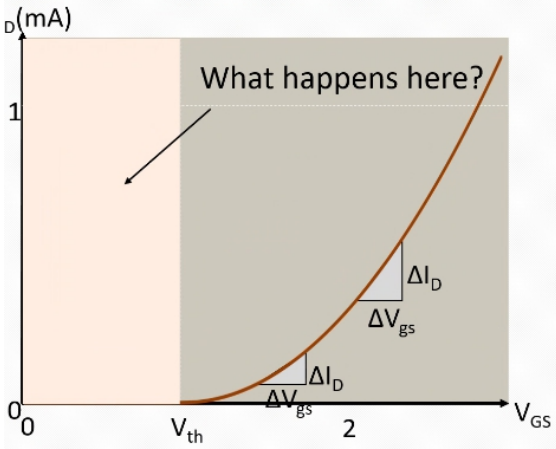
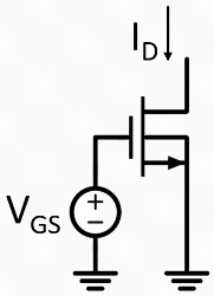
Transconductance





gm

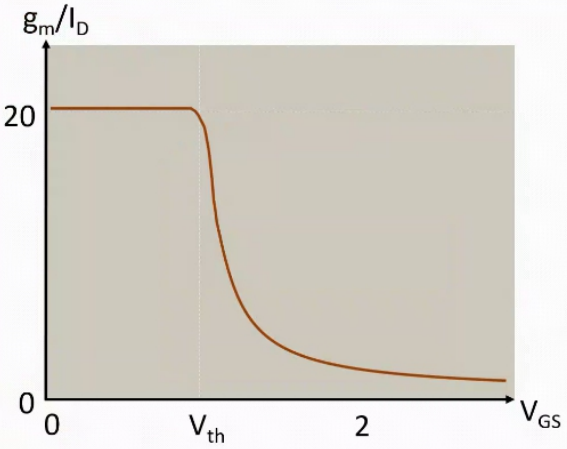
gm/ID

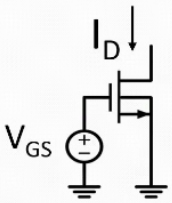
f_T

rds

Adc

gm over ID





gm

gm/ID

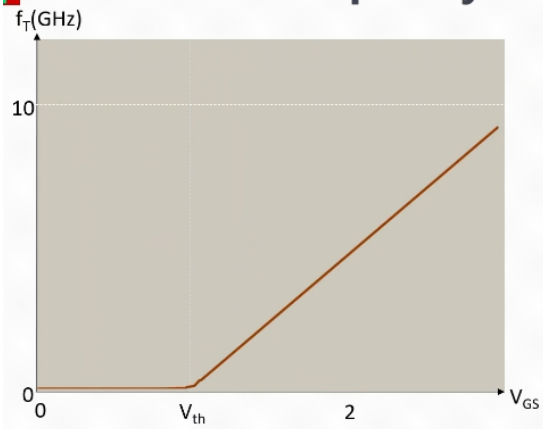
f_T

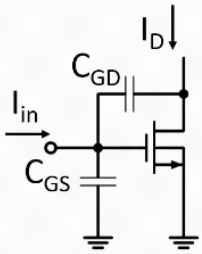
rds

Adc

Transconductance efficiency highest in subthreshold

Transition Frequency



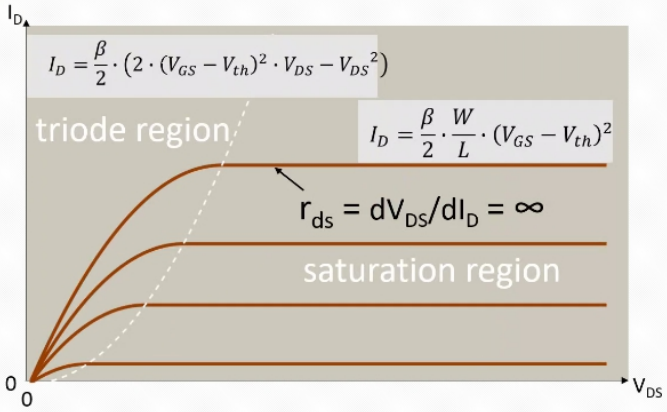


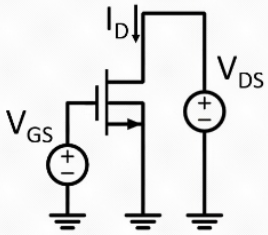
gm
gm/ID
f_T
rds
Adc

$$f_T = \frac{1}{2\pi} \cdot \frac{g_m}{C_{GS} + C_{GD}}$$

f_T is defined as the frequency where $I_D/I_{in} = 1$

Output Resistance



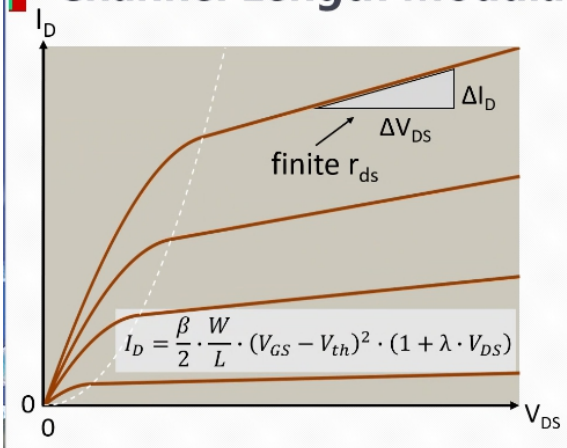


gm
gm/ID
f_T
rds
Adc

Operate as **switch in triode** for $V_{DS} < V_{GS}$-V_{th} (V_{ov})

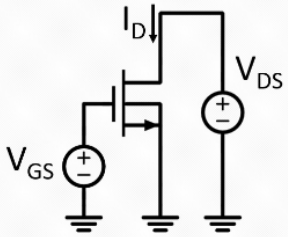
Operate as **amplifier in saturation** for $V_{DS} > V_{GS}$-V_{th} (V_{ov})

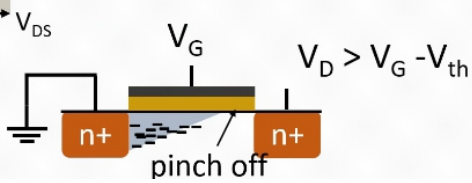
Channel Length Modulation



$$I_D = \frac{\beta}{2} \cdot \frac{W}{L} \cdot (V_{GS} - V_{th})^2 \cdot (1 + \lambda \cdot V_{DS})$$

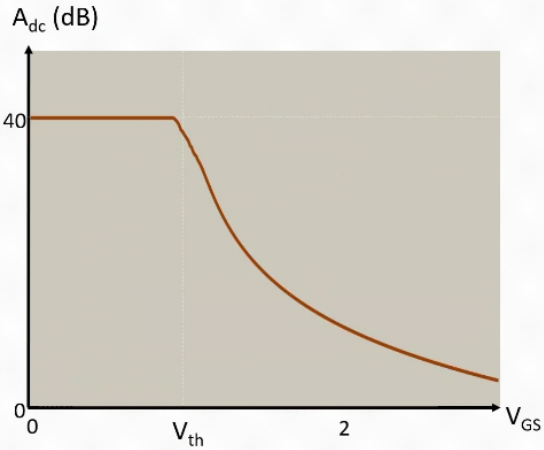
$$r_{ds} = \frac{1}{\lambda \cdot I_D}$$

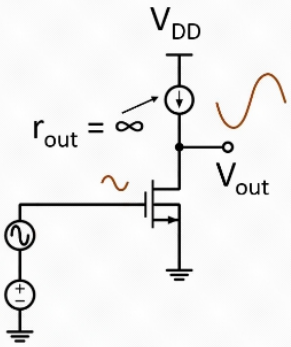




gm
gm/I_D
f_T
rds
Adc

Intrinsic Gain





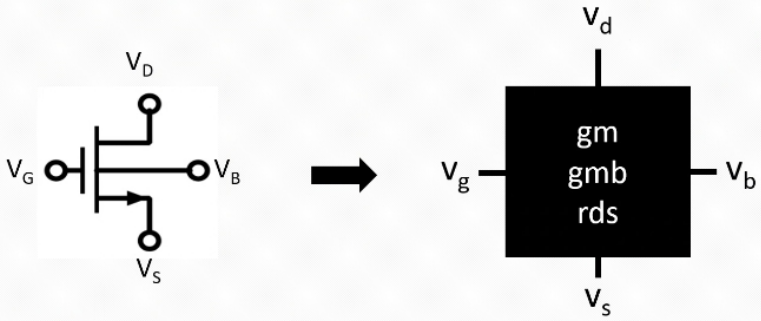
gm
gm/I_D
f_T
rds
Adc

For an ideal current source load the gain is only limited r_{ds}.

➡ The intrinsic DC gain is the highest possible gain we can hope for.

Small Signal Model

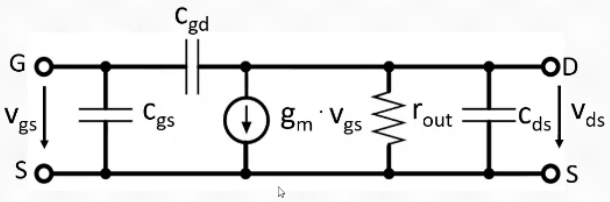
What can we do with these small signal parameters?



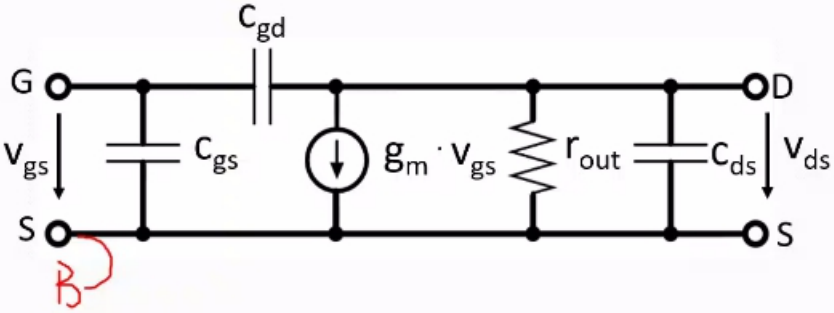
They allow us to see the transistor as linearized black box

Small Signal Model

Let‘s look inside the black box:



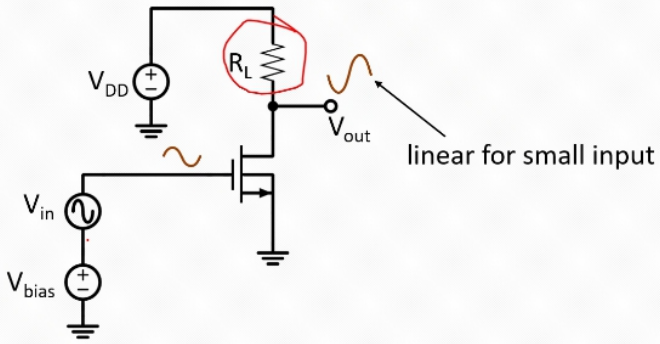
Also called AC model because it is valid for small variations (AC) around the DC operating point



四部分 GDSB

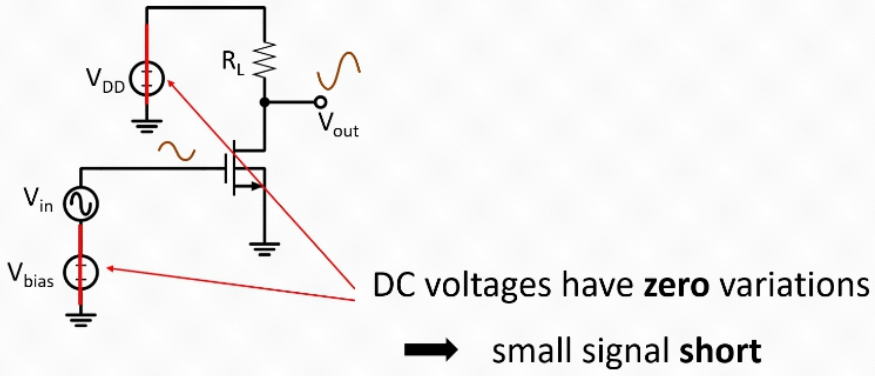
Small Signal Model

Example of an amplifier:



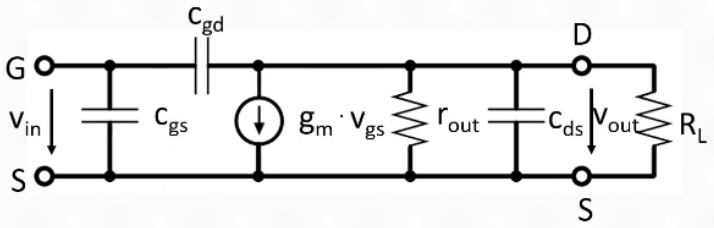
Small Signal Model

Example of an amplifier:



Small Signal Model

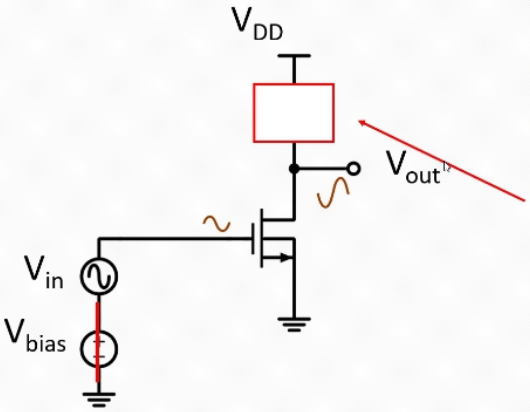
Let‘s derive the small signal model for this amplifier:



$$\frac{v_{out}}{v_{in}} = -g_m(r_{out}||R)$$

Small Signal Model

A better amplifier:

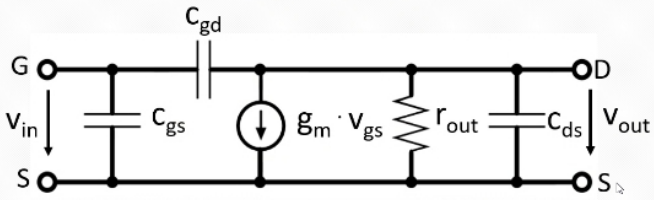


DC current sources have **zero** current variation

➡ **open circuit** for AC

Small Signal Model

Let‘s derive the small signal model for this amplifier:

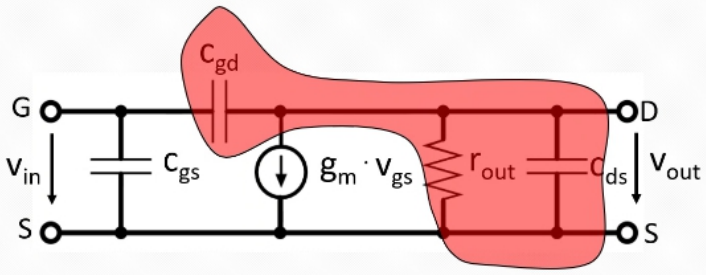


$$\frac{v_{out}}{v_{in}} = -g_m r_{out}$$

➡ Current source loading gives intrinsic gain.

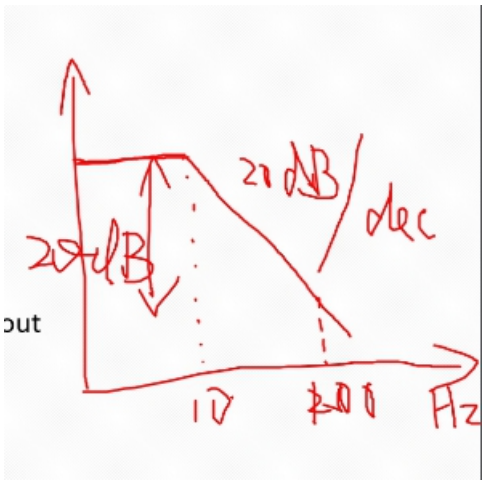
Small Signal Model

What about the capacitances?

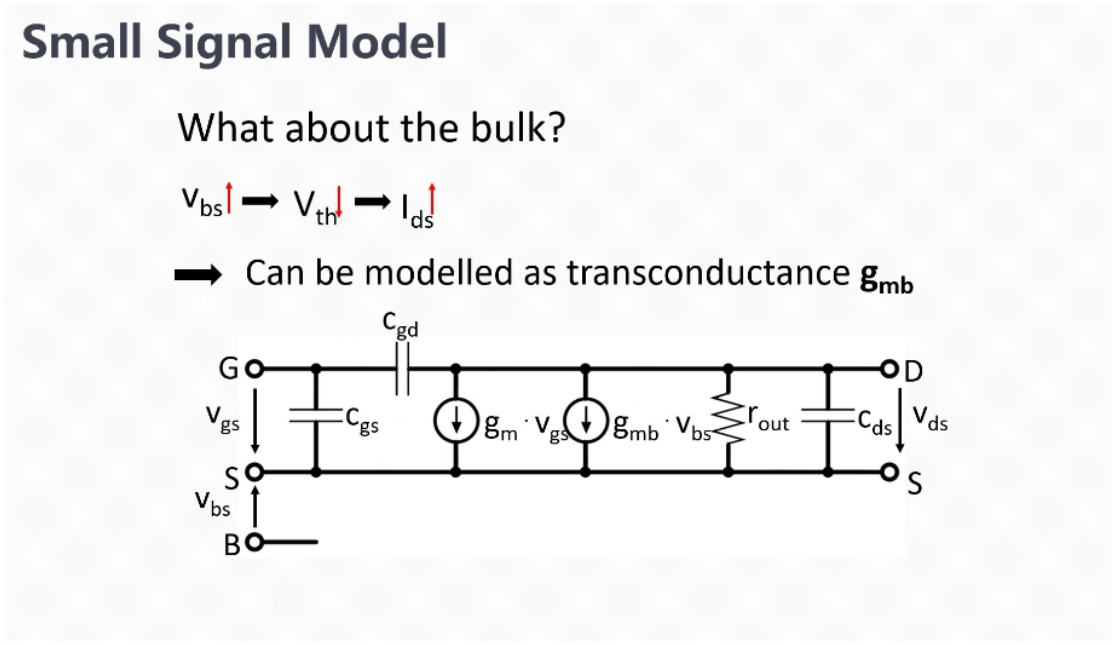


$$\frac{v_{out}}{v_{in}} = -g_m r_{out} \frac{1 - sC_{gd}/g_m}{1 + s(C_{gd} + C_{ds}) r_{out}}$$

经过一个极点会下降 20dB



Ads 是幅度频谱的纵坐标



Ids 与(Vgs-Vth)有关

注意 Vbs 是正是负，还是 0