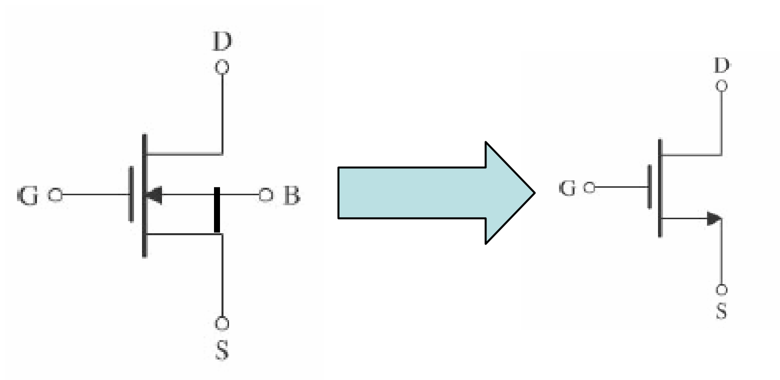
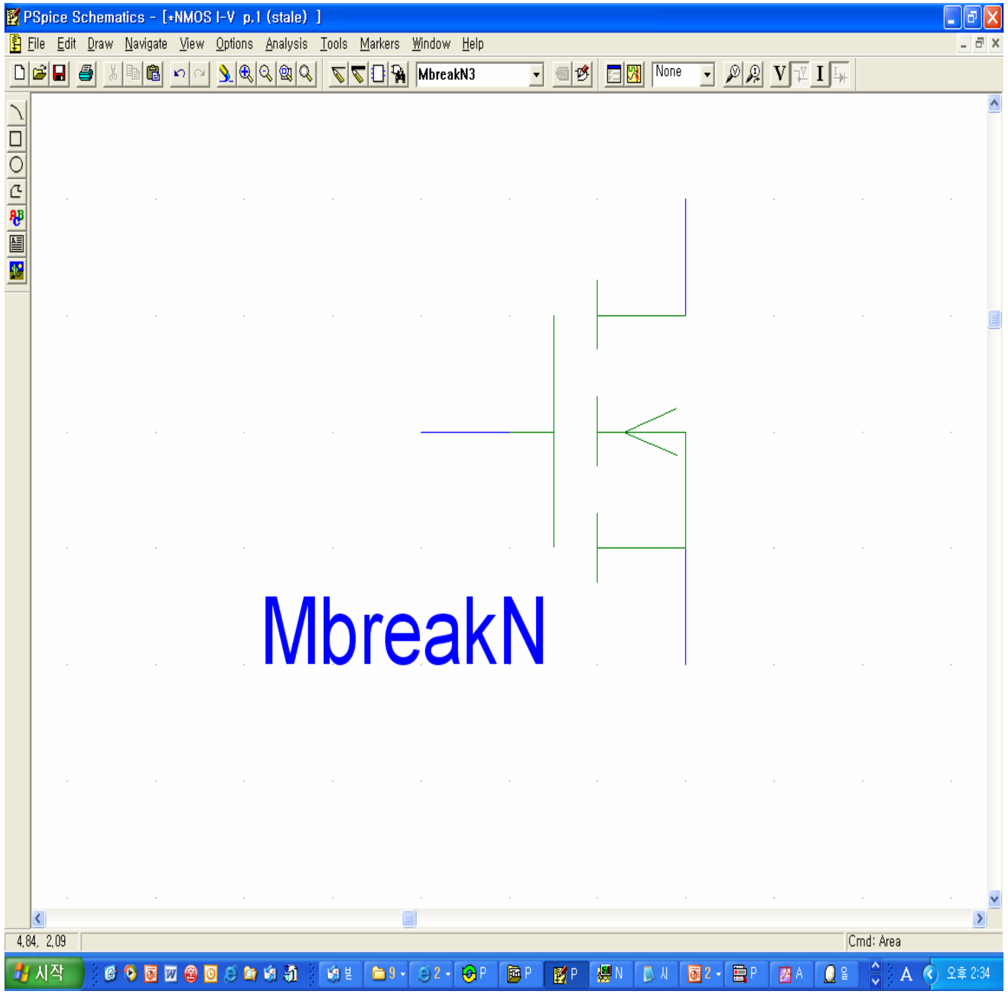
Lect. 8: MOSFET Simulation

PSPICE simulation of NMOS

1. Use MbreakN3 model in PSPICE
(S and B are tied)





Lect. 8: MOSFET Simulation

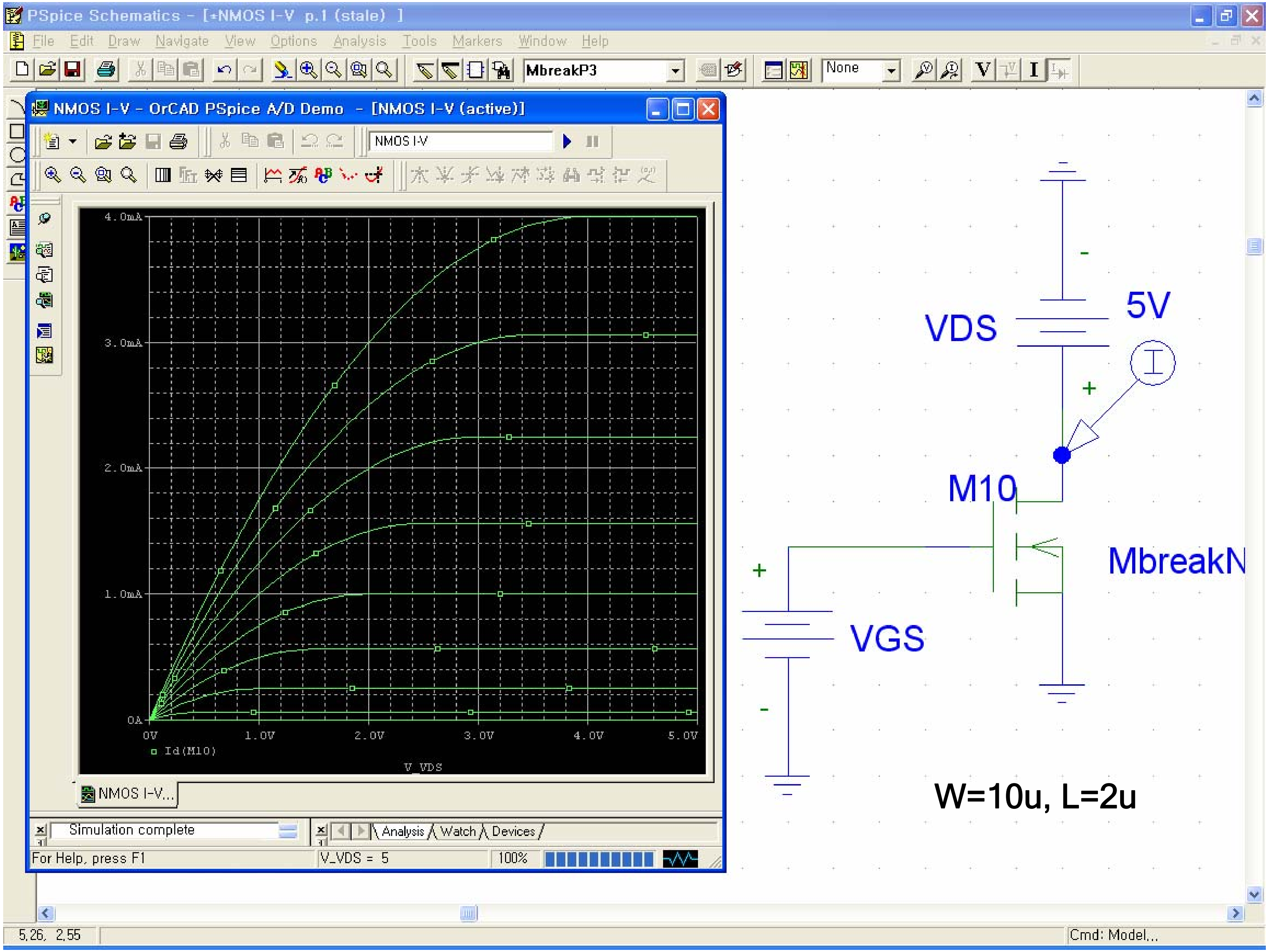
PSPICE simulation of NMOS

2. Set values for v_T, k (=$\mu_n C_{ox}$) in Edit/Model/Edit Instance Model after clicking NbreakN3.

.model MbreakN-X NMOS VTO=1, KP=1e-4

3. Set values for W and L by double clicking MbreakN3

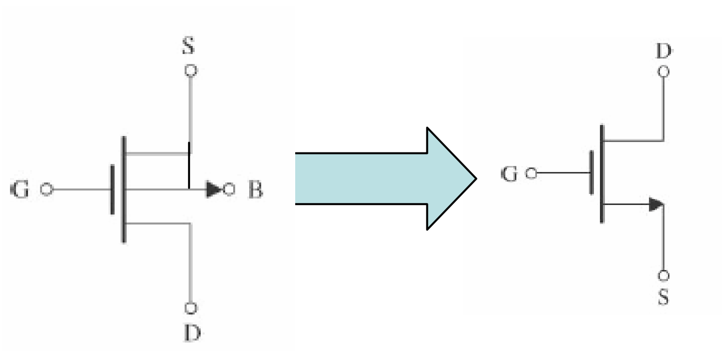
=> Simulate I-V characteristics of NMOS

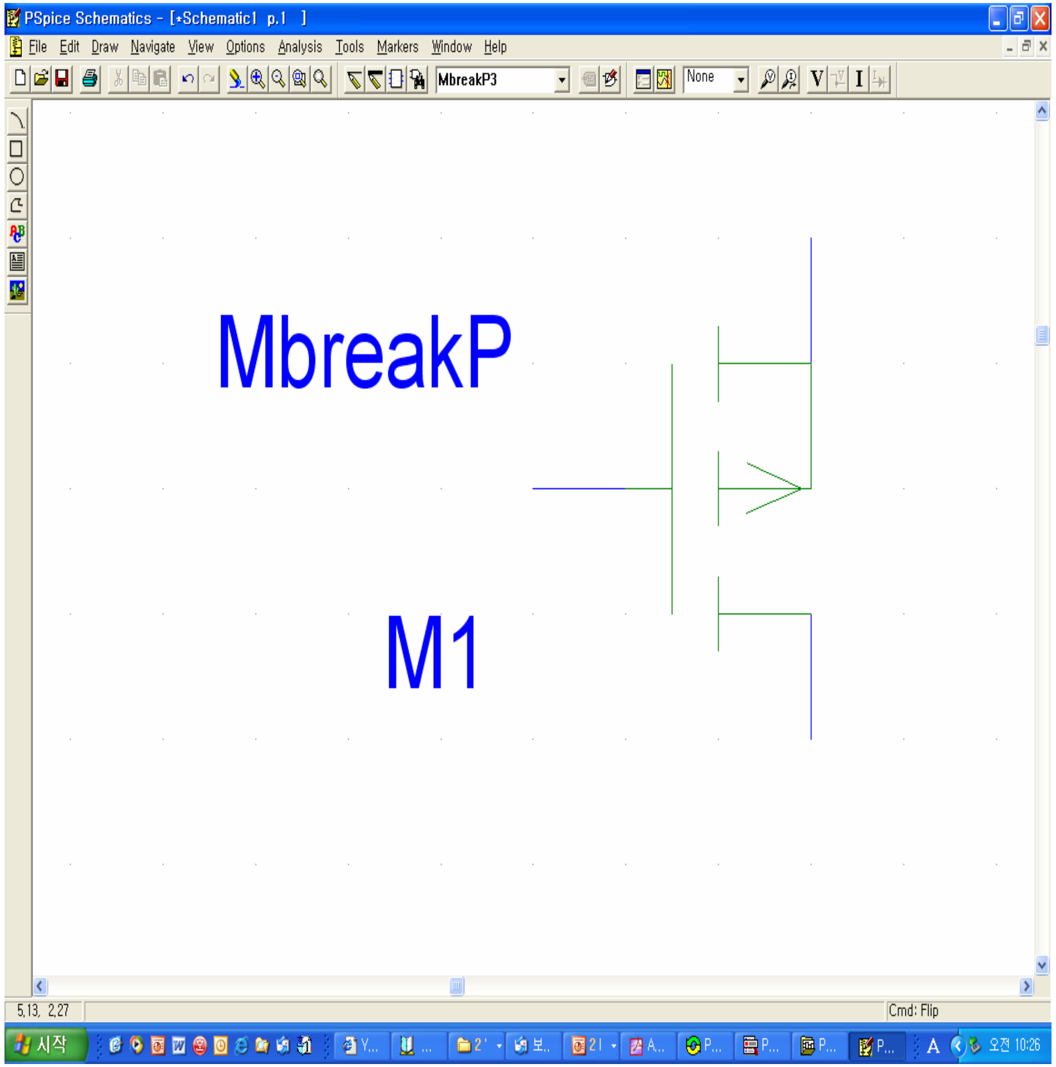

PSpice Schematics - [*NMOS I-V p.1 (stale)]
File Edit Draw Navigate View Options Analysis Tools Markers Window Help
MbreakP3
None
NMOS I-V - OrCAD PSpice A/D Demo - [NMOS I-V (active)]
NMOS I-V
4.0mA
3.0mA
2.0mA
1.0mA
0A
0V
1.0V
2.0V
3.0V
4.0V
5.0V
Id(M10)
V_VDS
NMOS I-V...
Simulation complete
Analysis
Watch
Devices
For Help, press F1
V_VDS = 5
100%
VDS
5V
M10
MbreakN
VGS
W=10u, L=2u
5.26, 2.55
Cmd: Model...

Lect. 8: MOSFET Simulation

PSPICE simulation of PMOS

1. Use MbreakP3 model in PSPICE
(S and B are tied)





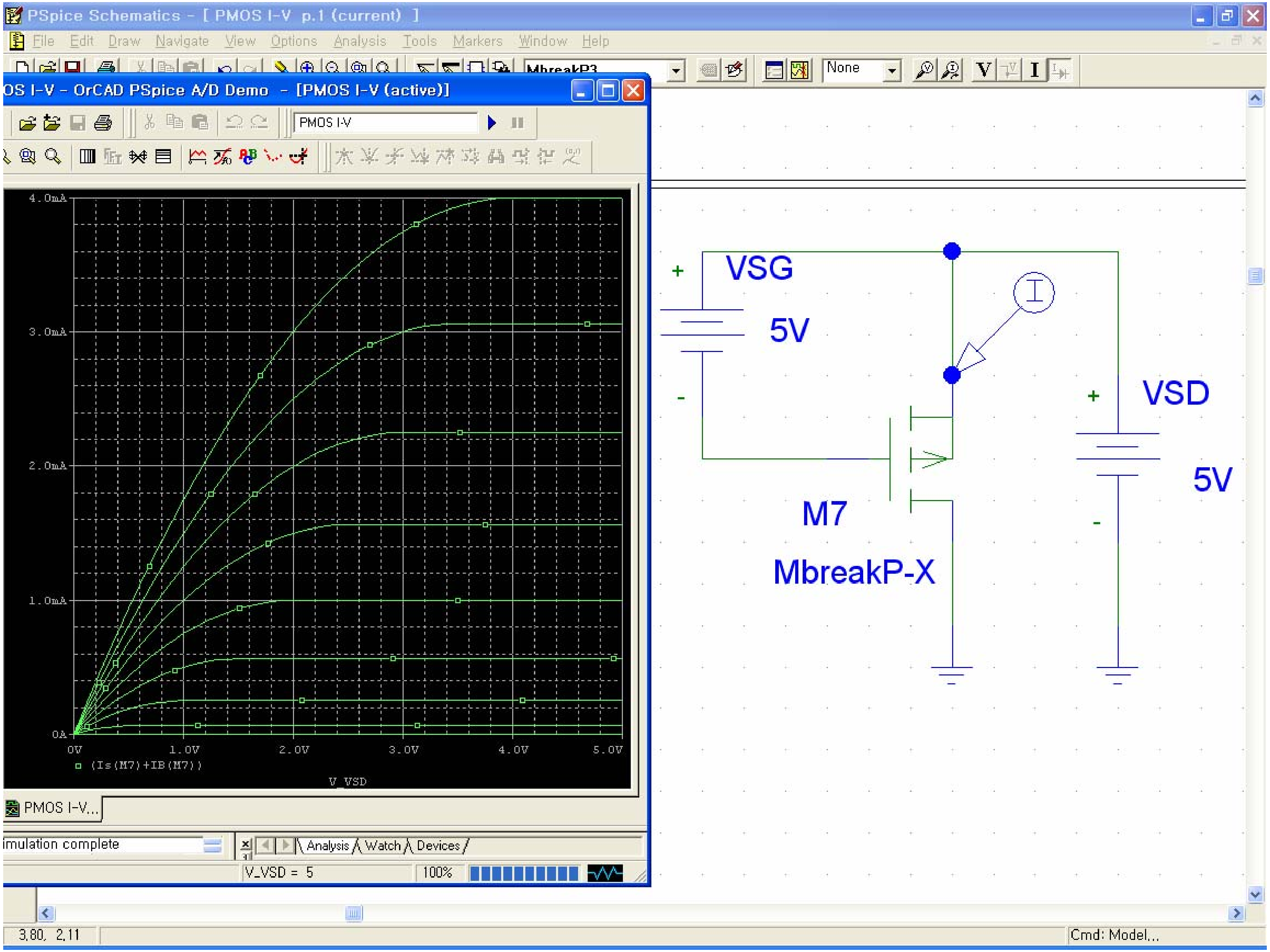
PSPICE simulation of PMOS

2. Set values for v_T, k ($=\mu_n C_{ox}$) in Edit/Model/Edit Instance Model after clicking MbreakP3.

.model MbreakP-X NMOS VTO=-1, KP=1e-4

3. Set values for W and L by double clicking MbreakP3

=> Simulate I-V characteristics of PMOS


PSpice Schematics - [PMOS I-V p.1 (current)]
File Edit Draw Navigate View Options Analysis Tools Markers Window Help
None
OS I-V - OrCAD PSpice A/D Demo - [PMOS I-V (active)]
PMOS I-V
4.0mA
3.0mA
2.0mA
1.0mA
0A
0V
1.0V
2.0V
3.0V
4.0V
5.0V
(Is(M7)+IB(M7))
V_VSD
PMOS I-V...
imulation complete
Analysis
Watch
Devices
V_VSD = 5
100%
3.80, 2.11
Cmd: Model...
VSG
5V
VSD
5V
M7
MbreakP-X

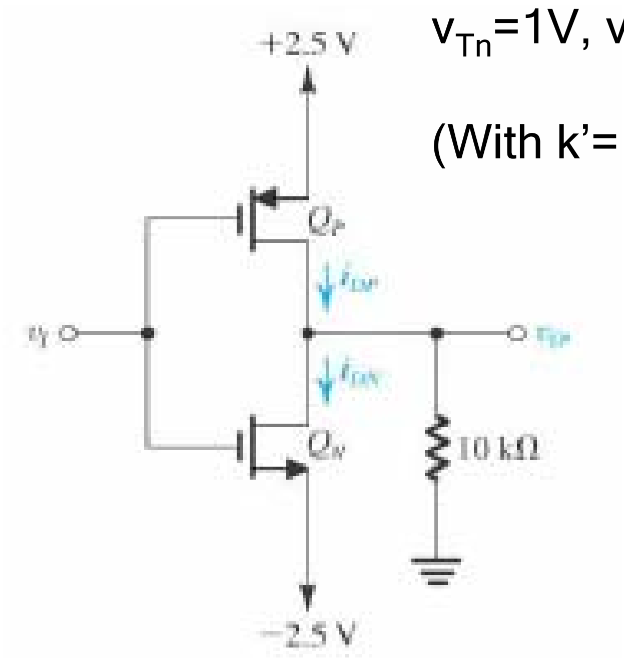
Lect. 8: MOSFET Simulation

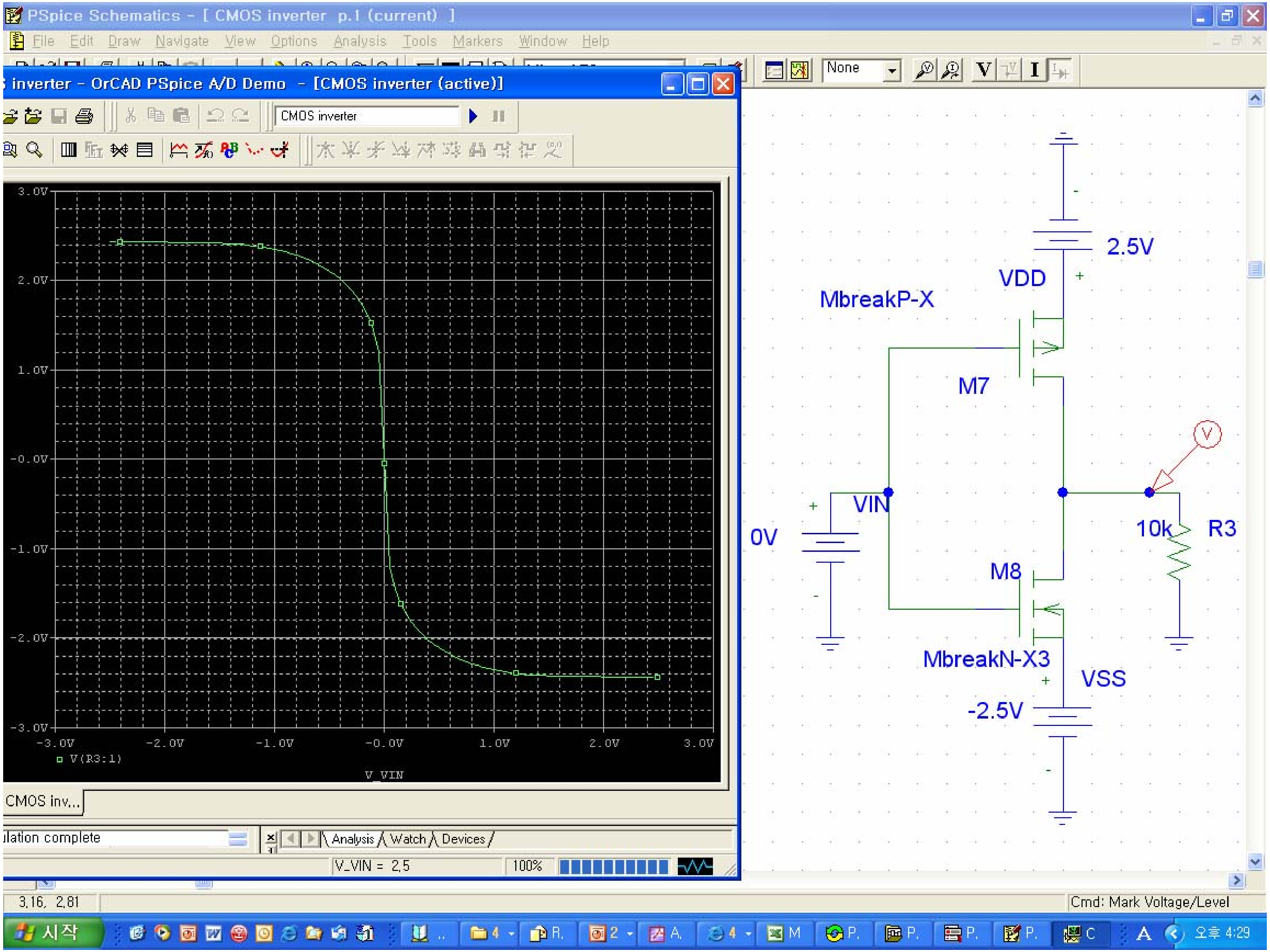
Example 4.7 (p. 269)

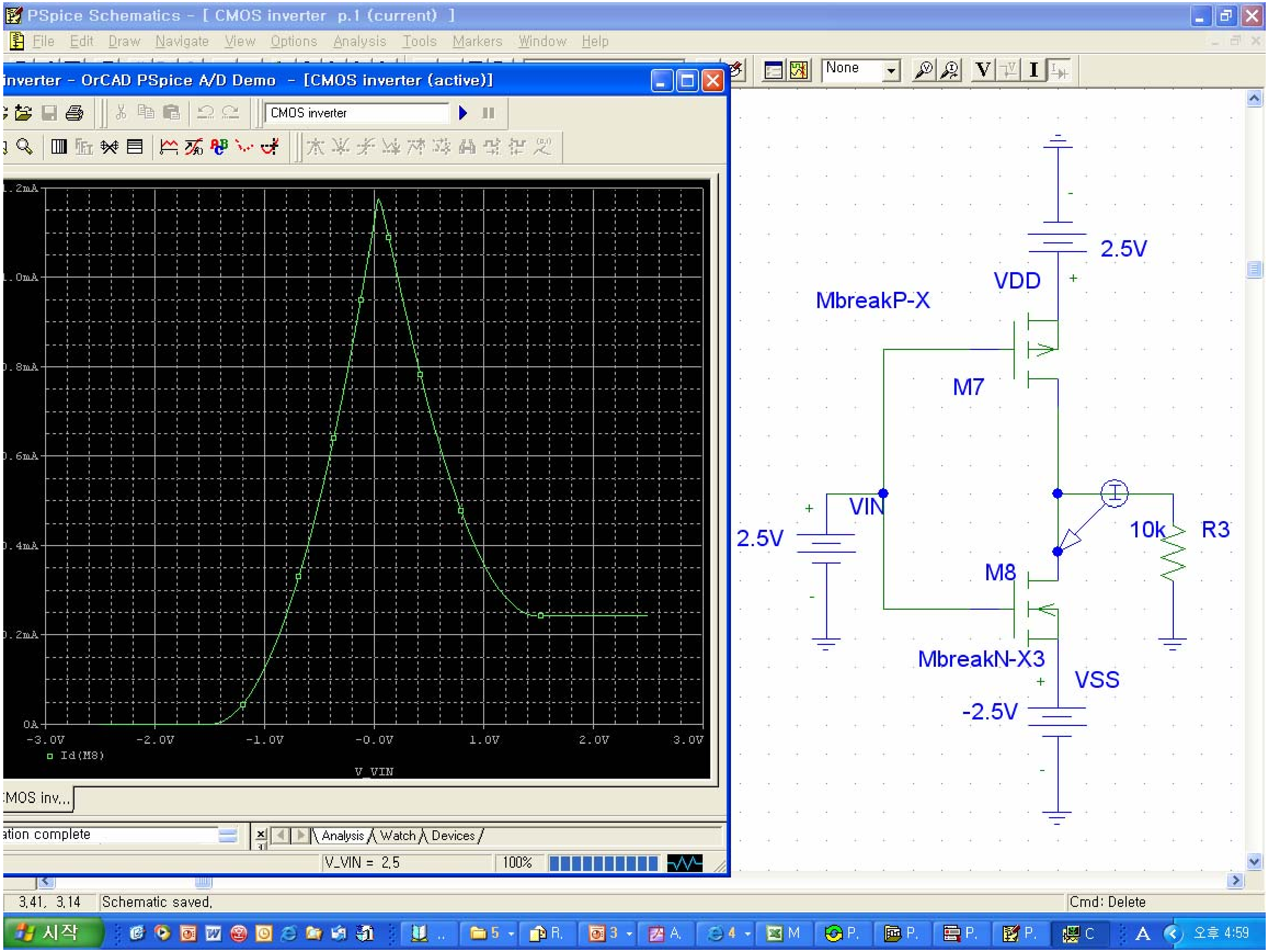
Determine i_{Dn}, i_{Dp}, v_O for $-2.5V < v_I = 2.5$ by PSPICE simulation.

v_{Tn}=1V, v_{Tp}= -1V, both transistors have k'(W/L)=1mA/V^2.

(With k'=1e-4 A/V^2, W/L=10)




PSpice Schematics - [CMOS inverter p.1 (current)]
File Edit Draw Navigate View Options Analysis Tools Markers Window Help
inverter - OrCAD PSpice A/D Demo - [CMOS inverter (active)]
CMOS inverter
3.0V
2.0V
1.0V
-0.0V
-1.0V
-2.0V
-3.0V
-3.0V -2.0V -1.0V -0.0V 1.0V 2.0V 3.0V
V(R3:1)
V_VIN
CMOS inv...
lation complete
Analysis Watch Devices
V_VIN = 2.5
100%
None
2.5V
VDD
MbreakP-X
M7
VIN
0V
10k
R3
M8
MbreakN-X3
VSS
-2.5V
3.16, 2.81
Cmd: Mark Voltage/Level
시작
오후 4:29



PSpice Schematics - [CMOS inverter p.1 (current)]
File Edit Draw Navigate View Options Analysis Tools Markers Window Help
inverter - OrCAD PSpice A/D Demo - [CMOS inverter (active)]
CMOS inverter
1.2mA
1.0mA
0.8mA
0.6mA
0.4mA
0.2mA
0A
-3.0V
-2.0V
-1.0V
-0.0V
1.0V
2.0V
3.0V
Id(M8)
V_VIN
Analysis
Watch
Devices
V_VIN = 2.5
100%
2.5V
VDD
MbreakP-X
M7
VIN
2.5V
10k
R3
M8
MbreakN-X3
VSS
-2.5V
3.41, 3.14
Schematic saved.
Cmd: Delete
시작
오후 4:59

Lect. 8: MOSFET Simulation

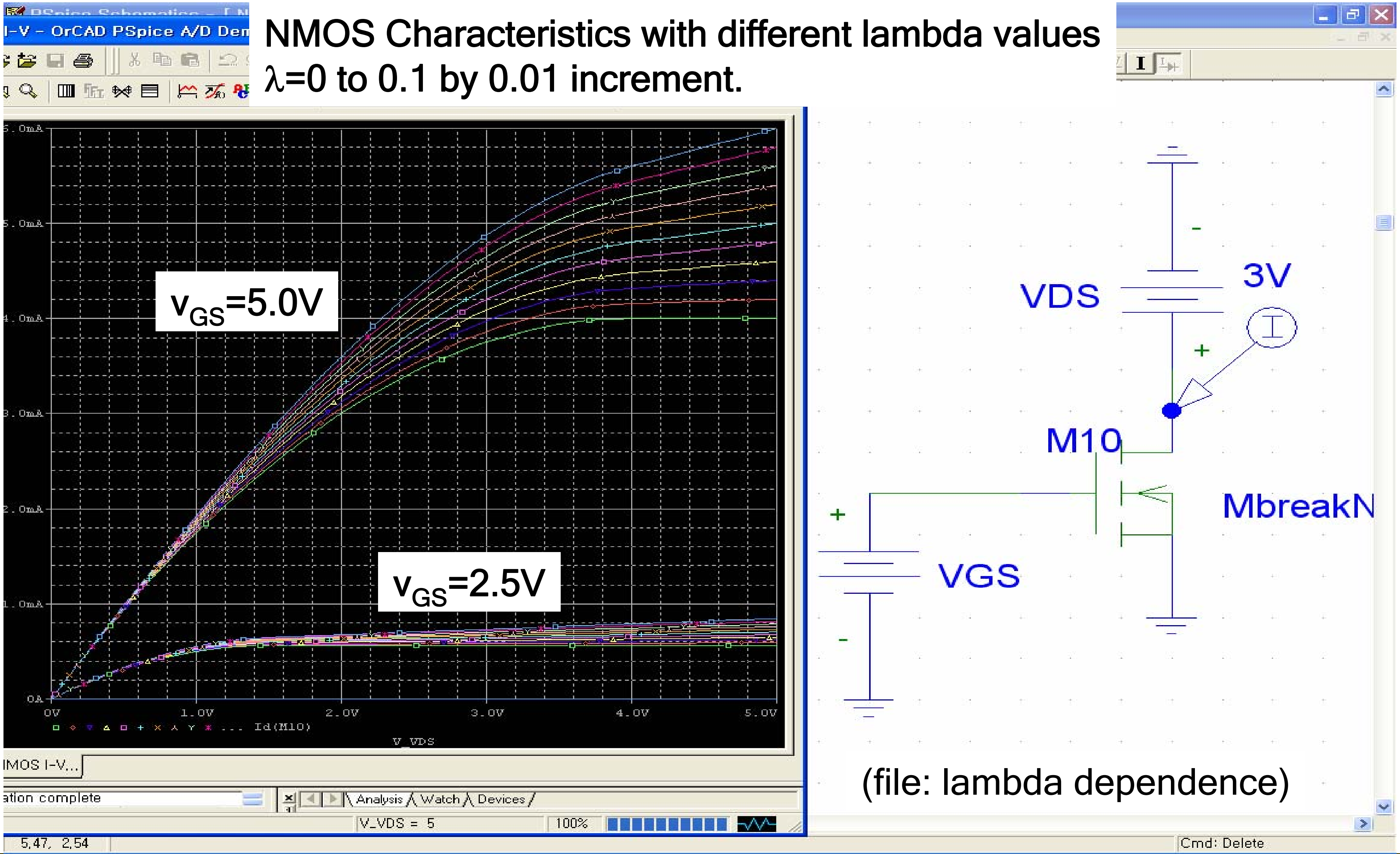
- Modern transistors are very complicated in their structure.
  Many parameters are needed to model their characteristics accurately in SPICE

An exampe of Advanced MOSFET models
(2μm double poly double metal technology)

```
.MODEL orbit2L2N NMOS LEVEL=2 PHI=0.700000 TOX=3.9800E-08 XJ=0.200000U TPG=1
+ VTO=0.8005 DELTA=4.2080E+00 LD=7.3840E-08 KP=6.6703E-05
+ UO=768.8 UEXP=1.1190E-01 UCRIT=7.3170E+03 RSH=3.8420E+00
+ GAMMA=0.5369 NSUB=6.5360E+15 NFS=9.2810E+10 VMAX=4.9600E+04
+ LAMBDA=3.2330E-02 CGDO=9.6098E-11 CGSO=9.6098E-11
+ CGBO=3.4582E-10 CJ=1.23000E-04 MJ=0.7500 CJSW=5.6800E-10
+ MJSW=0.26300 PB=0.6700000
* Weff = Wdrawn - Delta_W
* The suggested Delta_W is 2.0000E-09
```

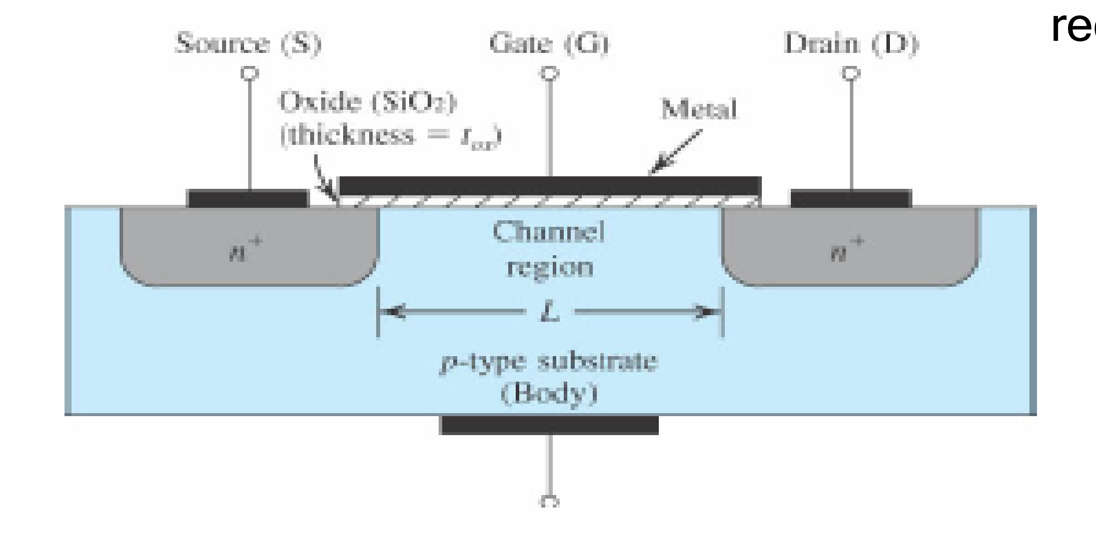
Lect. 8: MOSFET Simulation

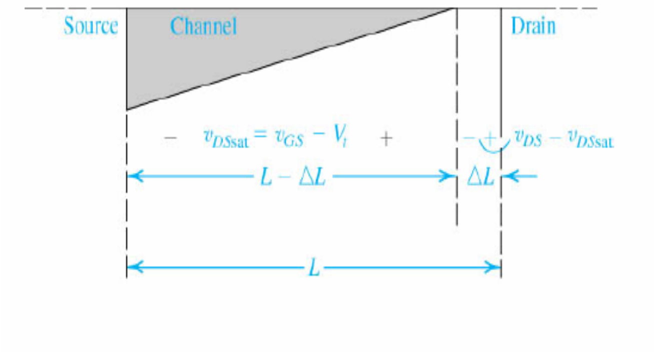
NMOS Characteristics with different lambda values
λ=0 to 0.1 by 0.01 increment.



Lect. 8: MOSFET Simulation

Why? Channel length modulation





In saturation, v_{DS} increase causes reduction in actual channel length.

$$i_D = \frac{1}{2}k'\frac{W}{L}(v_{GS} - V_t)^2$$

$$=> \frac{1}{2}k'\frac{W}{L - \Delta L(v_{DS})}(v_{GS} - V_t)^2$$

$$= \frac{1}{2}k'\frac{W}{L(1 - \frac{\Delta L(v_{DS})}{L})}(v_{GS} - V_t)^2$$

$$\simeq \frac{1}{2}k'\frac{W}{L}(1 + \frac{\Delta L(v_{DS})}{L})(v_{GS} - V_t)^2$$

Assuming $\frac{\Delta L(v_{DS})}{L} = \lambda \cdot v_{DS}$

$$i_D = \frac{1}{2}k'\frac{W}{L}(1 + \lambda \cdot v_{DS})(v_{GS} - V_t)^2$$

Lect. 8: MOSFET Simulation

Homework: Example 4.7 (p. 269)

Determine v_O for -2.5V < v_I = 2.5 by PSPICE simulation.

v_{Tn}=1V, v_{Tp}= -1V, both transistors have k'(W/L)=1mA/V^2.

(With k'=1e-4 A/V^2, W/L=10)