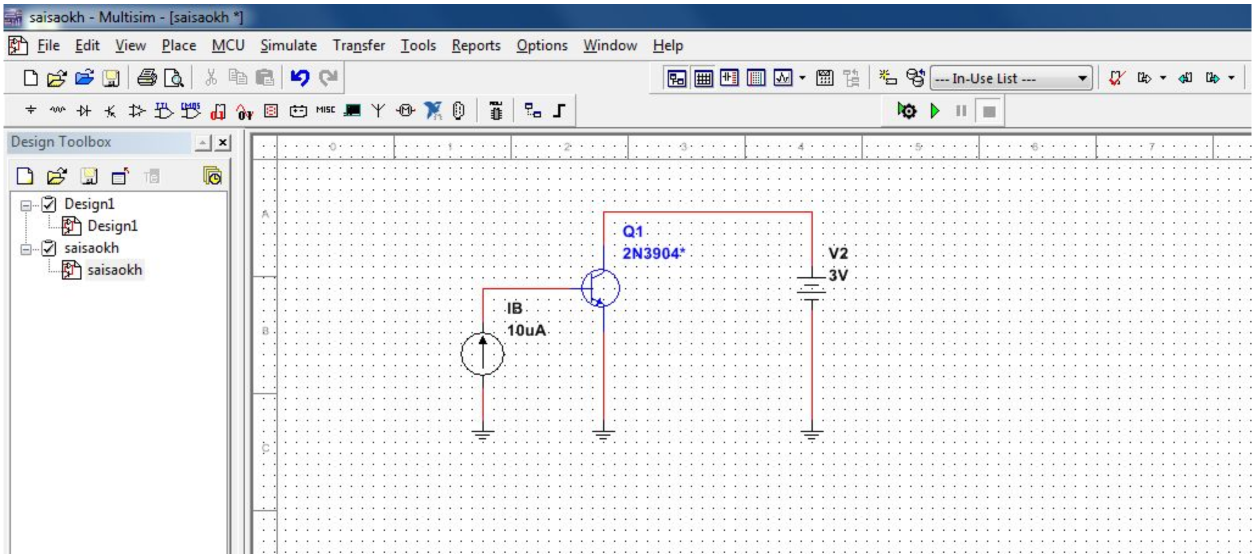
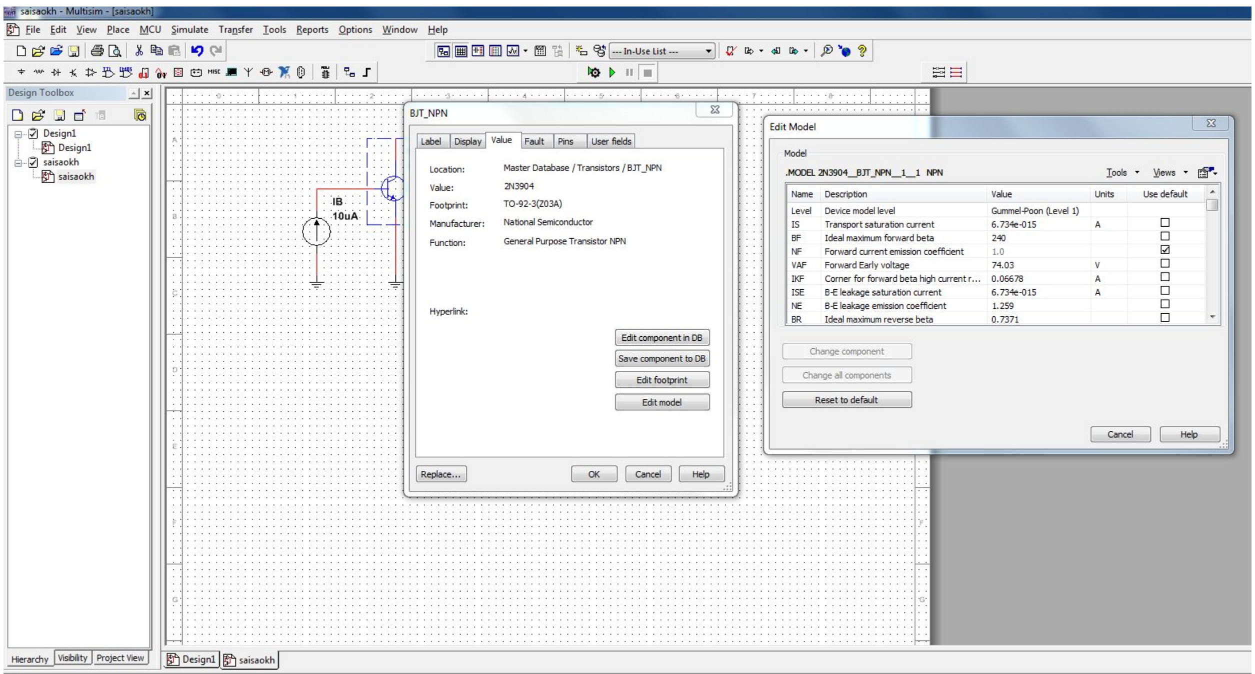
NAME:	SAI SAO KHAM (50168989)
INSTRUCTOR	DR. WIE
ASSIGNMENT	EE 310 SIMULATION 3
DUE DATE	OCT 25 2016 (Extended Nov 1 2016)
REC SESSION:	R6

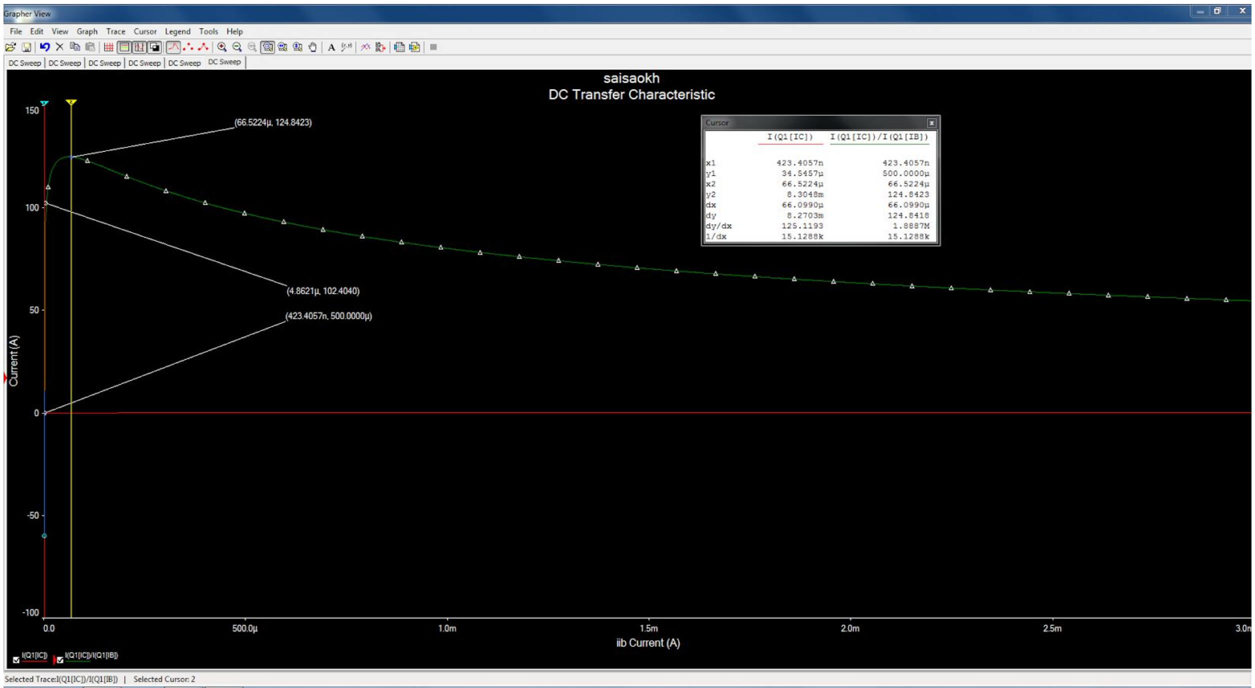
3A (PART1)

Schematic





Plot IC/IB (which is equals to beta dc) versus IC

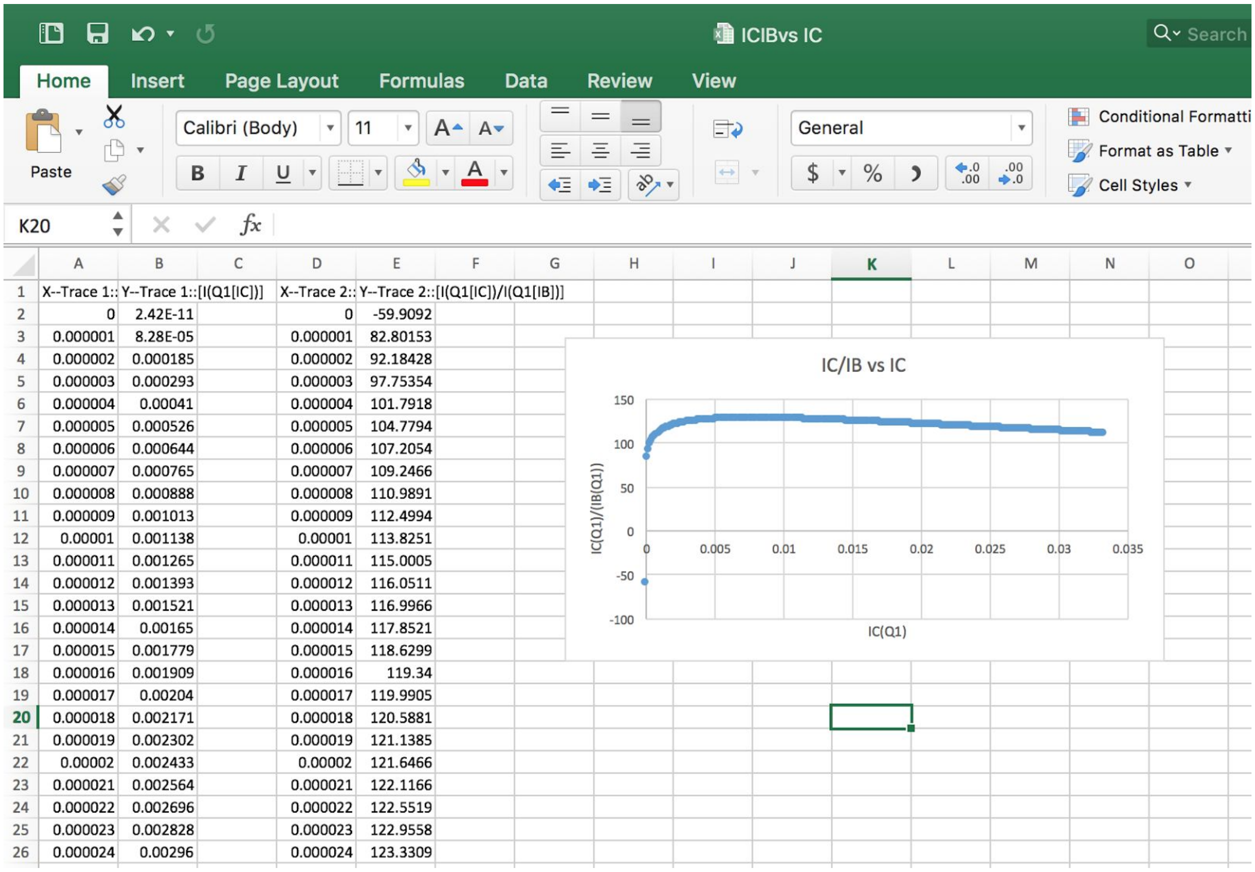


Green line: (beta dc), max point= 142.8423, (x,y), y=0.5 mA
Red line: (IC), (x,y), y=Ic= 0.5mA

Discuss simulation results and the tradeoff between

Set variable IB range to be from 0 to 0.0003A, set step at 1e-006A.

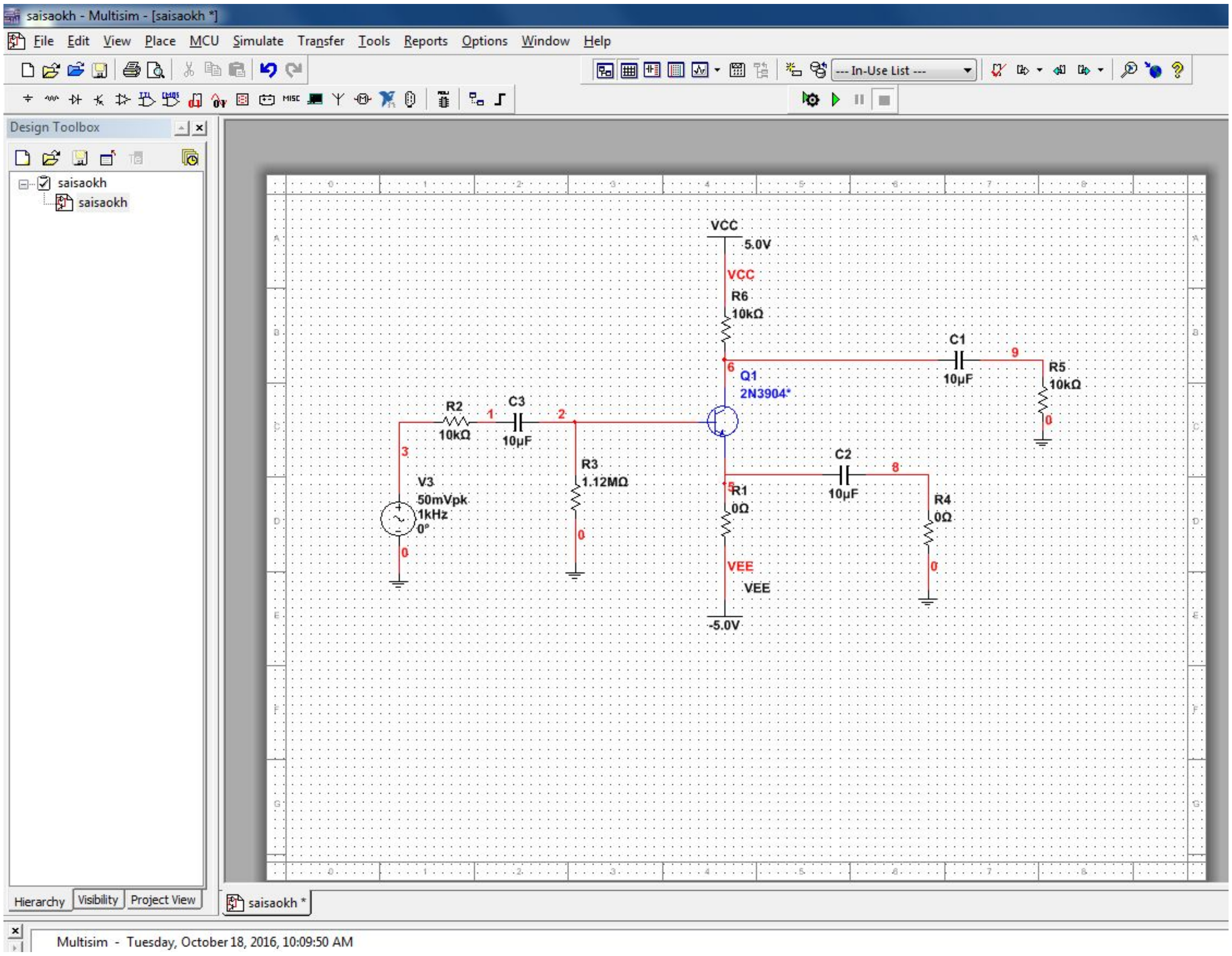
Click ‘Output’ and click ‘add expression’ in which set IC/IB as an output, also set I(V1) as another output. Click ‘Run’ and you will see two outputs, one is IC/IB vs. IB and the other is IC vs. IB, since we need to examine IC/IB vs. IC, in the graph view, click ‘Tools’ and click ‘Export to excel’, then we can draw IC/IB vs. IC as below.



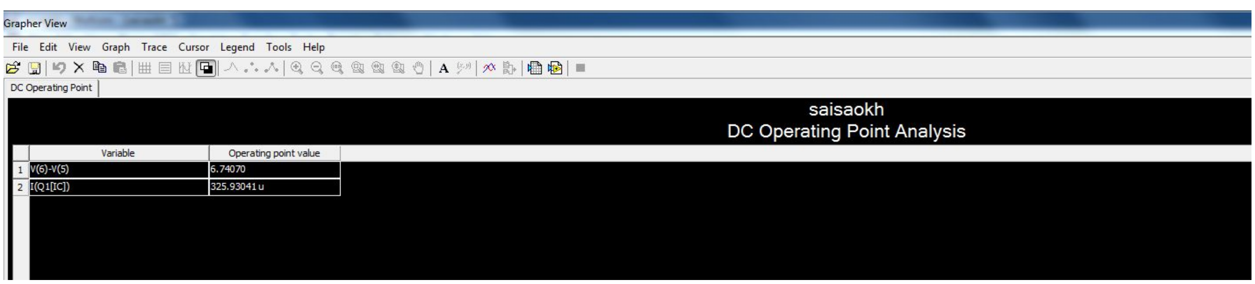
	A	B	C	D	E
1	X--Trace 1::	Y--Trace 1::[I(Q1[IC])]		X--Trace 2::	Y--Trace 2::[I(Q1[IC])/I(Q1[IB])]
2	0	2.42E-11		0	-59.9092
3	0.000001	8.28E-05		0.000001	82.80153
4	0.000002	0.000185		0.000002	92.18428
5	0.000003	0.000293		0.000003	97.75354
6	0.000004	0.00041		0.000004	101.7918
7	0.000005	0.000526		0.000005	104.7794
8	0.000006	0.000644		0.000006	107.2054
9	0.000007	0.000765		0.000007	109.2466
10	0.000008	0.000888		0.000008	110.9891
11	0.000009	0.001013		0.000009	112.4994
12	0.00001	0.001138		0.00001	113.8251
13	0.000011	0.001265		0.000011	115.0005
14	0.000012	0.001393		0.000012	116.0511
15	0.000013	0.001521		0.000013	116.9966
16	0.000014	0.00165		0.000014	117.8521
17	0.000015	0.001779		0.000015	118.6299
18	0.000016	0.001909		0.000016	119.34
19	0.000017	0.00204		0.000017	119.9905
20	0.000018	0.002171		0.000018	120.5881
21	0.000019	0.002302		0.000019	121.1385
22	0.00002	0.002433		0.00002	121.6466
23	0.000021	0.002564		0.000021	122.1166
24	0.000022	0.002696		0.000022	122.5519
25	0.000023	0.002828		0.000023	122.9558
26	0.000024	0.00296		0.000024	123.3309

<u>3A(PART2)</u>

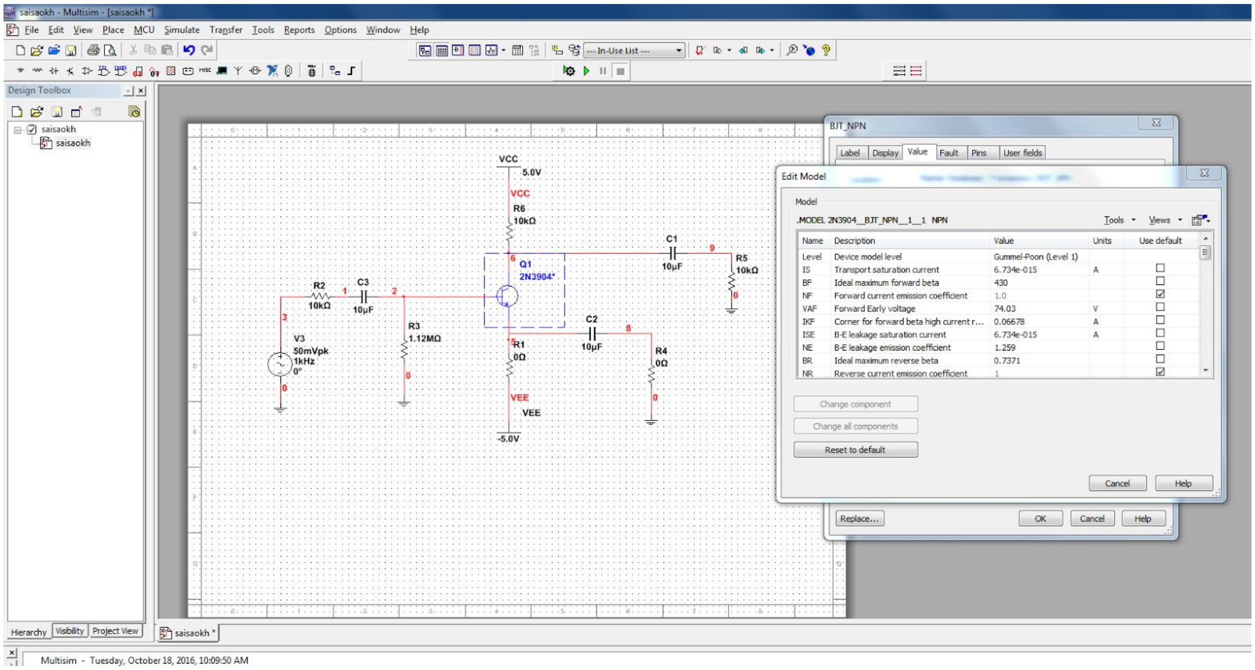
Correct Schematic with VCE and IC value for Rce =0, RE=0, RB= 1.12M and BF 155/430/1050

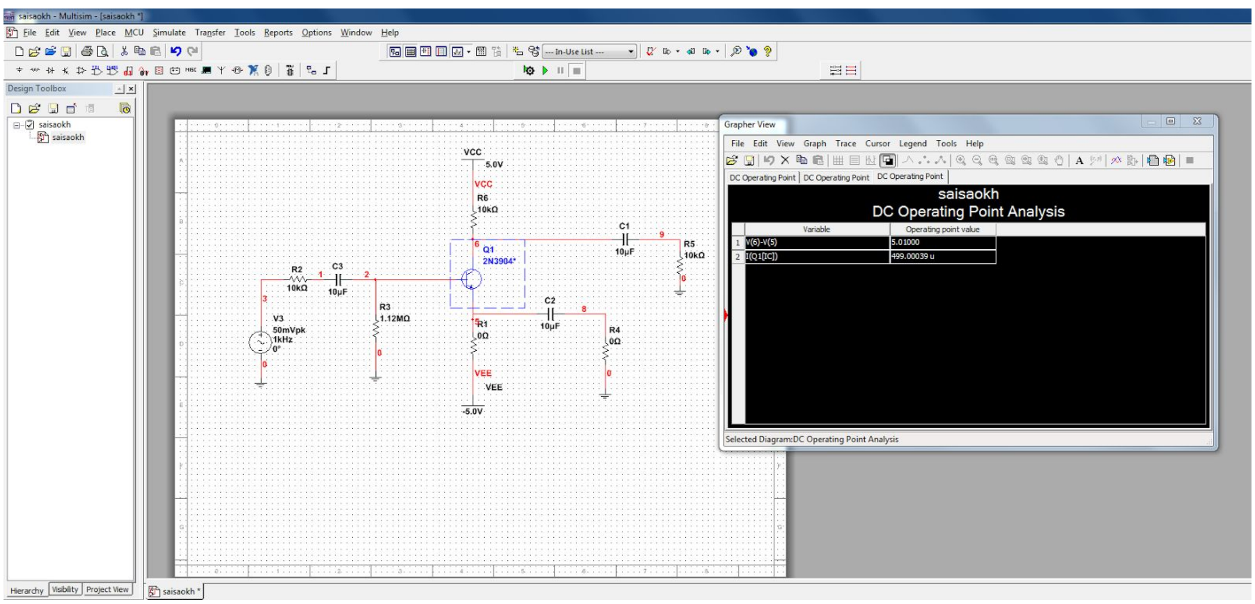


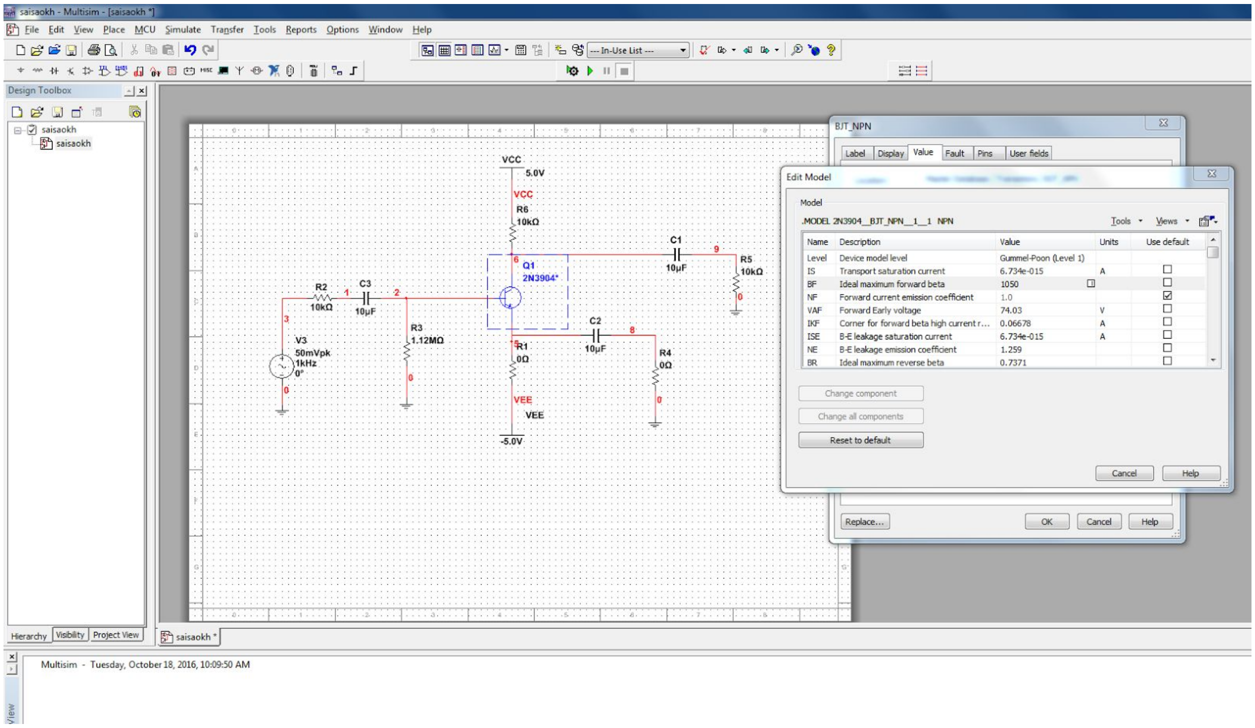
saisaokh - Multisim - [saisaokh *]
File Edit View Place MCU Simulate Transfer Tools Reports Options Window Help
--- In-Use List ---
Design Toolbox
saisaokh
saisaokh
VCC
5.0V
VCC
R6
10kΩ
C1
10µF
9
R5
10kΩ
0
6
Q1
2N3904*
R2
10kΩ
1
C3
10µF
2
3
R3
1.12MΩ
V3
50mVpk
1kHz
0°
0
0
C2
10µF
8
5
R1
0Ω
R4
0Ω
0
VEE
VEE
-5.0V
Hierarchy
Visibility
Project View
saisaokh *
Multisim - Tuesday, October 18, 2016, 10:09:50 AM



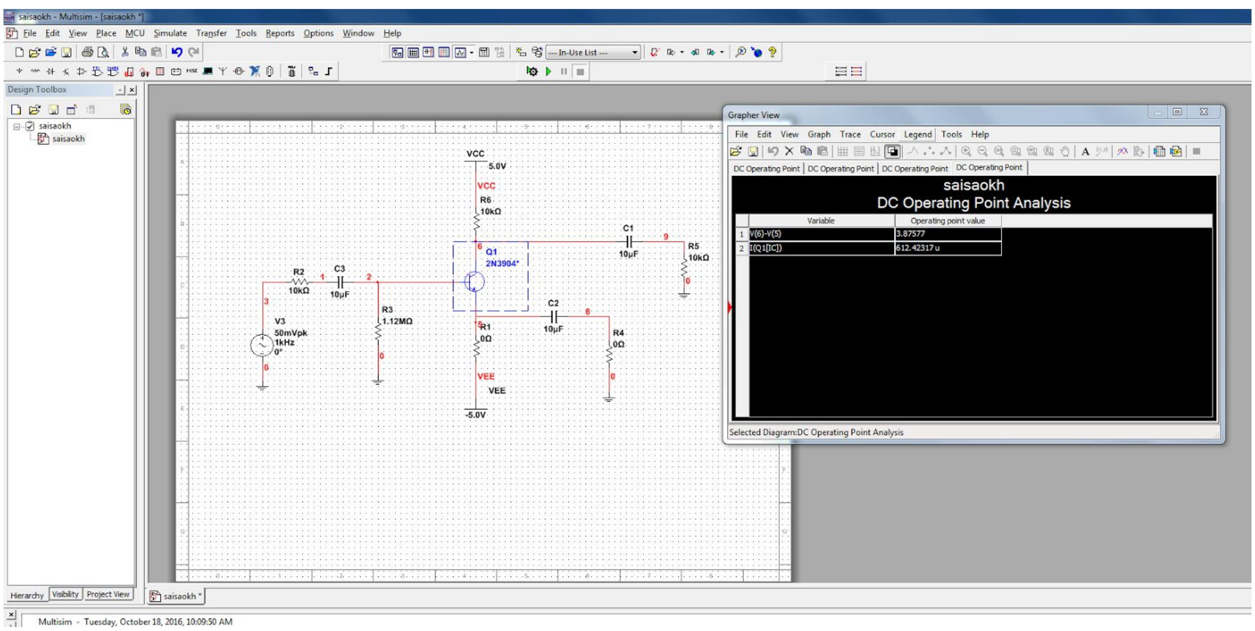
Grapher View
File Edit View Graph Trace Cursor Legend Tools Help
DC Operating Point
saisaokh
DC Operating Point Analysis
Variable
Operating point value
1 V(6)-V(5) 6.74070
2 I(Q1[IC]) 325.93041 u


saisaokh - Multisim - [saisaokh *]
VCC
5.0V
R6
10kΩ
Q1
2N3904*
C1
10µF
R5
10kΩ
R2
10kΩ
C3
10µF
R3
1.12MΩ
C2
10µF
R1
0Ω
R4
0Ω
V3
50mVpk
1kHz
0°
VEE
-5.0V
BJT_NPN
Edit Model
.MODEL 2N3904__BJT_NPN__1__1 NPN
Level Device model level Gummel-Poon (Level 1)
IS Transport saturation current 6.734e-015 A
BF Ideal maximum forward beta 430
NF Forward current emission coefficient 1.0
VAF Forward Early voltage 74.03 V
IKF Corner for forward beta high current r... 0.06678 A
ISE B-E leakage saturation current 6.734e-015 A
NE B-E leakage emission coefficient 1.259
BR Ideal maximum reverse beta 0.7371
NR Reverse current emission coefficient 1
Multisim - Tuesday, October 18, 2016, 10:09:50 AM


saisaokh - Multisim - [saisaokh *]
Grapher View
saisaokh
DC Operating Point Analysis
Variable Operating point value
1 V(6)-V(5) 5.01000
2 I(Q1[IC]) 499.00039 u
Selected Diagram:DC Operating Point Analysis

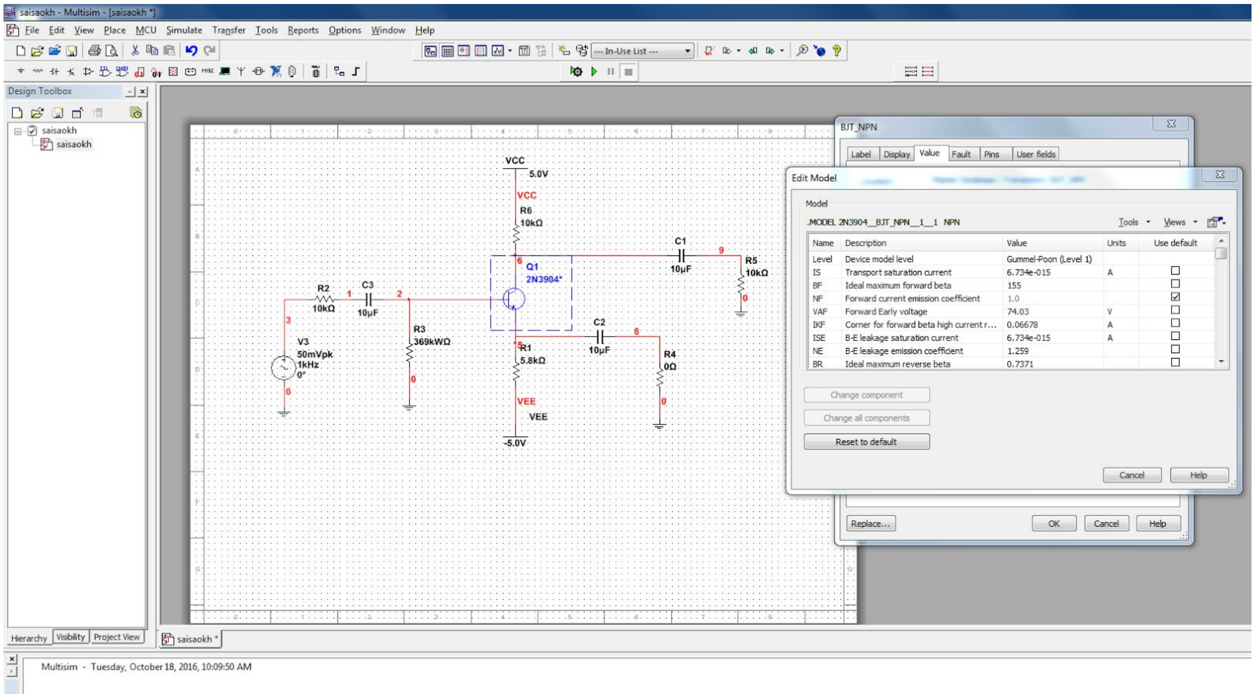


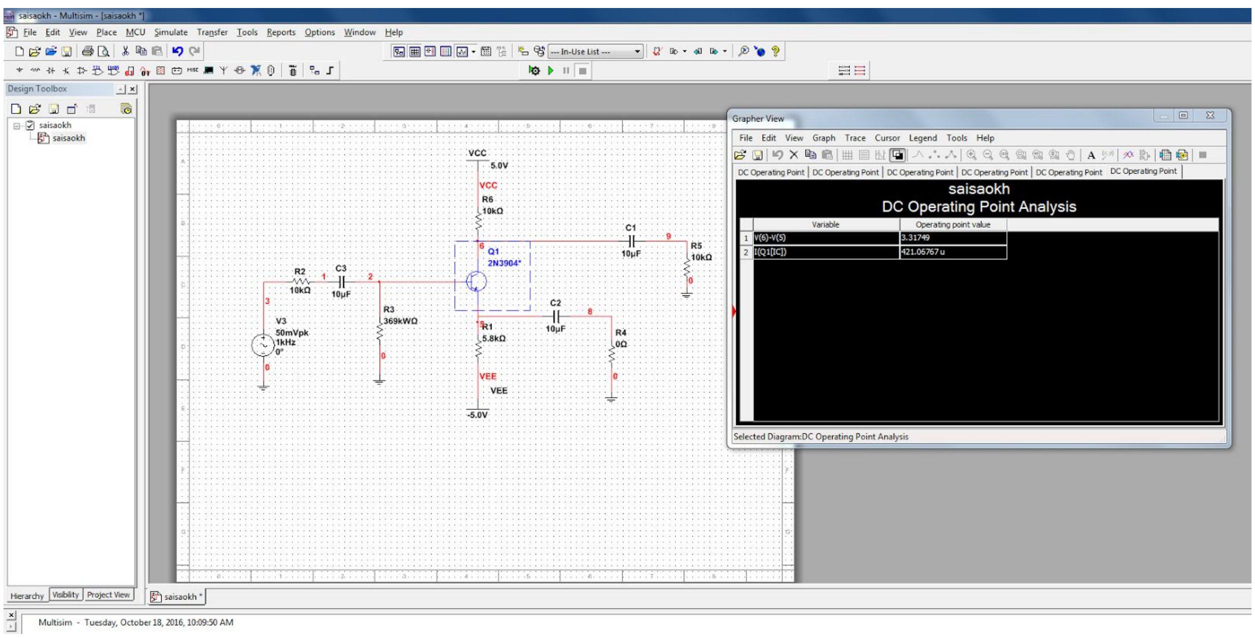
saisaokh - Multisim - [saisaokh *]
VCC
5.0V
R6
10kΩ
C1
10µF
R5
10kΩ
Q1
2N3904*
R2
10kΩ
C3
10µF
R3
1.12MΩ
V3
50mVpk
1kHz
0°
R1
0Ω
C2
10µF
R4
0Ω
VEE
-5.0V
BJT_NPN
Label
Display
Value
Fault
Pins
User fields
Edit Model
Model
.MODEL 2N3904__BJT_NPN__1__1 NPN
Name | Description | Value | Units | Use default
Level | Device model level | Gummel-Poon (Level 1)
IS | Transport saturation current | 6.734e-015 | A
BF | Ideal maximum forward beta | 1050
NF | Forward current emission coefficient | 1.0
VAF | Forward Early voltage | 74.03 | V
IKF | Corner for forward beta high current r… | 0.06678 | A
ISE | B-E leakage saturation current | 6.734e-015 | A
NE | B-E leakage emission coefficient | 1.259
BR | Ideal maximum reverse beta | 0.7371
Change component
Change all components
Reset to default
Cancel
Help
Replace...
OK
Cancel
Help
Multisim - Tuesday, October 18, 2016, 10:09:50 AM

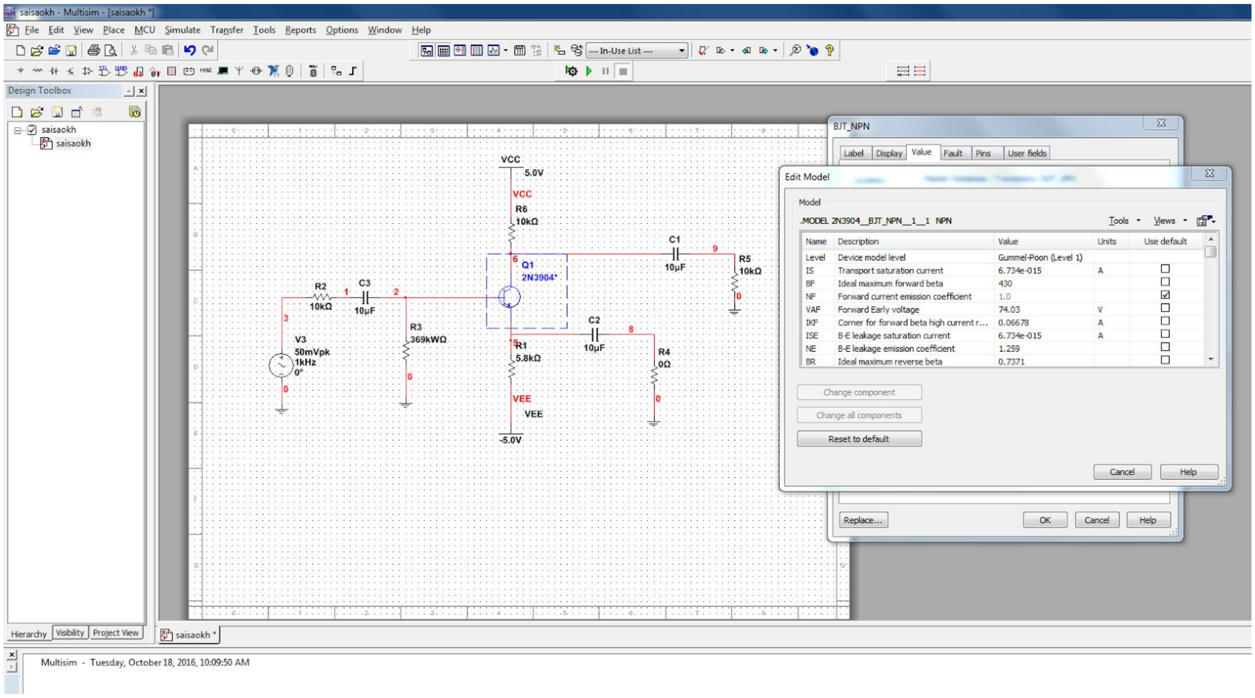


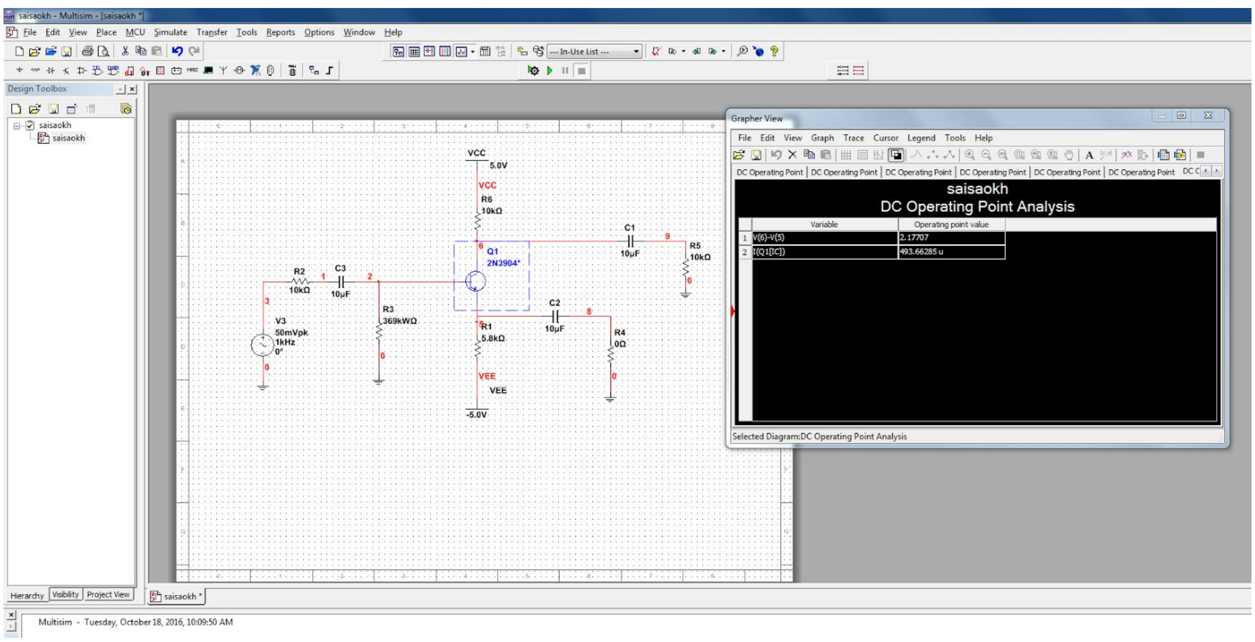
saisaokh - Multisim - [saisaokh *]
Grapher View
DC Operating Point
saisaokh
DC Operating Point Analysis
Variable | Operating point value
1 | V(6)-V(5) | 3.87577
2 | I(Q1[IC]) | 612.42317 u
Selected Diagram:DC Operating Point Analysis
Multisim - Tuesday, October 18, 2016, 10:09:50 AM

Correct Schematic with VCE and IC value for Rce =0, RE=5.8k, RB =369k and BF = 155/430/1050






saisaokh - Multisim - [saisaokh *]
Edit Model
.MODEL 2N3904__BJT_NPN__1__1 NPN
Name Description Value Units Use default
Level Device model level Gummel-Poon (Level 1)
IS Transport saturation current 6.734e-015 A
BF Ideal maximum forward beta 430
NF Forward current emission coefficient 1.0
VAF Forward Early voltage 74.03 V
IKF Corner for forward beta high current r... 0.06678 A
ISE B-E leakage saturation current 6.734e-015 A
NE B-E leakage emission coefficient 1.259
BR Ideal maximum reverse beta 0.7371
Change component
Change all components
Reset to default
Cancel
Help
Replace...
OK
VCC 5.0V
R6 10kΩ
Q1 2N3904*
C1 10µF
R5 10kΩ
R2 10kΩ
C3 10µF
R3 369kWΩ
V3 50mVpk 1kHz 0°
R1 5.8kΩ
C2 10µF
R4 0Ω
VEE -5.0V
Multisim - Tuesday, October 18, 2016, 10:09:50 AM

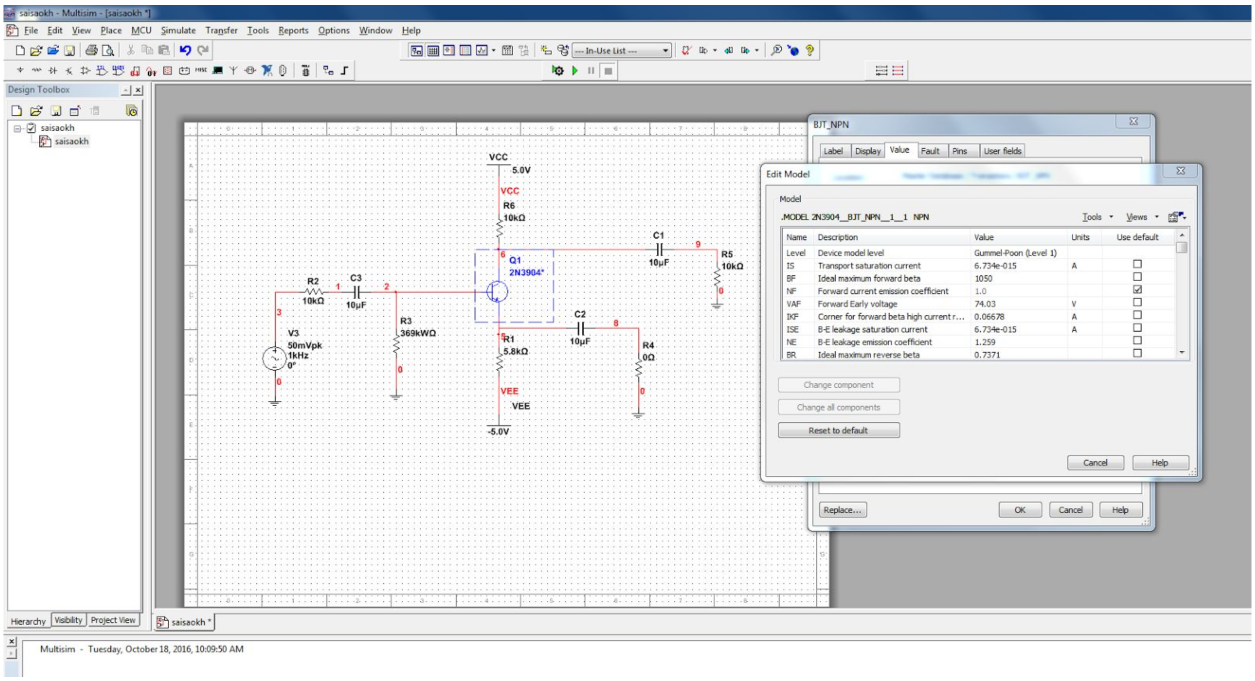

saisaokh - Multisim - [saisaokh *]
Grapher View
saisaokh
DC Operating Point Analysis
Variable Operating point value
1 V(6)-V(5) 2.17707
2 I(Q1[IC]) 493.66285 u
Selected Diagram:DC Operating Point Analysis
Multisim - Tuesday, October 18, 2016, 10:09:50 AM

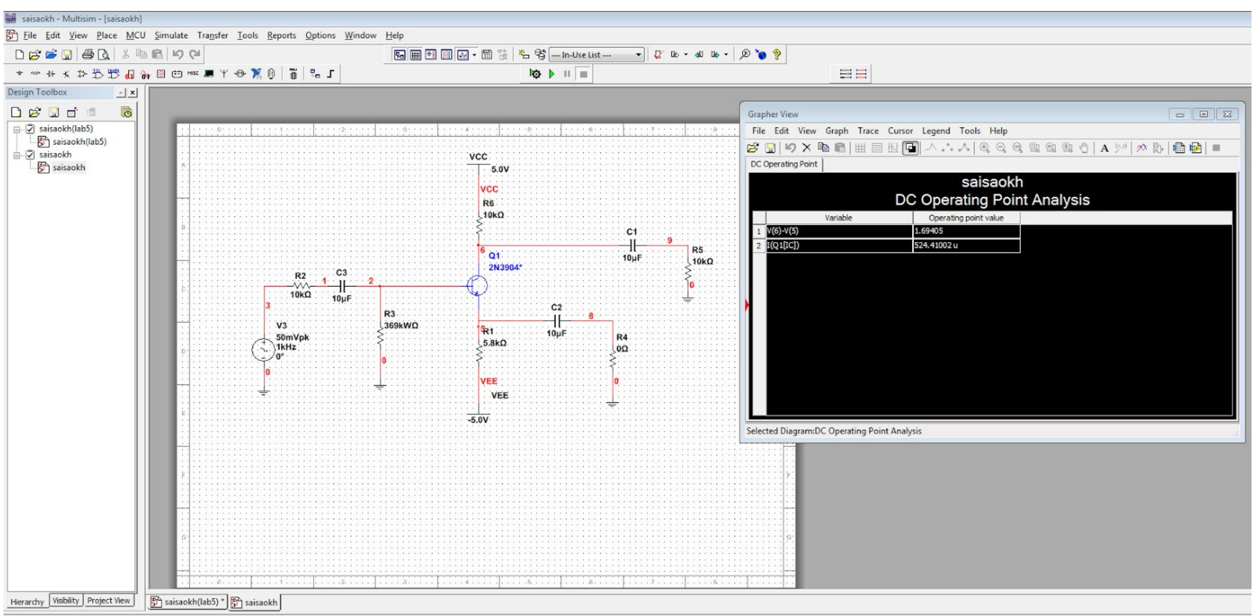
(beta ac) and (beta dc) for each case

(beta ac) = (delta IC / delta IB) (where IC = current at collector, IB= current at base)

(beta dc) = (IC / IB)

the dependence on RE of the stability of Q-point. That is, discuss how much the QP (VCE, IC) varies for different BF when RE= 0 and when RE ≠ 0





(x,y) = (Ic, Vce)	RE=0, (x,y)	RE=5.8, (x,y)
	(6.74,325.9 u)	(3.32, 421.07 u)
	(5,499 u)	(2.177,493.66 u)
	(3.876, 612.4u)	(1.69405,524.41002u)

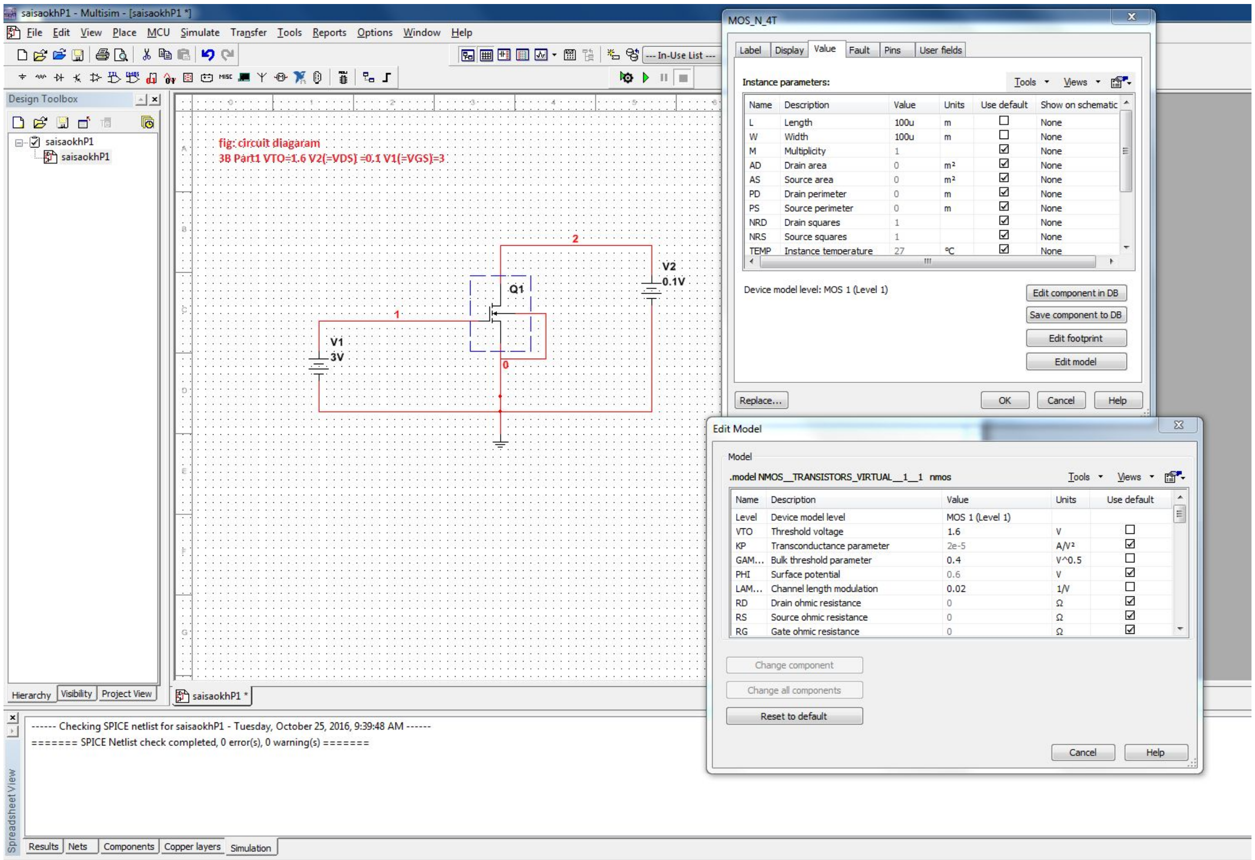
Discuss the effect of RE on the stability of DC Bias point the circuit

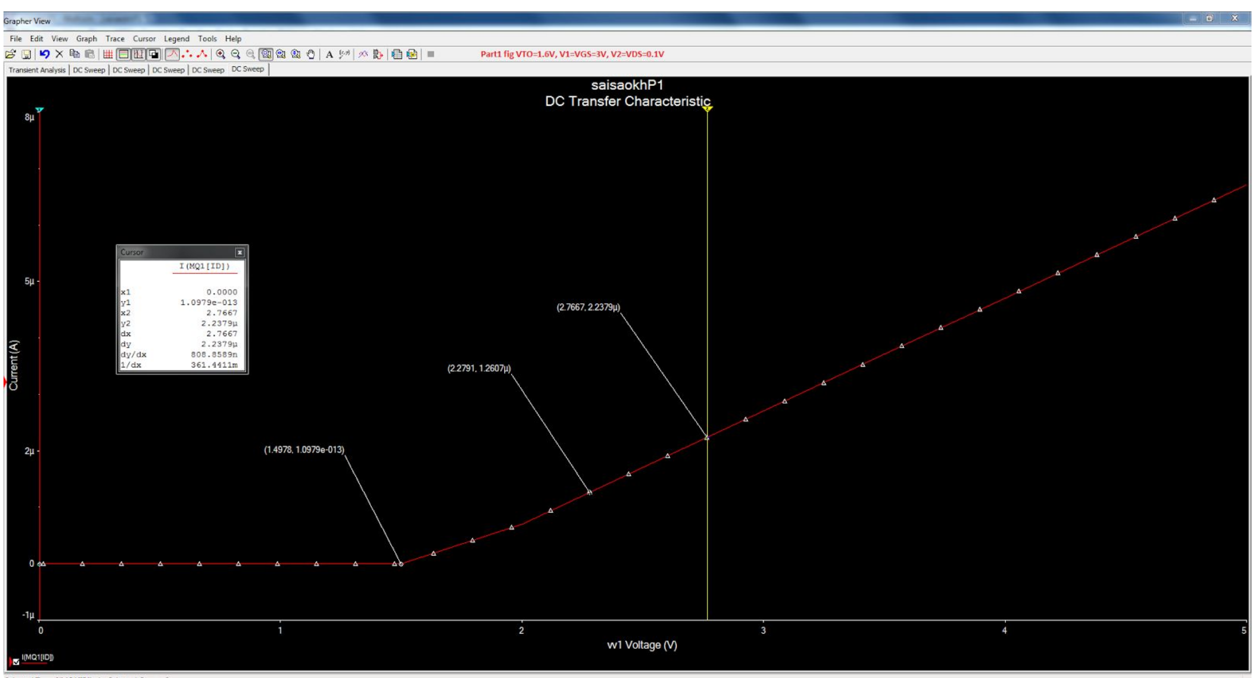
The correct biasing of the transistor is achieved using a process known commonly as Base Bias.The function of the “DC Bias level” or “no input signal level” is to correctly set the transistors Q-point by setting its Collector current (IC) to a constant and steady state value without an input signal applied to the transistors Base.This steady-state or DC operating point is set by the values of the circuits DC supply voltage (Vcc) and the value of the biasing resistors connected the transistors Base terminal.

<u>3B: Part 1 (Threshold Voltage)</u>

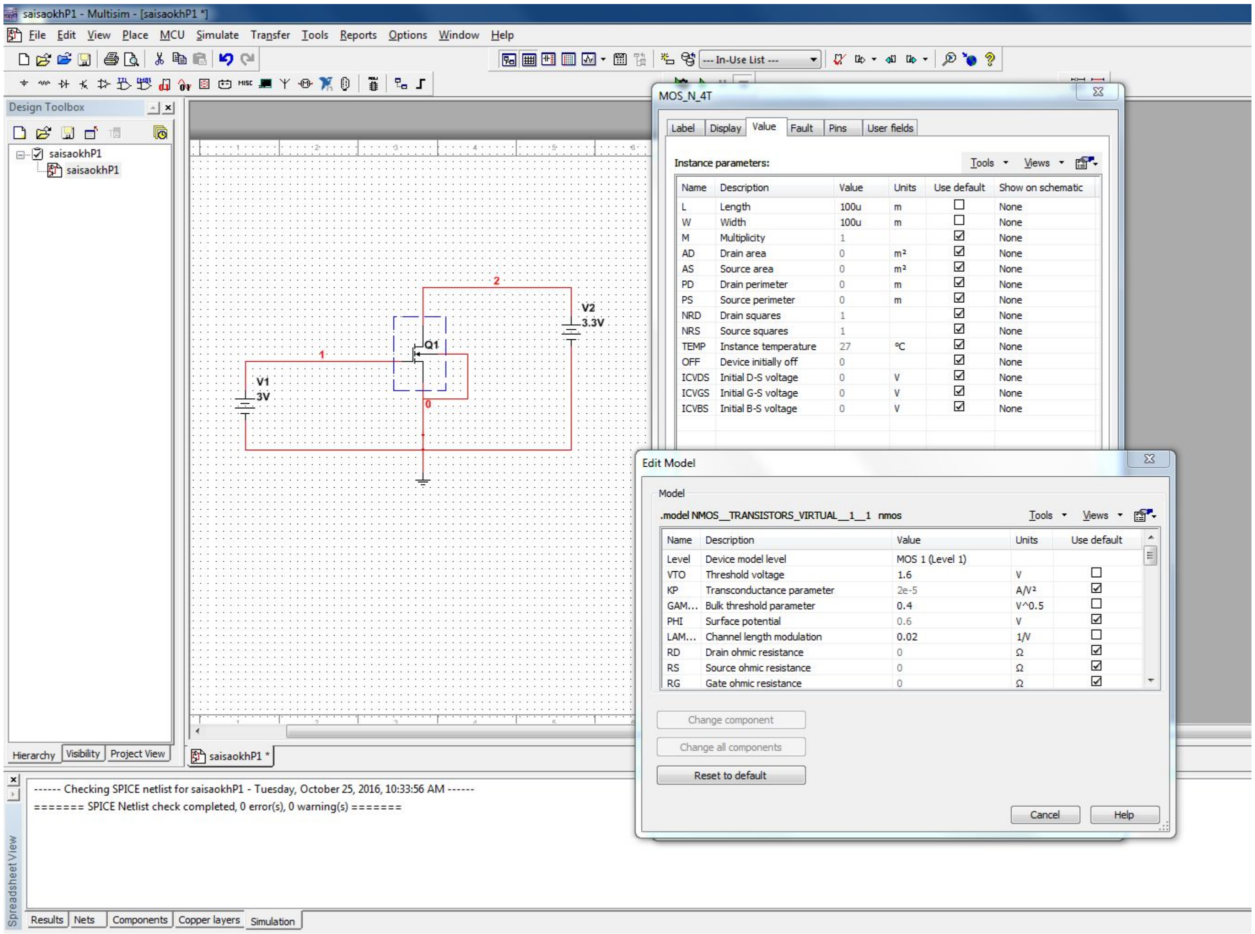
Schematic

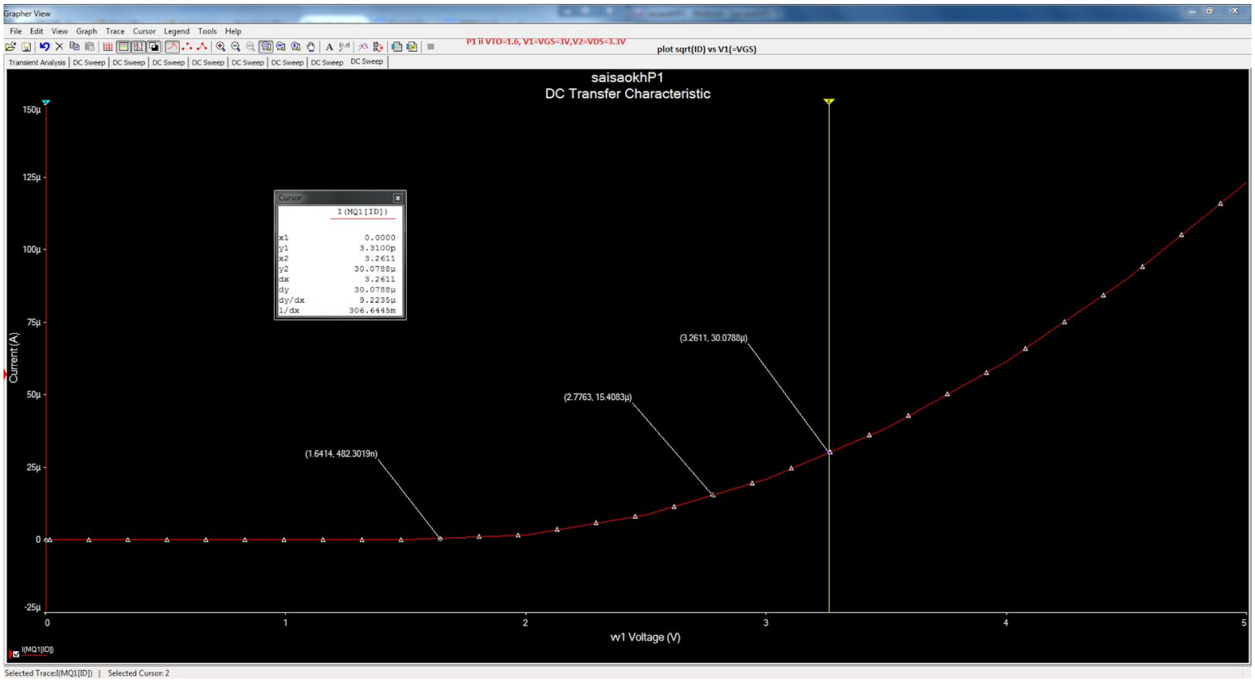
(i)Plot of I_D-V_{GS}(=V1) for linear mode(VT0 =1.6V, V1=VGS=3V,V2=VDS=0.1V)



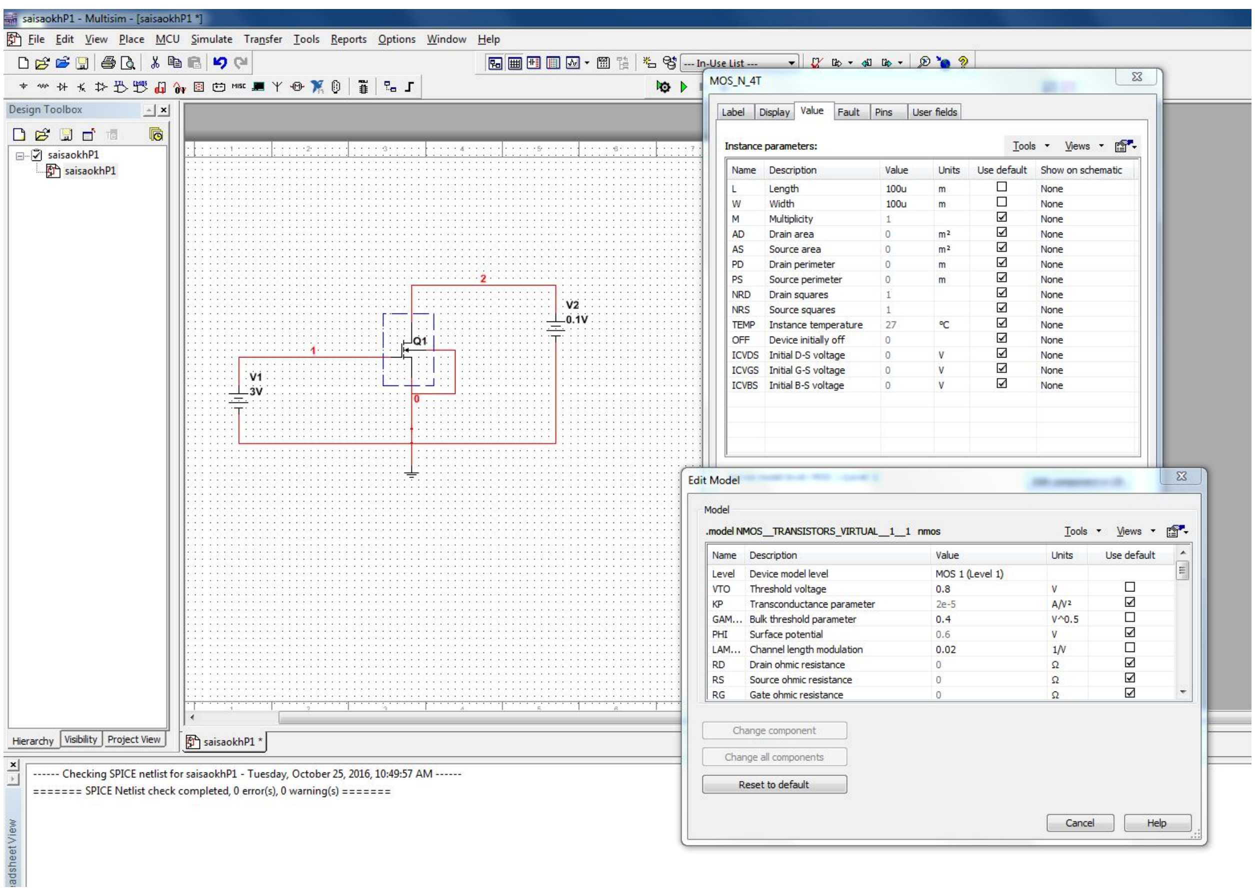


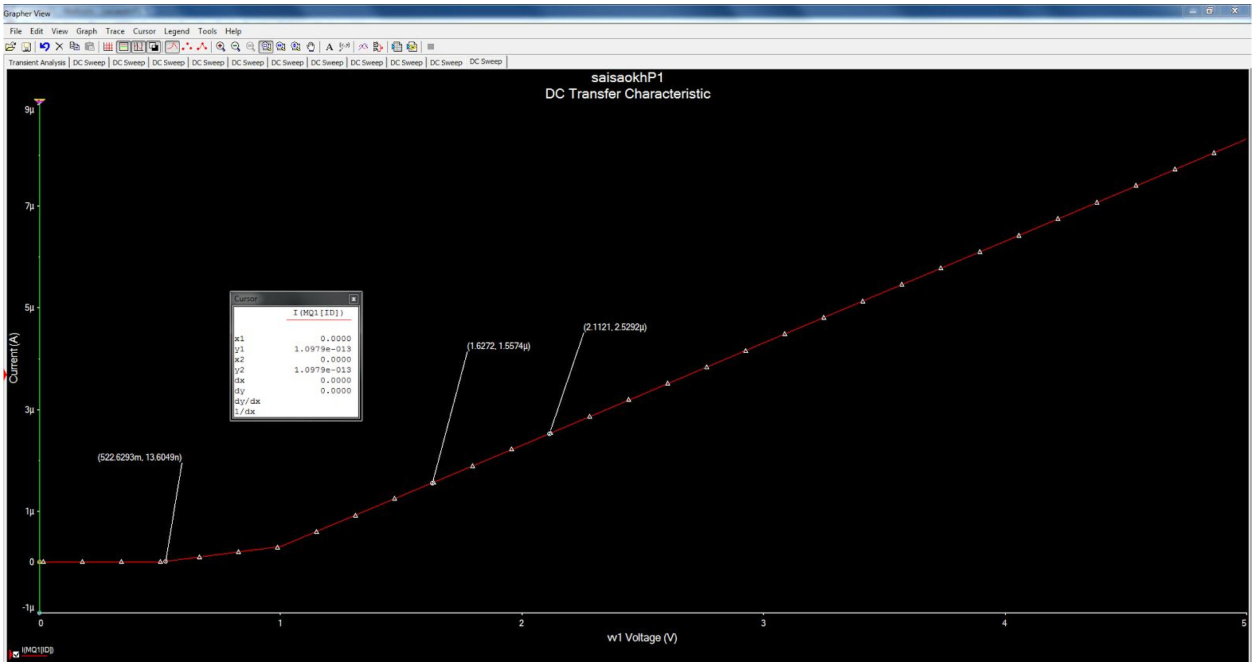
(ii)Plot of sqrt(I_D)-V_{GS} (=V1) for Saturation mode (VT0 =1.6V, V1=VGS=3V, V2=VDS=3.3V)



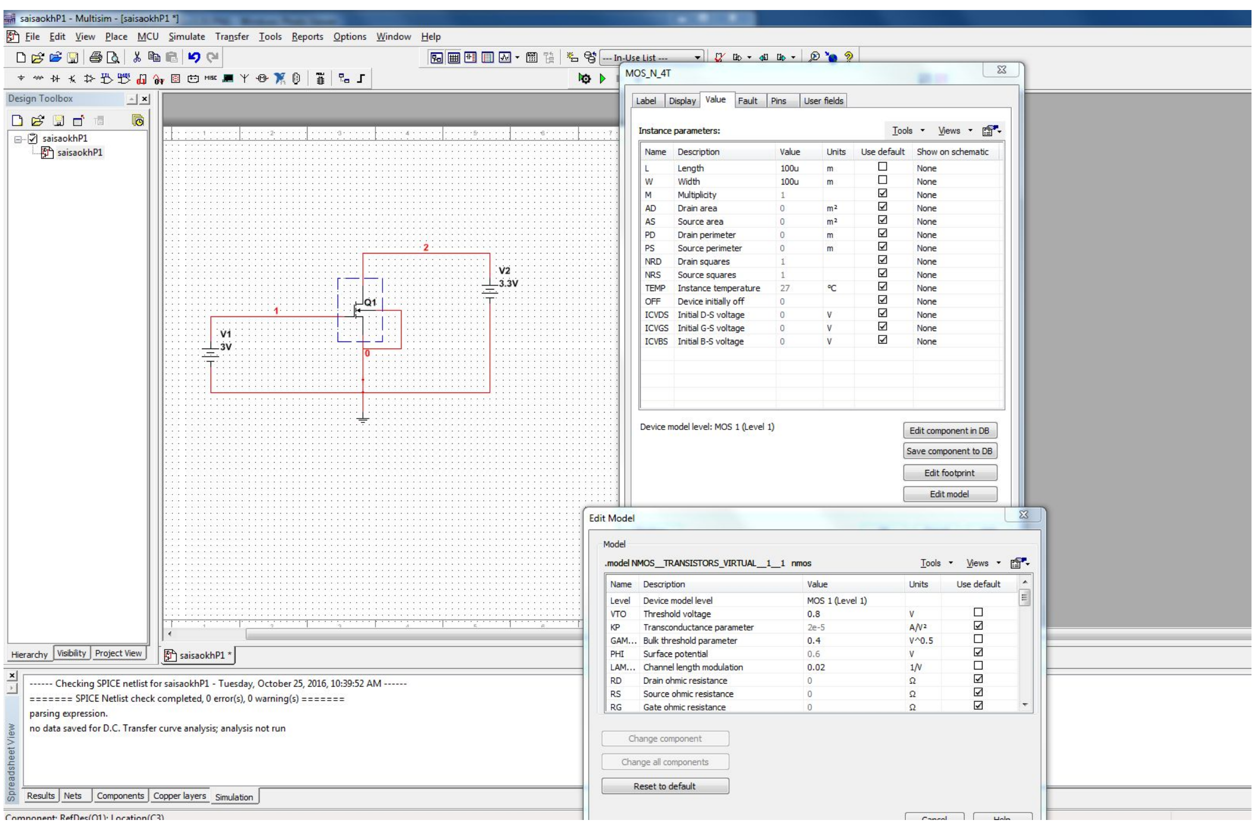


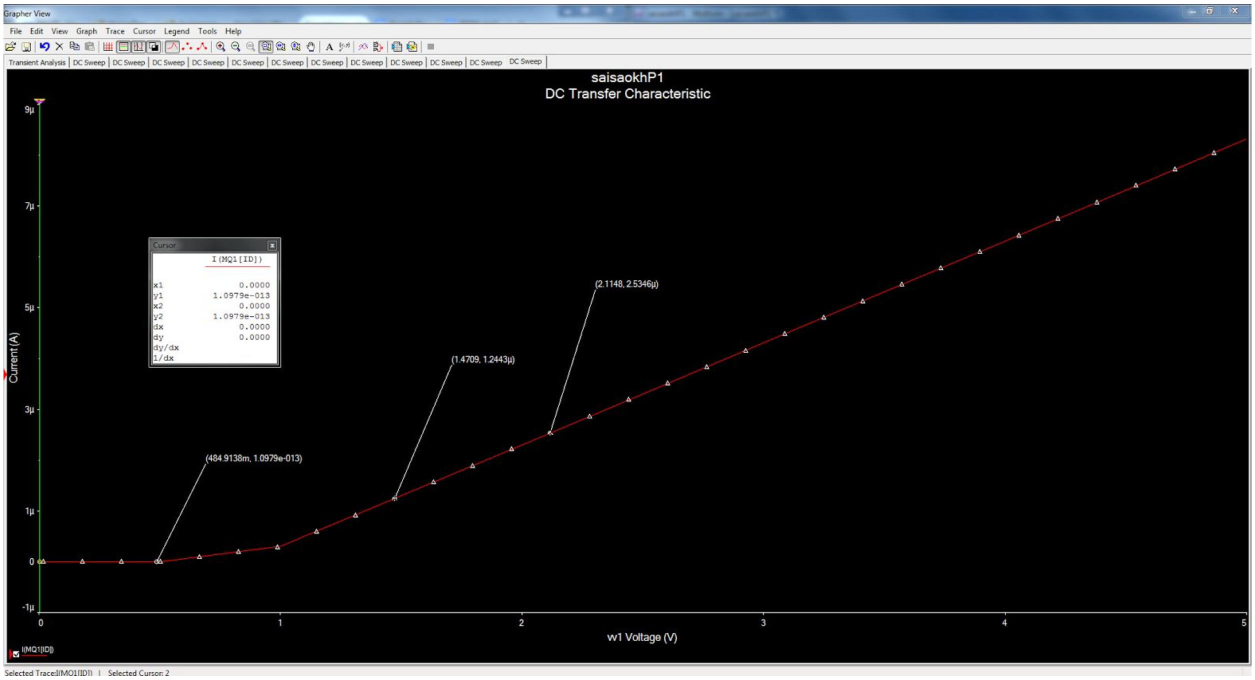
(iii)Plot of I_D-V_{GS}(=V1) for linear mode(VT0 =0.8V, V1=VGS=3V,V2=VDS=0.1V)





Plot of sqrt(I_D)-V_{GS} (=V1) for Saturation mode(VT0 =0.8V, V1=VGS=3V, V2=VDS=3.3V)





Comparison between the simulated curve slope and the theoretical calculated value

When V_{T0}=1.6 V, slope (m) = $\frac{y_2-y_1}{x_2-x_1} = \frac{2.7130m-1.6478m}{2.3579-2.0211} = \frac{1.0652m}{0.3368} = 0.000316\,\frac{A}{V}$

When V_{T0}=.8 V, slope (m) = $\frac{y_2-y_1}{x_2-x_1} = \frac{4.2942m-3.2290m}{2.3579-2.0211} = \frac{1.0652m}{0.3368} = 0.000316\,\frac{A}{V}$

$$I_D = \sqrt{\frac{1}{2}k_n}(V_{GS}-V_T)^2$$

$$\frac{I_D}{(V_{GS}-V_T)^2} = \sqrt{\frac{1}{2}k_n}$$

$$\frac{0.0027130}{(2.3579-1.5)^2} = \sqrt{\frac{1}{2}k_n}$$

$$\sqrt{\frac{1}{2}k_n} = 0.003686\,\frac{A}{V}$$

$$I_D = \sqrt{\frac{1}{2}k_n}(V_{GS}-V_T)^2$$

$$\frac{I_D}{(V_{GS}-V_T)^2} = \sqrt{\frac{1}{2}k_n}$$

$$\frac{0.0042942}{(2.3579-1.0)^2} = \sqrt{\frac{1}{2}k_n}$$

$$\sqrt{\frac{1}{2}k_n} = 0.002328\frac{A}{V}$$

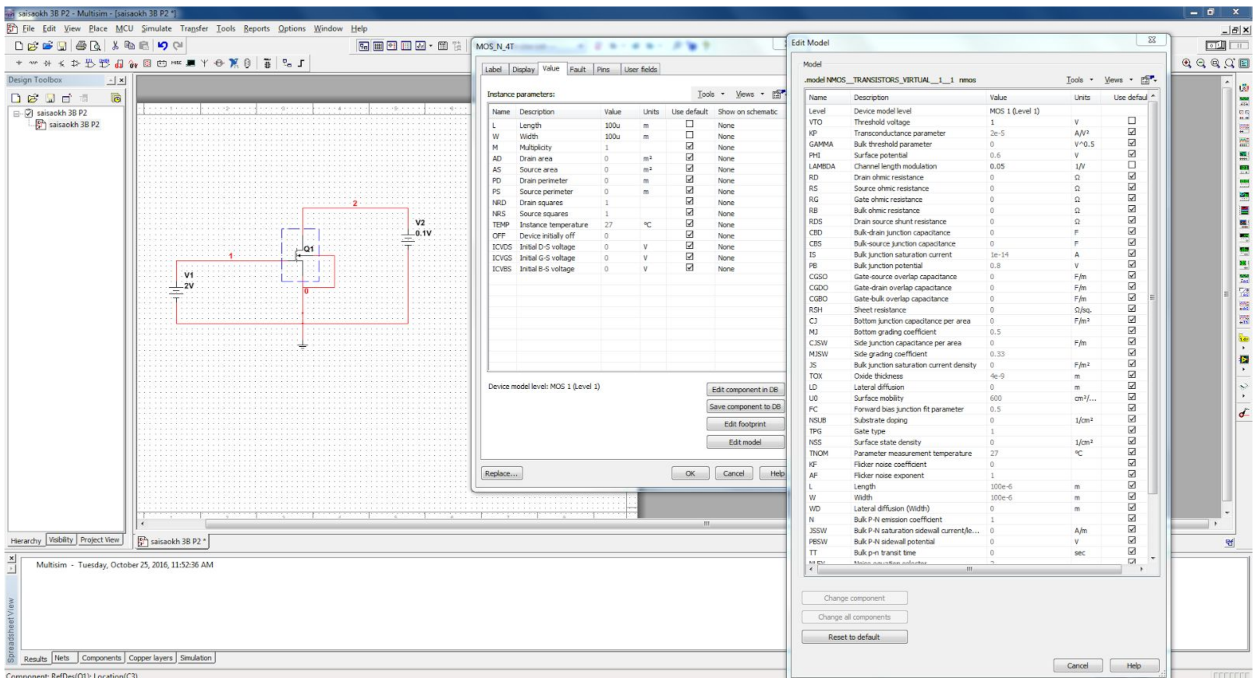
According to the above calculations, the slope of when V_{T0}=1.6 V, the slope of the two points taken after 2V was the same as the value obtained for $\sqrt{\frac{1}{2}k_n}$. In addition, by looking at the graph we can see that the threshold voltage obtained through simulation (V_{T0}=1.6 V) equals the model parameter value of the threshold voltage (V_T=1.6 V).

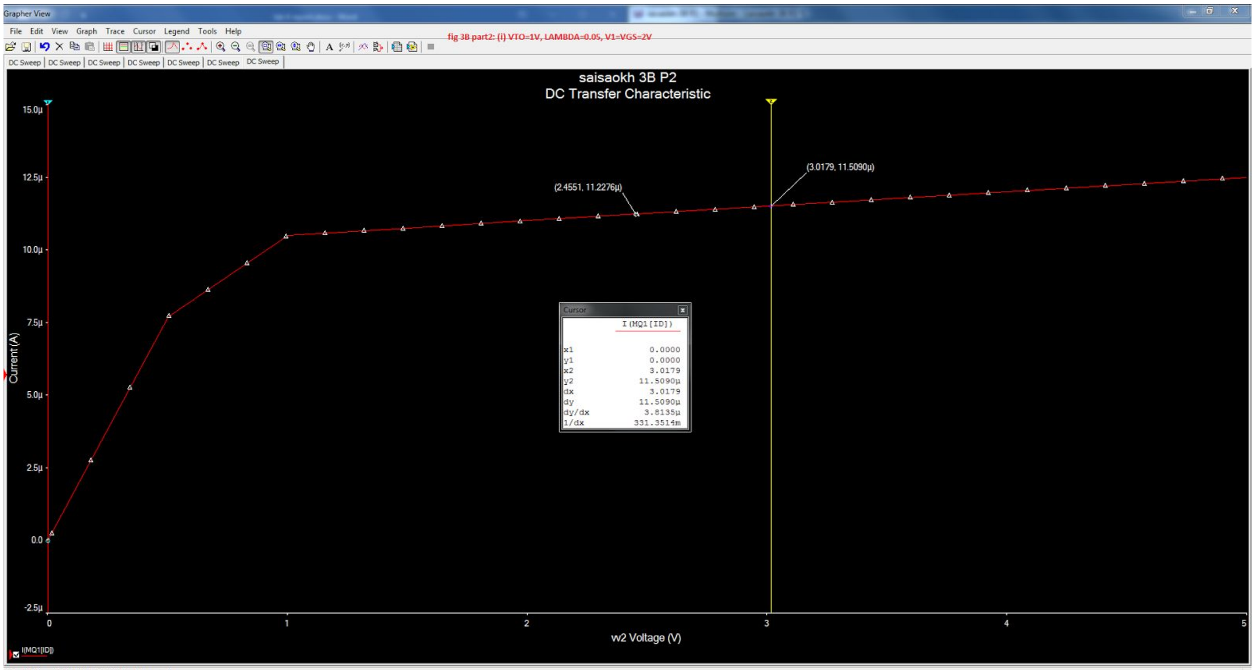
The slope of when V_{T0}=.8 V, the slope of the two points taken after 2V was a bit higher than the value obtained for $\sqrt{\frac{1}{2}k_n}$.To be exact the value obtained through calculating $\sqrt{\frac{1}{2}k_n}$ was 0.00201 units higher than the slope that was obtained. However, by looking at the graph we can see that the threshold voltage obtained through simulation (V_T=1.0031 V) almost equals the model parameter value of the threshold voltage (V_{T0}=1.6 V).

3B: Part 2 (Channel Length Modulation & Early Voltage)

Plot of I_D -V_{DS} for VT=2, 3, 4V

(i)





When V_{GS}=2.0 V, slope (m) = $\frac{y_2-y_1}{x_2-x_1} = \frac{11.5081\mu-11.2258\mu}{3.0162-2.4517} = \frac{0.2831\mu}{0.5645} = 0.5\mu\frac{A}{V}$

$y = mx + b$

11.5081μ = $(0.5\mu)(3.0162)$ + b

11.5081μ = 1.50845μ + b

$11.5081\mu - 1.50845\mu \ = b$

10μ A = b

I_C = 10μA

$y_2 - y_1 = m(x_2 - x_1)$

$(11.5081\mu - 0)$ =$.5\mu$ (3.0162 - x_1)

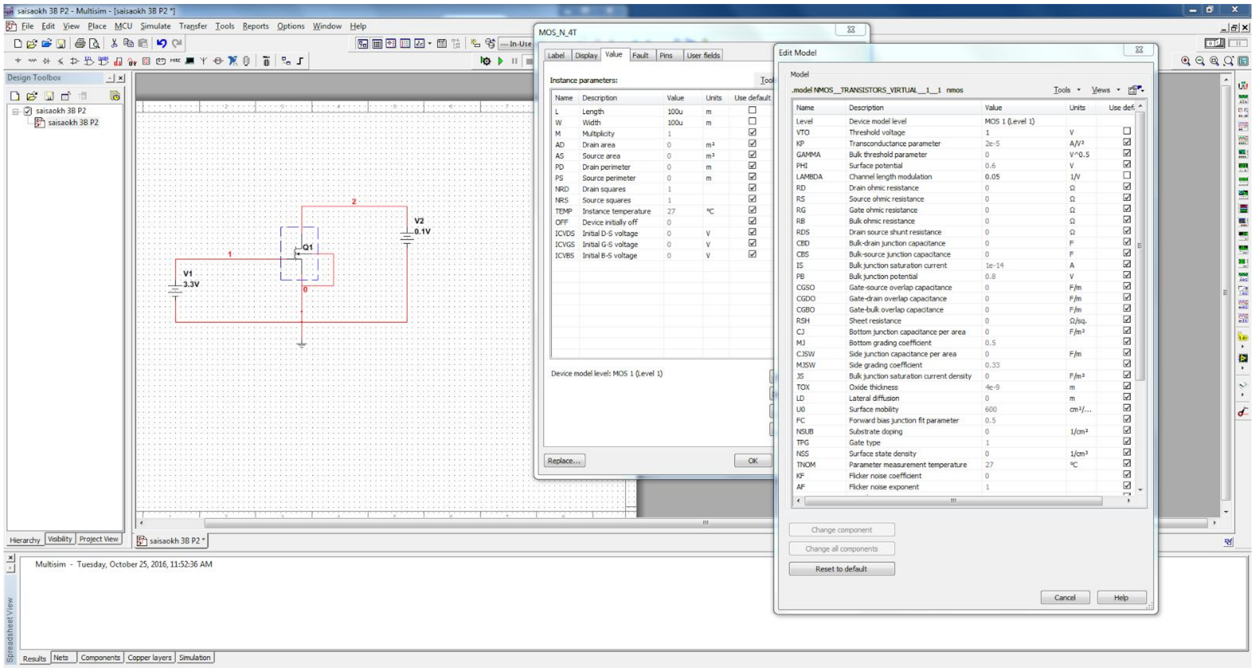
(11.5081μ) = 1.50845μ - $.50\mu x_1$

10μ = $-.50\mu x_1$

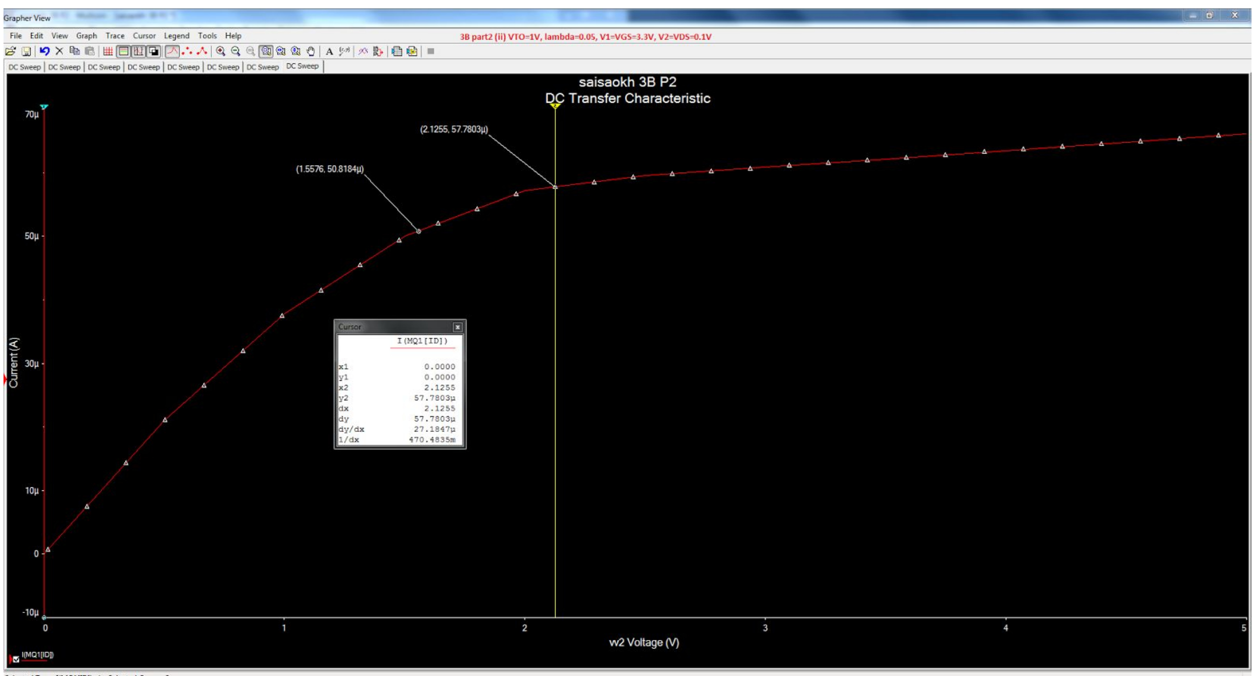
$x = -20V$

$-V_A$= -20V

(ii)



saisaokh 3B P2 - Multisim - [saisaokh 3B P2 *]
MOS_N_4T
Edit Model
Q1
V1
3.3V
V2
0.1V
.model NMOS__TRANSISTORS_VIRTUAL__1__1 nmos
VTO Threshold voltage 1 V
KP Transconductance parameter 2e-5 A/V²
LAMBDA Channel length modulation 0.05 1/V
L Length 100u m
W Width 100u m
Device model level: MOS 1 (Level 1)
Multisim - Tuesday, October 25, 2016, 11:52:36 AM



Grapher View
3B part2 (ii) VTO=1V, lambda=0.05, V1=VGS=3.3V, V2=VDS=0.1V
saisaokh 3B P2
DC Transfer Characteristic
(2.1255, 57.7803µ)
(1.5576, 50.8184µ)
Current (A)
w2 Voltage (V)
Cursor
I(MQ1[ID])
x1 0.0000
y1 0.0000
x2 2.1255
y2 57.7803µ
dx 2.1255
dy 57.7803µ
dy/dx 27.1847µ
1/dx 470.4835m
Selected Trace:I(MQ1[ID]) | Selected Cursor: 2

When V_{GS}=3.3 V, slope (m) = $\frac{y_2-y_1}{x_2-x_1} = \frac{46.3766\mu-44.5121\mu}{3.1883-2.2561} = \frac{1.8645\mu}{0.9322} = 2\mu\frac{A}{V}$

$y = mx + b$ $\qquad\qquad$ $y_2 - y_1 = m(x_2 - x_1)$

$46.3766\mu = (2\mu)(3.1883) + b$ $\qquad\qquad$ $(46.3766\mu - 0) = 2\mu\,(3.1883 - x_1)$

$46.3766\mu = 6.3766\mu + b$ $\qquad\qquad$ $(46.3766\mu) = 6.3766\mu - 2\mu x_1$

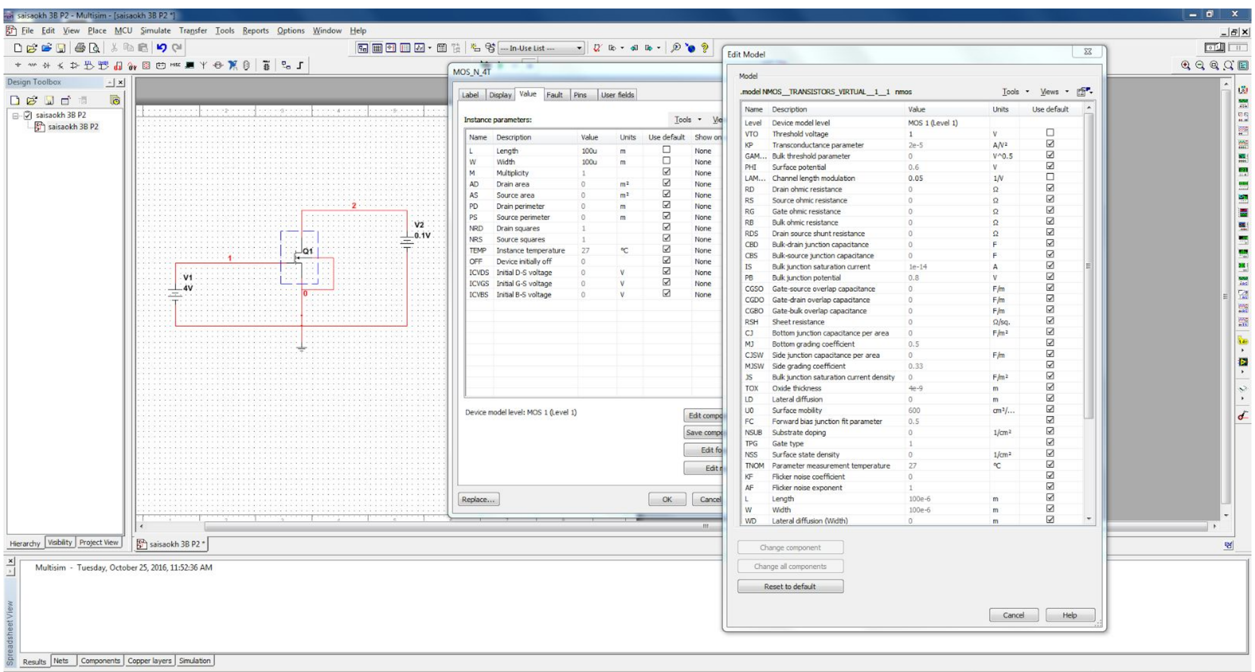
$46.3766\mu - 6.3766\mu = b$ $\qquad\qquad$ $40\mu = -2\mu x_1$

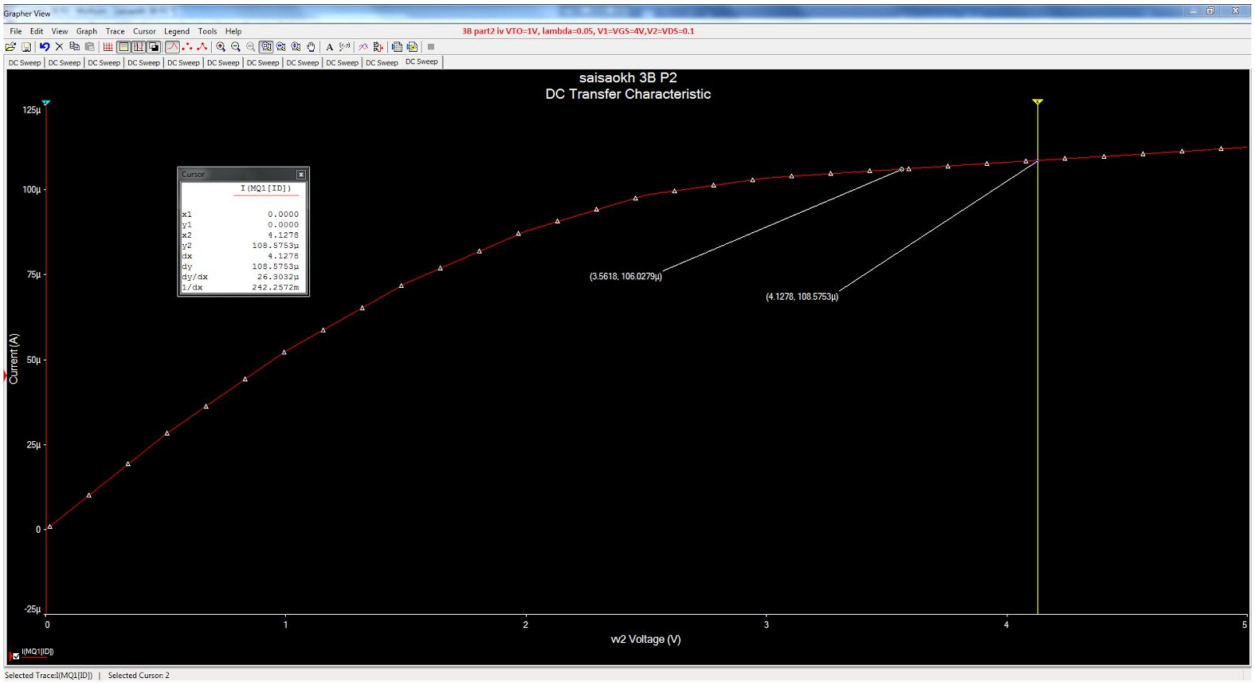
$40\,\mu = b$ $\qquad\qquad$ $x = -20\,V$

$I_C = 40\,\mu\,A$ $\qquad\qquad$ $-V_A = -20V$

Note: maximum V_{DS} should be well above V_{GS}-V_{T0}so that you cover a large portion of the saturation region in the output characteristic. This is because the channel length modulation is a property of the saturation region Correct values of V_A, 1/LAMBDA and r_o

(iii)

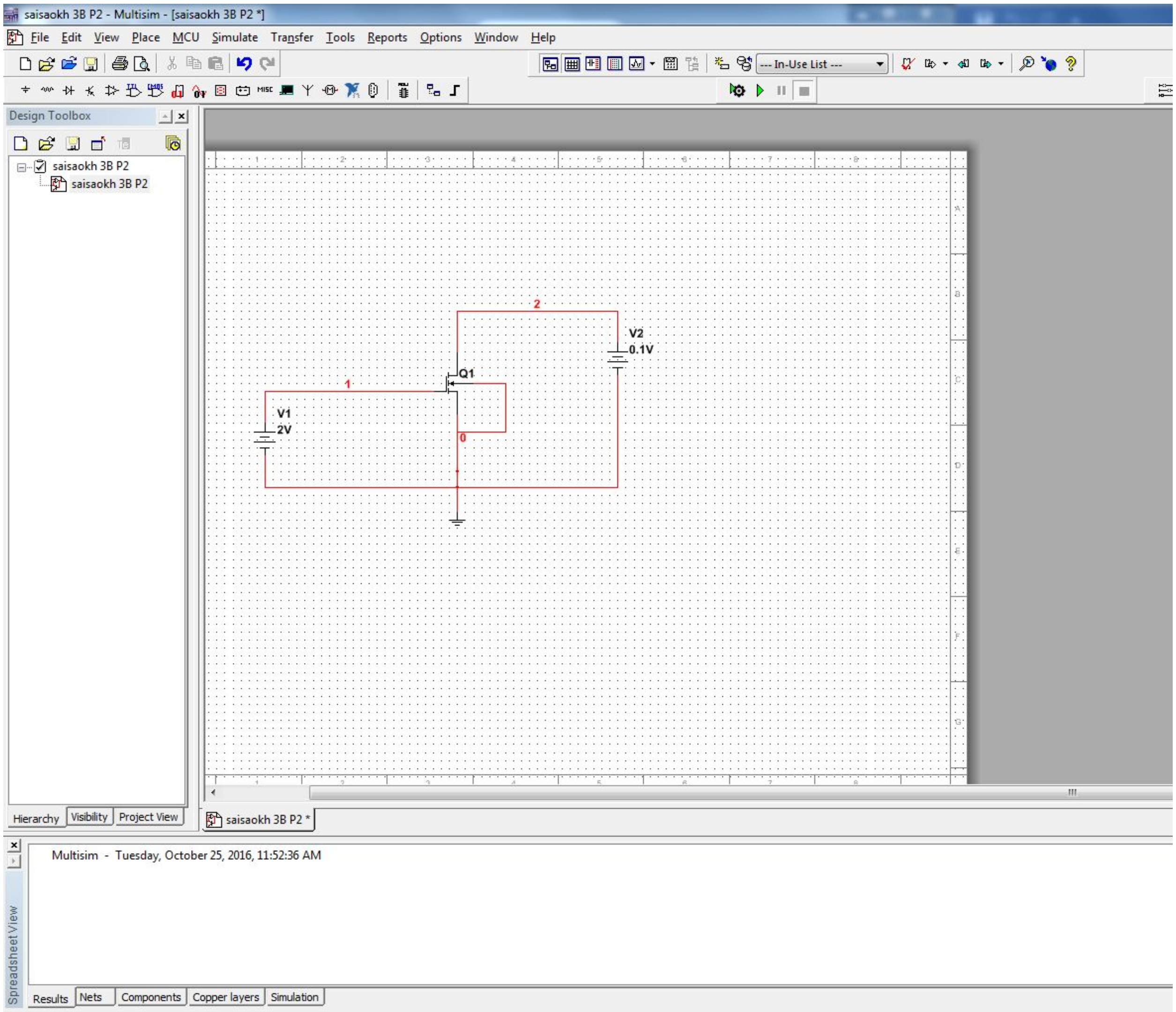


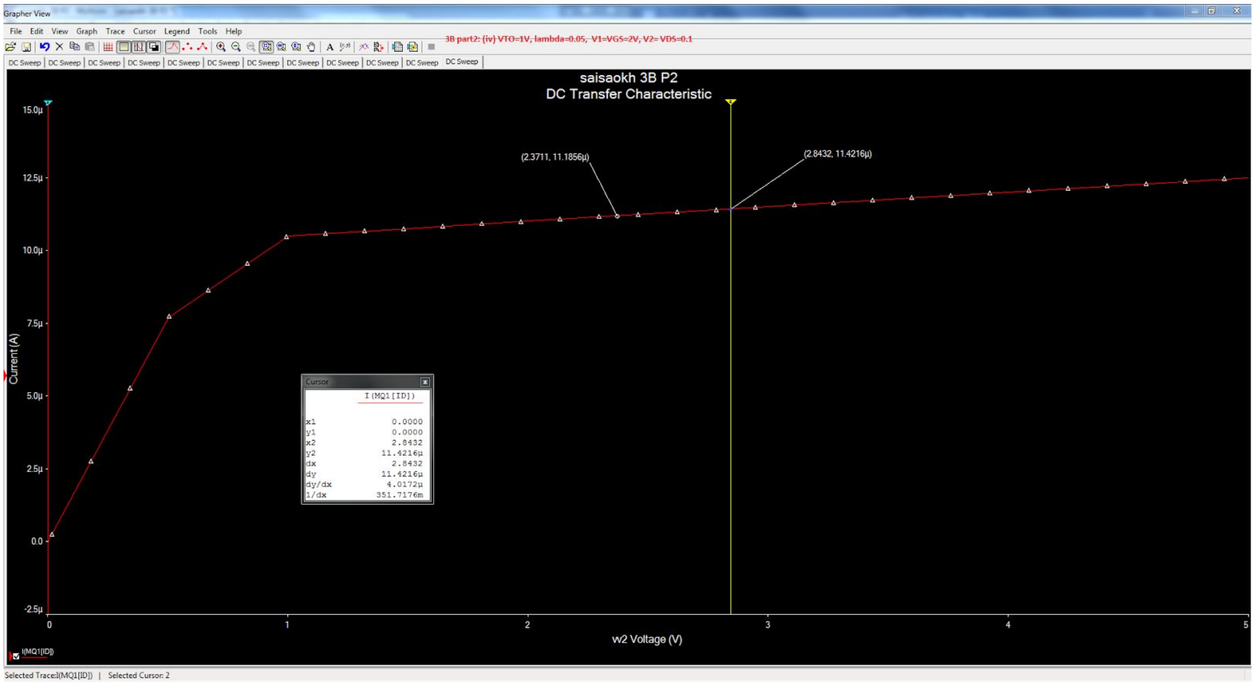


When V_{GS}=4.0 V, slope (m) = $\frac{y_2-y_1}{x_2-x_1} = \frac{108.5772\mu-106.0014\mu}{4.1283-3.5648} = \frac{2.5758\mu}{0.5635} = 4.5710\mu\frac{A}{V}$

$y = mx + b$	$y_2 - y_1 = m(x_2 - x_1)$
$108.5772\mu = (4.5710\mu)(4.1283) + b$	$(108.5772 - 0) = 4.5710\mu\ (4.1283 - x_1)$
$108.5772\mu = 18.8705\mu + b$	$(108.5772\mu) = 18.8705\mu - 4.5710\mu x_1$
$108.5772\mu - 18.8705\mu = b$	$89.706\mu = -4.5710\mu x_1$
$89.706\mu A = b$	$x = -19.625\ V$

(iv)


saisaokh 3B P2 - Multisim - [saisaokh 3B P2 *]
File Edit View Place MCU Simulate Transfer Tools Reports Options Window Help
--- In-Use List ---
Design Toolbox
saisaokh 3B P2
saisaokh 3B P2
V2
0.1V
Q1
V1
2V
Hierarchy Visibility Project View
saisaokh 3B P2 *
Multisim - Tuesday, October 25, 2016, 11:52:36 AM
Spreadsheet View
Results Nets Components Copper layers Simulation



When V_{GS}=2.0 V, slope (m) = $\frac{y_2-y_1}{x_2-x_1} = \frac{10.5664\mu-10.4523\mu}{2.8322-2.2614} = \frac{0.7434\mu}{0.9291} = 0.1999\mu\frac{A}{V}$

$y = mx + b$

$10.5664\mu = (0.1999\mu)(2.8322) + b$

$10.5664\mu = 0.5661\mu + b$

$10.5664\mu - 2.5485\mu = b$

$10.0003\ \mu A = b$

$I_C = 10.0003\mu A$

$y_2 - y_1 = m(x_2 - x_1)$

$(10.5664\mu - 0) = 0.1999\mu\ (2.8322 - x_1)$

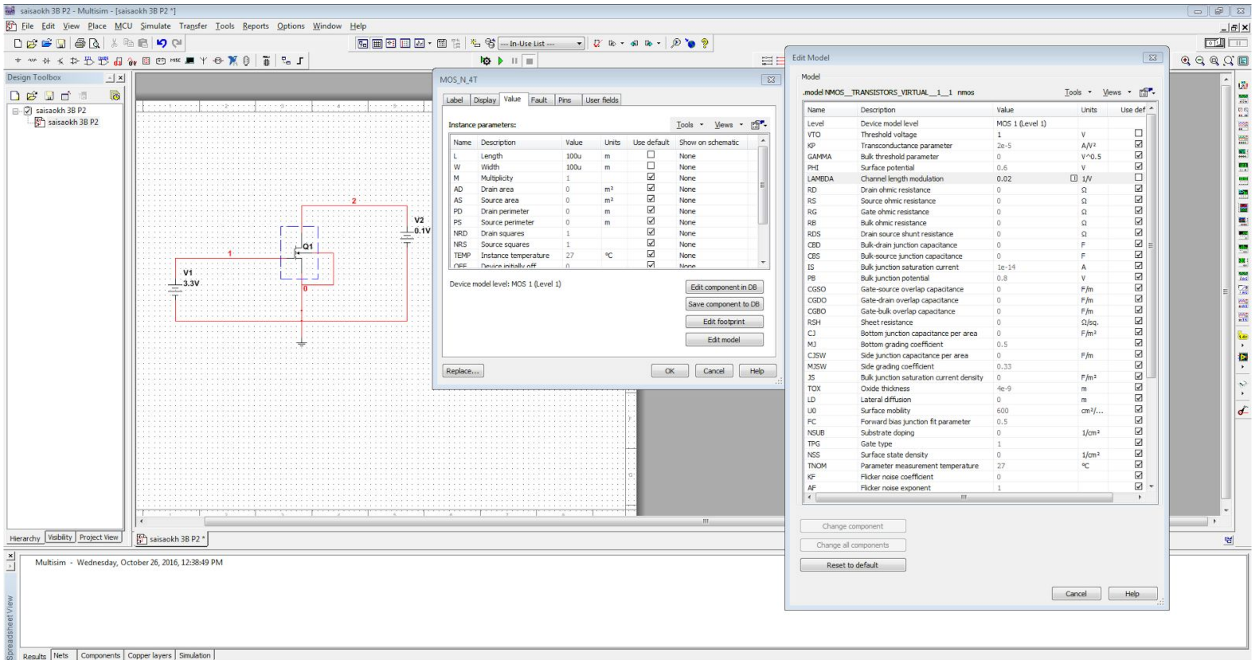
$(10.5664\mu) = 0.5661\mu - 0.1999\mu x_1$

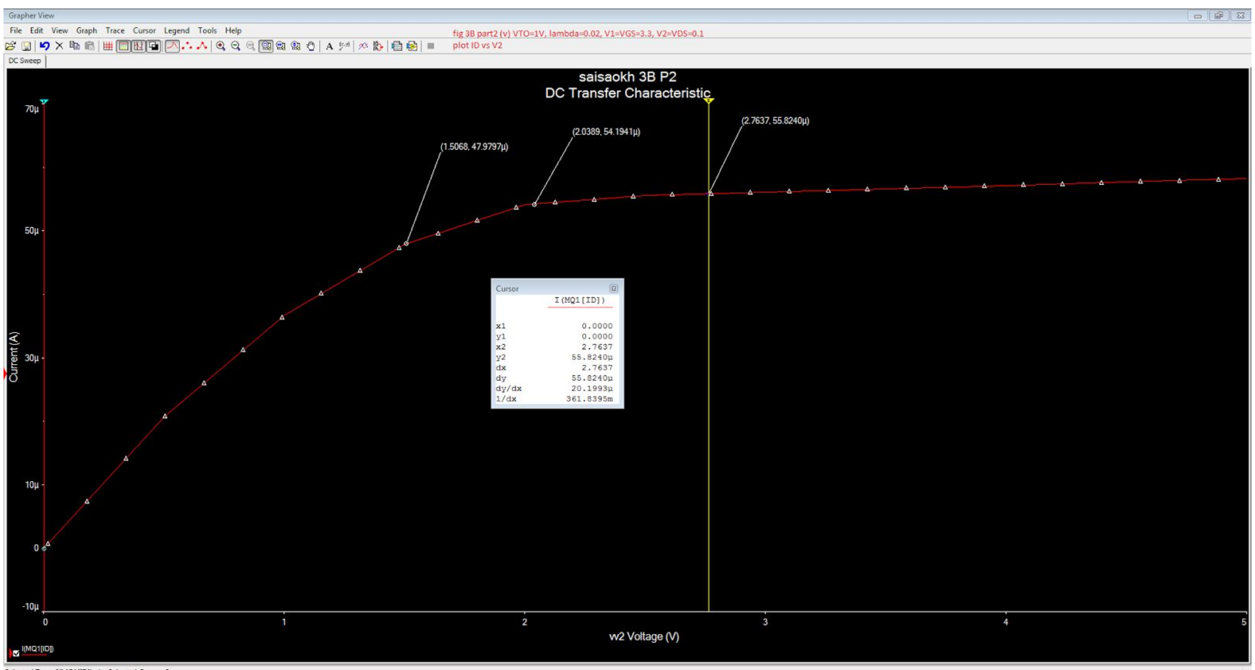
$10.0003\mu = -.1999\mu x_1$

$x = -50.0265\ V$

$-V_A = -50.0265V$

(V)


saisaokh 3B P2 - Multisim - [saisaokh 3B P2 *]
MOS_N_4T
Device model level: MOS 1 (Level 1)
Edit Model
.model NMOS__TRANSISTORS_VIRTUAL__1__1 nmos
Multisim - Wednesday, October 26, 2016, 12:38:49 PM


Grapher View
fig 3B part2 (v) VTO=1V, lambda=0.02, V1=VGS=3.3, V2=VDS=0.1
plot ID vs V2
saisaokh 3B P2
DC Transfer Characteristic
(1.5068, 47.9797µ)
(2.0389, 54.1941µ)
(2.7637, 55.8240µ)
Cursor
I(MQ1[ID])
x1 0.0000
y1 0.0000
x2 2.7637
y2 55.8240µ
dx 2.7637
dy 55.8240µ
dy/dx 20.1993µ
1/dx 361.8395m
Current (A)
w2 Voltage (V)
Selected Trace:I(MQ1[ID]) | Selected Cursor: 2

When V_{GS}=3.3 V, slope (m) = $\frac{y_2-y_1}{x_2-x_1} = \frac{42.5482\mu-41.8048\mu}{3.1852-2.2561} = \frac{0.7434\mu}{0.9291} = 0.8001\mu\frac{A}{V}$

$y = mx + b$

$42.5482\mu = (0.8001\mu)(3.1852) + b$

$42.5482\mu = 2.5485\mu + b$

$42.5482\mu - 2.5485\mu = b$

39.9998μ A = b

$I_C = 39.9998\ \mu$ A

$y_2 - y_1 = m(x_2 - x_1)$

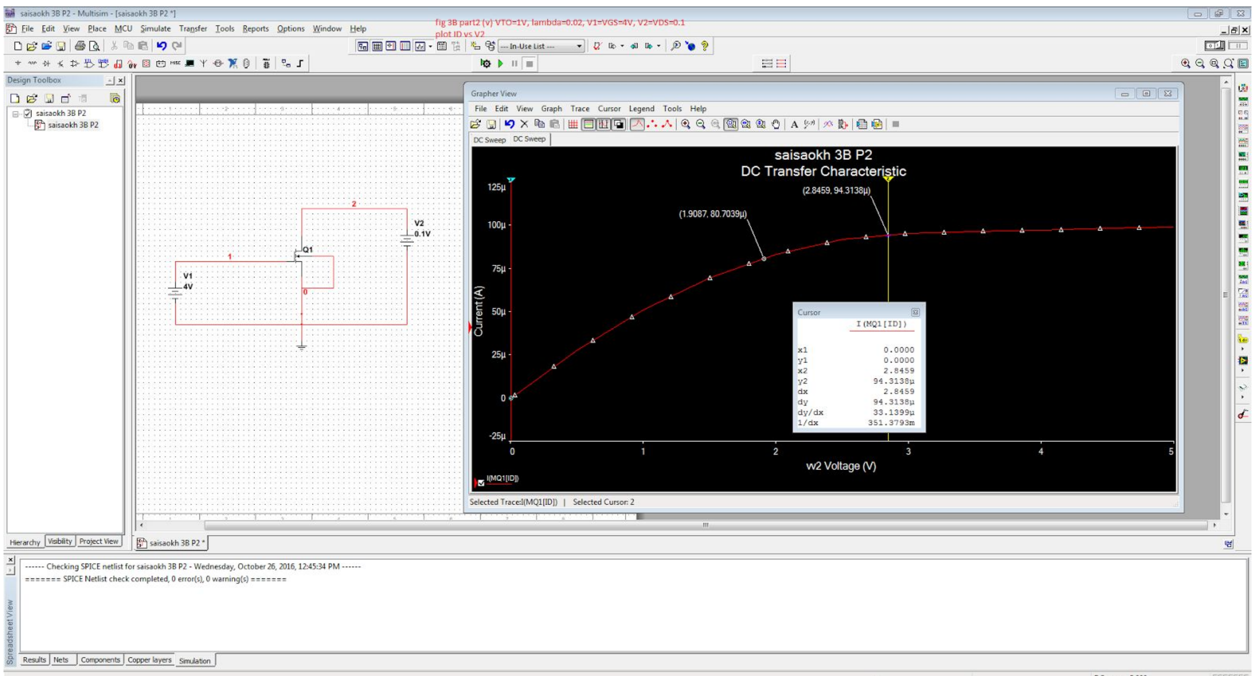
$(42.5482\mu - 0) = .8001\mu\,(3.1852 - x_1)$

$(42.5482\mu) = 2.5485\mu - .8001\mu x_1$

$39.9998\mu = -.8001\mu x_1$

$x = -49.9933\ V$

$-V_A = -49.9933V$



When V_{GS}=4.0 V, slope (m) = $\frac{y_2-y_1}{x_2-x_1} = \frac{96.7528\mu-96.0747\mu}{3.7516-3.3748} = \frac{.6781\mu}{0.3768} = 1.8\mu\frac{A}{V}$

$y = mx + b$

$96.7528\mu = (1.8\mu)(3.7516) + b$

$96.7528\mu = \mu + b$

$96.7528\mu - 6.7528\mu = b$

90μ A = b

$I_C = 90\mu$A

$y_2 - y_1 = m(x_2 - x_1)$

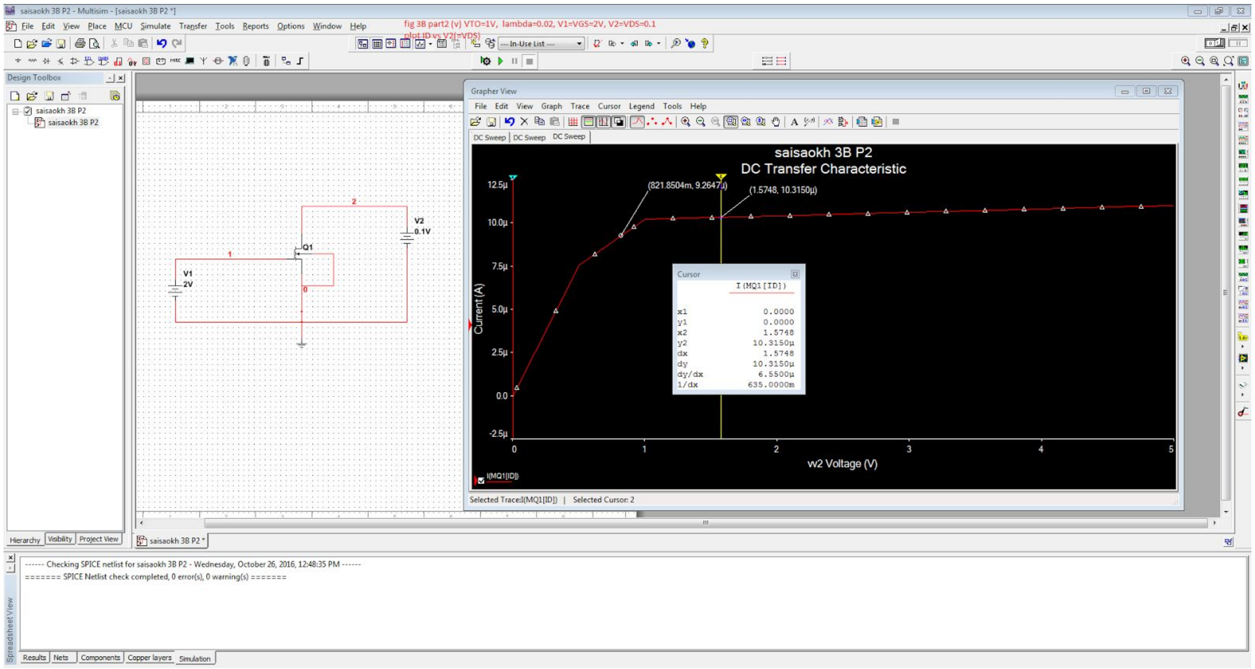
$(96.7528\mu - 0) = 1.8\mu\,(3.7516 - x_1)$

$(96.7528\mu) = 6.7528\mu - 1.8\mu x_1$

$90\mu = -1.8\mu x_1$

$x = -50\ V$

$-V_A = -50V$



Correct values of V_A, $\frac{1}{\lambda}$, r_o:

When $\lambda = 0.05$ & $V_{GS} = 2V$:

$\frac{1}{\lambda} = \frac{1}{0.05} = 20$ $-V_A = -20V = 20V$ $r_o = \frac{V_A}{I_C} = \frac{20V}{10\mu A} = 2M\Omega$

When $\lambda = 0.05$ & $V_{GS} = 3.3V$:

$\frac{1}{\lambda} = \frac{1}{0.05} = 20$ $-V_A = -20V = 20V$ $r_o = \frac{V_A}{I_C} = \frac{20V}{40\,\mu A} = 500k\Omega$

When $\lambda = 0.05$ & $V_{GS} = 4V$:

$\frac{1}{\lambda} = \frac{1}{0.05} = 20$ $-V_A = -19.625 = 19.625V$ $r_o = \frac{V_A}{I_C} = \frac{19.625}{89.706\mu A} = 218.770k\Omega$

When $\lambda = 0.02$& $V_{GS} = 2V$:

$\frac{1}{\lambda} = \frac{1}{0.02} = 50$ $-V_A = -50.0265V = 50.0265V$ $r_o = \frac{V_A}{I_C} = \frac{50.0265V}{10.0003\mu A} = 500.249k\Omega$

When $\lambda = 0.02$& $V_{GS} = 3.3V$:

$\frac{1}{\lambda} = \frac{1}{0.02} = 50$ $-V_A = -49.9933V = 49.9933V$ $r_o = \frac{V_A}{I_C} = \frac{49.9933V}{39.9998\,\mu A} = 124.984k\Omega$

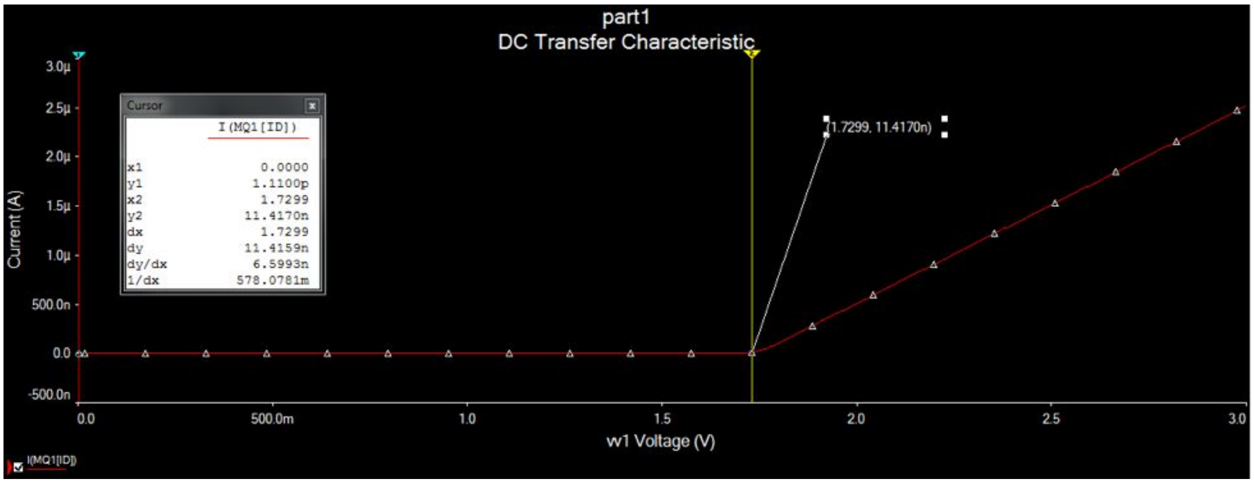
When $\lambda = 0.02$& $V_{GS} = 4V$:

$\frac{1}{\lambda} = \frac{1}{0.02} = 50$ $-V_A = -50V = 50V$ $r_o = \frac{V_A}{I_C} = \frac{50}{90\mu A} = 555.555\ k\Omega$

<u>3B: Part 3 (Study the Body-effect by simulation)</u>

Calculation of GAMMA (γ)

Plot of I_D – V_{GS} to measure V_T= 1.6V and V_{GS}= 1V



$$V_t = V_{t0} + \gamma\left[\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f}\right], \text{ Where, } 2\phi_f = 0.6\text{V}, V_{t0} = 1.6\ V,\ V_{SB} = 1V$$

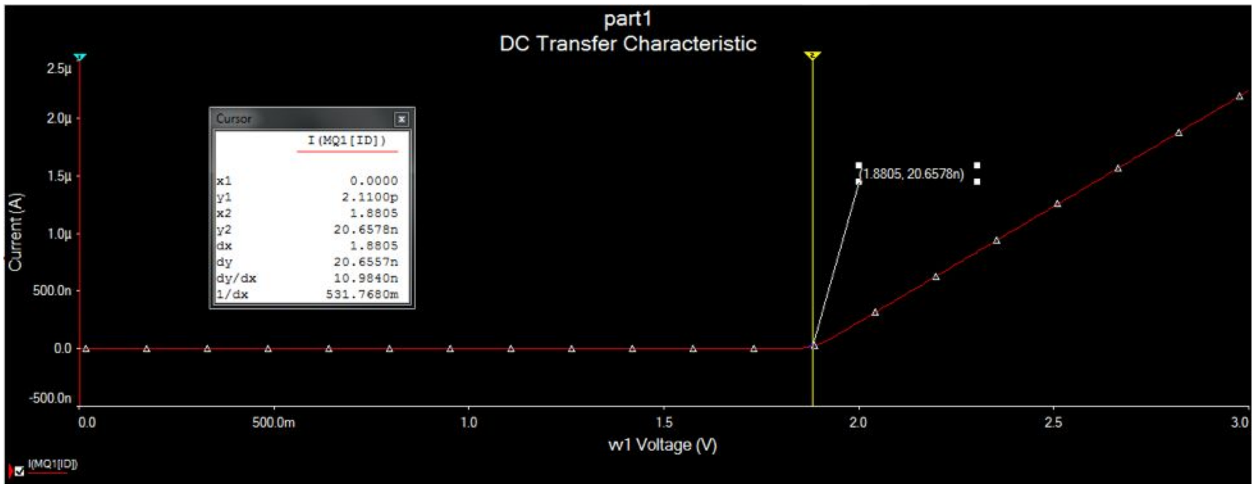
$$1.7299 = 1.6 + \gamma\left[\sqrt{0.6 + 1} - \sqrt{0.6}\right]$$

$$1.7299 - 1.6 = \gamma[\sqrt{1.6} - \sqrt{0.6}]$$

$$\frac{0.2299}{[\sqrt{1.6} - \sqrt{0.6}]} = \gamma$$

$$0.2649 = \gamma$$

Plot of I_D – V_{GS} to measure V_T= 1.6V and V_{GS}= 2V



$$V_t = V_{t0} + \gamma\left[\sqrt{2\emptyset_f + V_{SB}} - \sqrt{2\emptyset_f}\right], \text{Where, } 2\emptyset_f = 0.6\text{V}, V_{t0} = 1.6\ V,\ V_{SB} = 2V$$

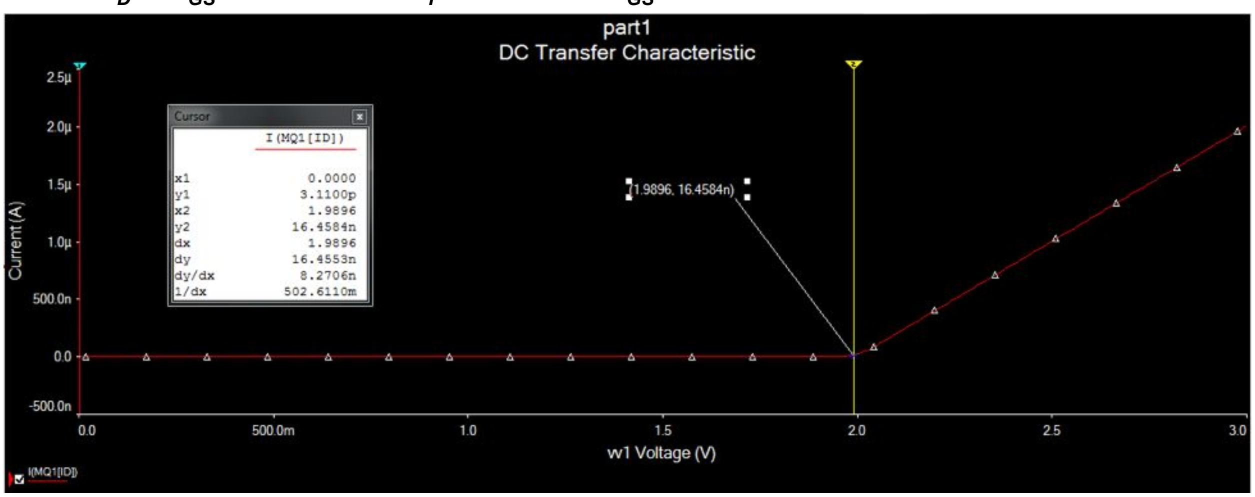
$$1.8805 = 1.6 + \gamma\left[\sqrt{0.6 + 2} - \sqrt{0.6}\right]$$

$$1.8805 - 1.6 = \gamma\left[\sqrt{2.6} - \sqrt{0.6}\right]$$

$$\frac{0.2805}{\left[\sqrt{2.6} - \sqrt{0.6}\right]} = \gamma$$

$$0.3348 = \gamma$$

Plot of I_D – V_{GS} to measure V_T= 1.6V and V_{GS}= 3V



$V_t = V_{t0} + \gamma\left[\sqrt{2\emptyset_f + V_{SB}} - \sqrt{2\emptyset_f}\right]$, Where, $2\emptyset_f$ = 0.6V, $V_{t0} = 1.6\ V,\ V_{SB} = 3V$

$1.9896 = 1.6 + \gamma\left[\sqrt{0.6 + 3} - \sqrt{0.6}\right]$

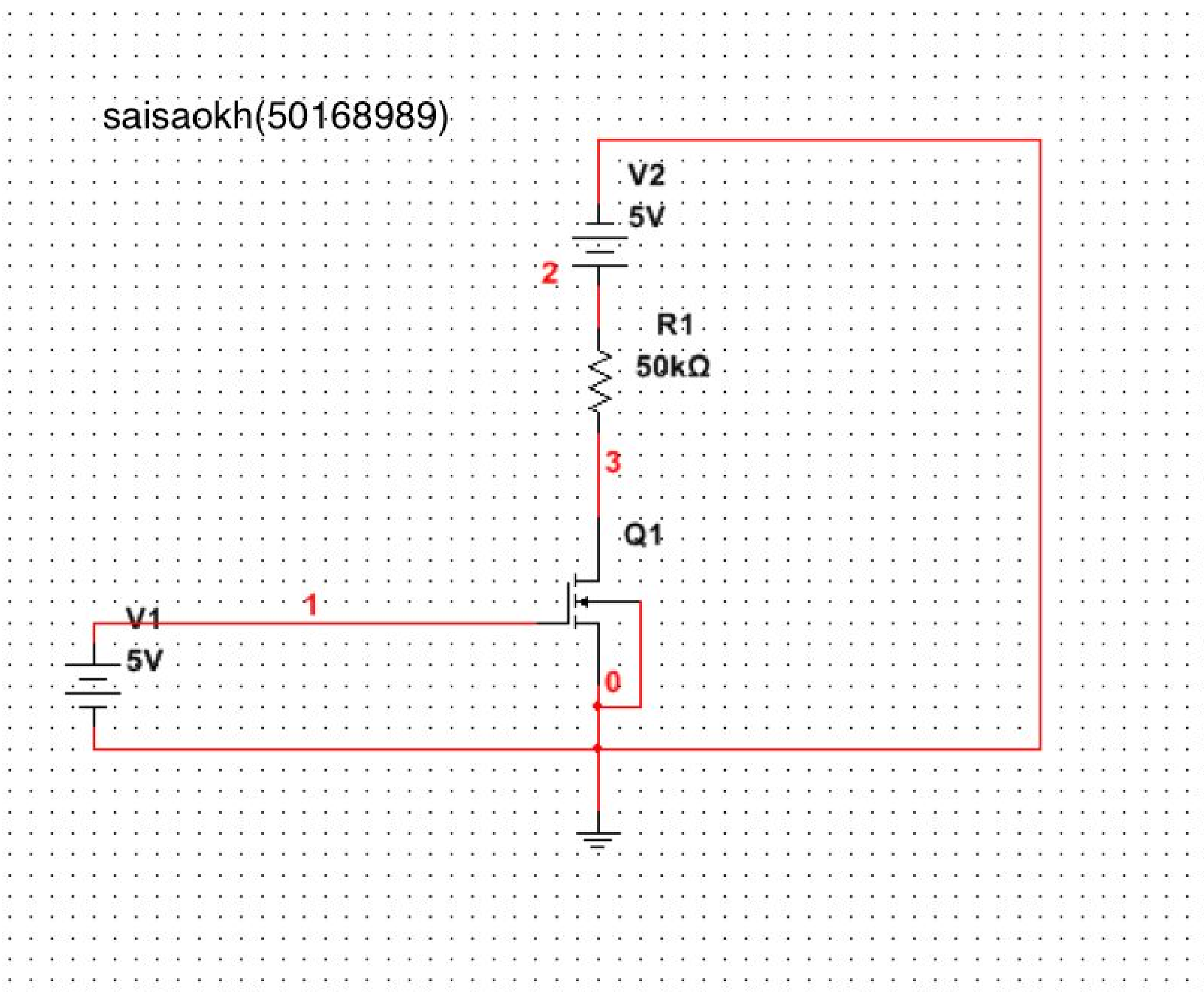
$1.9896 - 1.6 = \gamma[\sqrt{3.6} - \sqrt{0.6}]$

$\frac{0.3896}{[\sqrt{3.6} - \sqrt{0.6}]} = \gamma$

$0.34699 = \gamma$

3B; Part 4 (Design & Study the Q-point)

Correct circuit schematic



Plot of Output voltage vs.Gate-source voltage & reasonable Q-point