Digital Electronics

CA #1

Name: Mohammad

Last Name: Taghizadeh Givari

Student No: 810198373

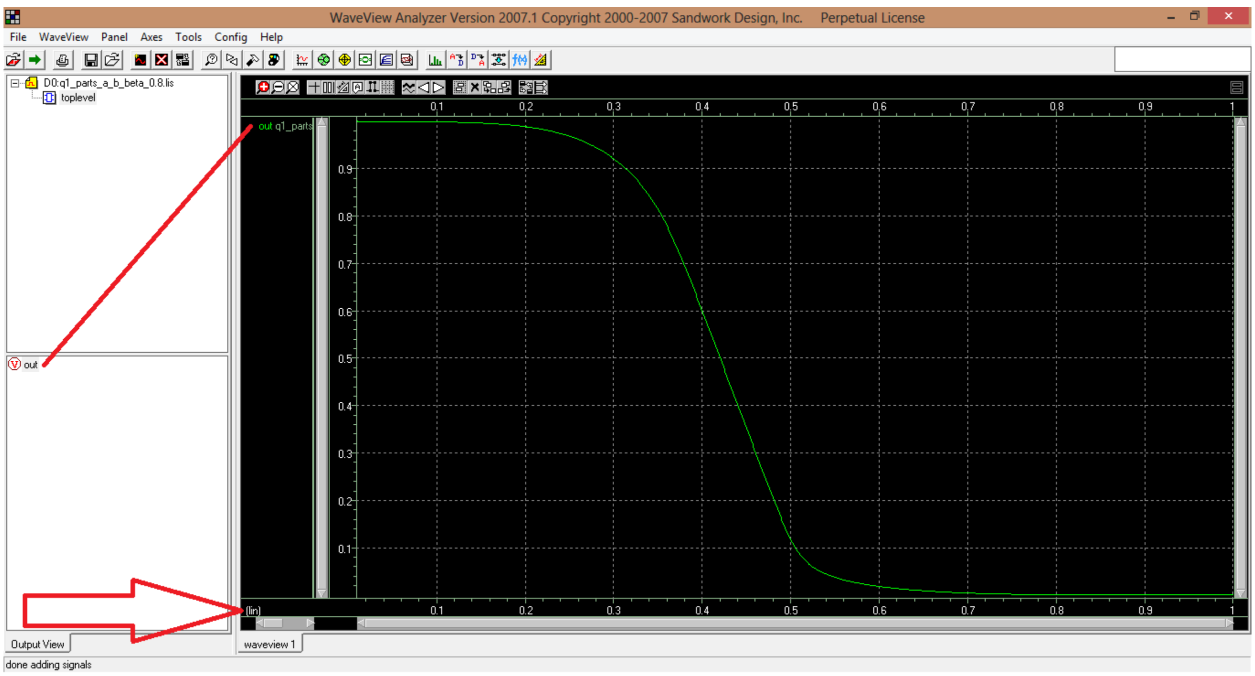
Contents

Question 1:

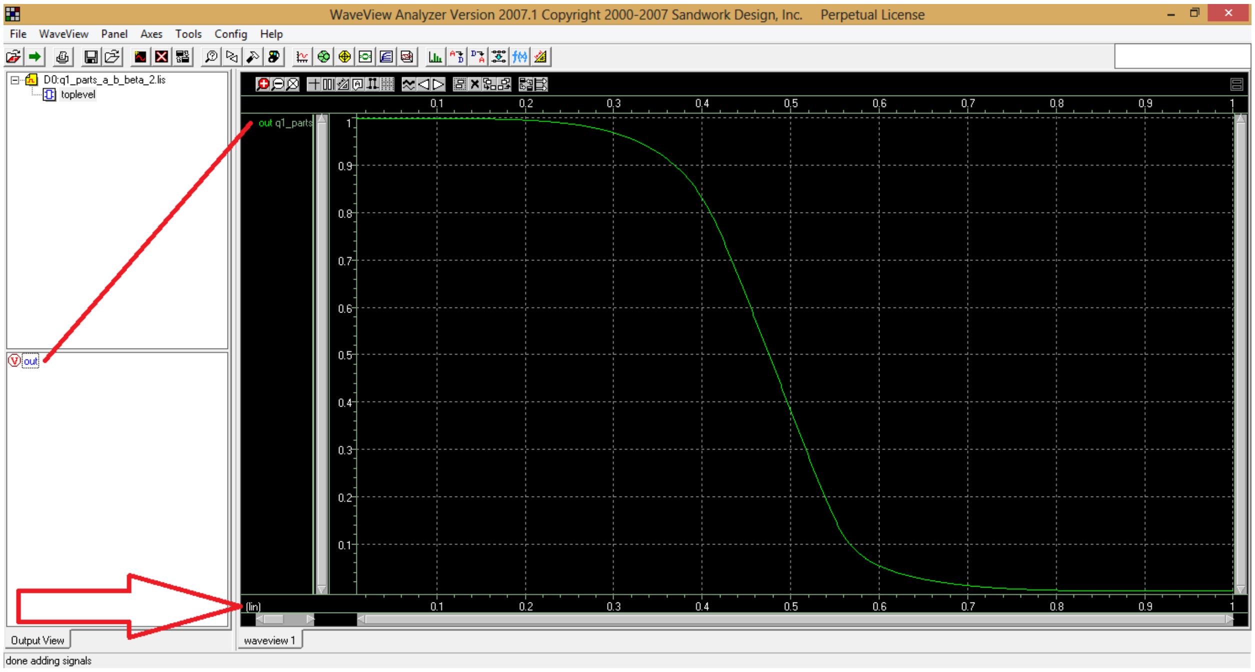
Transfer characteristic of an inverter

Part a:

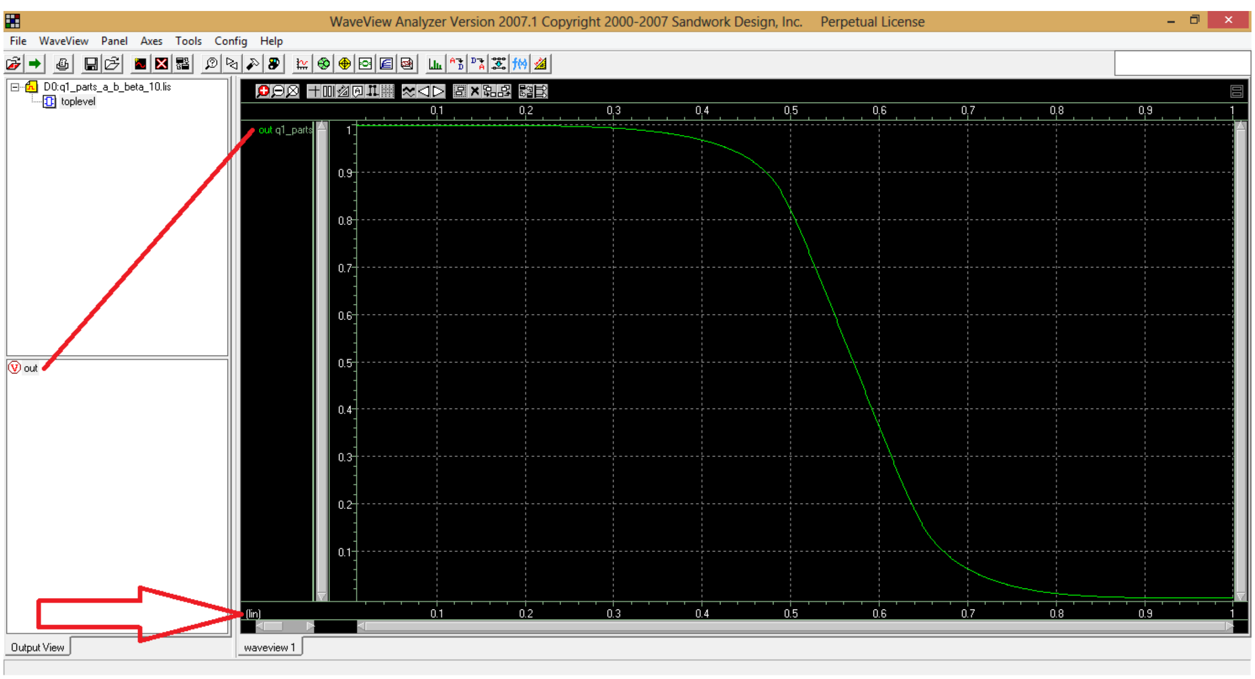
VTC(Voltage Transfer Characteristic) for β = 0.8



VTC(Voltage Transfer Characteristic) for **β** = 2

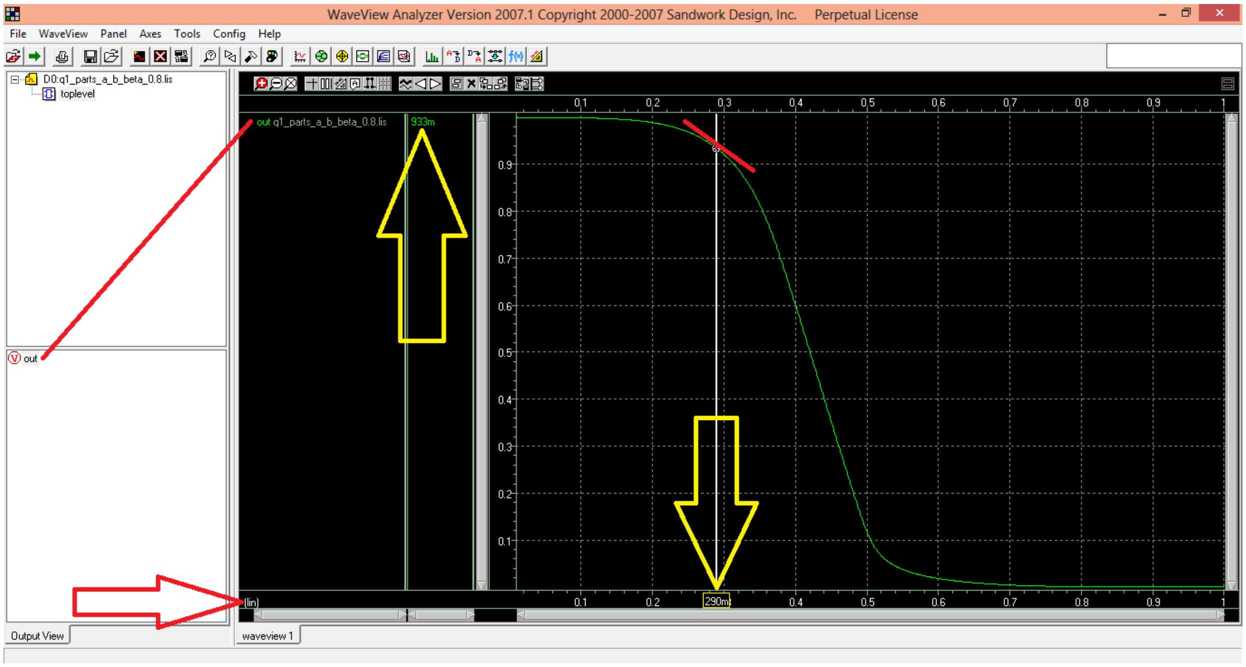


VTC(Voltage Transfer Characteristic) for **β** = 10



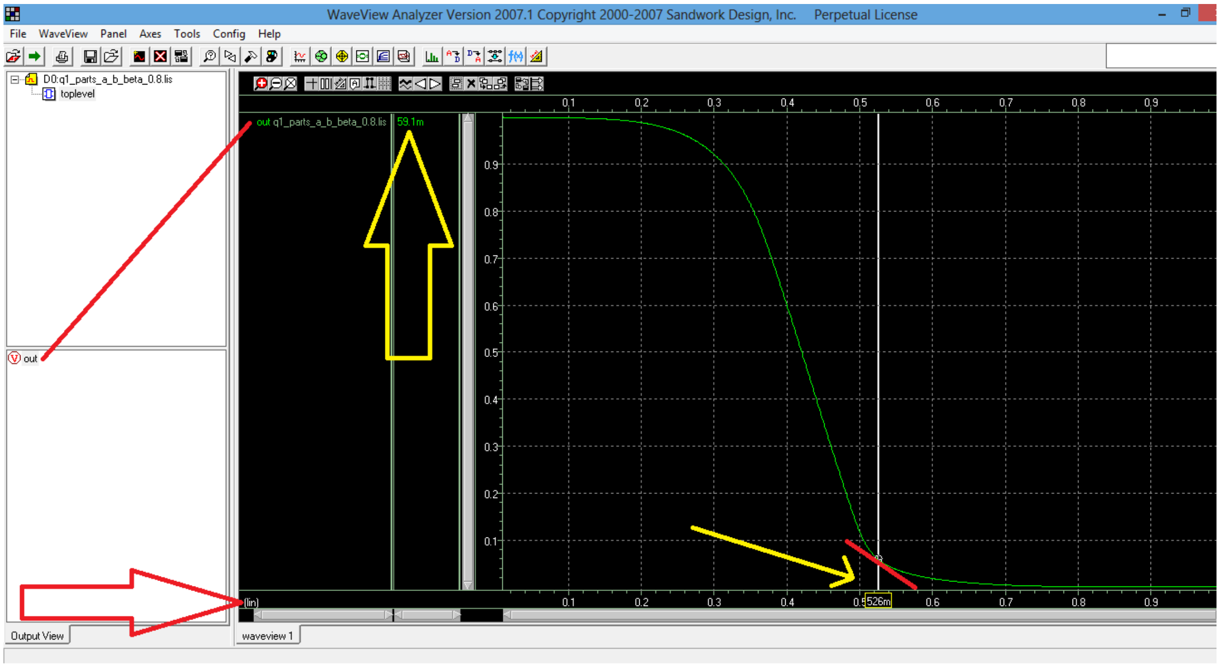
Part b:

$V_{OH}V_{IL}$ for $\boldsymbol{\beta} = 0.8$



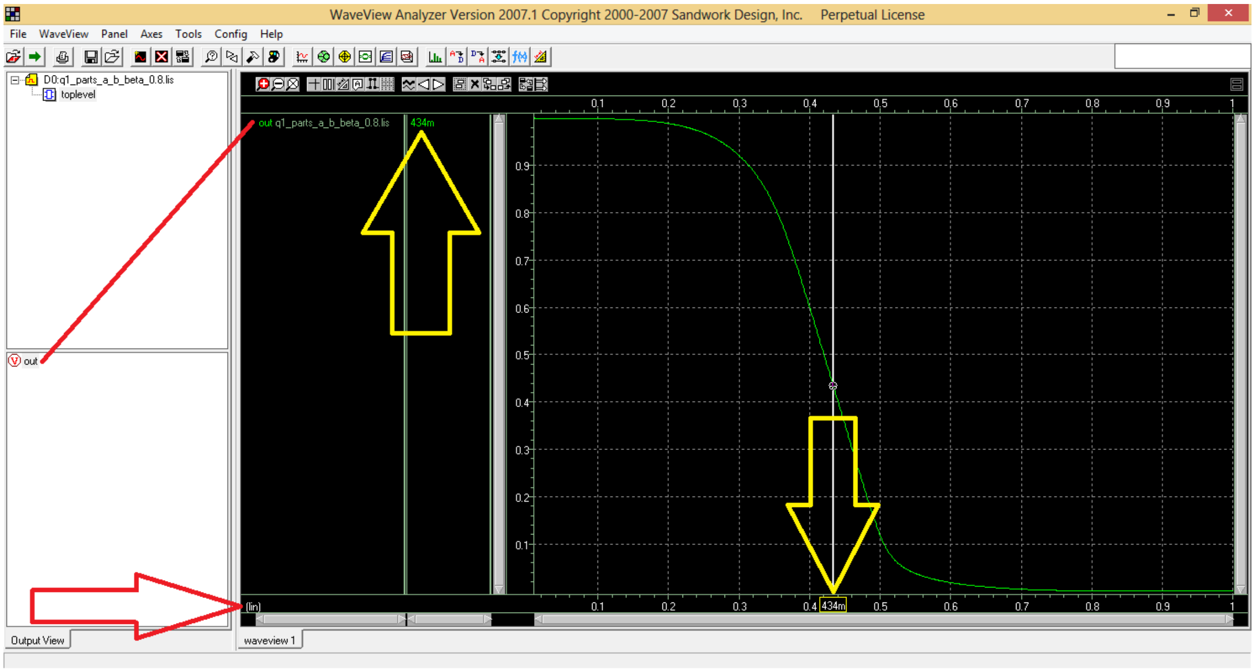
=> V_{OH} = 933 mv, V_{IL} = 290 mv

$V_{OL}V_{IH}$ for $\boldsymbol{\beta} = 0.8$



=> V_{OL} = 59.1 mv, V_{IH} = 526 mv

V_M for $\boldsymbol{\beta} = 0.8$

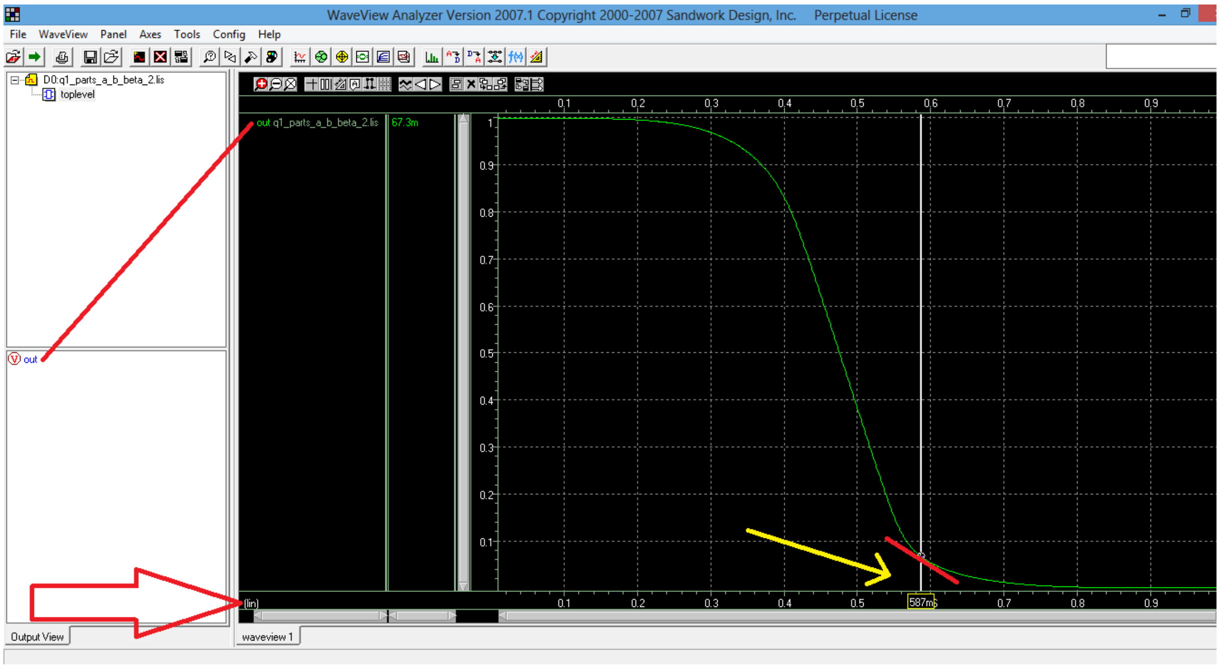


$\Rightarrow V_M = 434$ mv

$V_{OH}V_{IL}$ for **β** = 2

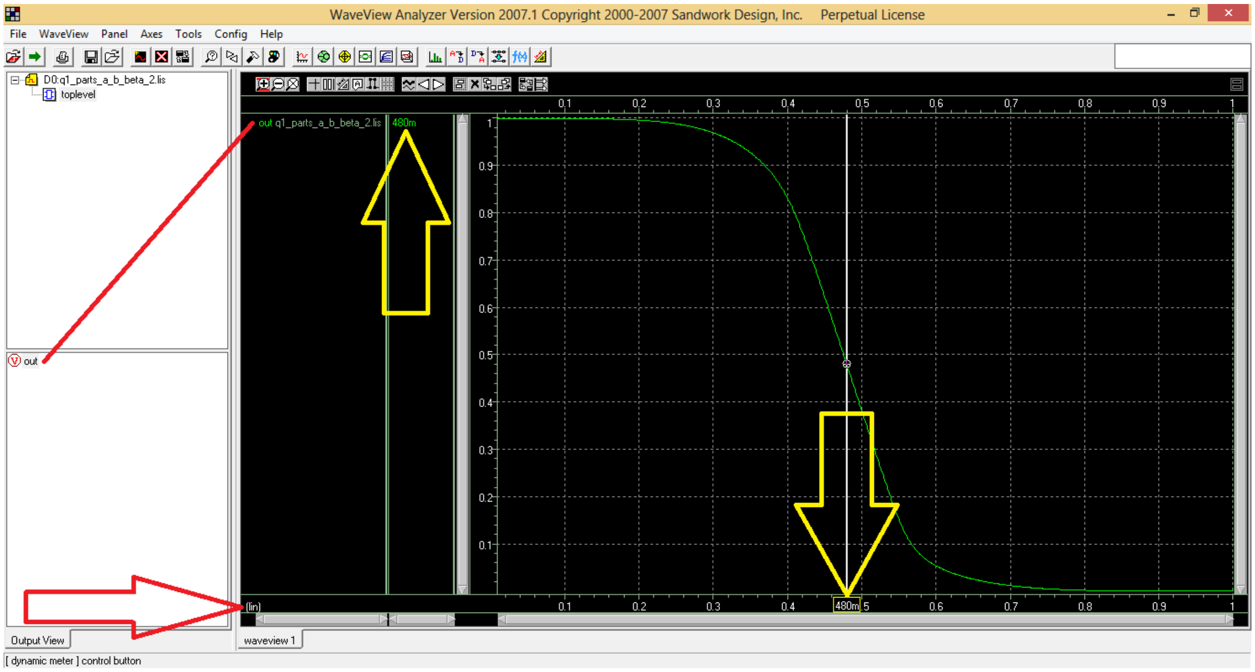
=> V_{OH} = 940 mv, V_{IL} = 338 mv

$V_{OL}V_{IH}$ for $\boldsymbol{\beta} = 2$



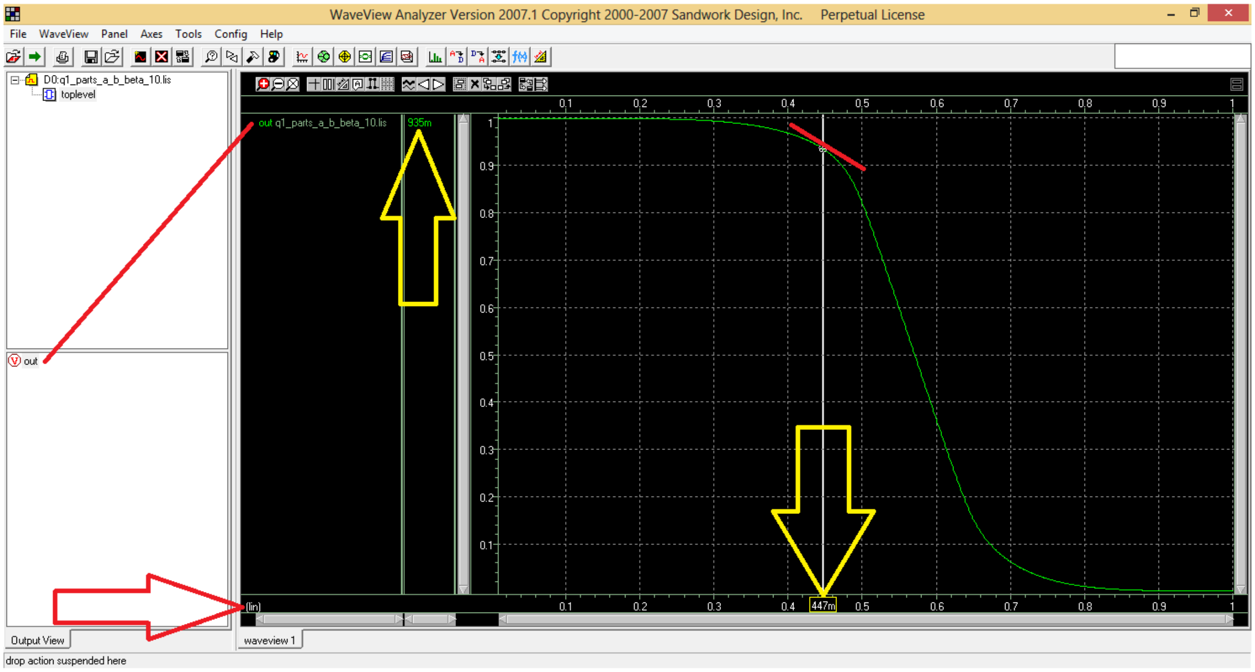
=> V_{OL} = 67.3 mv, V_{IH} = 587 mv

V_M for $\boldsymbol{\beta} = 2$



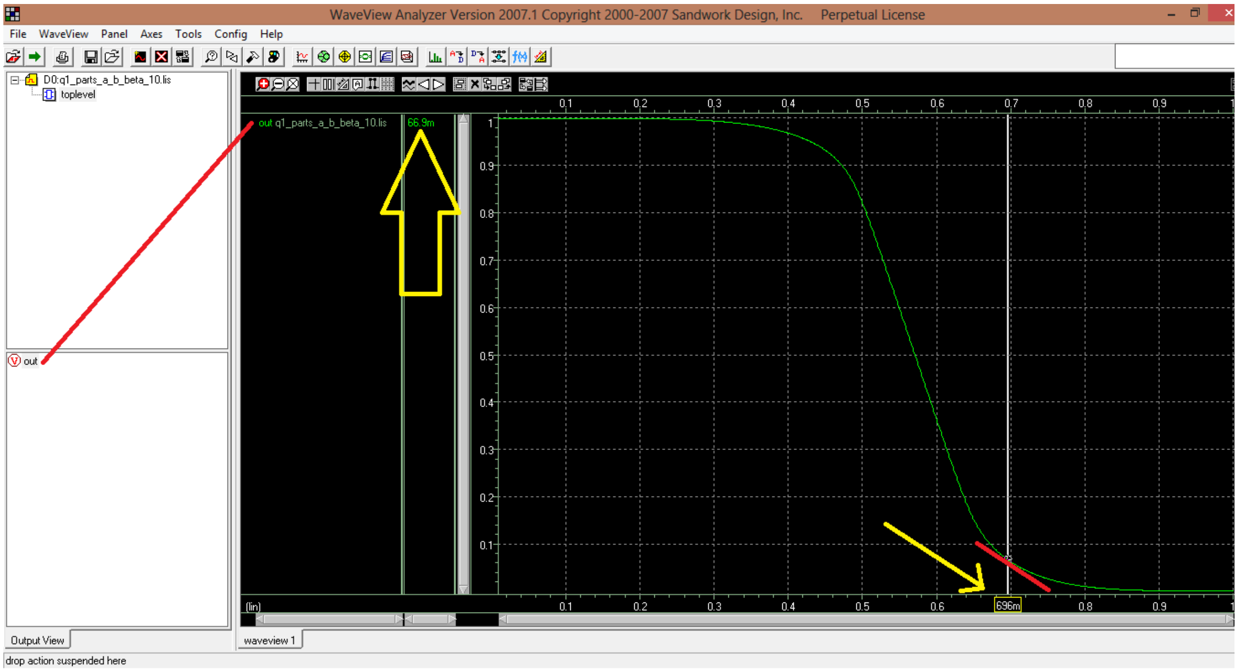
=> V_M = 480 mv

$V_{OH}V_{IL}$ for $\boldsymbol{\beta} = 10$



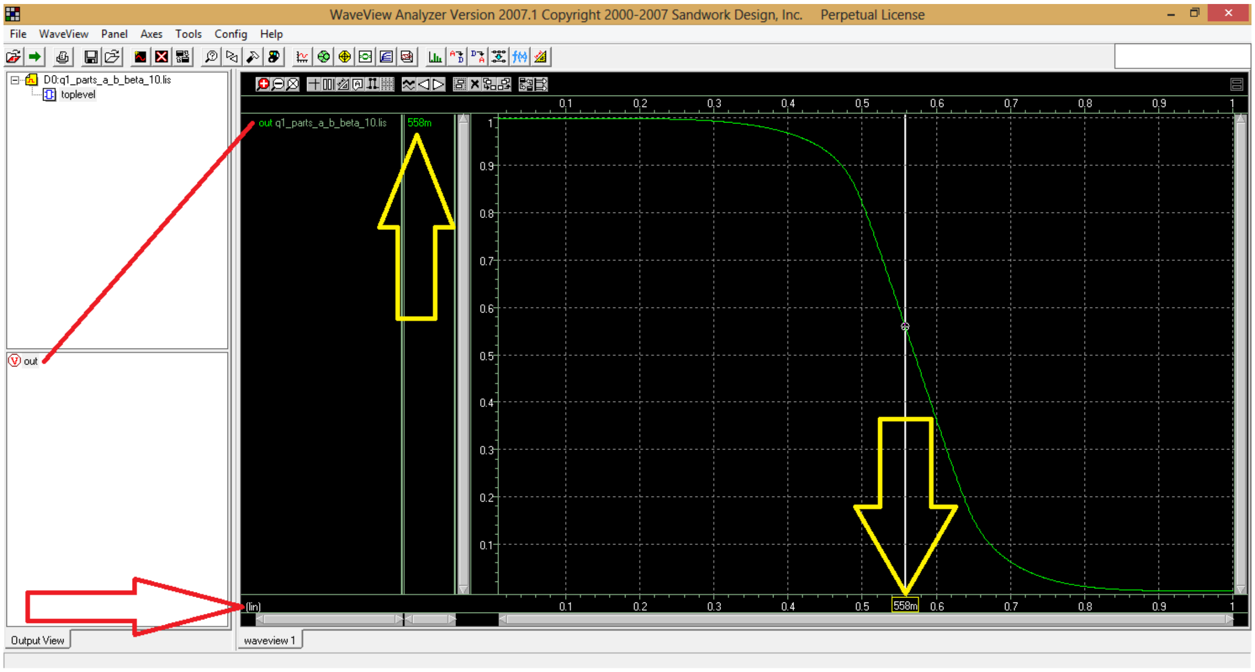
=> V_{OH} = 935 mv, V_{IL} = 447 mv

$V_{OL}V_{IH}$ for $\boldsymbol{\beta} = 10$



=> V_{OL} = 66.9 mv, V_{IH} = 696 mv

V_M for $\boldsymbol{\beta}$ = 10

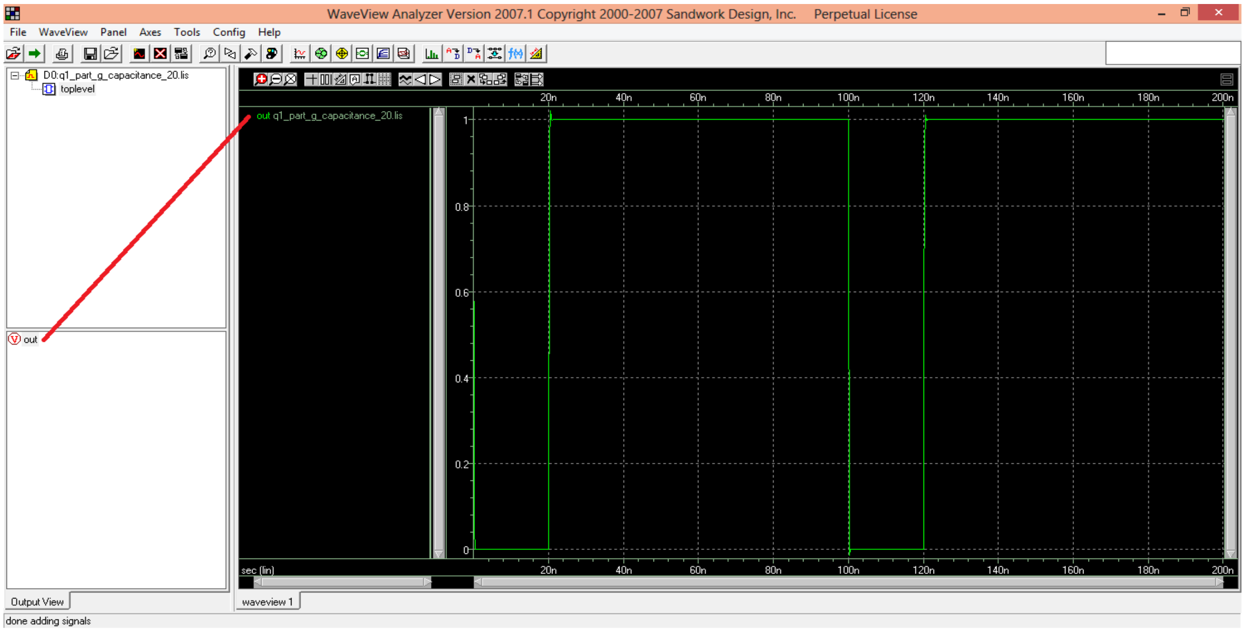


=> V_M = 558 mv

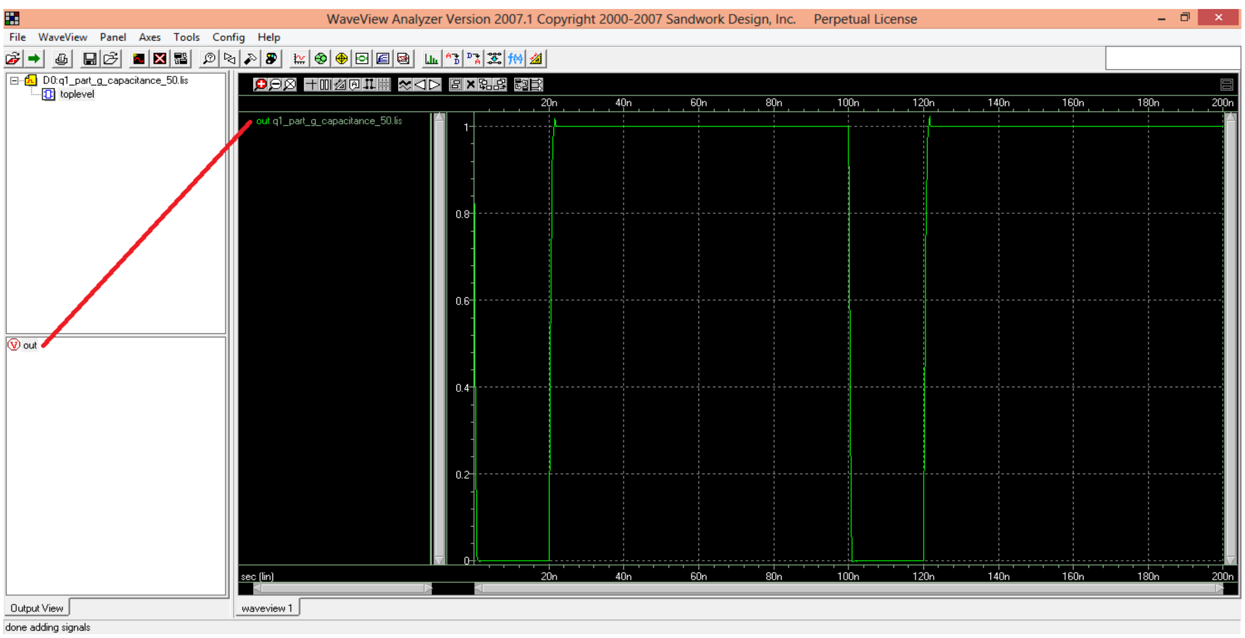
$\boldsymbol{\beta}$	V_{IL}	V_{IH}	V_{OL}	V_{OH}	V_M
0.8	290 mv	526 mv	59.1 mv	933 mv	434 mv
2	338 mv	587 mv	67.3 mv	940 mv	480 mv
10	447 mv	696 mv	66.9 mv	935 mv	558 mv

Part g:

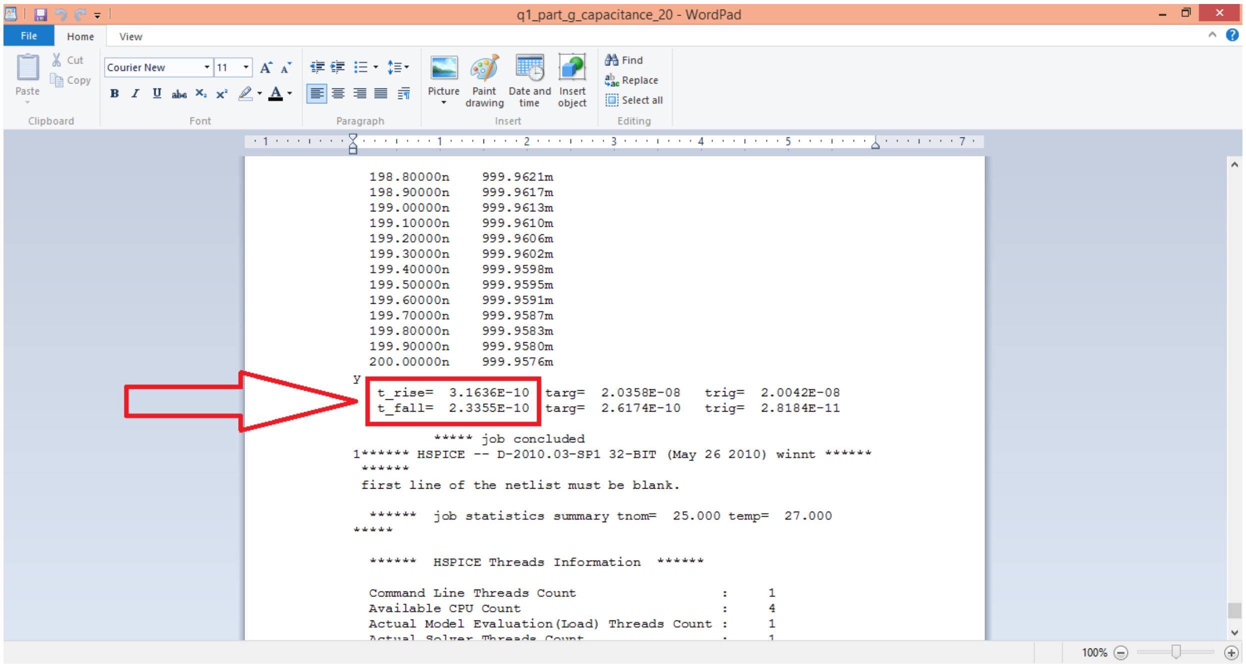
Output waveform of capacitor(20fF)



Output waveform of capacitor(50fF)



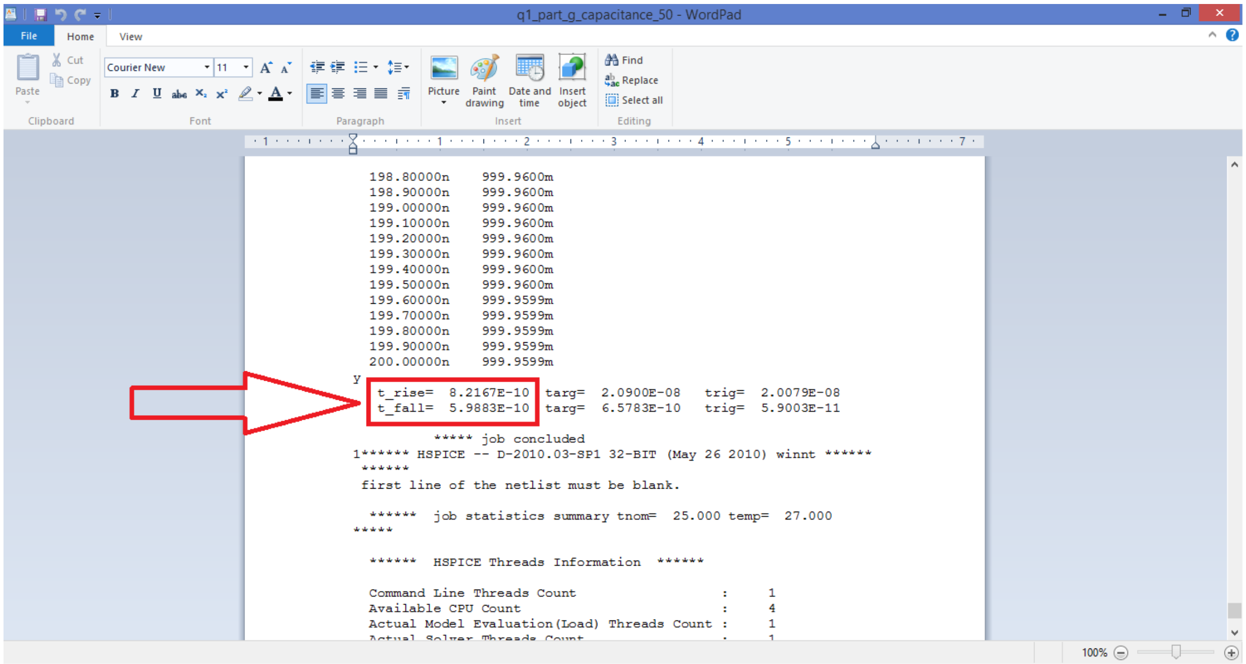
T_{rise} ,T_{fall} of output voltage of capacitor(20fF)




```
198.80000n    999.9621m
198.90000n    999.9617m
199.00000n    999.9613m
199.10000n    999.9610m
199.20000n    999.9606m
199.30000n    999.9602m
199.40000n    999.9598m
199.50000n    999.9595m
199.60000n    999.9591m
199.70000n    999.9587m
199.80000n    999.9583m
199.90000n    999.9580m
200.00000n    999.9576m
y
 t_rise=  3.1636E-10  targ=  2.0358E-08   trig=  2.0042E-08
 t_fall=  2.3355E-10  targ=  2.6174E-10   trig=  2.8184E-11

          ***** job concluded
1****** HSPICE -- D-2010.03-SP1 32-BIT (May 26 2010) winnt ******
 ******
 first line of the netlist must be blank.

  ******  job statistics summary tnom=  25.000 temp=  27.000
 *****

  ******  HSPICE Threads Information  ******

  Command Line Threads Count                     :     1
  Available CPU Count                            :     4
  Actual Model Evaluation(Load) Threads Count :     1
```

=> T_{rise} = 3.1636E-10, T_{fall} = 2.3355E-10

T_{rise} ,T_{fall} of output voltage of capacitor(50fF)



=> T_{rise} = 8.2167E-10, T_{fall} = 5.9883E-10

Cap	t_{fall}(ps)	t_{rise}(ps)
20fF	233.55	316.36
50fF	598.83	821.67

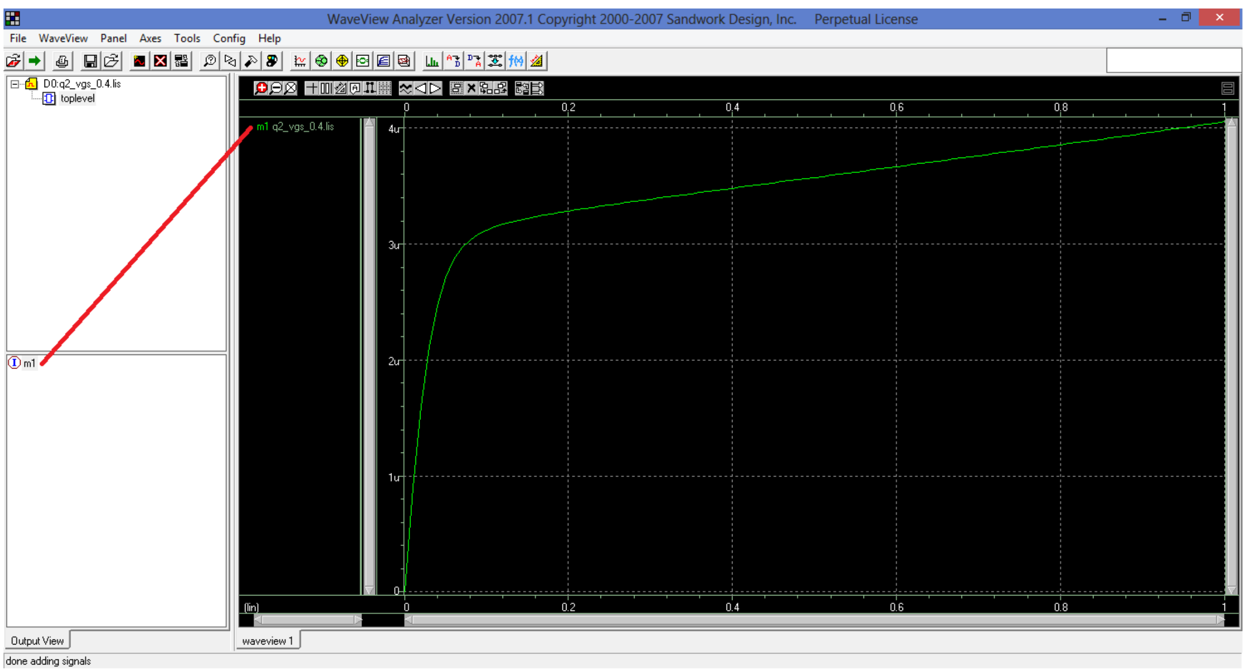
As the capacitance increases, the value of RC(Time Constant) increases, then duration of the transient state(5 × Time Constant) increases, so T_{rise} and T_{fall} increase.

Question 2:

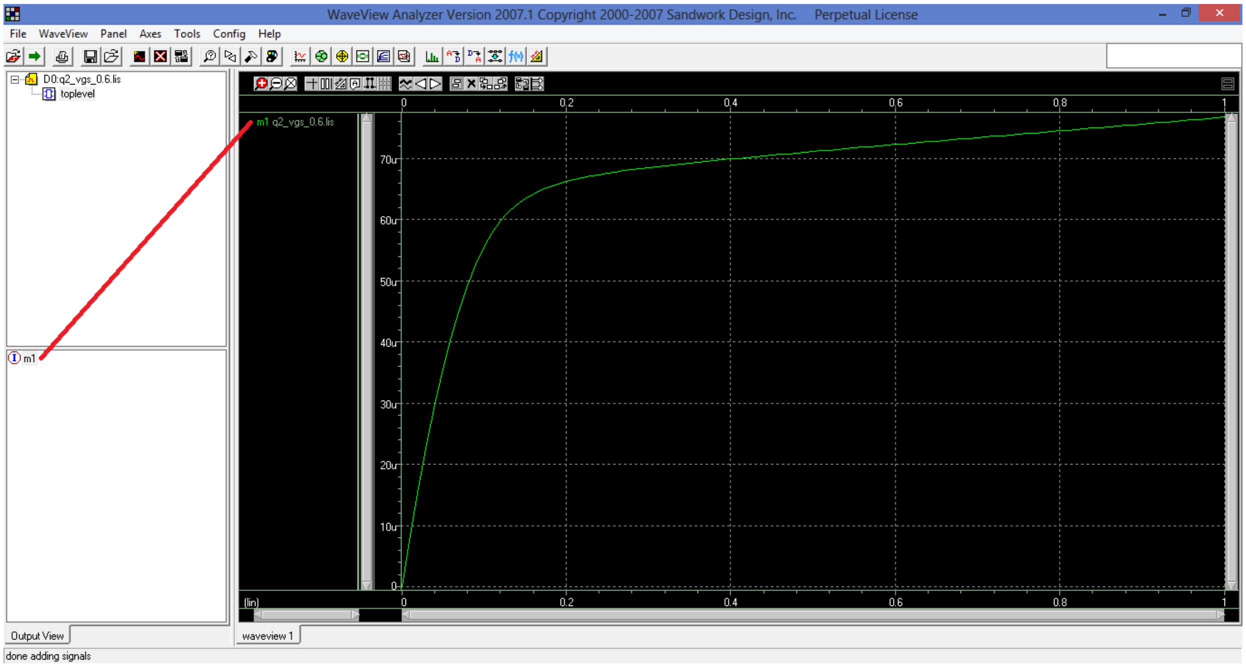
Extracting Model's Parameters from Simulation

Part a:

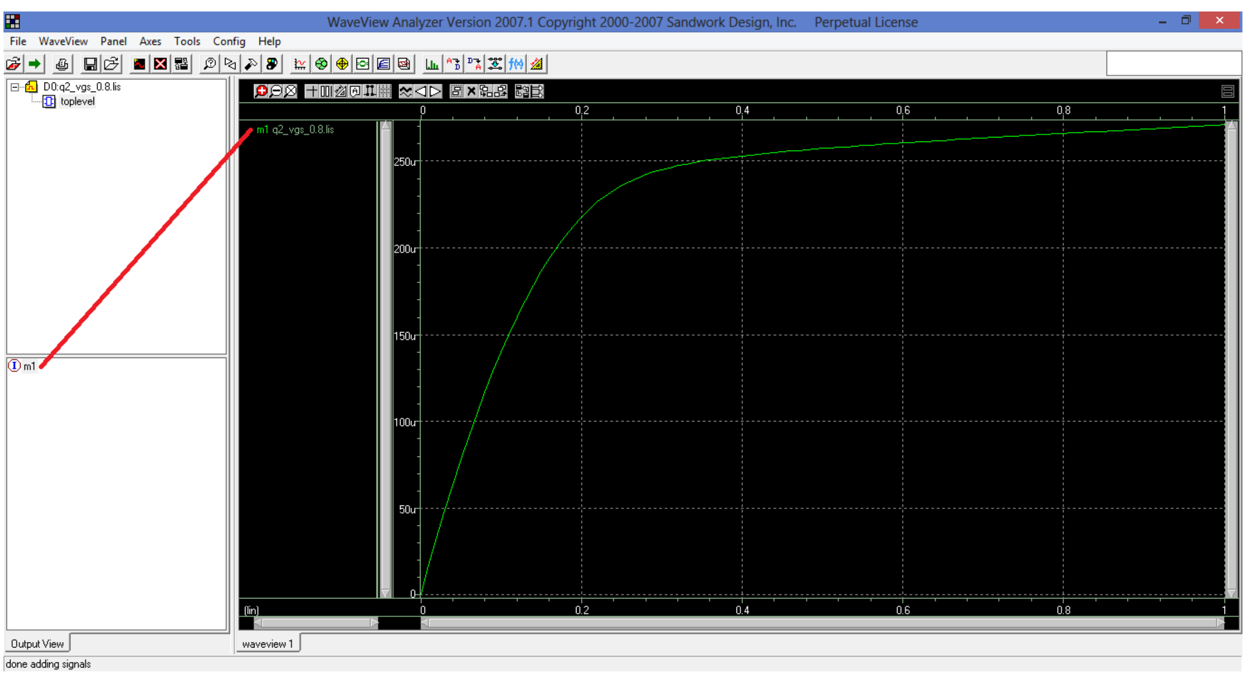
IV characteristic for V_{gs} = 0.4v



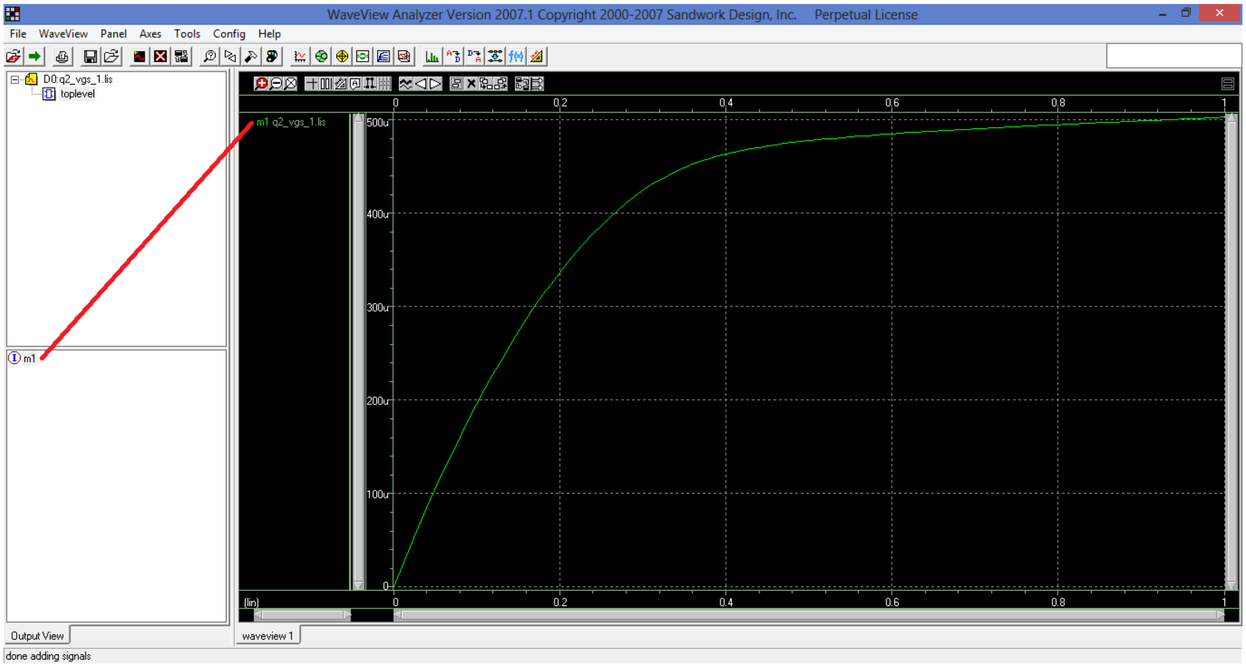
IV characteristic for V_{gs} = 0.6v



IV characteristic for V_{gs} = 0.8v



IV characteristic for V_{gs} = 1v



Part b:

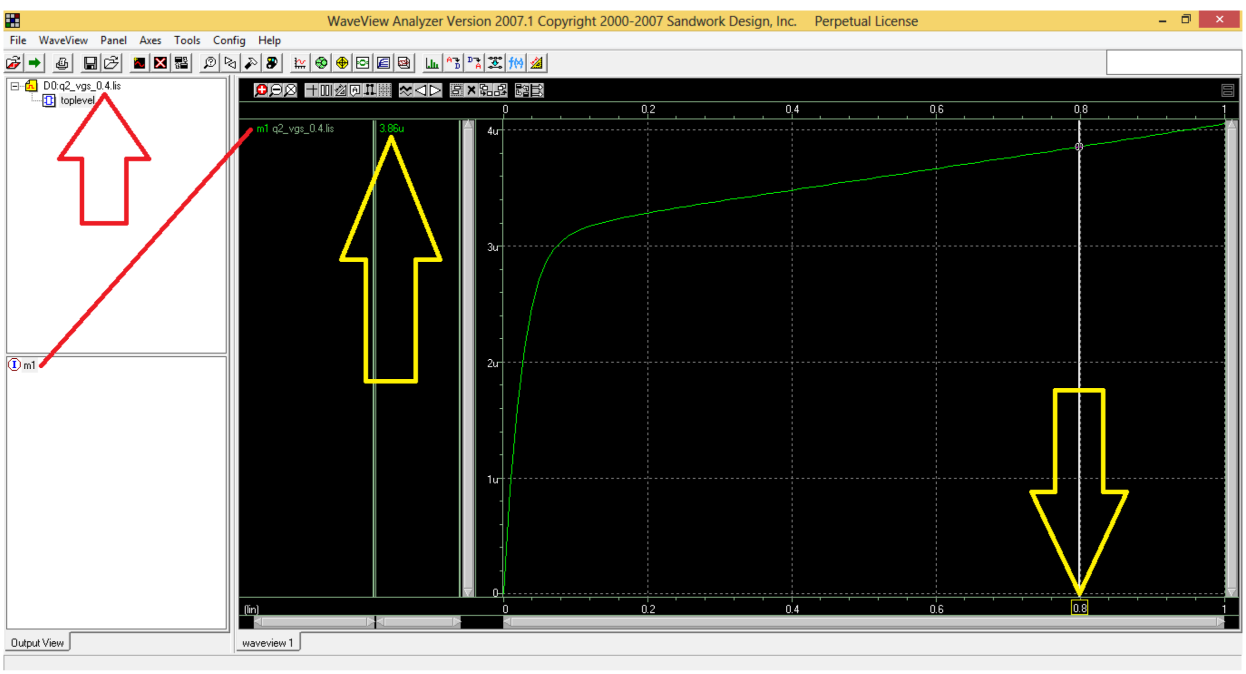
VT0:

To calculate VT0, we consider 2 points of IV characteristic with the same V_{DS} but different V_{GS} then we have:

I_{DS1} = I_{DS} of first considered point, I_{DS2} = I_{DS} of second considered point

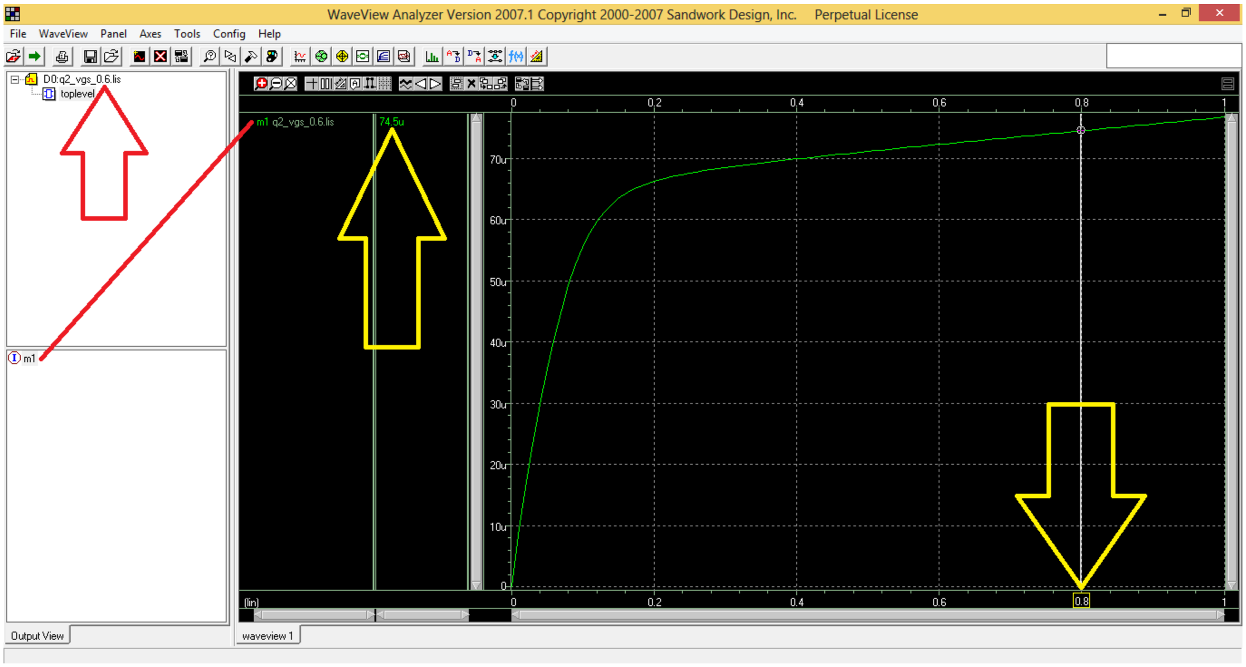
$$\frac{\mathrm{Ids1}}{\mathrm{Ids2}} = \frac{(Vgs1 - VT0)^2}{(Vgs2 - VT0)^2} \quad => \quad VT0 = \frac{\sqrt{\frac{\mathrm{Ids1}}{\mathrm{Ids2}}}Vgs2 - Vgs1}{\sqrt{\frac{\mathrm{Ids1}}{\mathrm{Ids2}}} - 1}$$

First considered point of IV for VT0 calculation:



=> I_{DS1} = 3.86 uA, V_{gs1} = 0.8 v

Second considered point of IV for VT0 calculation:



=> I_{DS2} = 74.5 uA, V_{gs2} = 0.6 v

$$=> \boldsymbol{VT0} = \frac{\sqrt{\frac{3.86\ \text{uA}}{74.5\ \text{uA}}}\,0.6 - 0.8}{\sqrt{\frac{3.86\ \text{uA}}{74.5\ \text{uA}}} - 1} = \mathbf{0.34\ v}$$

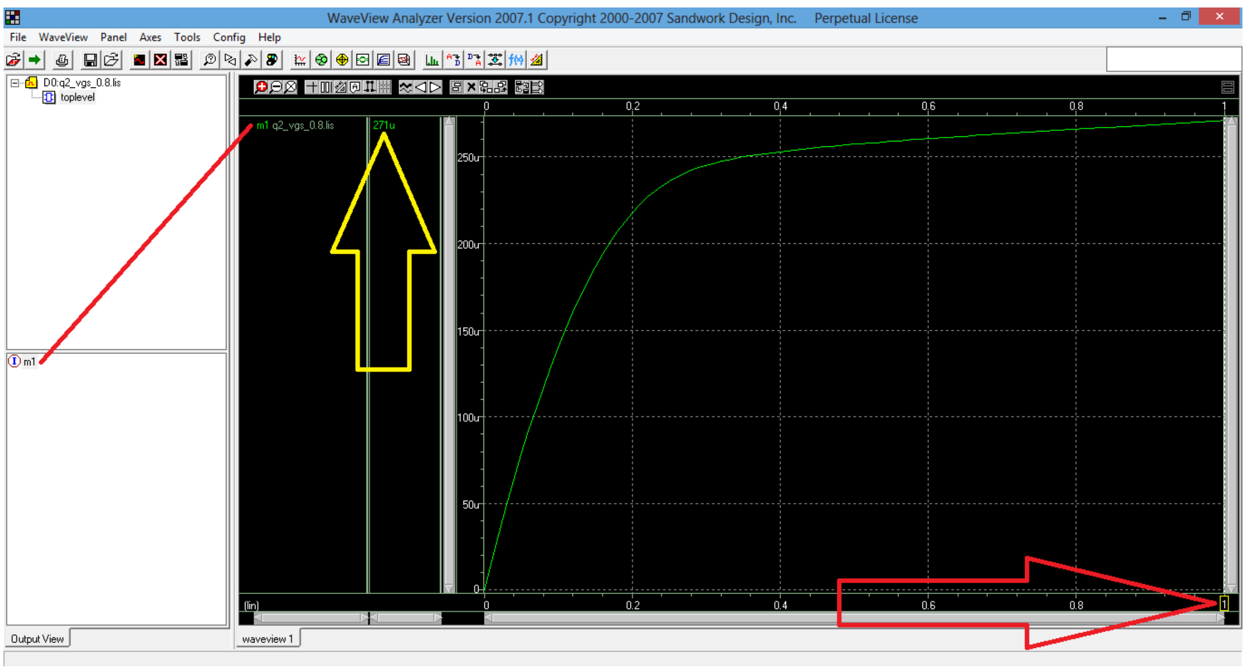
λ:

To calculate λ, we consider 2 points of IV characteristic with the same V_{GS} but different V_{DS} then we have:

I_{DS1} = I_{DS} of first considered point, I_{DS2} = I_{DS} of second considered point

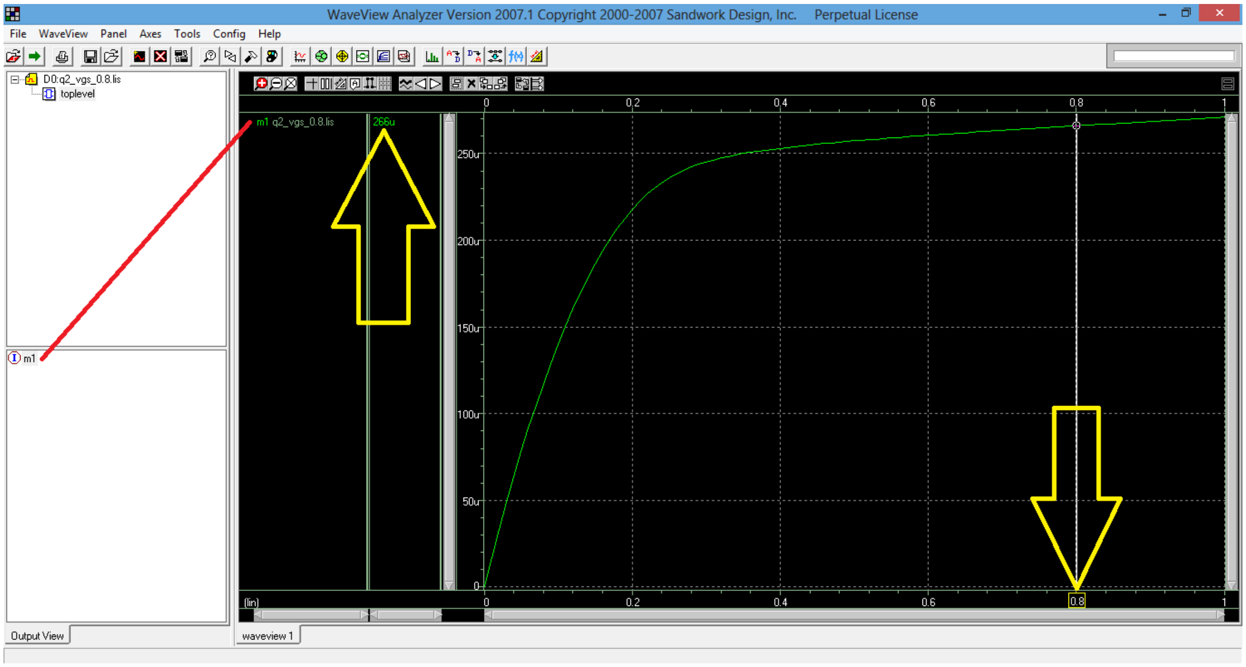
$$\frac{\mathrm{Ids1}}{\mathrm{Ids2}} = \frac{1+\lambda Vds1}{1+\lambda Vds2} \quad => \quad \lambda = \frac{1-\frac{\mathrm{Ids1}}{\mathrm{Ids2}}}{\frac{\mathrm{Ids1}}{\mathrm{Ids2}}Vds2 - Vds1}$$

First considered point of IV for λ calculation:



=> I_{DS1} = 271 uA, V_{ds1} = 1 v

Second considered point of IV for λ calculation:



=> I_{DS2} = 266 uA, V_{ds2} = 0.8 v

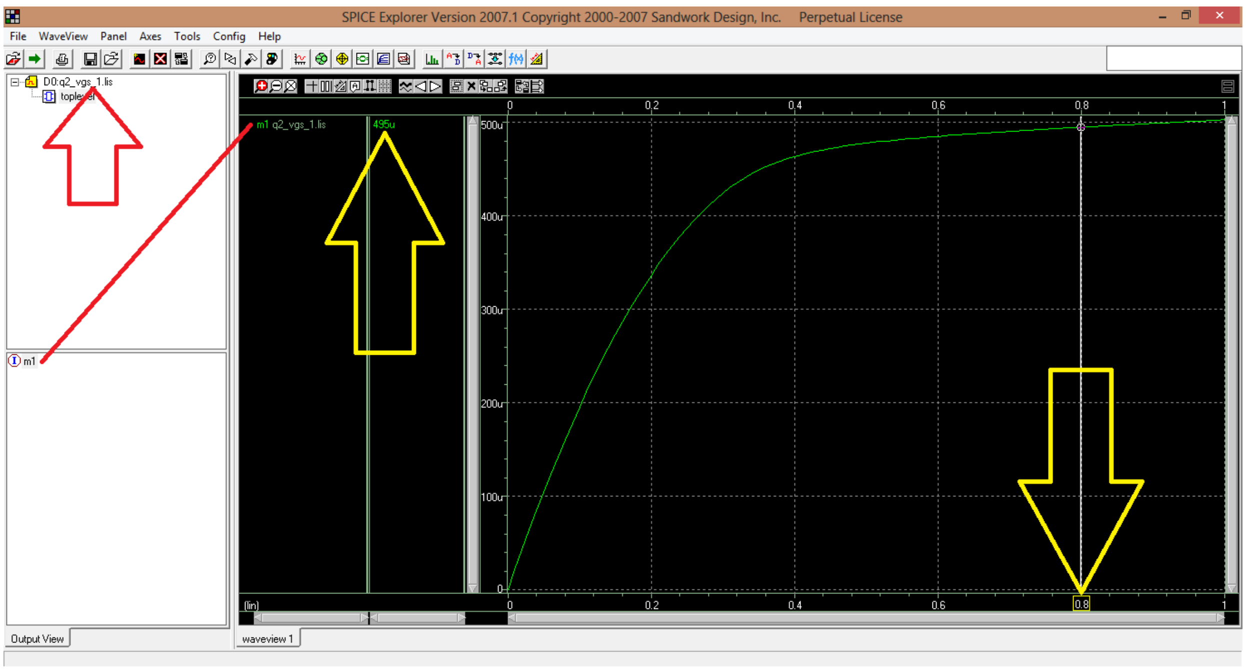
$$\Rightarrow \boldsymbol{\lambda} = \frac{1 - \frac{271\ \mathrm{uA}}{266\ \mathrm{uA}}}{\frac{271\ \mathrm{uA}}{266\ \mathrm{uA}} 0.8 - 1} = \mathbf{0.1}\ \boldsymbol{v}^{-1}$$

k_p:

To calculate k_p, we consider a single point of IV characteristic in saturation region then we have:

$$k_p = \frac{Ids}{\frac{1}{2}\frac{W}{L}(Vgs - VT0)^2(1+\lambda Vds)}$$

single considered point of IV for k_p calculation:



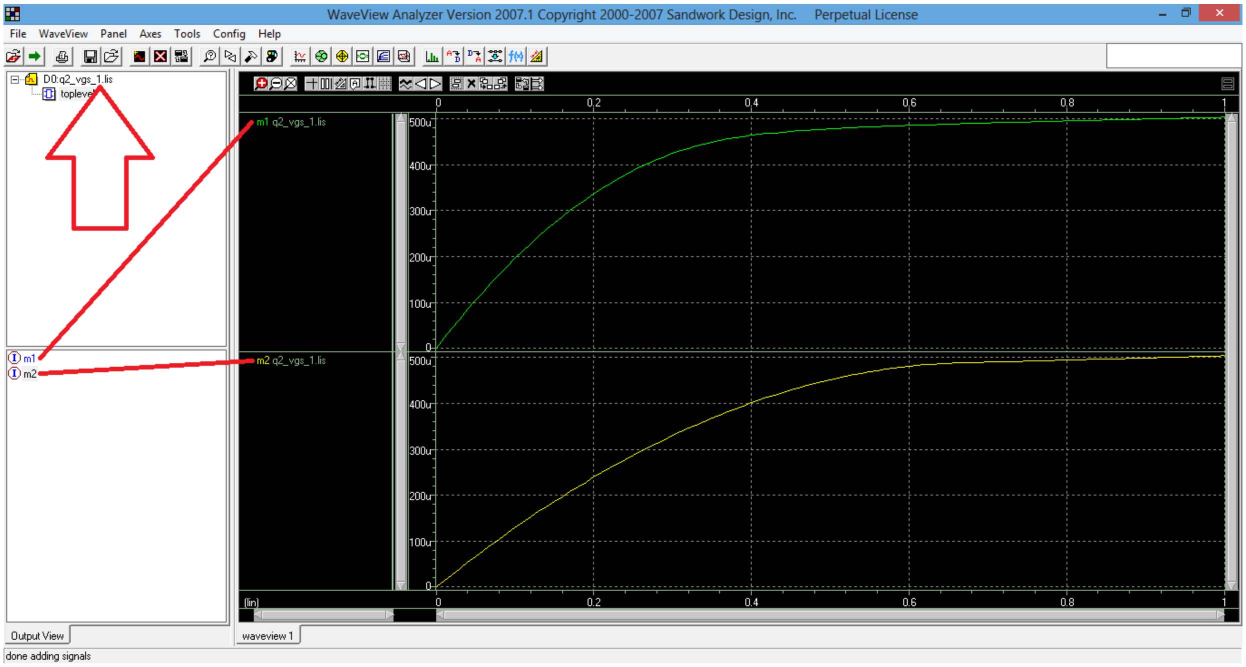
=> I_{ds} = 495 uA, V_{gs} = 1 v, V_{ds} = 0.8 v

$$k_p = \frac{\mathbf{495\ uA}}{\frac{1}{2}\frac{1u}{0.1u}(1-0.34)^2(1+0.1\times 0.8)} = \mathbf{210}\ \frac{\mu A}{V^2}$$

VT0	0.34
λ	0.1
k_p	210

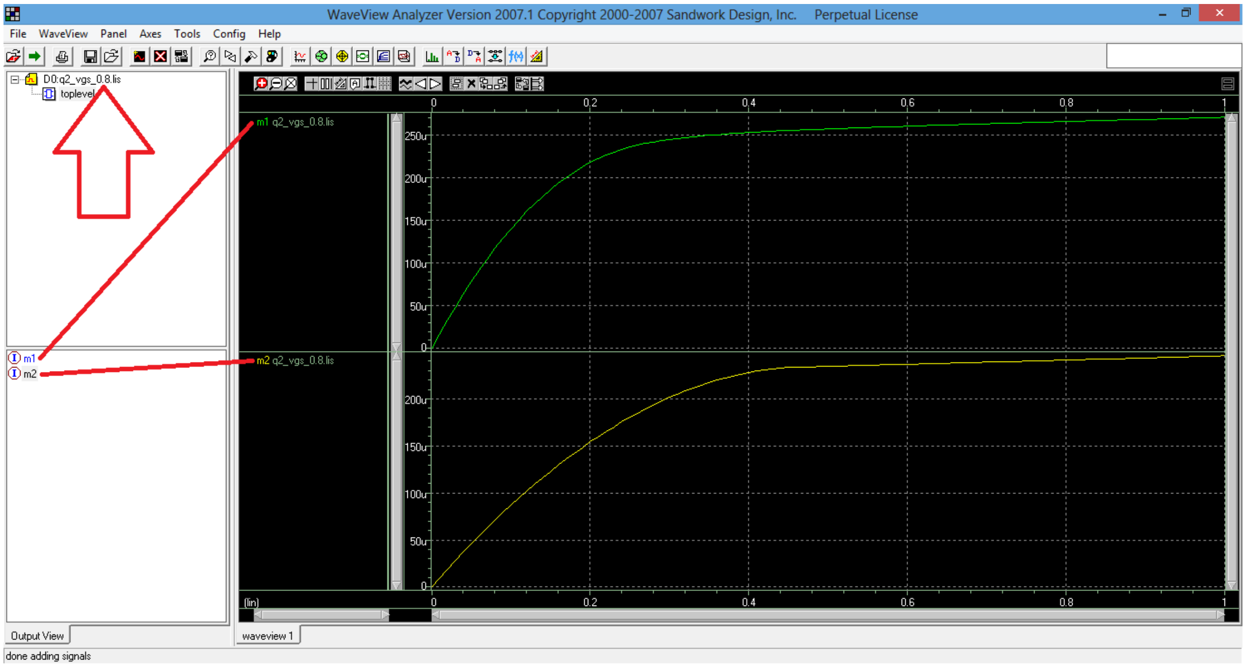
Part g:

IV characteristic of original NMOS and simple NMOS for V_{gs} = 1v

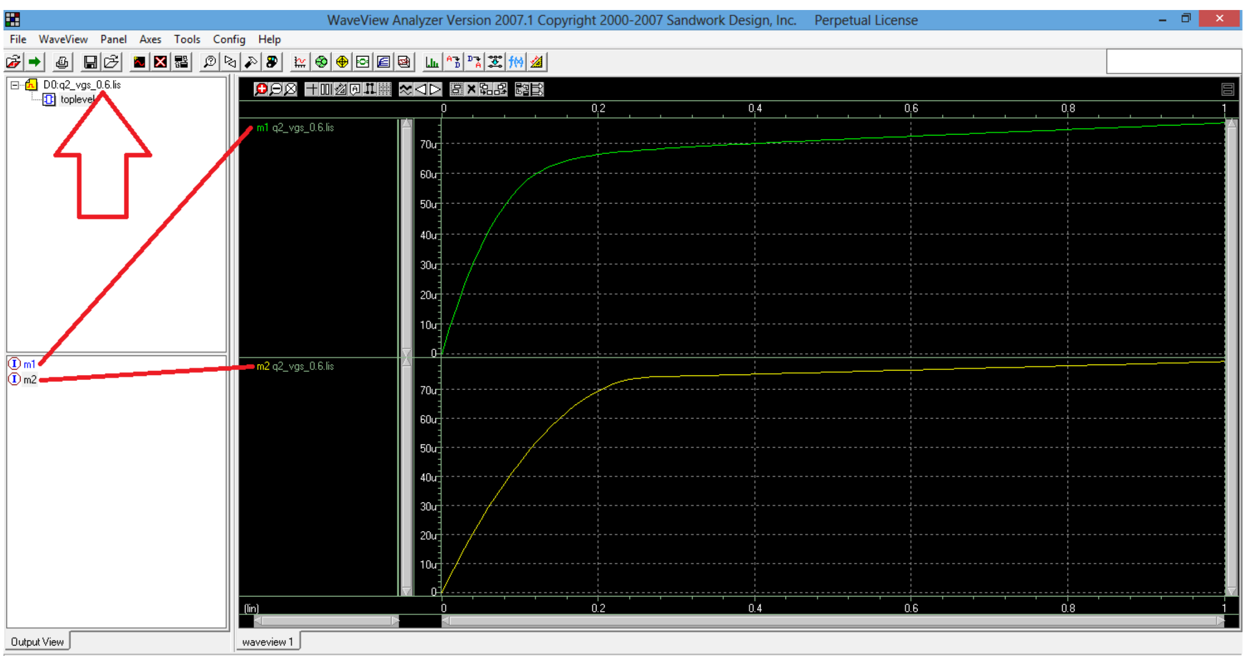


I_{m1} = I_{DS} original NMOS, I_{m2} = I_{DS} simple NMOS

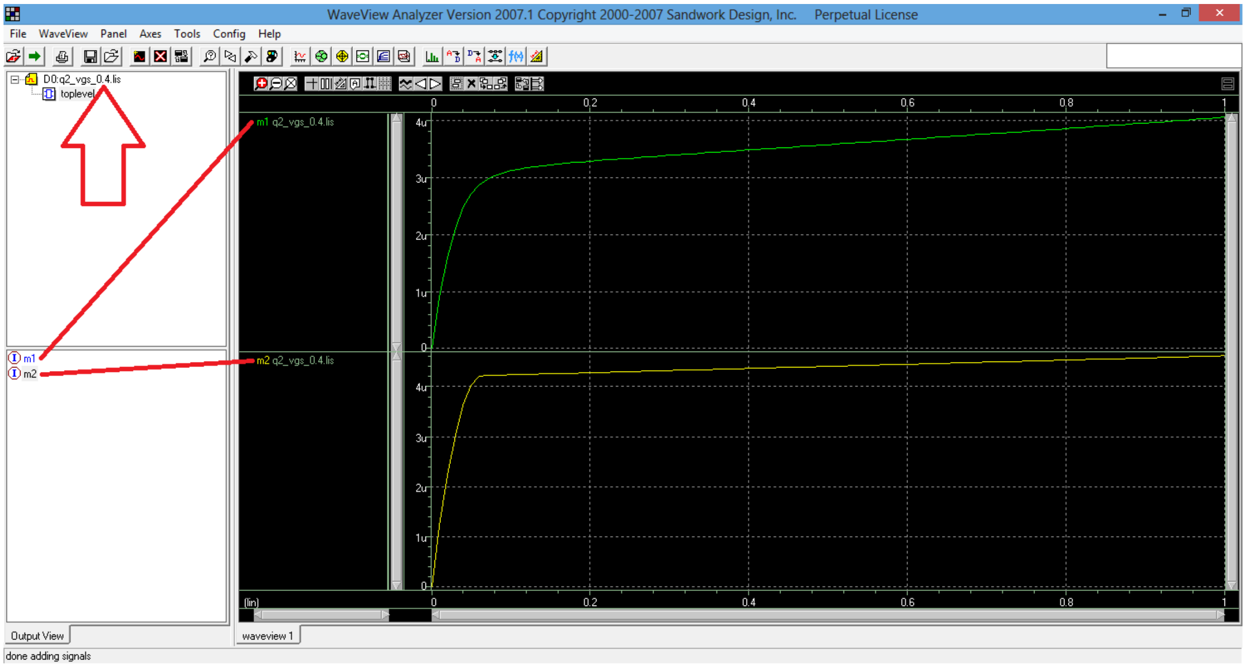
IV characteristic of original NMOS and simple NMOS for V_{gs} = 0.8v



IV characteristic of original NMOS and simple NMOS for V_{gs} = 0.6v



IV characteristic of original NMOS and simple NMOS for V_{gs} = 0.4v



As you can see the IV characteristic of original NMOS and simple NMOS are almost same. There is a small difference(about μA) due to the approximation of kp, λ and VT0 and the fact that kp, λ and VT0 are not exactly equal to the original kp, λ and VT0.