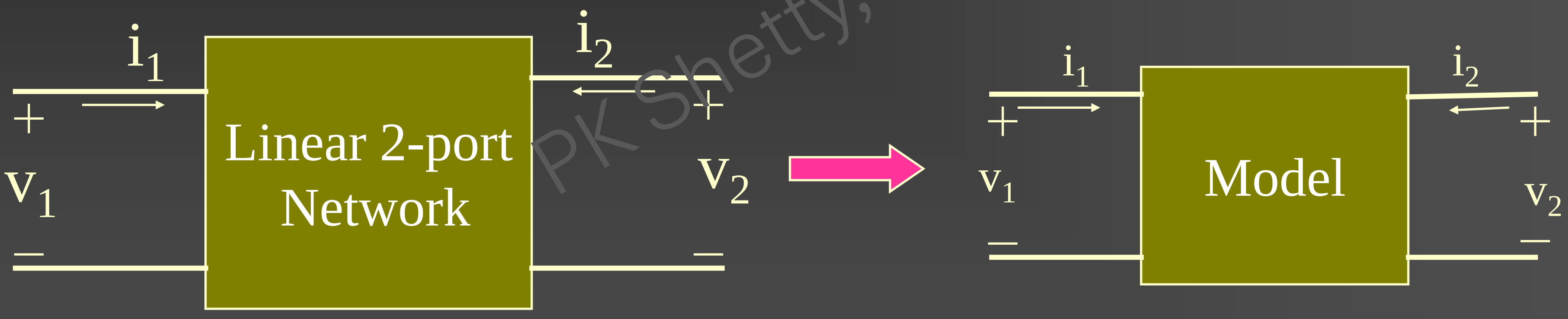
MOSFET Models

Use of a Model

- Developing Design Equations
- Hand Analysis and Initial Computer Simulation

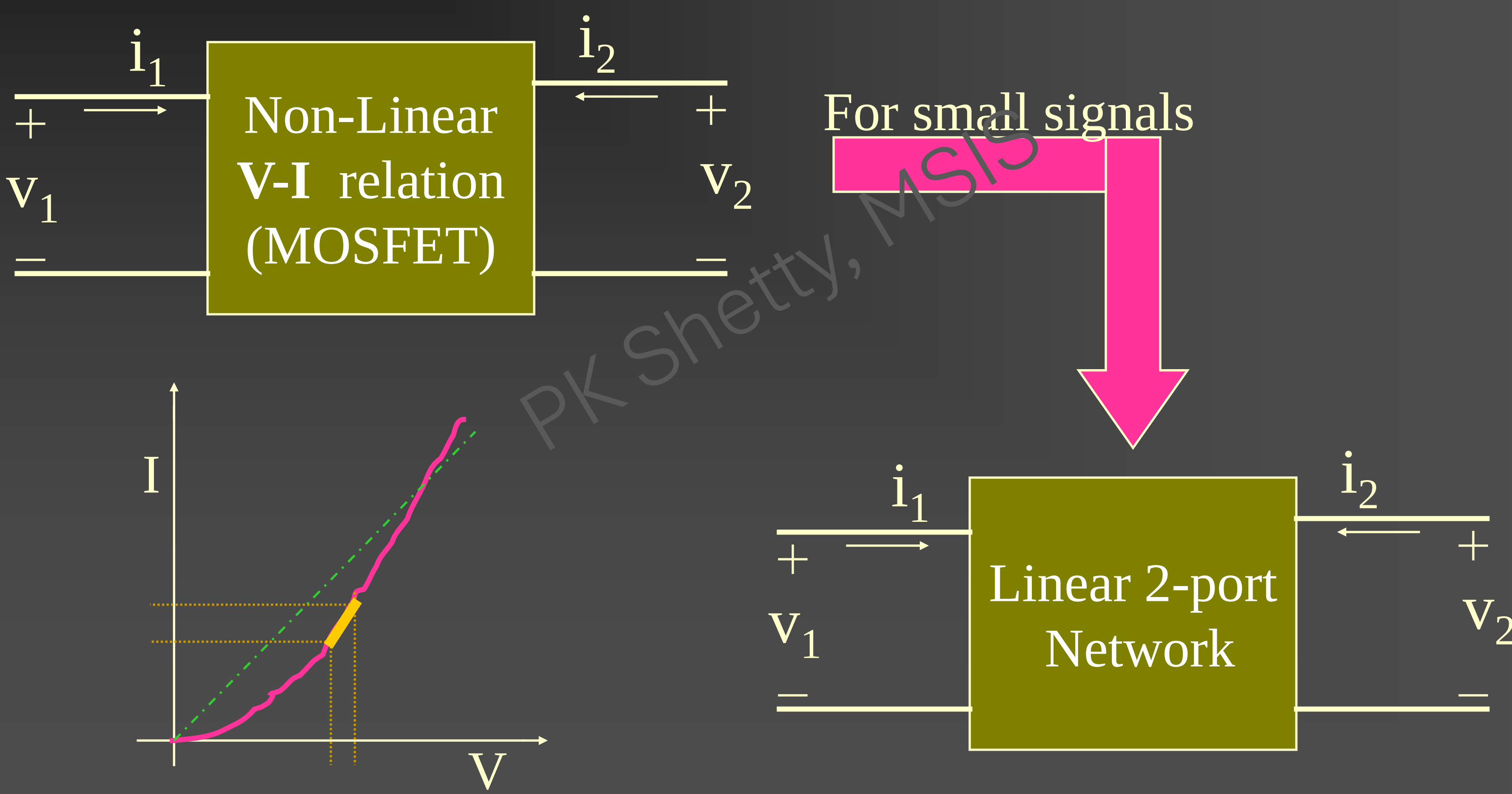
Model

We can have a model for any linear 2-port network.



MOSFET Small Signal Model

Two Port Network:

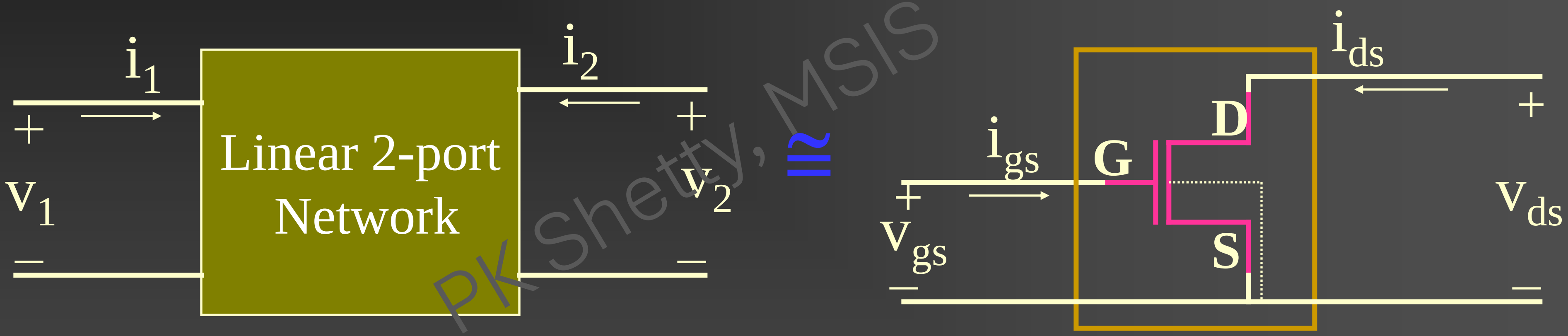


Various models

The electrical behavior of linear 2-port n/w can be modeled in terms of the following established sets of transfer function parameters:

- h - parameter model (hybrid)
- y - parameter model (admittance)
- g - parameter model (conductance)

MOSFET y-parameter model



$$i_1 = y_{11}v_1 + y_{12}v_2$$
$$i_2 = y_{21}v_1 + y_{22}v_2$$

$$i_{gs} = y_{11}v_{gs} + y_{12}v_{ds}$$
$$i_{ds} = y_{21}v_{gs} + y_{22}v_{ds}$$

MOSFET y-parameter model

$$i_{gs} = y_{11}v_{gs} + y_{12}v_{ds} \quad \text{——} \quad (1)$$
$$i_{ds} = y_{21}v_{gs} + y_{22}v_{ds} \quad \text{——} \quad (2)$$

For low frequencies, impedance between G and S is very high and hence $\mathbf{i_{gs} \approx 0}$.

$\therefore$ from eqn. (1),

$$0 = y_{11}v_{gs} + y_{12}v_{ds}$$

i.e., input conductance, $y_{11} = \partial i_{gs}/\partial v_{gs} = 0;$

and, forward transconductance, $y_{12} = \partial i_{gs}/\partial v_{ds} = 0;$

MOSFET y-parameter model

$$i_{ds} = y_{21}v_{gs} + y_{22}v_{ds} \quad (2)$$

For MOSFETs biased in saturation rergion,

$I_{ds} = ½KW/L(v_{gs}-v_t)^2(1+\lambda v_{ds})$ (3) where $K=\mu C_{ox}$

From eqns. (2) and (3),

$y_{21} = \partial i_{ds}/\partial v_{gs} = KW/L(v_{gs}-v_t)(1+\lambda v_{ds})$;

= reverse transconductance, g_m.

$y_{22} = \partial i_{ds}/\partial v_{ds} = ½\, \lambda KW/L(v_{gs}-v_t)^2$;

= output conductance, $g_o \approx \lambda\, i_{ds}$

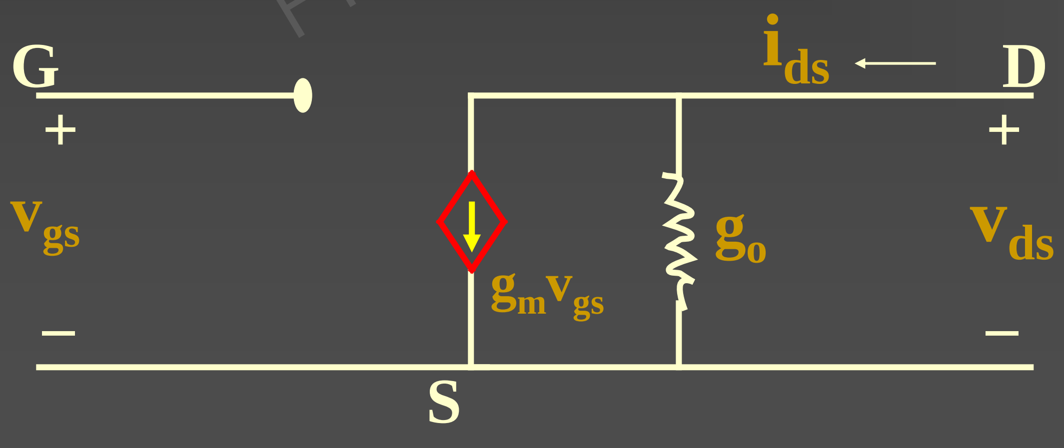
MOSFET y-parameter model

$$i_{ds} = y_{21}v_{gs} + y_{22}v_{ds} \qquad (2)$$

Substituting the values for y_{21} and y_{22},

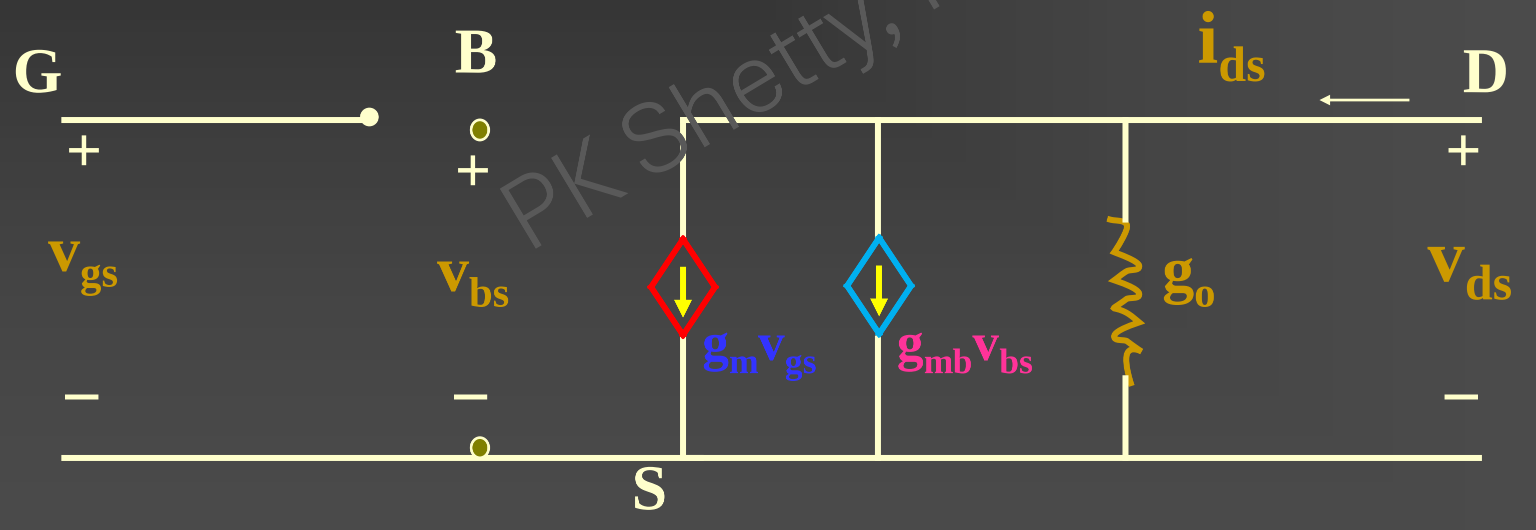
$$i_{ds} = g_m v_{gs} + g_o v_{ds}$$

$\therefore$ **MOSFET model is,**



Complete MOSFET model

If we consider the "***body effect***", then the model requires another transconductance generator source, $\mathbf{g_{mb}v_{bs}}$.

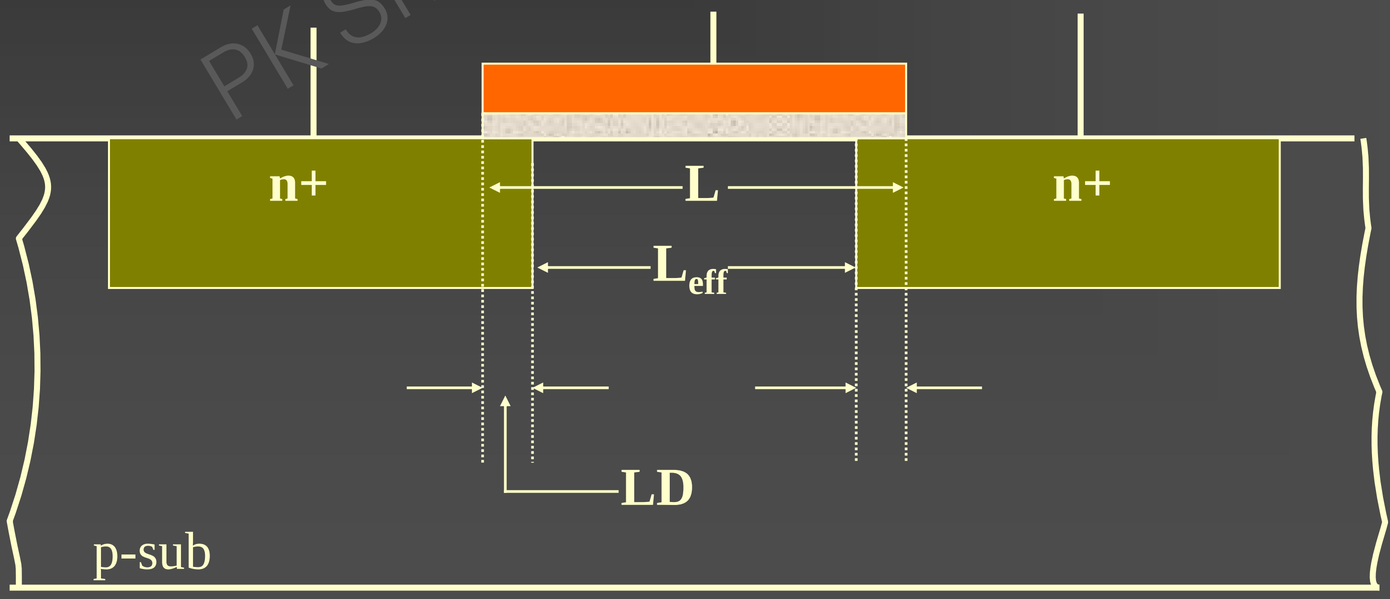


High Frequency MOSFET model

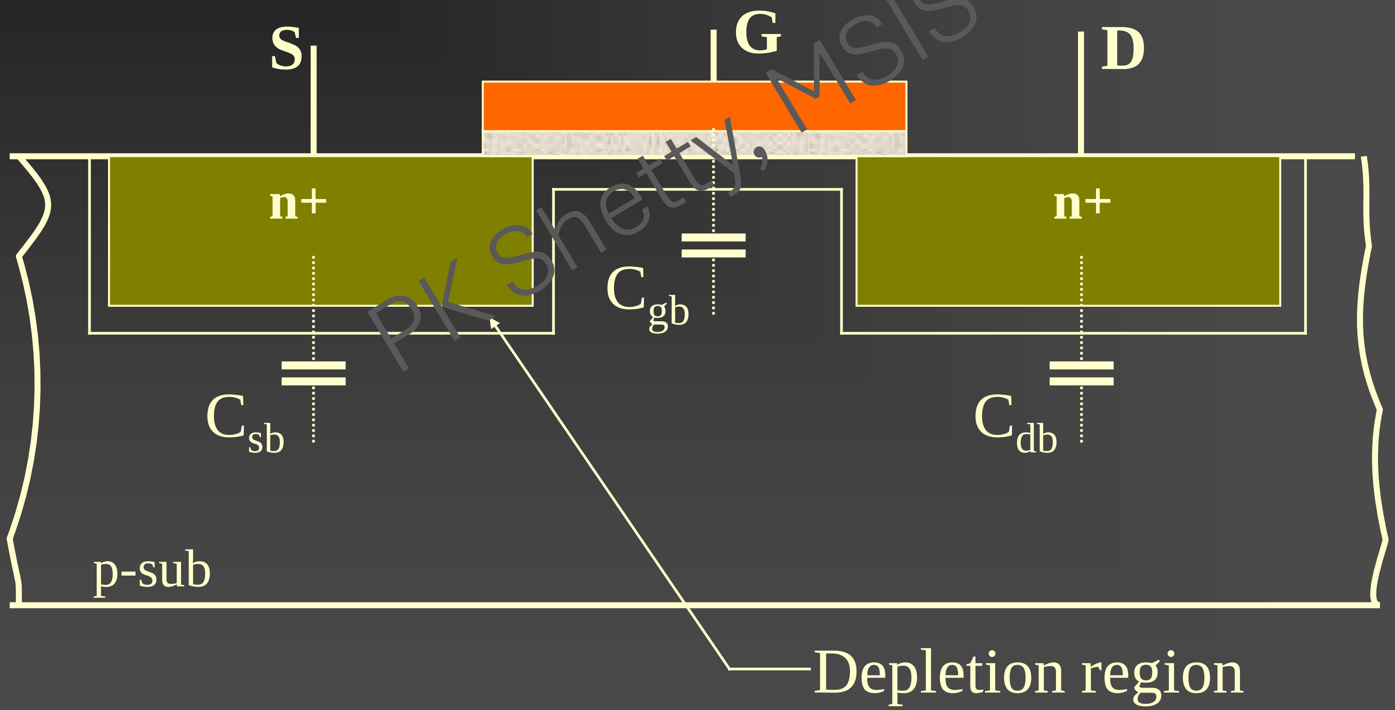
H. F. model = L. F. model + MOSFET capacitances.

$L_{eff} = (L - 2LD)$

Capacitances introduced: C_{gs} and C_{gd}

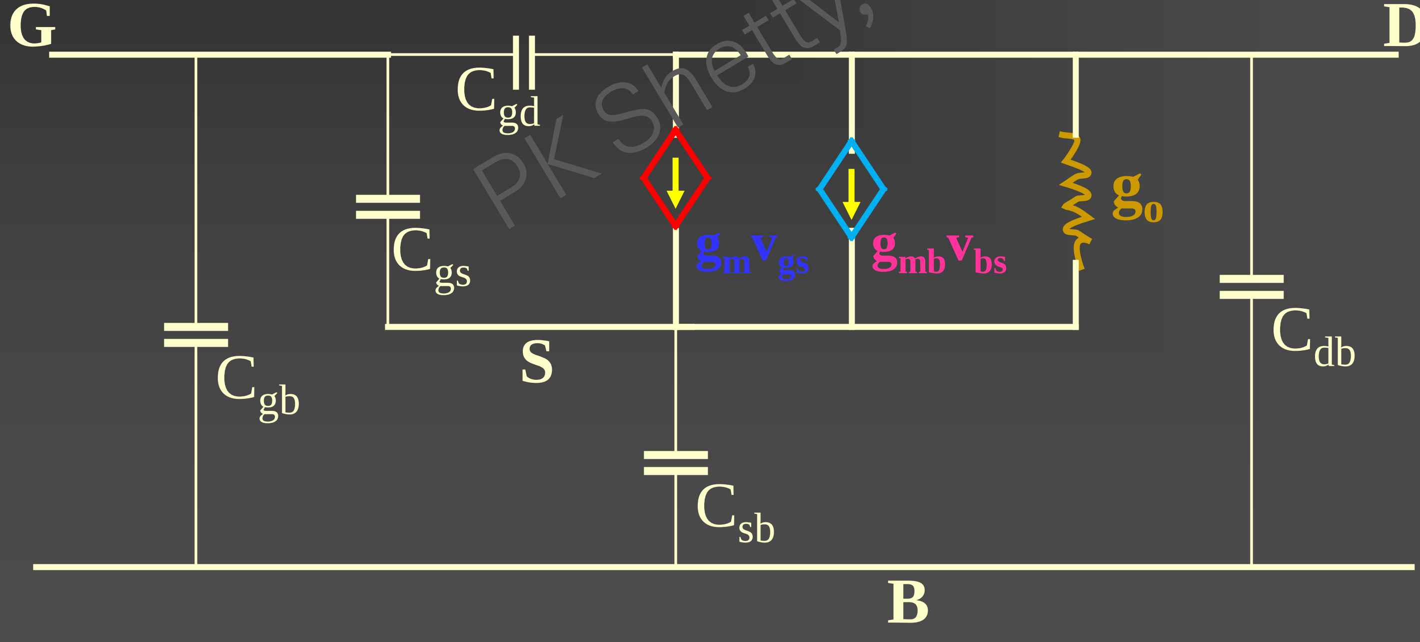


High Frequency MOSFET model



High Frequency MOSFET model

Adding these 5 capacitances to the L. F. MOSFET model:



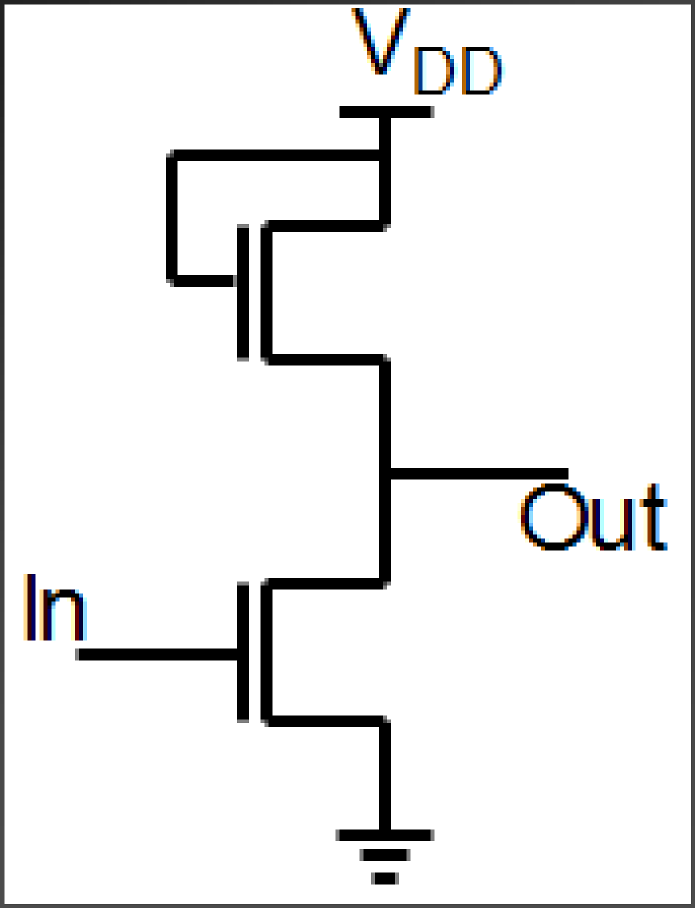
Capacitance Estimation

1. $C_{gb} = \varepsilon_{ox}(L\text{-}2LD)W / t_{ox} = C_{ox}(L_{eff})W$
2. $C_{gd} = \varepsilon_{ox}(LD)W / t_{ox} = C_{ox}(LD)\ W = CGDO.\ W$
3. $C_{gs} = \varepsilon_{ox}(LD)W / t_{ox} = C_{ox}(LD)\ W = CGSO.\ W$
4. $C_{sb} = C_{sb,bottom} + C_{sb,sidewall}$
5. $C_{db} = C_{db,bottom} + C_{db,sidewall}$

where, $C_{s(d)b,bottom} = \dfrac{CJ.AS(D)}{(1+V_{DB}/PB)^{MJ}}$

$$C_{s(d)b,sidewall} = \frac{CJSW.PS(D)}{(1+V_{DB}/PBSW)^{MJSW}}$$

Draw the small signal model for the circuit shown below:



MOSFET Model

$$I_{DS} = \frac{1}{2} \mathbf{K_n} W/L(V_{GS} - \mathbf{V_{TH}})^2(1+\lambda V_{DS})$$

SPICE Models

Used to simulate CMOS ICs. These MOSFET models provide a description of how a transistor will behave in the designed circuit. Thus, the models serve as the connection between the designed circuit and the underlying fabrication technology.

- SPICE model Level1, Level2, Level3
- BSIM (**B**erkeley **S**hort-Channel **I**GFET **M**odel)

Eg.:- BSIM1, BSIM2, BSIM3, ……..

BSIM4.0.0 (released on 24.03.2000), ……..

BSIM4.4.0 (released on 04.03.2004), ……..

BSIM Model

- At one time, nearly every company developed its own compact models
- In 1996, the Compact Model Council, an industry standard setting group sponsored by most of the world's largest semiconductor manufacturers and design tool companies, set out to select one standard model
- It selected **BSIM** as the world's first industry standard model in 1997
- Now, nearly all the semiconductor companies in the world use BSIM to some degree.
- If the I_{ds} equation of BSIM is typed out on paper, it will fill two pages.

SPICE MODEL PARAMETERS OF MOSFETS

LEVEL	Model type (1, 2, or 3)
L	Channel length
W	Channel width
LD	Lateral diffusion length
WD	Lateral diffusion width
VTO	Zero-bias threshold voltage
KP	Transconductance
GAMMA	Bulk threshold parameter
PHI	Surface potential
LAMBDA	Channel-length modulation
CJ	Bulk p-n zero-bias bottom capacitance/length
CJSW	Bulk p-n zero-bias perimeter capacitance/length
MJ	Bulk p-n bottom grading coefficient