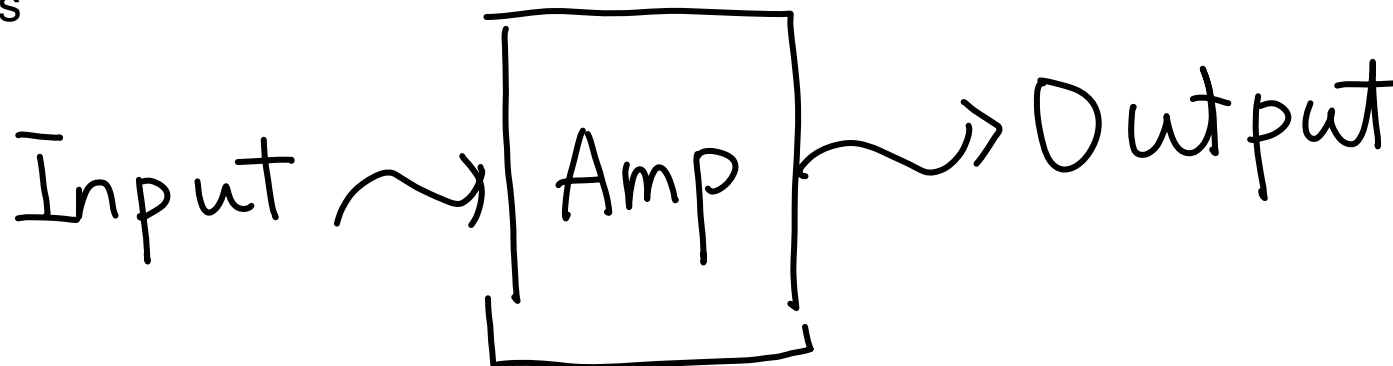


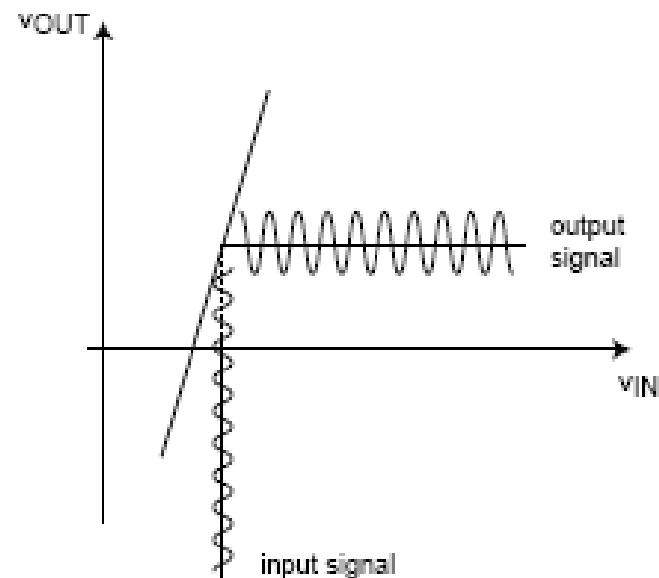
Lect. 5: Amplifiers (1)

Amplifiers



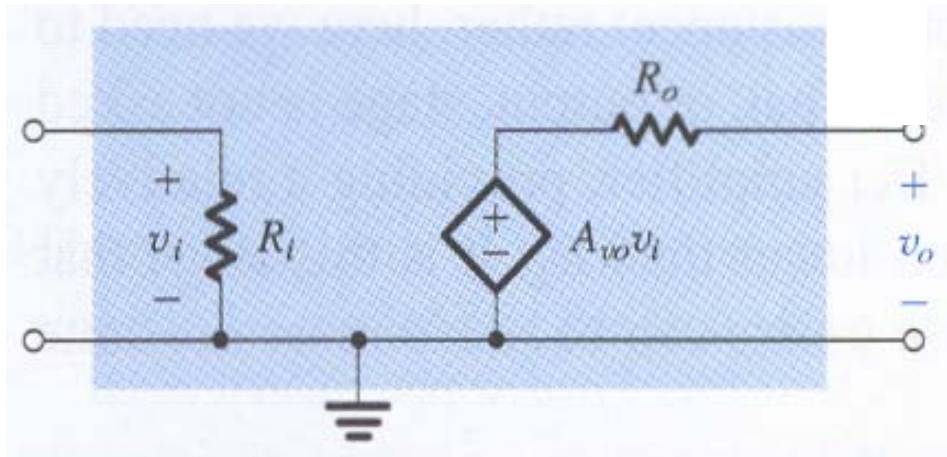
Output signal should be faithful replica
of input signal
with desired amount of amplification

Need linear transfer characteristics



Lect. 5: Amplifiers (1)

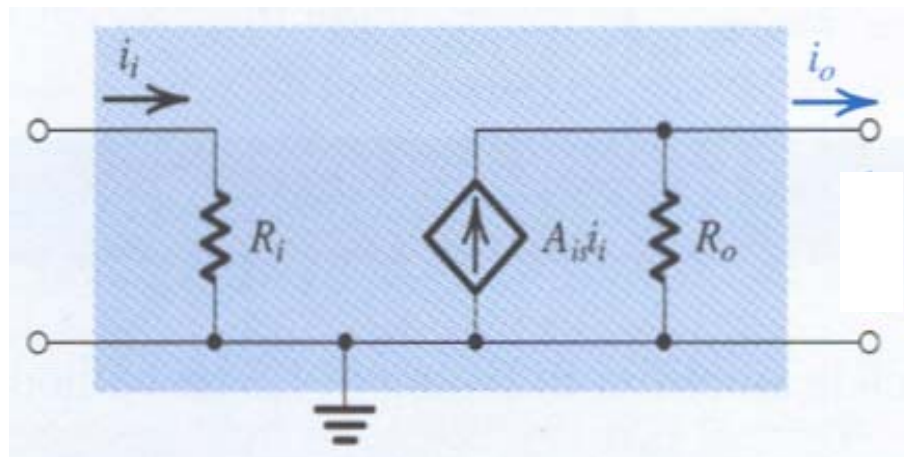
Equivalent circuit models for an amplifier



R_i : Input Resistance

A_{vo} : Open-Circuit Voltage Gain

R_o : Output Resistance

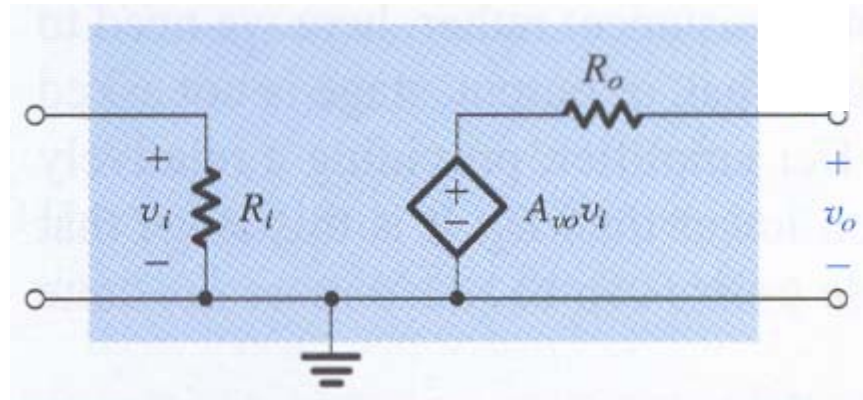


A_{is} : Short-Circuit Current Gain

Lect. 5: Amplifiers (1)

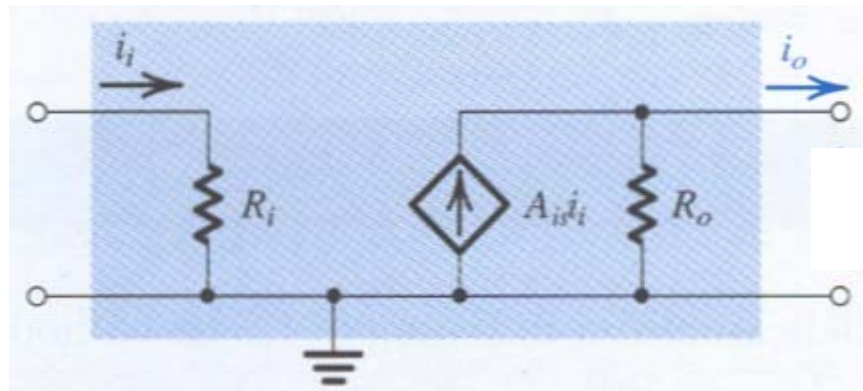
Various types of amplifiers

Voltage Amplifier



$$R_i = \infty$$
$$R_o = 0$$

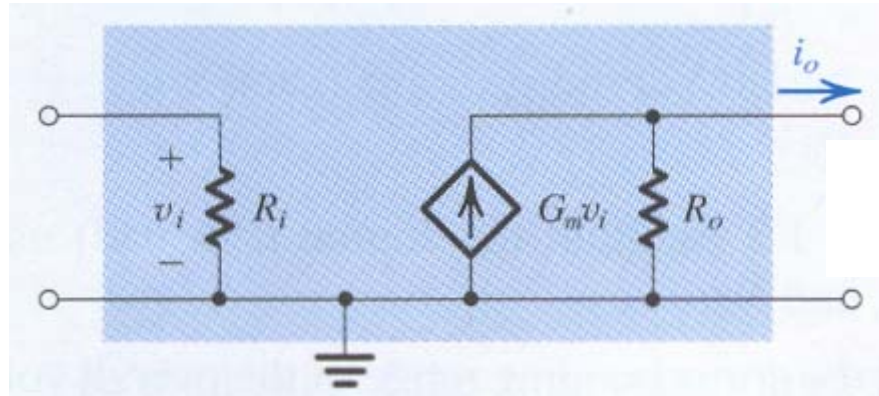
Current Amplifier



$$R_i = 0$$
$$R_o = \infty$$

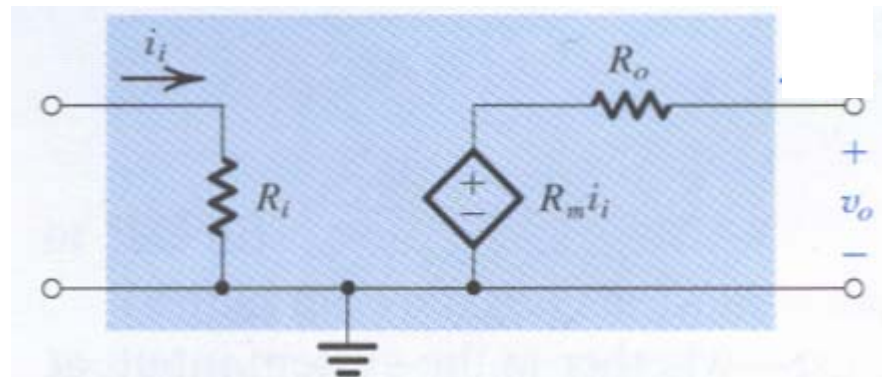
Lect. 5: Amplifiers (1)

Transconductance Amplifier



$$R_i = \infty$$
$$R_o = \infty$$

Transimpedance (Transresistance) Amplifier

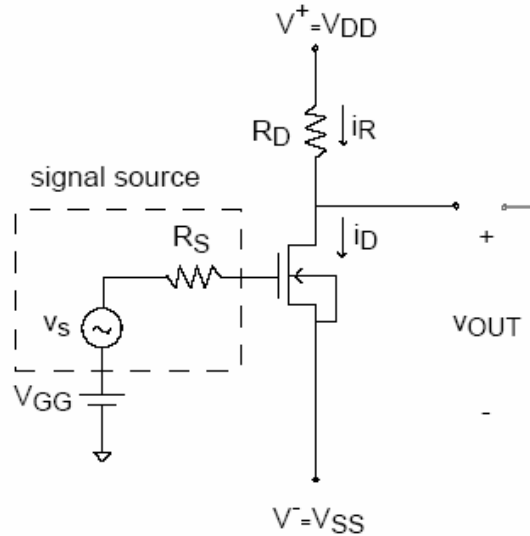


$$R_i = 0$$
$$R_o = 0$$

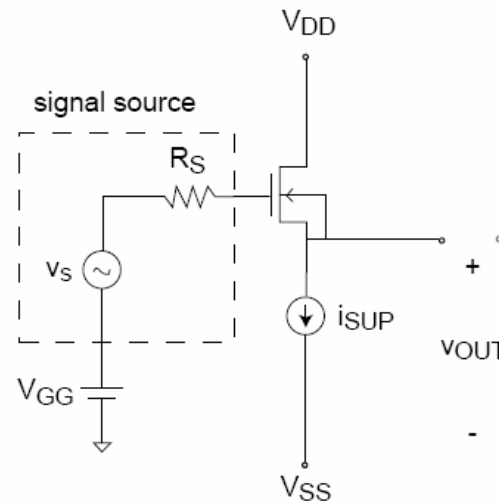
Lect. 5: Amplifiers (1)

How can we make amplifiers with MOSFET(s)?

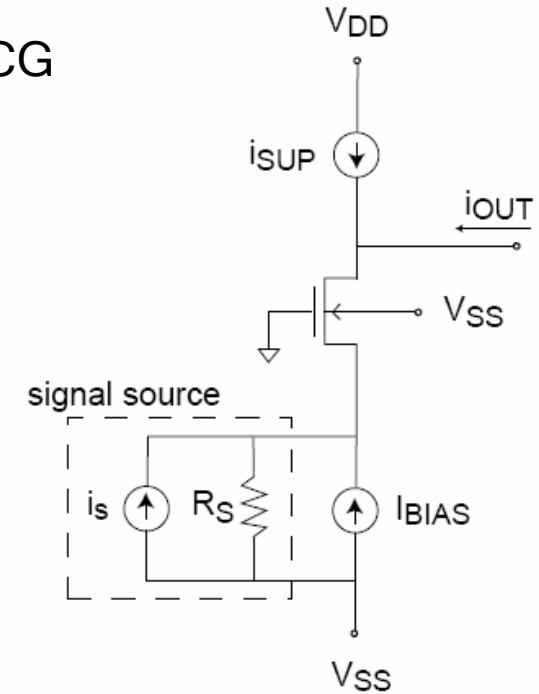
Three basic configurations: CS, CD, CG



Common Source



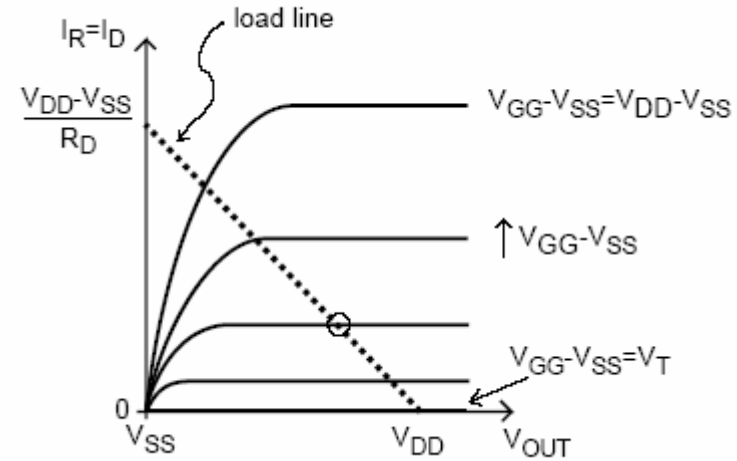
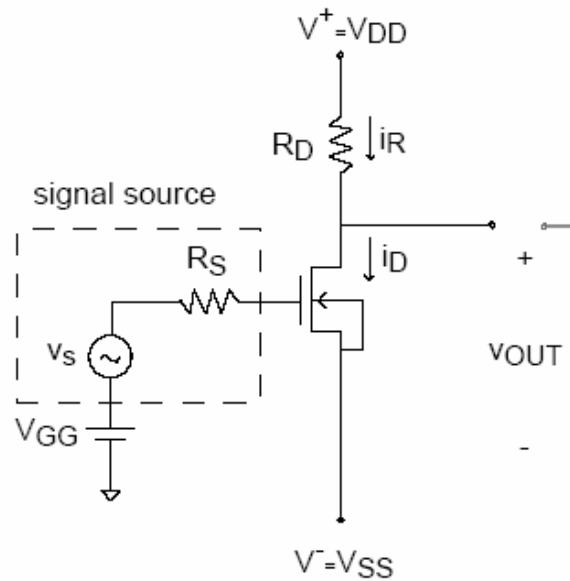
Common Drain
(Source Follower)



Common Gate

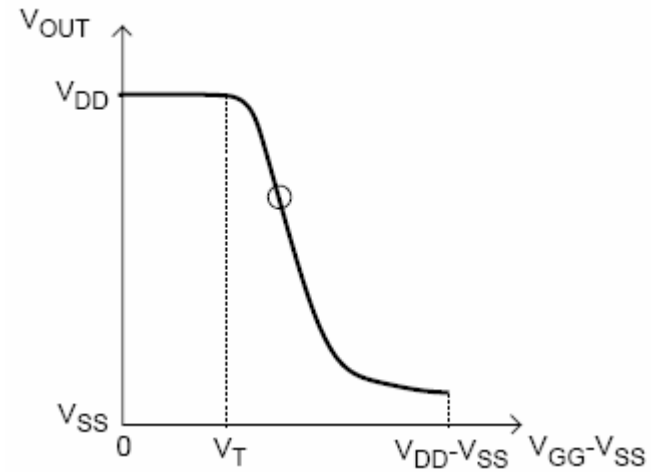
Lect. 5: Amplifiers (1)

CS Amplifiers



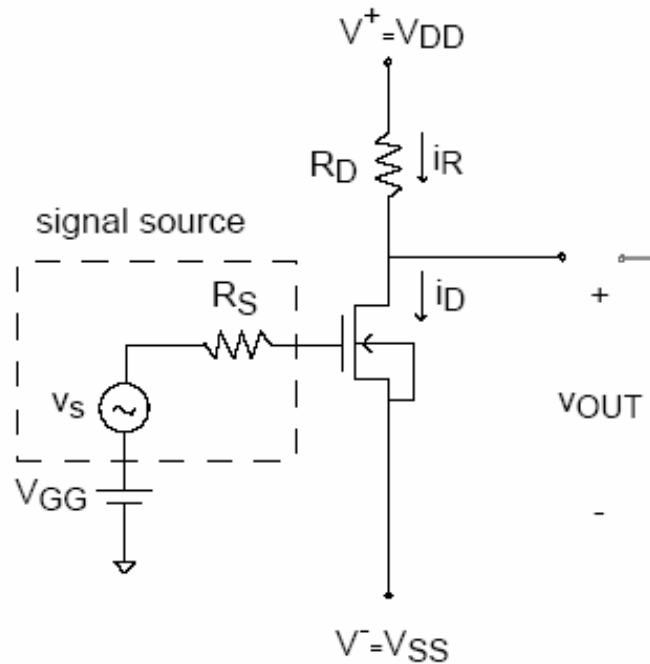
How does it work?

$$V_{GS} \uparrow \Rightarrow i_D \uparrow \Rightarrow v_{out} \downarrow$$

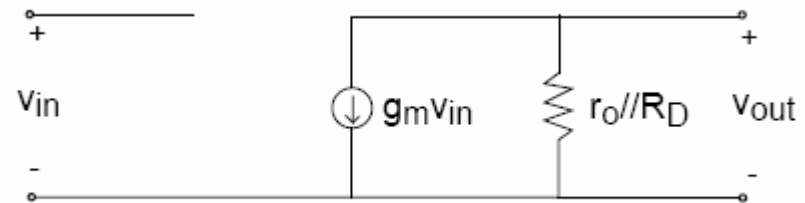


Lect. 5: Amplifiers (1)

CS Amplifiers



small-signal model



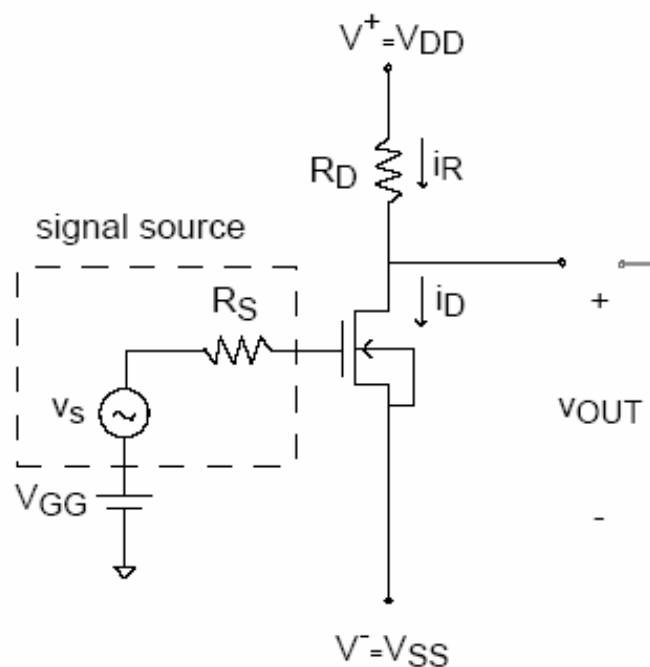
$$A_{vo} = \frac{v_{out}}{v_{in}} = -g_m(r_o // R_D)$$

$$R_{in} = \infty$$

$$R_{out} = r_o // R_D$$

Lect. 5: Amplifiers (1)

CS Amplifiers



Signal Swing?

Max. v_{OUT} ? V_{DD}

When MOSFET is in cut-off

Min. v_{OUT} ?

When MOSFET enters triode region

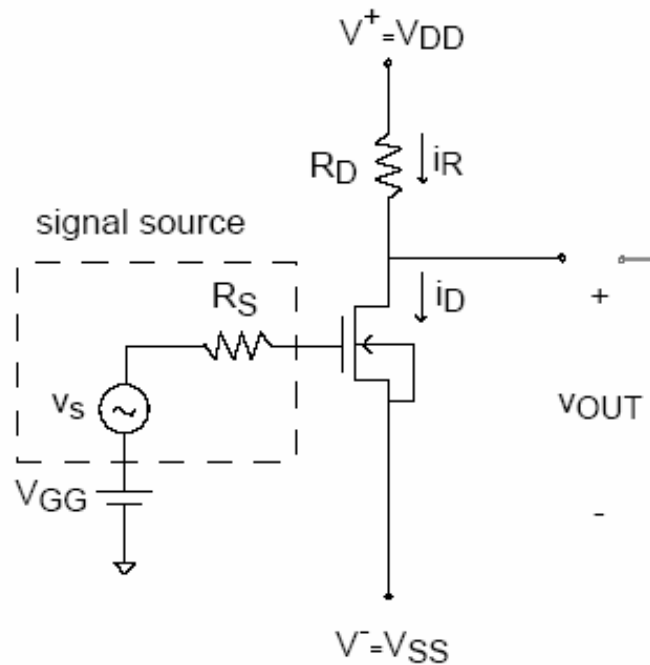
$$v_{DS} = v_{GS} - V_T$$

$$v_{OUT} - V_{SS} = V_{GG} - V_{SS} - V_T \text{ (ignoring } v_s)$$

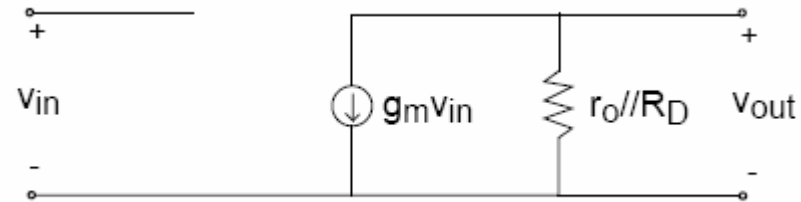
$$v_{OUT, \min} = V_{GG} - V_T$$

Lect. 5: Amplifiers (1)

CS Amplifiers



small-signal model



$$A_{vo} = \frac{v_{out}}{v_{in}} = -g_m(r_o // R_D)$$

$$R_{in} = \infty$$

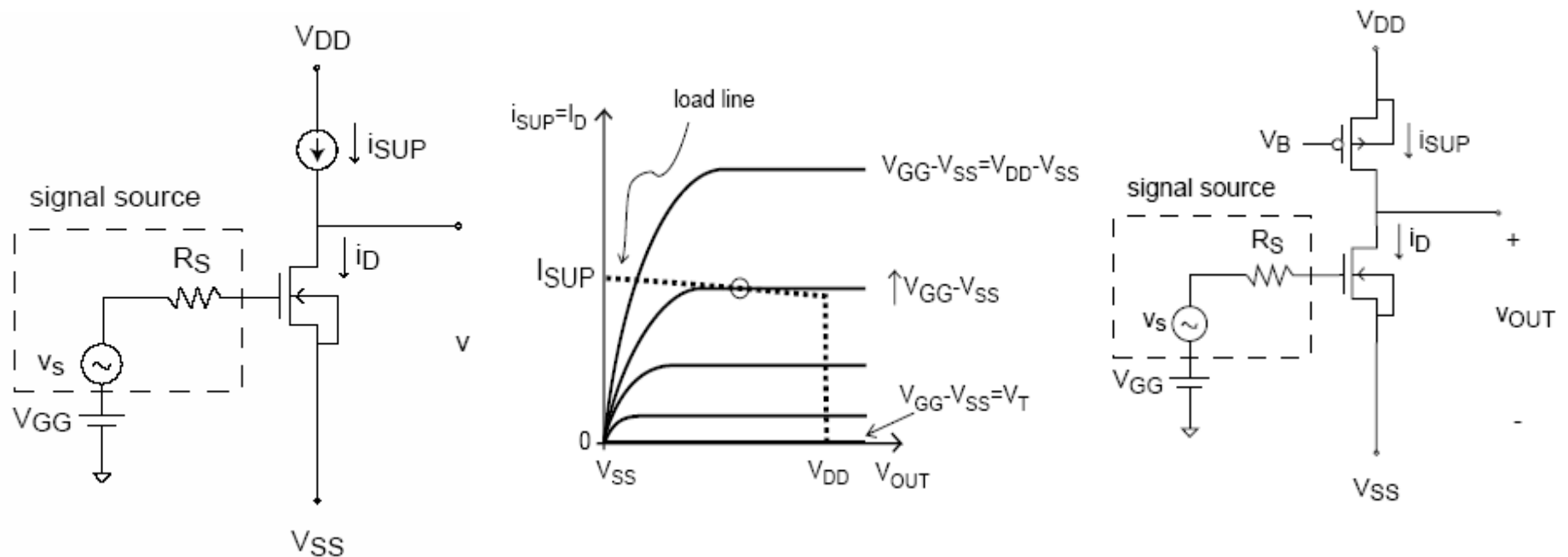
$$R_{out} = r_o // R_D$$

For large A_{vo} , R_D should be large
 → Good transconductance amplifier
 But large R_D is not desirable

→ Use current source instead of R_D
 (active load)

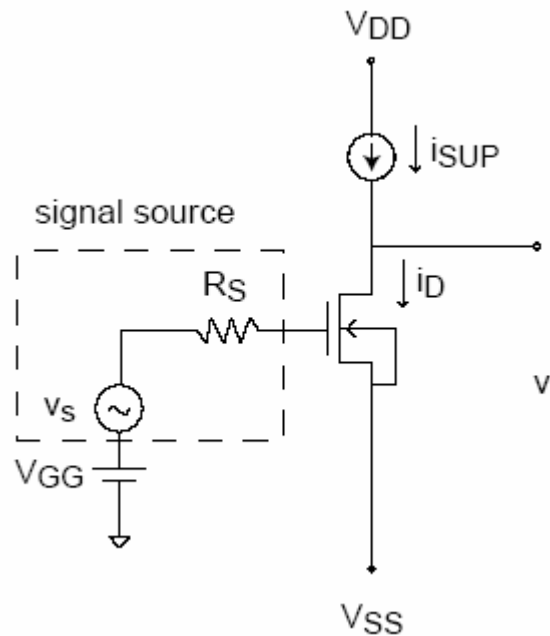
Lect. 5: Amplifiers (1)

CS Amplifier with current source
(active load)

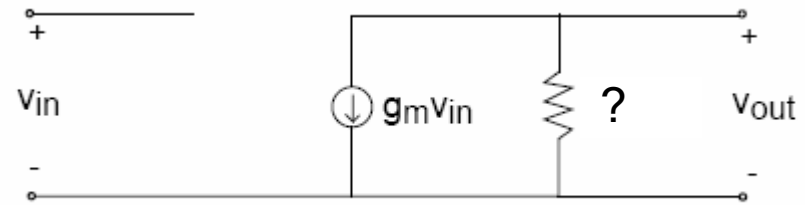


Lect. 5: Amplifiers (1)

CS Amplifier with current source
(active load)



small-signal model



$$A_v = -g_m (r_o // r_{oc})$$

$$R_{in} = ?$$

$$R_{out} = ?$$