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NGSPICE

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Introduction to SPICE

Simulation Program with Integrated Circuit Emphasis

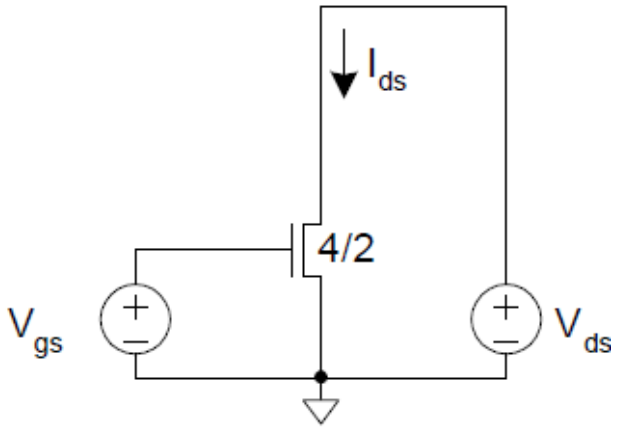
- Developed in 1970's at Berkeley
- Many commercial versions are available
  - HSPICE, PSPICE, SmartSPICE, NGSPICE, etc.
- HSPICE is a robust industry standard
  - Has many enhancements that we will use

Writing a SPICE deck is like writing a good program

- Plan: sketch schematic on paper or in editor
  - Modify existing decks whenever possible
- Code: strive for clarity
  - Start with name, email, date, purpose
  - Generously comment
- Test:
  - Predict what results should be
  - Compare with actual

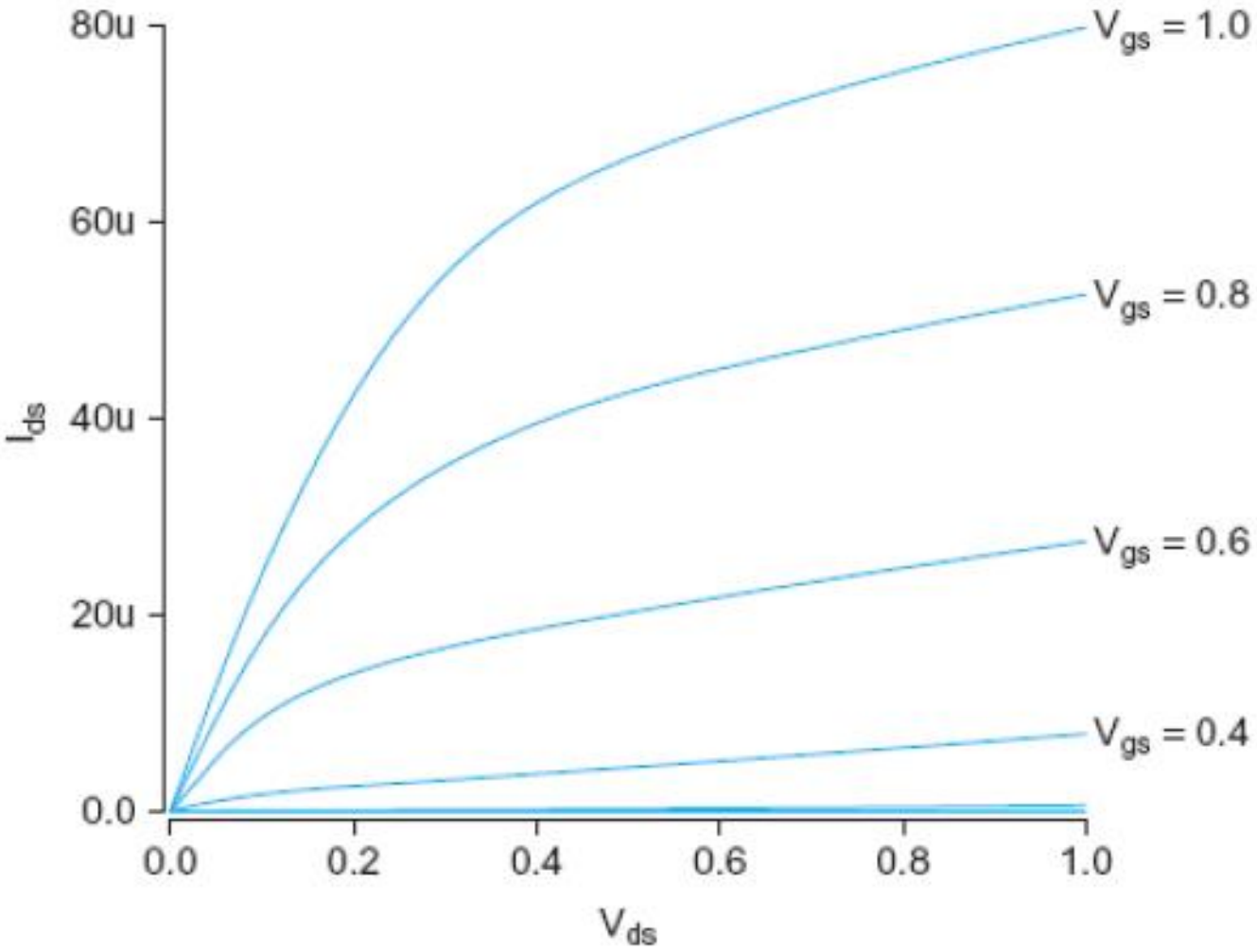
Example: MOSFET DC Analysis

```
* mosiv.sp

*-------------------------------------------------
* Parameters and models
*-------------------------------------------------
.include '../models/ibm065/models.sp'
.temp 70
.option post
*-------------------------------------------------
* Simulation netlist
*-------------------------------------------------
*nmos
Vgs       g         gnd       0
Vds       d         gnd       0
M1        d         g         gnd       gnd       NMOS      W=100n    L=50n

*-------------------------------------------------
* Stimulus
*-------------------------------------------------
.dc Vds 0 1.0 0.05 SWEEP Vgs 0 1.0 0.2
.end
```



Example: MOSFET DC Analysis

nMOS I-V Characteristics



Input Netlist File Rule

- Input file extension of NGSPICE is '.txt'.
- The first statement should start with the title statement.
- The last statement should end with '.end'.
- Use '+' sign when writing long sentences that take up more than 2 lines.
- When using comments, use '*' at the beginning of the line.
- Netlists are used regardless of case.
- In general, '0' and 'gnd' always mean ground.

Sources

- *DC* Source

  Vdd vdd gnd 2.5

- *Piecewise Linear* Source

  Vin in gnd pwl 0ps 0 100ps 0 150ps 1.0 1ns 1.0

- *Pulsed* Source

  Vck clk gnd PULSE 0 1.0 0ps 100ps 100ps 300ps 800ps

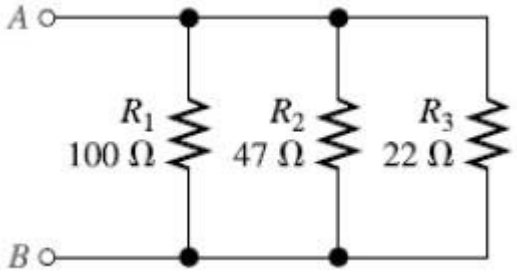
  ex) PULSE v1 v2 td tr tf pw per

- *Sinusiudal* Source

  Vin in gnd sin 0 50m 1k

SPICE Elements

Letter	Element
R	Resistor
C	Capacitor
L	Inductor
K	Mutual Inductor
V	Independent voltage source
I	Independent current source
M	MOSFET
D	Diode
Q	Bipolar transistor
W	Lossy transmission line
X	Subcircuit
E	Voltage-controlled voltage source
G	Voltage-controlled current source
H	Current-controlled voltage source
F	Current-controlled current source



R1 1 0 100
R2 1 0 47
R3 1 0 22

Units

Letter	Unit	Magnitude
a	atto	10^{-18}
f	fempto	10^{-15}
p	pico	10^{-12}
n	nano	10^{-9}
u	micro	10^{-6}
m	milli	10^{-3}
k	kilo	10^{3}
x (meg)	mega	10^{6}
g	giga	10^{9}

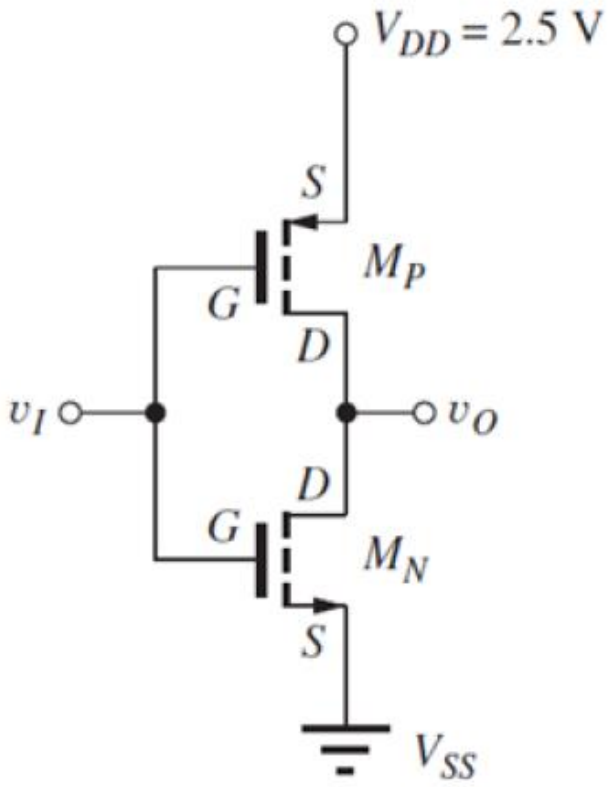
Ex) 100 femptofarad capacitor = 100fF, 100f, 100e-15

C1 out gnd 100fF

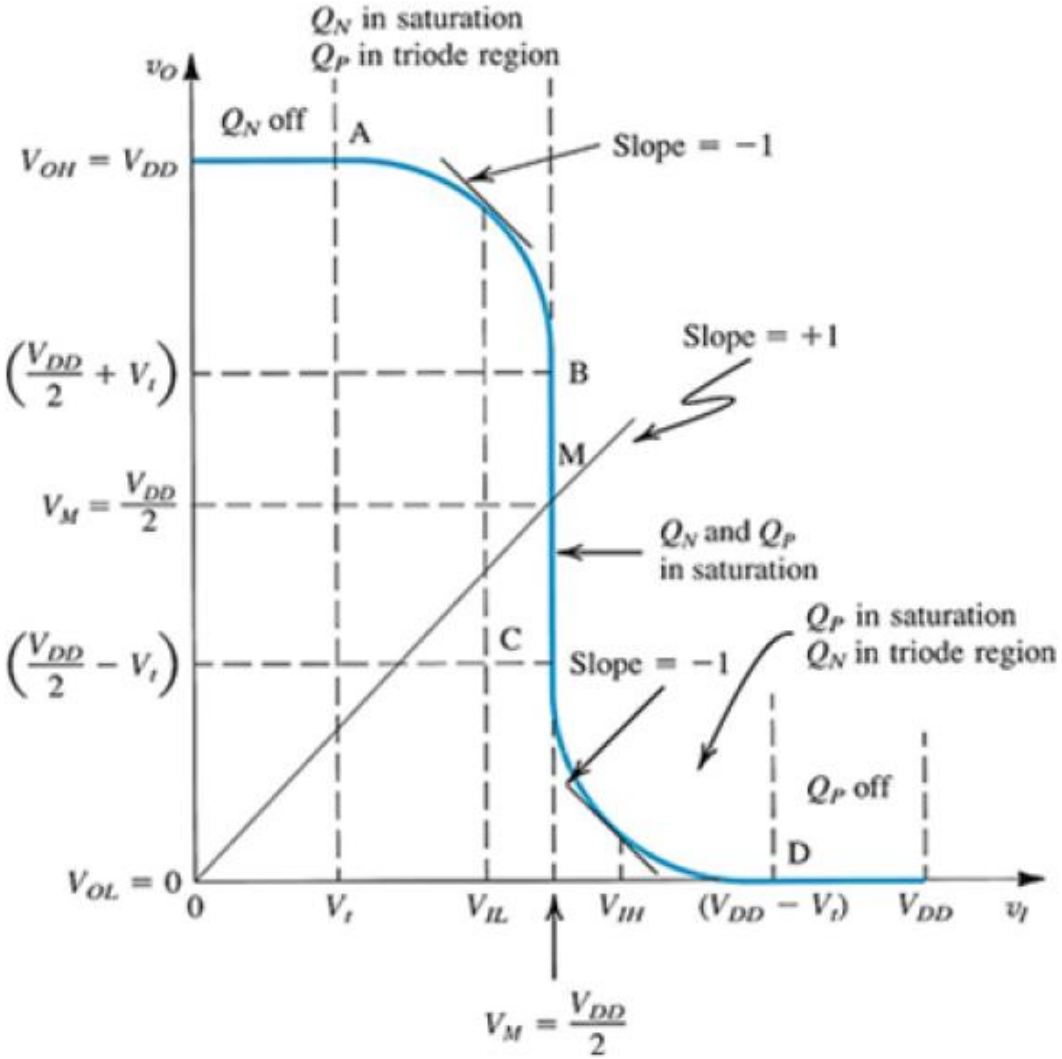
C1 out gnd 100f

C1 out gnd 100e-15

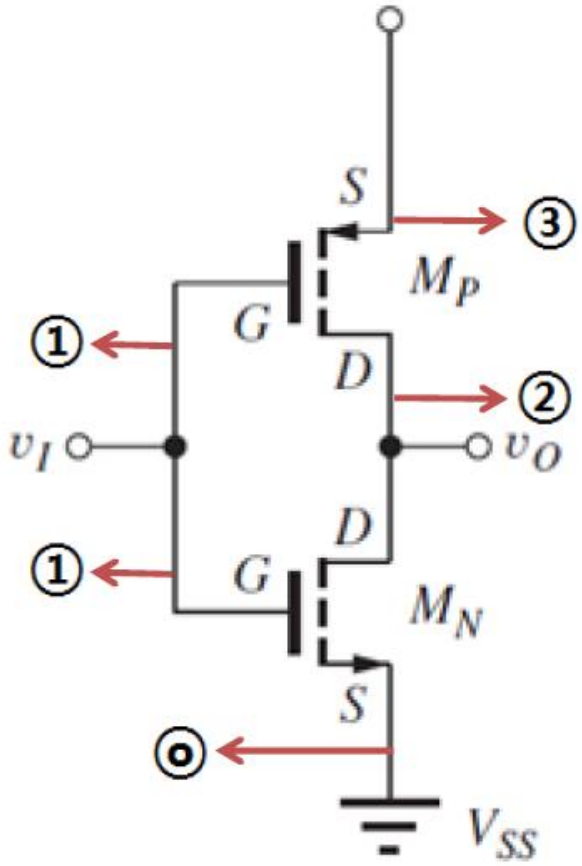
Example: CMOS Inverter Voltage Transfer Curve



CMOS Inverter Schematic



Example: CMOS Inverter Voltage Transfer Curve



CMOS Inverter Schematic

```
VIN  1 0 DC 0
VDD 3 0 DC 3

      D G  S  B
M1 2 1 0 0 MOSN W=2U L=1U
M2 2 1 3 3 MOSP W=5U L=1U

.DC VIN 0 3 0.01
    From to step
```

Example: CMOS Inverter Voltage Transfer Curve

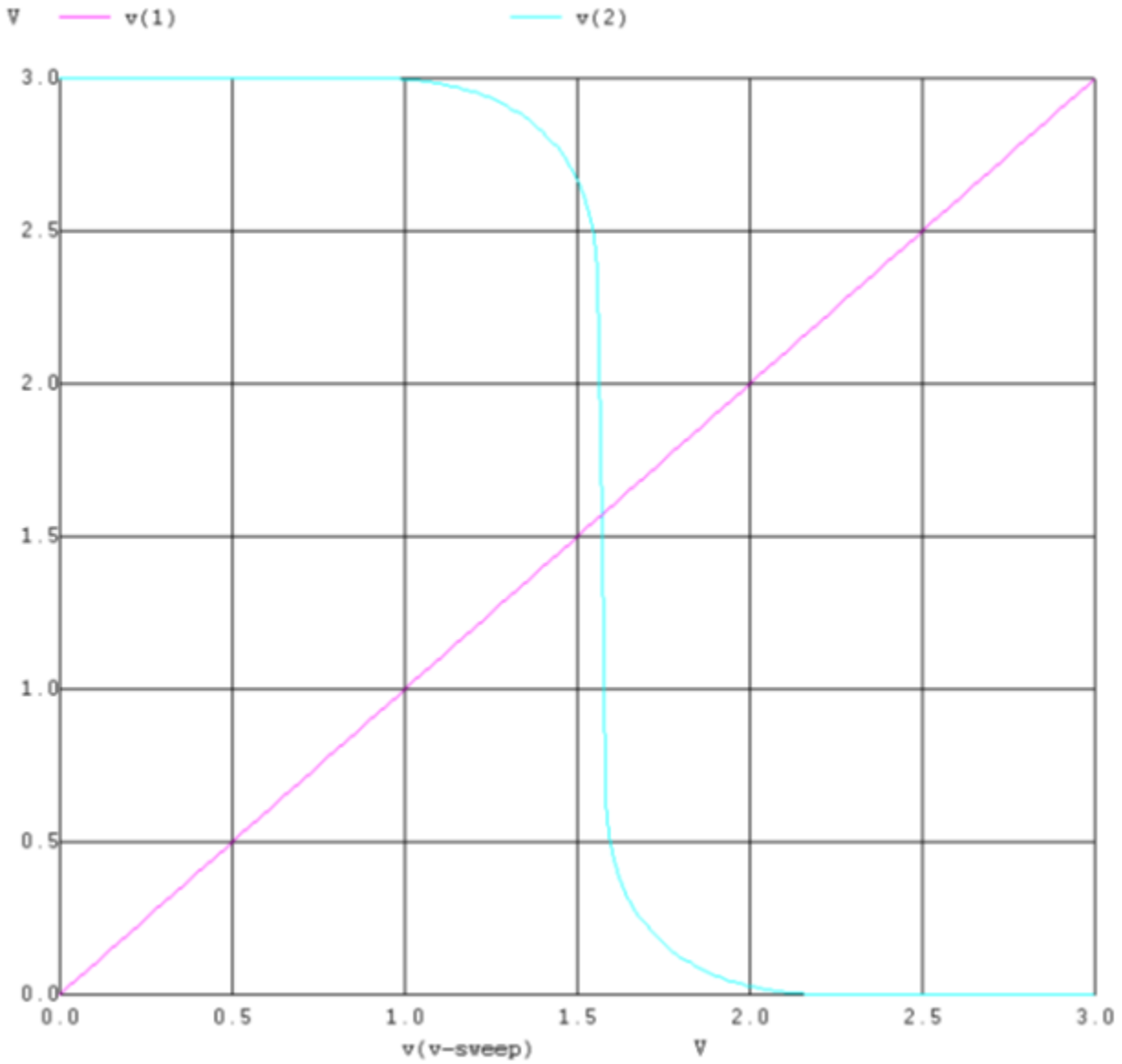
```
*CMOS inverter transfer characteristic

VIN 1 0 DC 0
VDD 3 0 DC 3

M1 2 1 0 0 MOSN W=2U L=1U
M2 2 1 3 3 MOSP W=4U L=1U

.DC VIN 0 3 0.01
```

DC Analyze

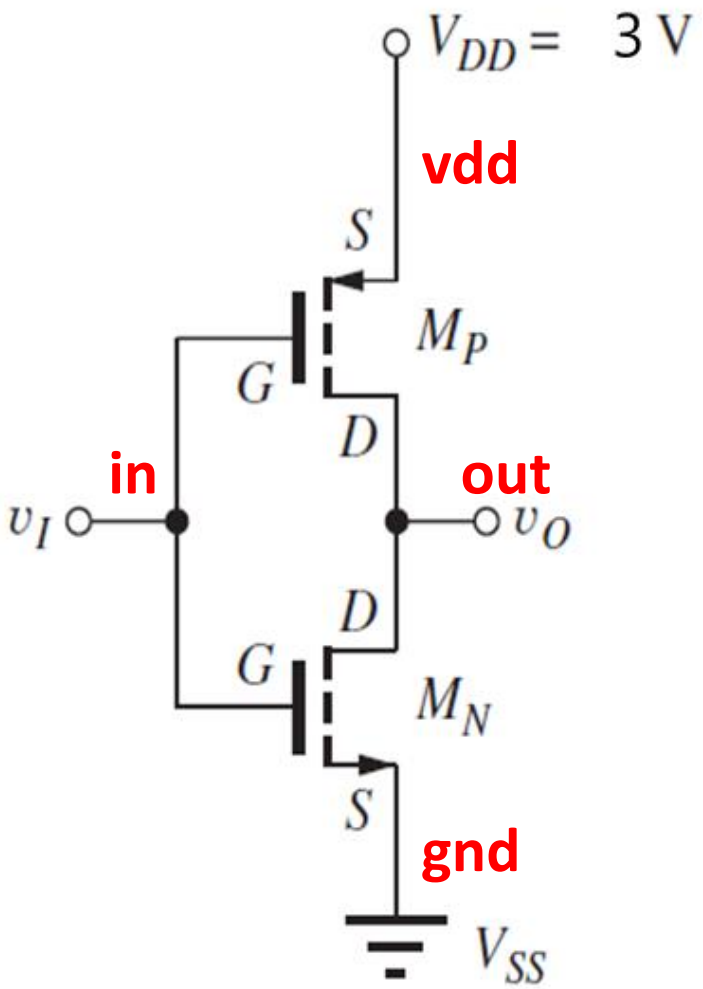
Parameter Setting Value

```
.MODEL MOSN NMOS KP=50E-6 VTO=0.91 GAMMA=0.99 PHI=0.7 LAMBDA=0.02  RD=0 RS=0 IS=0 PB=0
+CGDO=330p CGSO=330p CGBO=395p  CJ=3.9E-4 MJ=0.45
+ CJSW=510p MJSW=0.36 TOX=4.15E-8 LD=0.26u NSUB=2.1E16 NSS=1E10

.MODEL MOSP PMOS KP=20E-6 VTO=-0.77 GAMMA=0.53 PHI=0.7 LAMBDA=0.05  RD=0 RS=0 IS=0 PB=0
+CGDO=315p CGSO=315p CGBO=415p CJ=2.0E-4 MJ=0.47
+ CJSW=180p MJSW=0.09 TOX=4.15E-8 LD=0.25u NSUB=5.9E16 NSS=1E10

.END
```

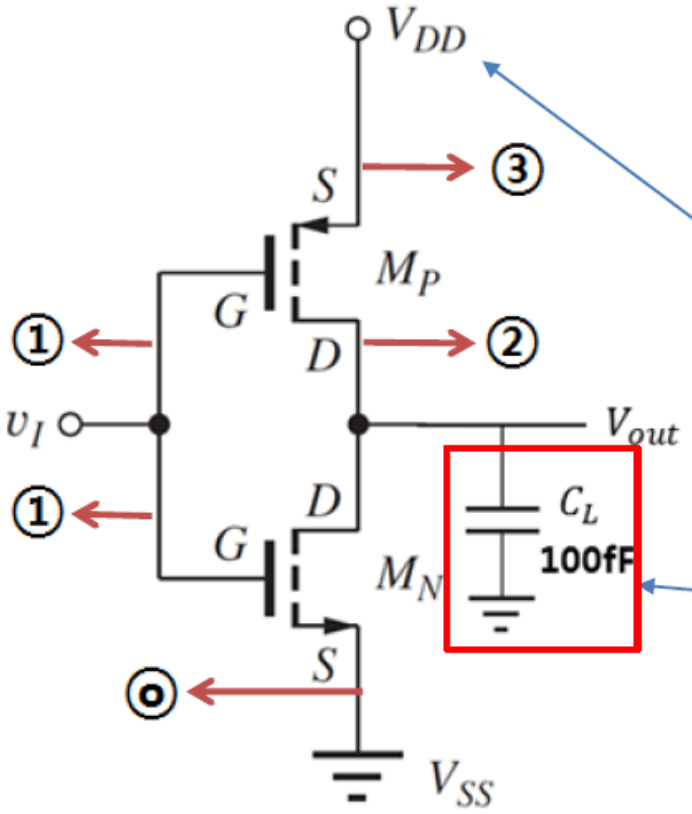
Example: CMOS Inverter Voltage Transfer Curve



Example: CMOS Inverter Voltage Transfer Curve



Example: Dynamic Characteristics of CMOS Inverter



*SIMULATION USES THE MODELS

VIN 1 0 PULSE (0 3 0 0.1N 0.1N 10N 20N)

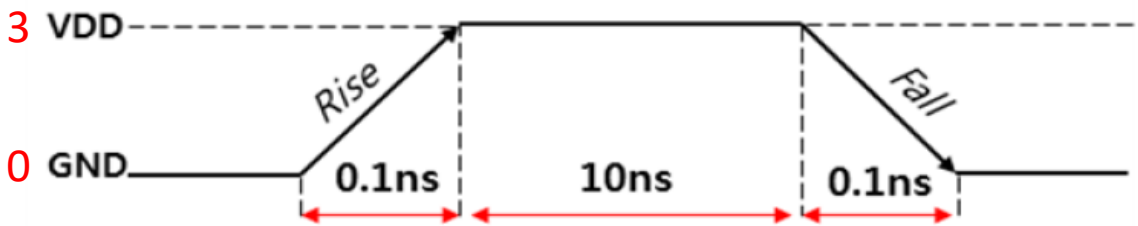
*FROM 0 TO 3V DELAY RISE FALL PULSE WIDTH PERIOD

VDD 3 0 DC 3

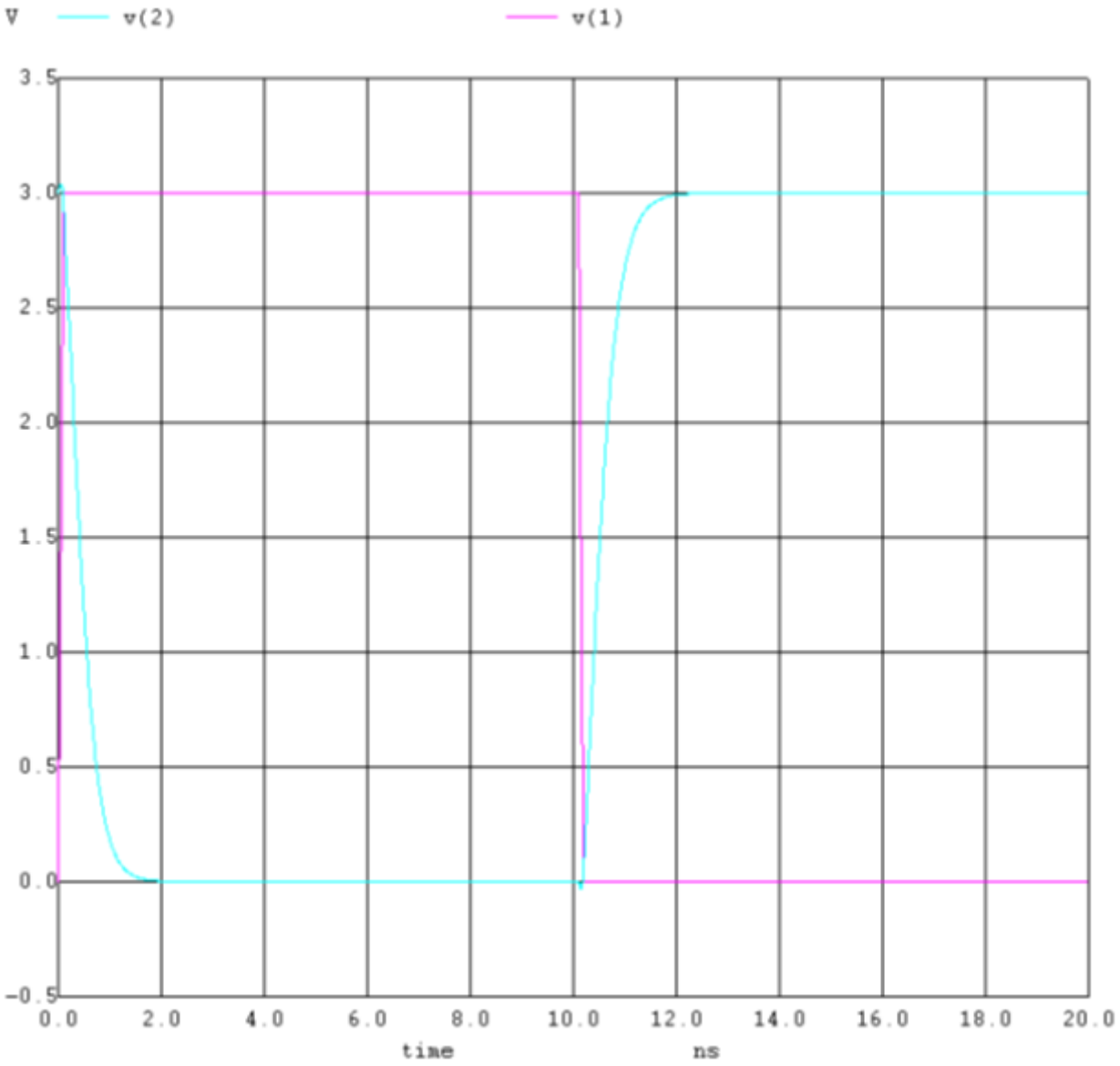
M1 2 1 0 0 MOSN W=2U L=1U
M2 2 1 3 3 MOSP W=5U L=1U

CL 2 0 100F

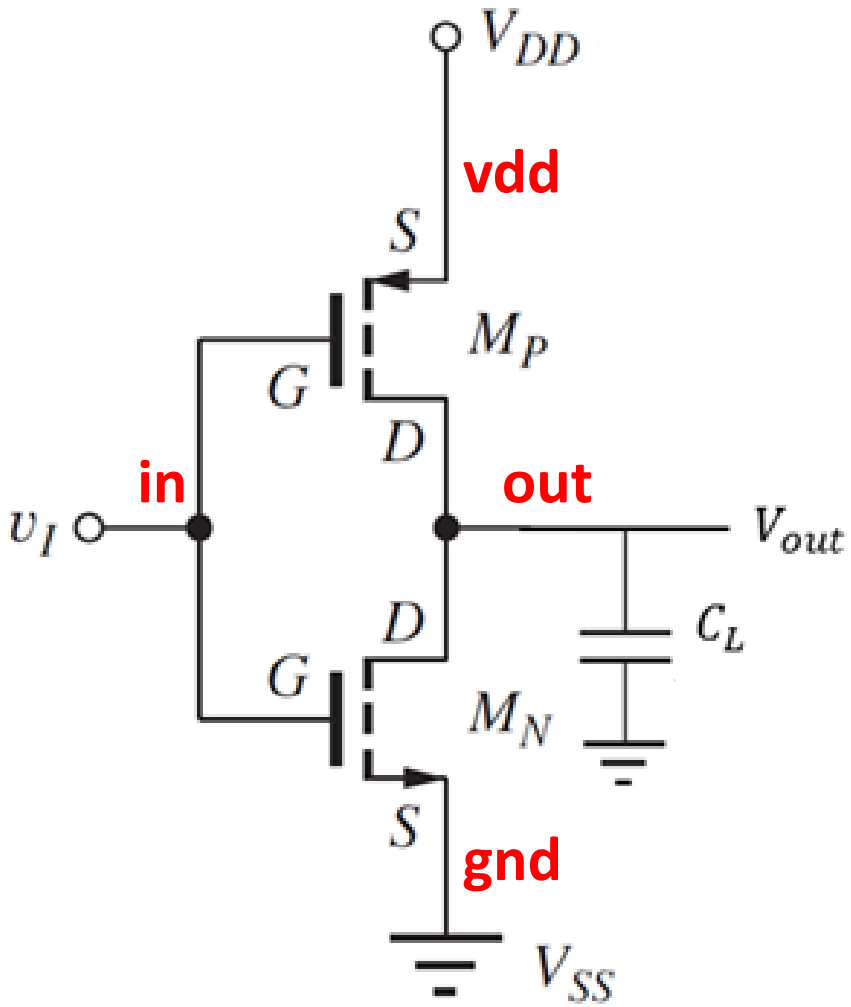
.TRAN 0.1N 20N



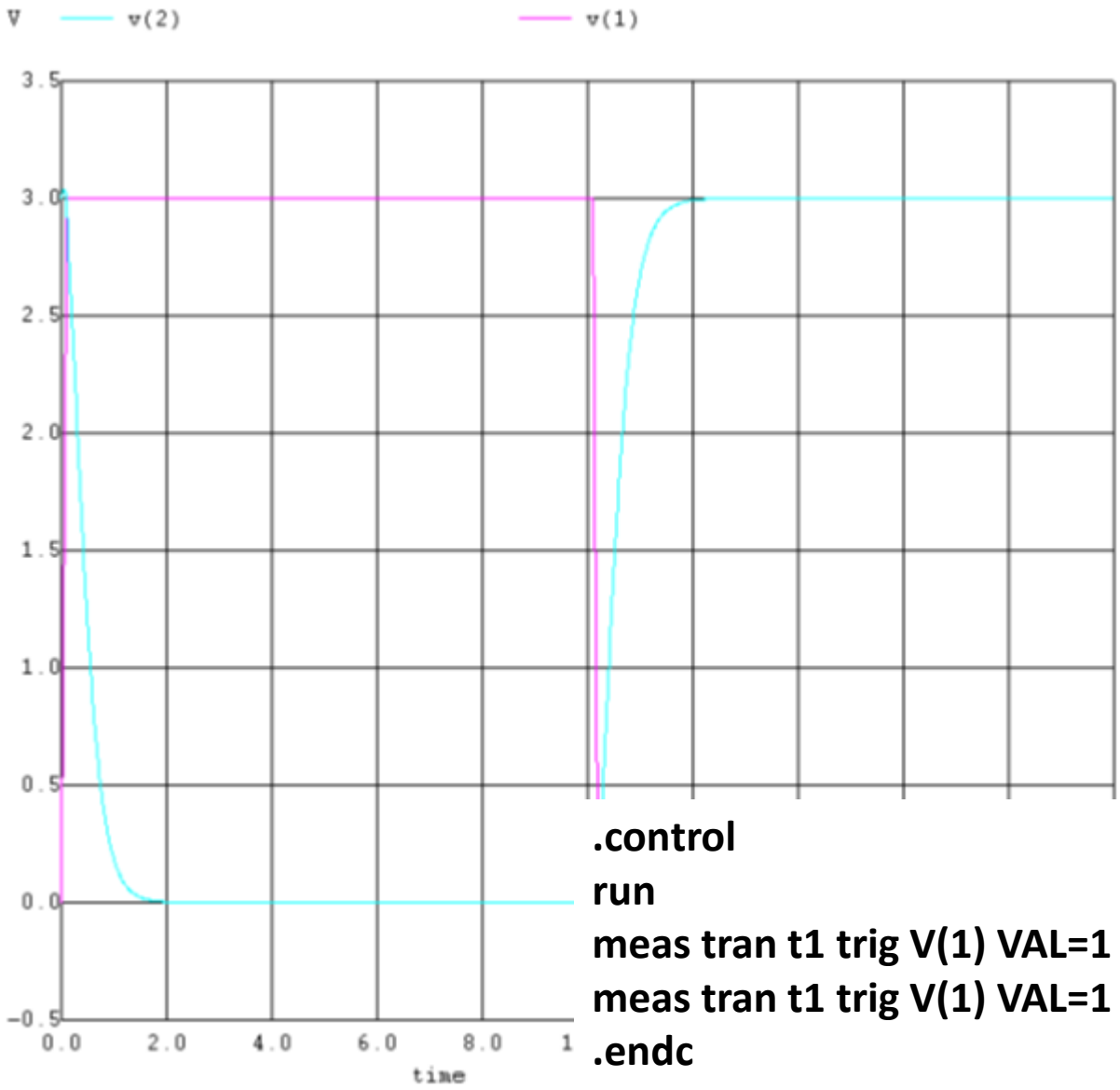
Example: Dynamic Characteristics of CMOS Inverter



Example: Dynamic Characteristics of CMOS Inverter



Example: Dynamic Characteristics of CMOS Inverter




```
.control
run
meas tran t1 trig V(1) VAL=1 RISE=1 TARG V(2) VAL=1 FALL=1
meas tran t1 trig V(1) VAL=1 RISE=1 TARG V(1) VAL=1 RISE=1
.endc
```