2]
File View Plot Settings Simulation Tools Window Help
Draft2 Draft2
-I(V1)
30mA
27mA
24mA
21mA
18mA
15mA
12mA
9mA
6mA
3mA
0mA
-3mA
0V
1V
2V
3V
4V
5V
6V
7V
8V
9V
10V
11V
12V
x = 4.10V y = 7.27mA
21:13
06-03-2025

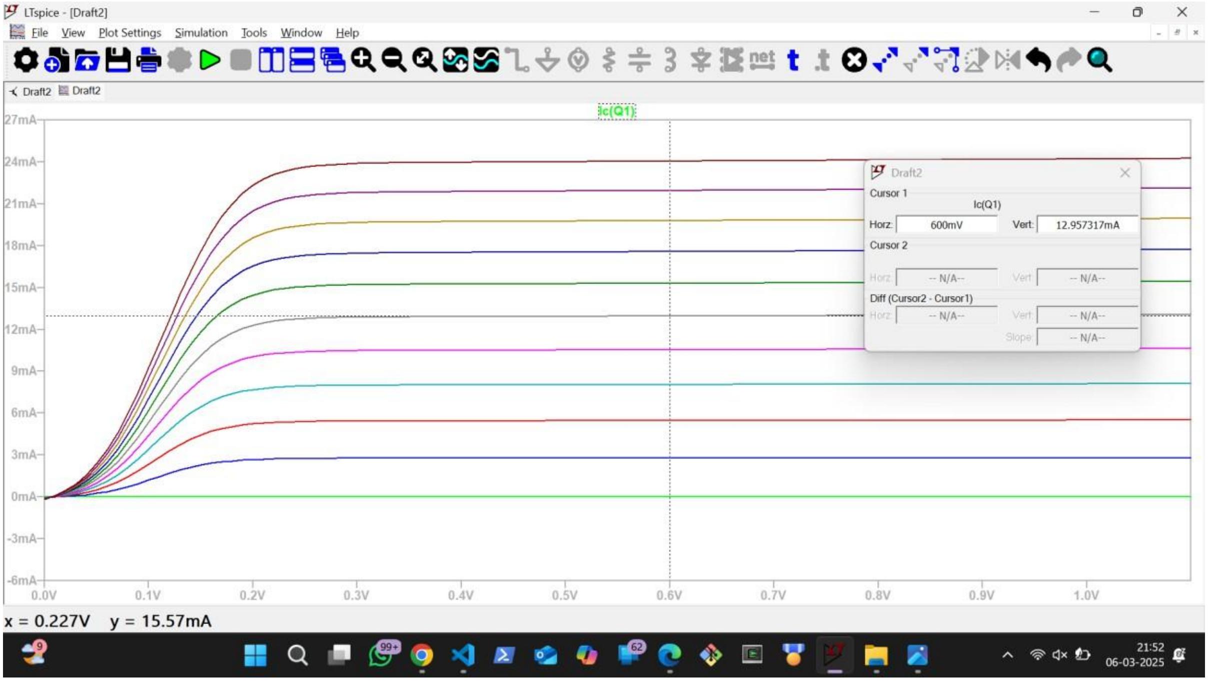
Calculation of beta(β) by change in currents of Ic and Ib at 50uA and 60uA

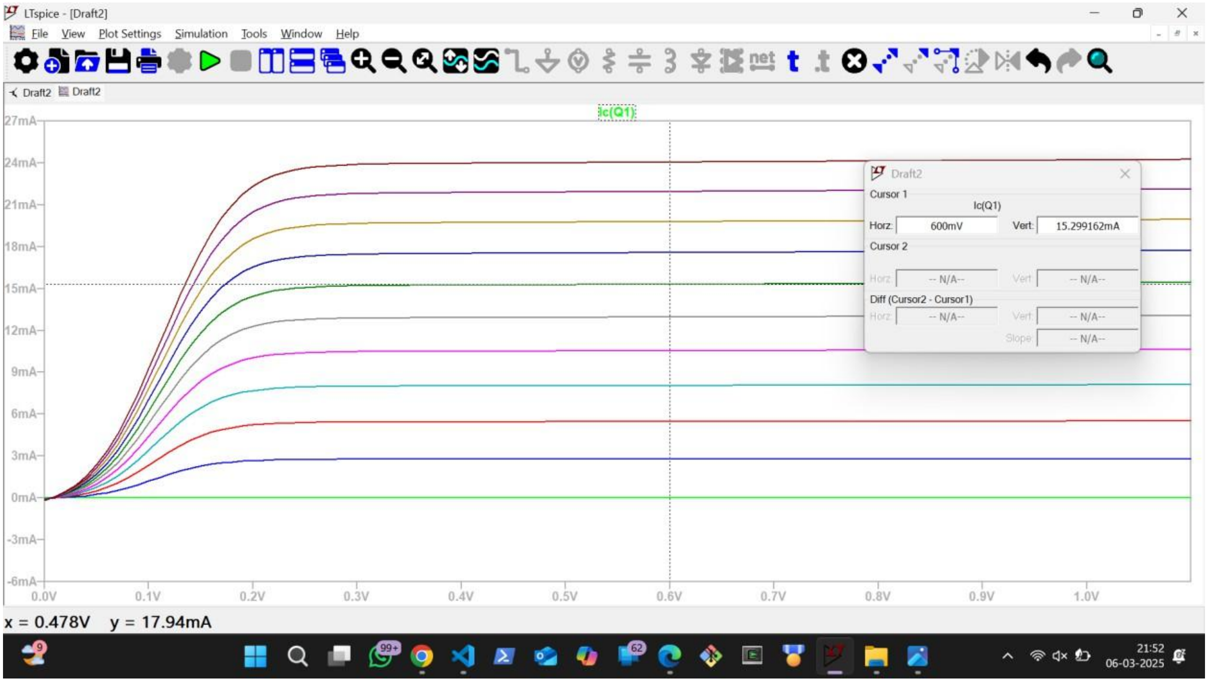
At 100mV



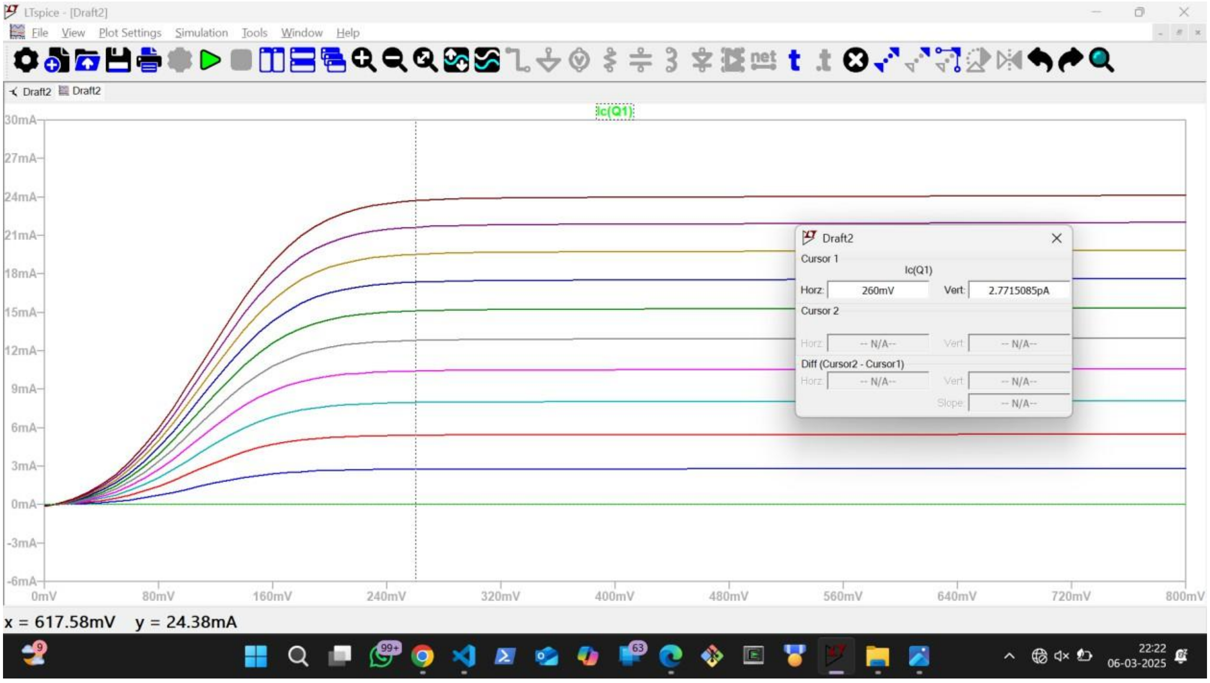


At 600mV


LTspice - [Draft2]
File View Plot Settings Simulation Tools Window Help
Ic(Q1)
Draft2
Cursor 1
Ic(Q1)
Horz: 600mV
Vert: 12.957317mA
Cursor 2
Diff (Cursor2 - Cursor1)
x = 0.227V y = 15.57mA
21:52
06-03-2025


LTspice - [Draft2]
File View Plot Settings Simulation Tools Window Help
Ic(Q1)
Draft2
Cursor 1
Ic(Q1)
Horz: 600mV
Vert: 15.299162mA
Cursor 2
Diff (Cursor2 - Cursor1)
x = 0.478V y = 17.94mA
21:52
06-03-2025

Saturation and Active mode mark

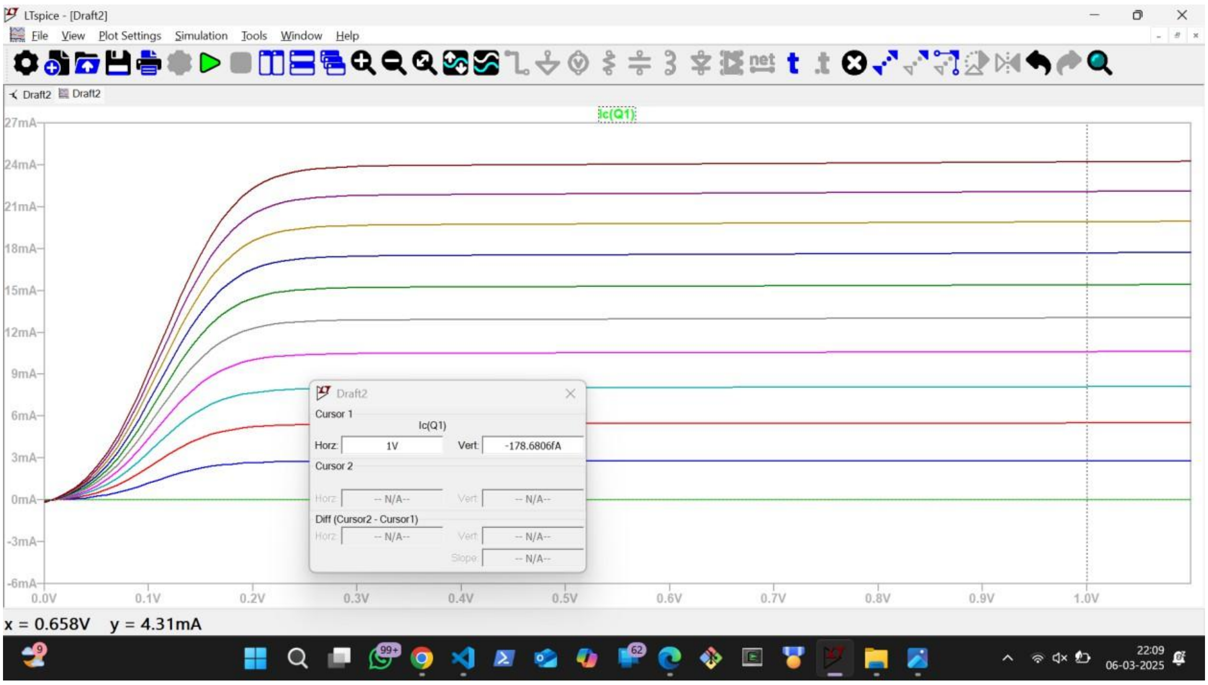


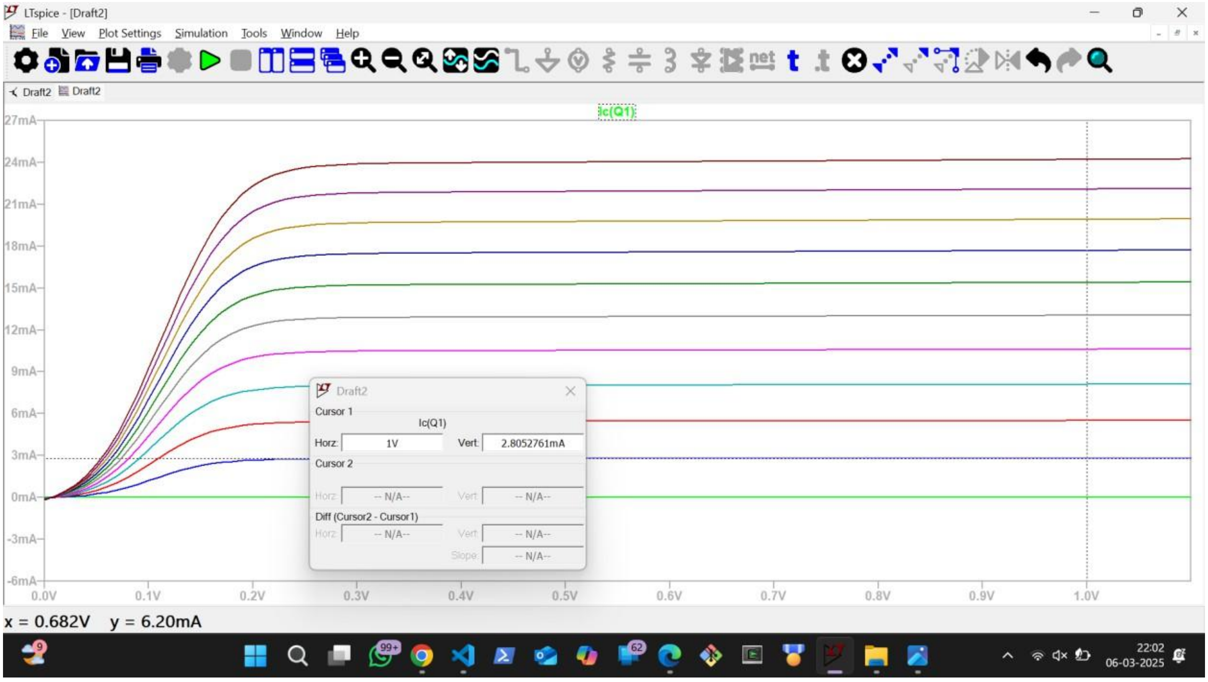
220mV-260mV-300mV saturation

Above it is active mode

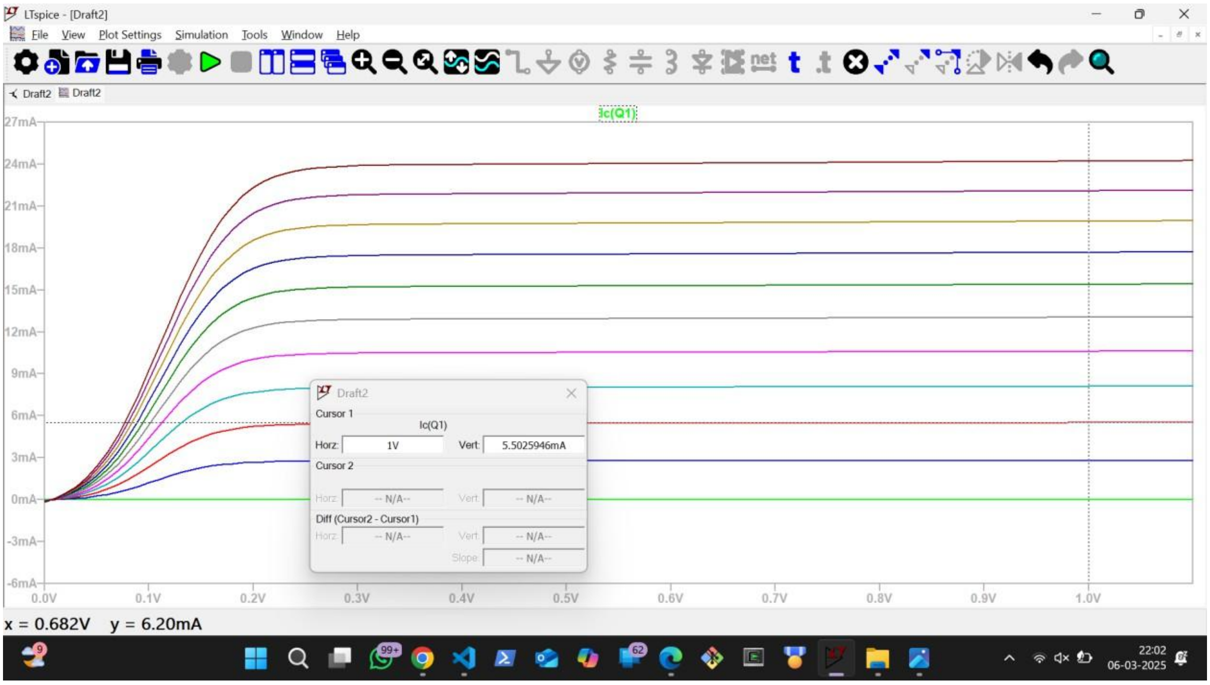
Below it is Ic~0 and cutoff mode

Tabulating β at 1V by Ic and Ib

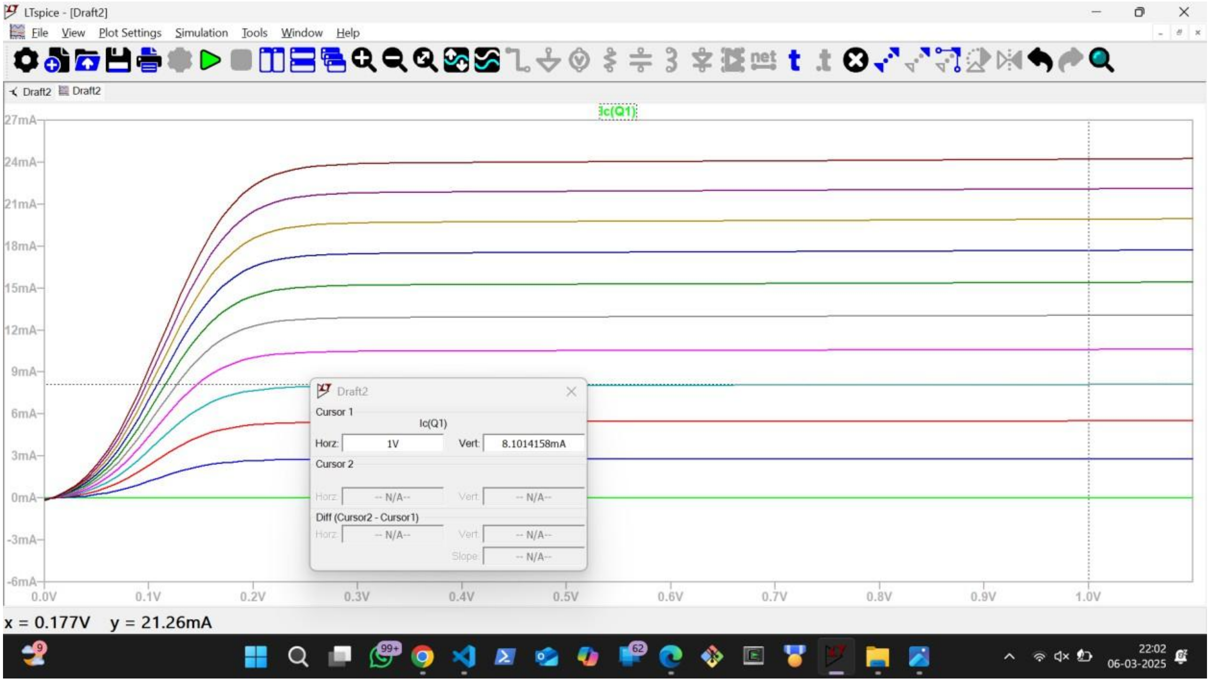


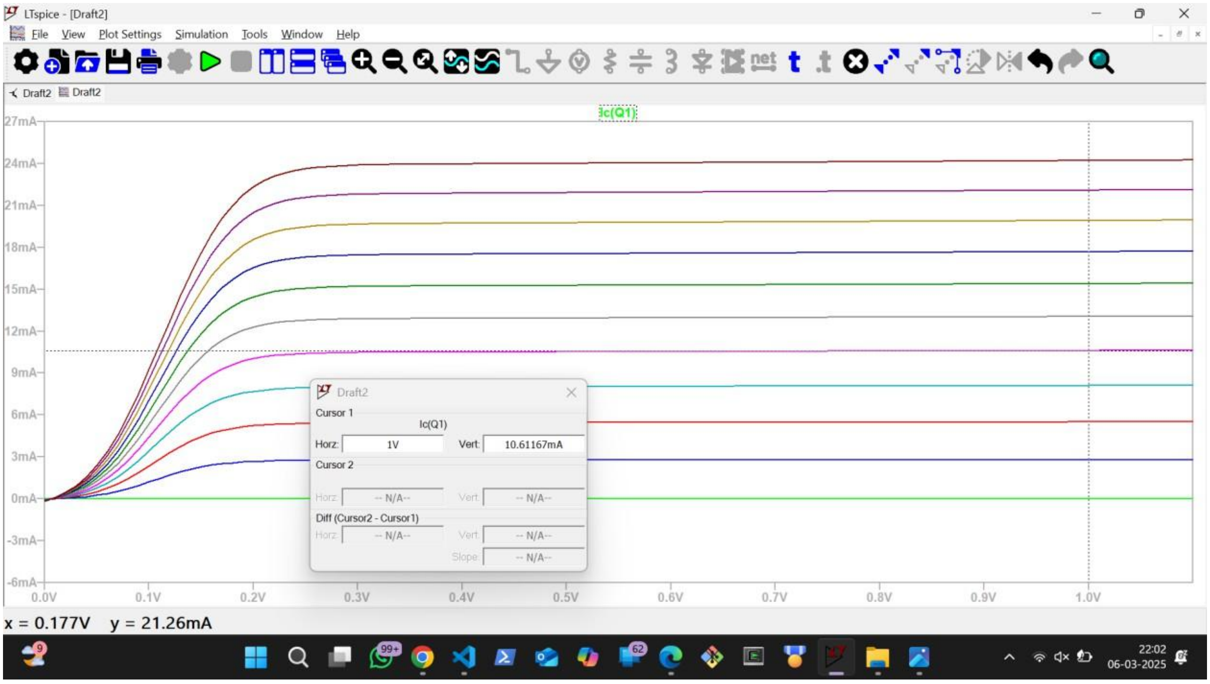


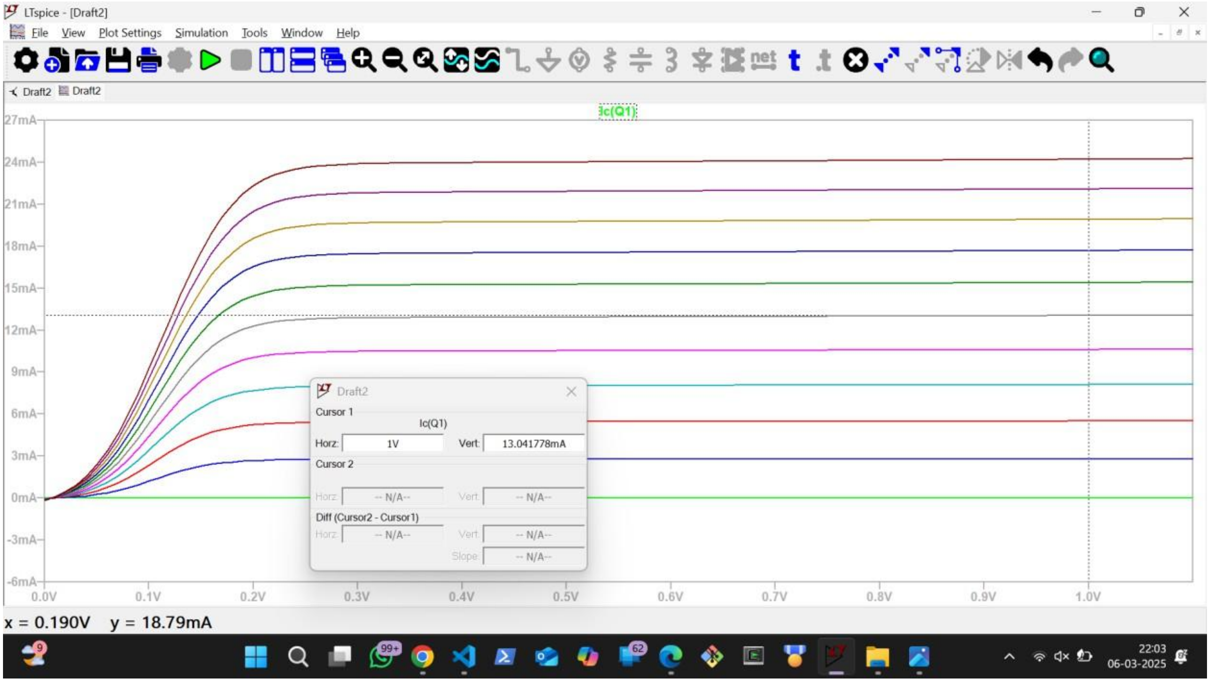
LTspice - [Draft2]
File View Plot Settings Simulation Tools Window Help
Ic(Q1)
27mA
24mA
21mA
18mA
15mA
12mA
9mA
6mA
3mA
0mA
-3mA
-6mA
0.0V 0.1V 0.2V 0.3V 0.4V 0.5V 0.6V 0.7V 0.8V 0.9V 1.0V
Draft2
Cursor 1
Ic(Q1)
Horz: 1V
Vert: 2.8052761mA
Cursor 2
Diff (Cursor2 - Cursor1)
x = 0.682V y = 6.20mA
22:02
06-03-2025

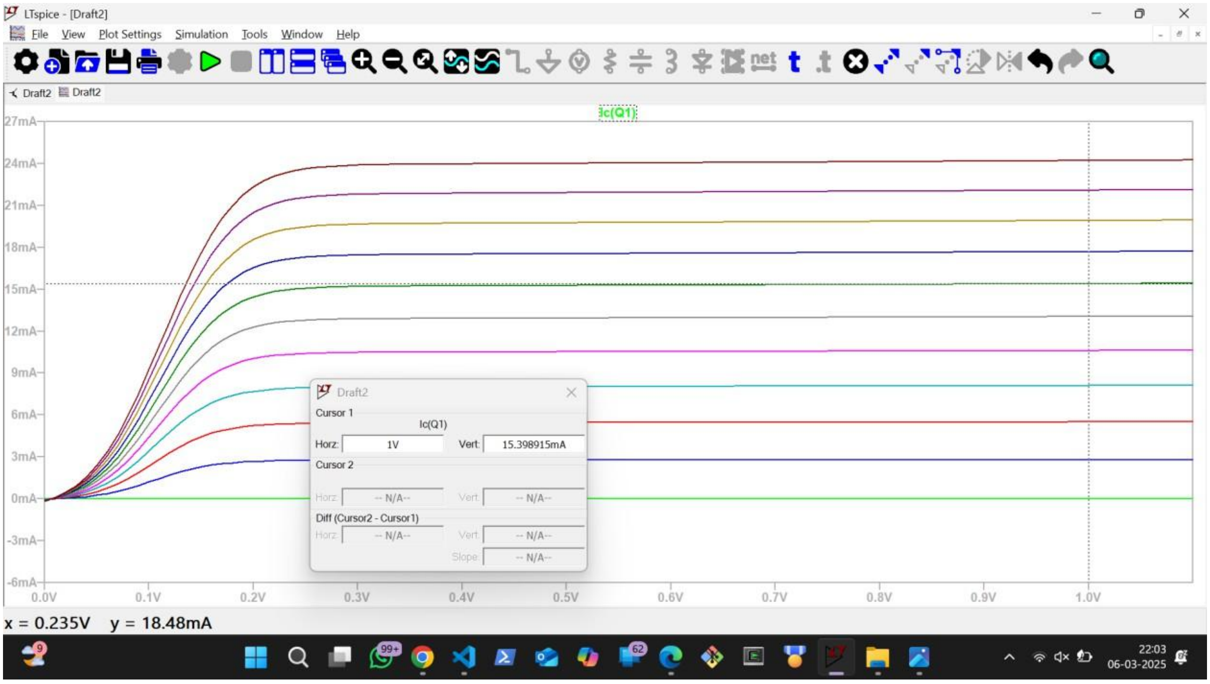


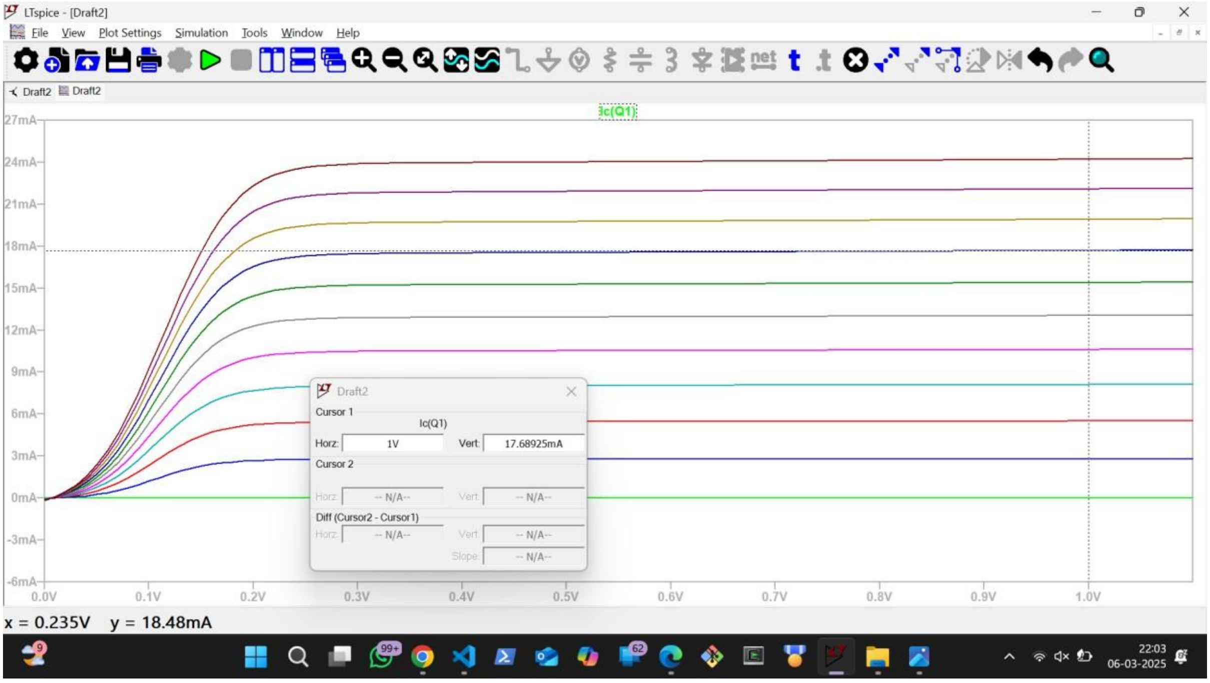
LTspice - [Draft2]
File View Plot Settings Simulation Tools Window Help
Ic(Q1)
27mA
24mA
21mA
18mA
15mA
12mA
9mA
6mA
3mA
0mA
-3mA
-6mA
0.0V 0.1V 0.2V 0.3V 0.4V 0.5V 0.6V 0.7V 0.8V 0.9V 1.0V
Draft2
Cursor 1
Ic(Q1)
Horz: 1V
Vert: 5.5025946mA
Cursor 2
Diff (Cursor2 - Cursor1)
x = 0.682V y = 6.20mA
22:02
06-03-2025


LTspice - [Draft2]
File View Plot Settings Simulation Tools Window Help
Draft2 Draft2
Ic(Q1)
27mA
24mA
21mA
18mA
15mA
12mA
9mA
6mA
3mA
0mA
-3mA
-6mA
0.0V
0.1V
0.2V
0.3V
0.4V
0.5V
0.6V
0.7V
0.8V
0.9V
1.0V
Draft2
Cursor 1
Ic(Q1)
Horz: 1V
Vert: 8.1014158mA
Cursor 2
Horz: -- N/A--
Vert: -- N/A--
Diff (Cursor2 - Cursor1)
Horz: -- N/A--
Vert: -- N/A--
Slope: -- N/A--
x = 0.177V y = 21.26mA
22:02
06-03-2025

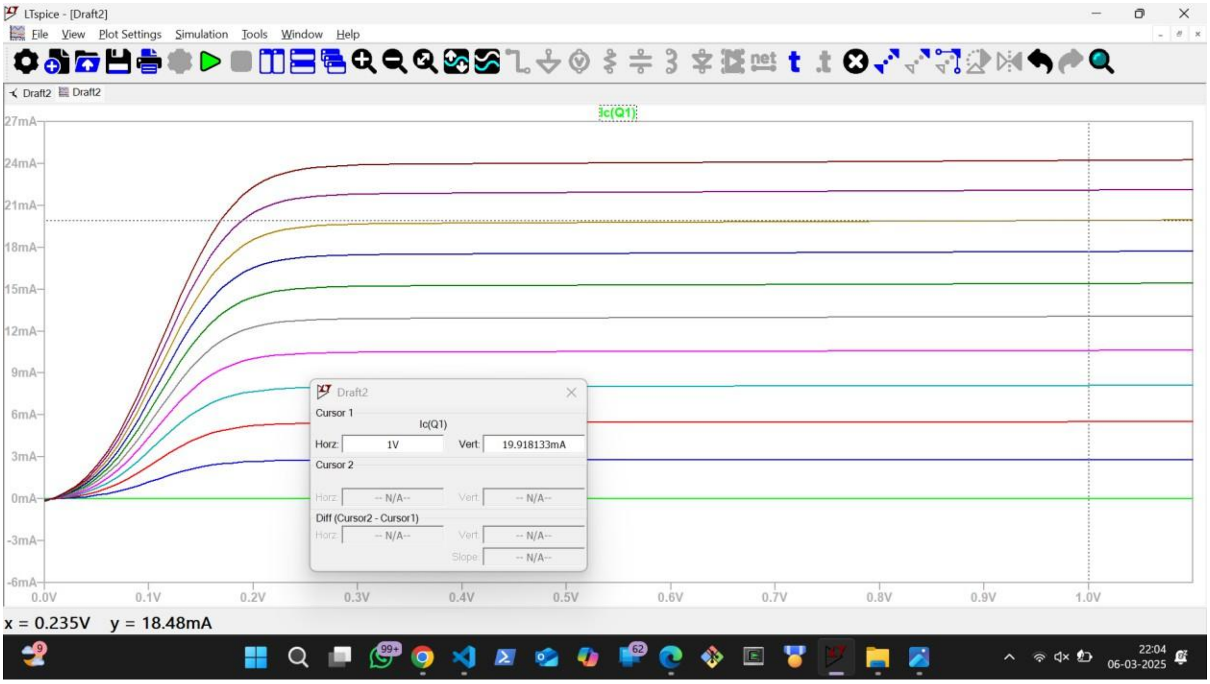

LTspice - [Draft2]
File View Plot Settings Simulation Tools Window Help
Draft2 Draft2
Ic(Q1)
27mA
24mA
21mA
18mA
15mA
12mA
9mA
6mA
3mA
0mA
-3mA
-6mA
0.0V
0.1V
0.2V
0.3V
0.4V
0.5V
0.6V
0.7V
0.8V
0.9V
1.0V
Draft2
Cursor 1
Ic(Q1)
Horz: 1V
Vert: 10.61167mA
Cursor 2
Horz: -- N/A--
Vert: -- N/A--
Diff (Cursor2 - Cursor1)
Horz: -- N/A--
Vert: -- N/A--
Slope: -- N/A--
x = 0.177V y = 21.26mA
22:02
06-03-2025


LTspice - [Draft2]
File View Plot Settings Simulation Tools Window Help
Draft2 Draft2
Ic(Q1)
27mA
24mA
21mA
18mA
15mA
12mA
9mA
6mA
3mA
0mA
-3mA
-6mA
0.0V 0.1V 0.2V 0.3V 0.4V 0.5V 0.6V 0.7V 0.8V 0.9V 1.0V
Draft2
Cursor 1
Ic(Q1)
Horz: 1V
Vert: 13.041778mA
Cursor 2
Horz: -- N/A--
Vert: -- N/A--
Diff (Cursor2 - Cursor1)
Horz: -- N/A--
Vert: -- N/A--
Slope: -- N/A--
x = 0.190V y = 18.79mA
22:03
06-03-2025

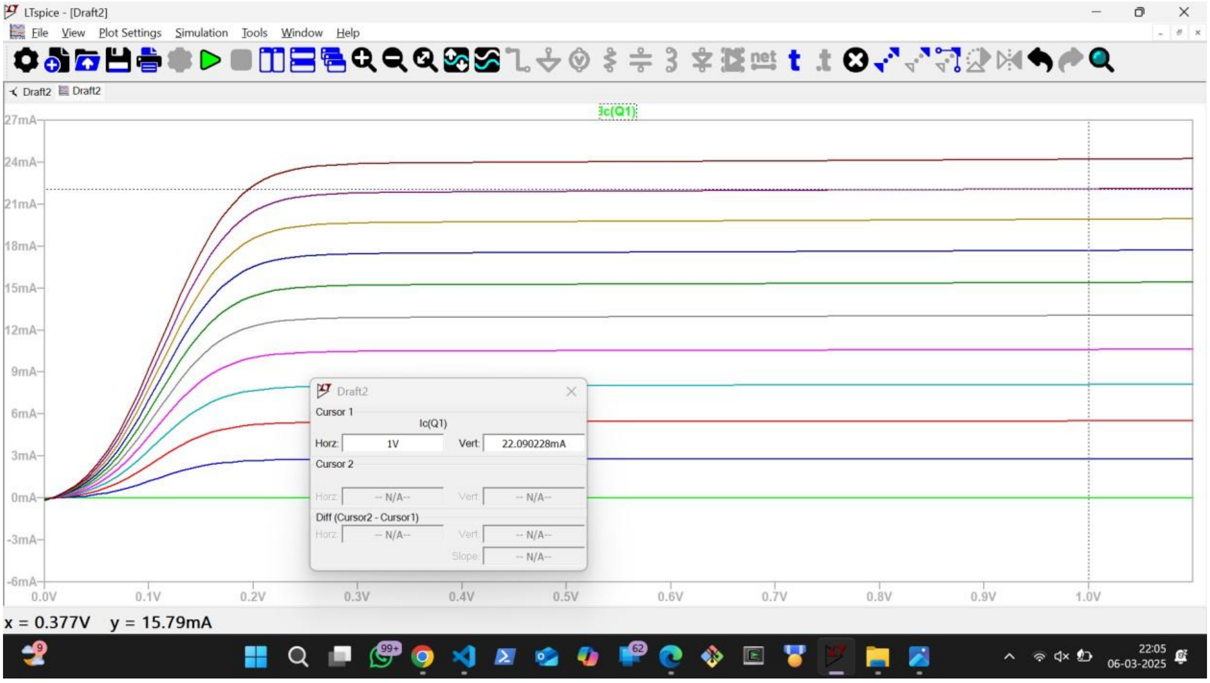

LTspice - [Draft2]
File View Plot Settings Simulation Tools Window Help
Draft2 Draft2
Ic(Q1)
27mA
24mA
21mA
18mA
15mA
12mA
9mA
6mA
3mA
0mA
-3mA
-6mA
0.0V 0.1V 0.2V 0.3V 0.4V 0.5V 0.6V 0.7V 0.8V 0.9V 1.0V
Draft2
Cursor 1
Ic(Q1)
Horz: 1V
Vert: 15.398915mA
Cursor 2
Horz: -- N/A--
Vert: -- N/A--
Diff (Cursor2 - Cursor1)
Horz: -- N/A--
Vert: -- N/A--
Slope: -- N/A--
x = 0.235V y = 18.48mA
22:03
06-03-2025

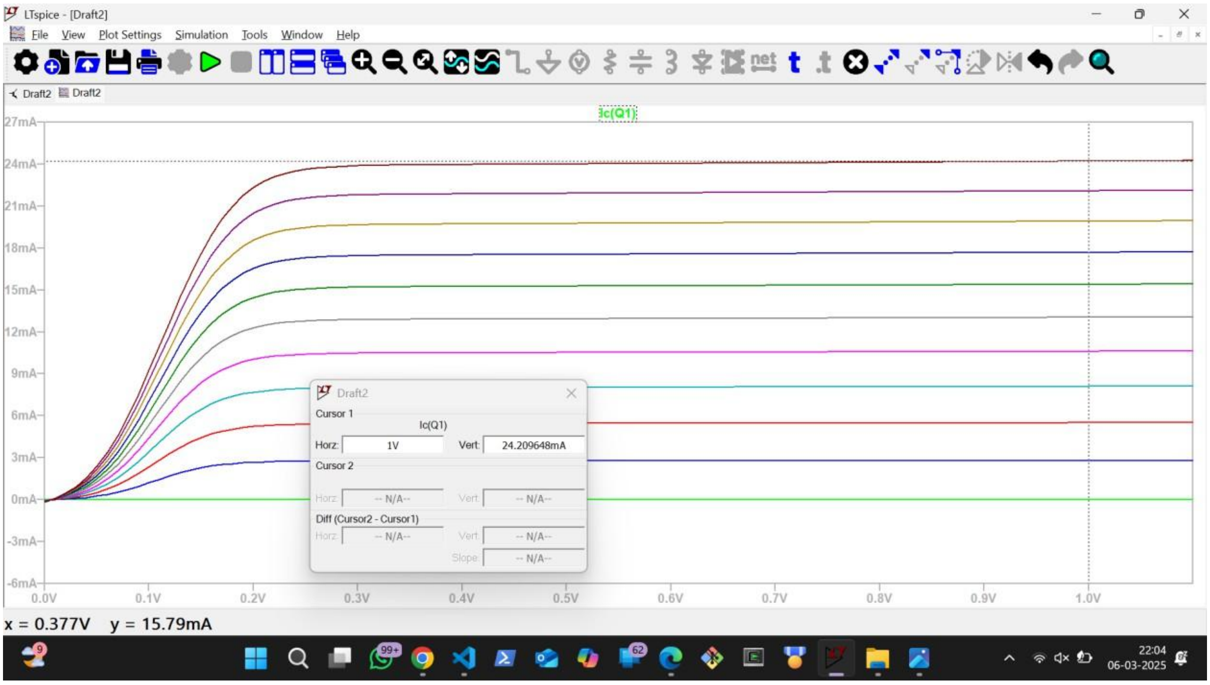


LTspice - [Draft2]
File View Plot Settings Simulation Tools Window Help
Draft2 Draft2
Ic(Q1)
27mA
24mA
21mA
18mA
15mA
12mA
9mA
6mA
3mA
0mA
-3mA
-6mA
0.0V 0.1V 0.2V 0.3V 0.4V 0.5V 0.6V 0.7V 0.8V 0.9V 1.0V
Draft2
Cursor 1
Ic(Q1)
Horz: 1V Vert: 17.68925mA
Cursor 2
Horz: -- N/A-- Vert: -- N/A--
Diff (Cursor2 - Cursor1)
Horz: -- N/A-- Vert: -- N/A--
Slope: -- N/A--
x = 0.235V y = 18.48mA
22:03
06-03-2025



LTspice - [Draft2]
File View Plot Settings Simulation Tools Window Help
Draft2 Draft2
Ic(Q1)
27mA
24mA
21mA
18mA
15mA
12mA
9mA
6mA
3mA
0mA
-3mA
-6mA
0.0V 0.1V 0.2V 0.3V 0.4V 0.5V 0.6V 0.7V 0.8V 0.9V 1.0V
Draft2
Cursor 1
Ic(Q1)
Horz: 1V Vert: 19.918133mA
Cursor 2
Horz: -- N/A-- Vert: -- N/A--
Diff (Cursor2 - Cursor1)
Horz: -- N/A-- Vert: -- N/A--
Slope: -- N/A--
x = 0.235V y = 18.48mA
22:04
06-03-2025





By these 11 values tabulated and calculated β

Early Voltage VA

VA is 60.47V