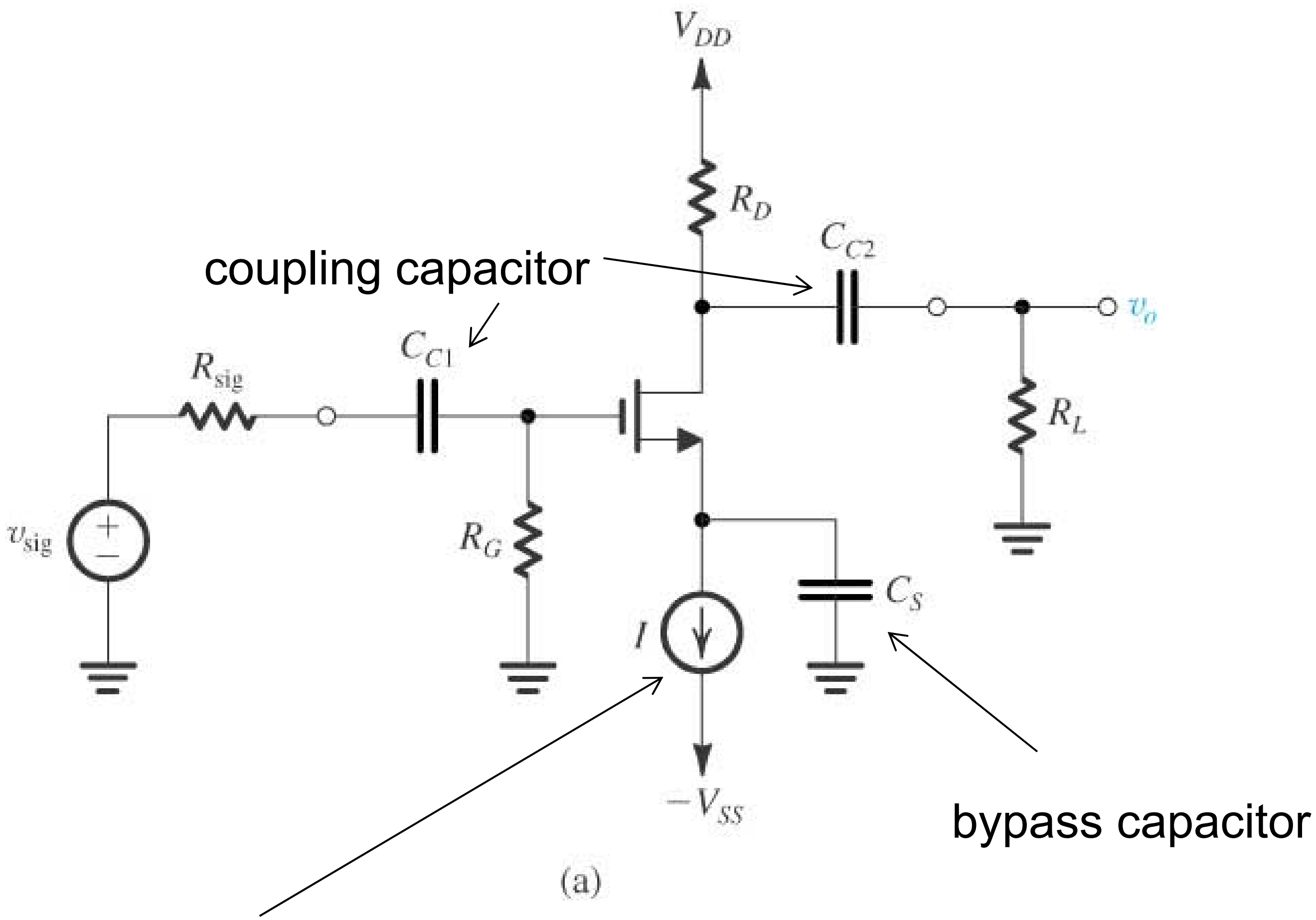
Single-Stage MOS Amplifiers

◆ Common Source Amplifier (biasing w/ current source)



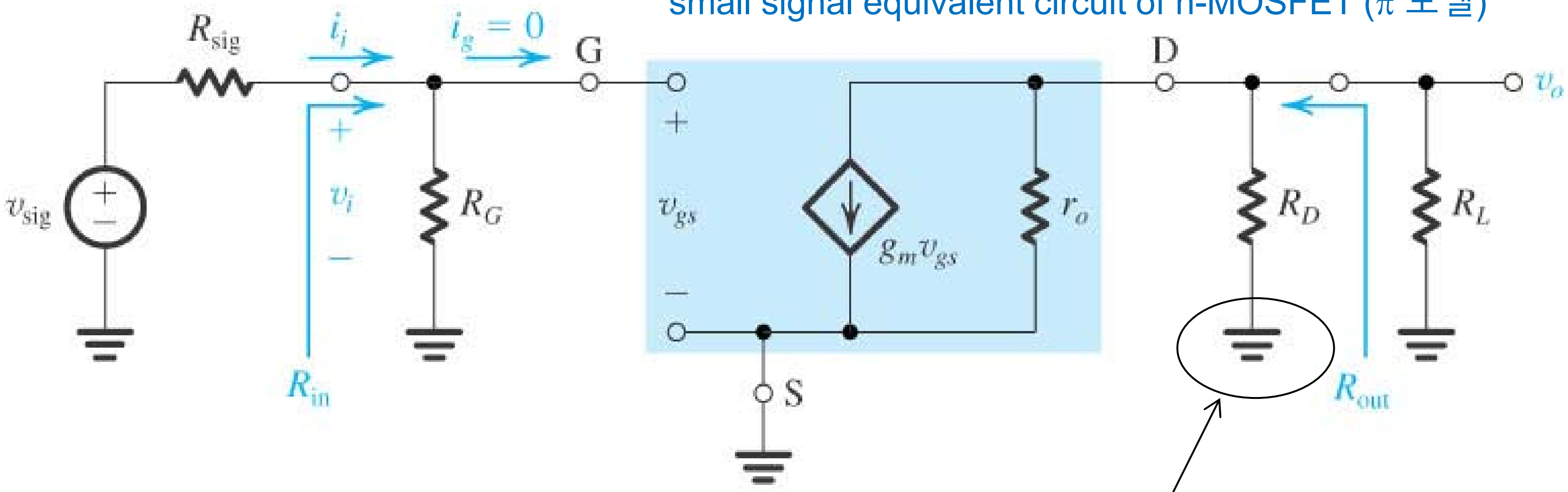
Biasing w/ current source

Single-Stage MOS Amplifiers

◆ Common Source Amplifier

$$g_m = \sqrt{2\mu_n C_{ox} \frac{W}{L} I_D}$$

small signal equivalent circuit of n-MOSFET (π 모델)



(b)

Equivalent circuit of the amplifier for small-signal analysis.

DC 회로 상의 고정 전압은 소신호 회로 상에서는 ground !

DC bias 전류의 크기는 소신호 등가회로 모델 상에서 g_m의 크기 결정.

$$i_g = 0$$

$$R_{\text{in}} = R_{\text{G}}$$

$$\upsilon_i = \upsilon_{\text{sig}} \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}} = \upsilon_{\text{sig}} \frac{R_{\text{G}}}{R_{\text{G}} + R_{\text{sig}}}$$

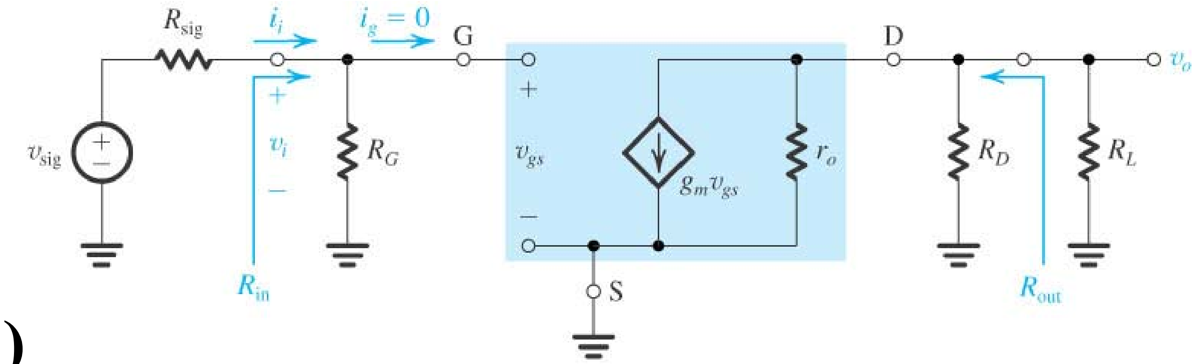
$$\upsilon_i \cong \upsilon_{\text{sig}}$$

$$\upsilon_{gs} = \upsilon_{\text{i}}$$

$$\upsilon_o = -g_m \upsilon_{\text{gs}} (r_o \parallel R_L \parallel R_L)$$

$$\text{A}_\upsilon = -g_m (r_o \parallel R_D \parallel R_L)$$

$$\text{A}_{\upsilon o} = -g_m (r_o \parallel R_D)$$



(b)

$$G_v = \frac{R_{in}}{R_{in} + R_{sig}} A_v$$

$$= \frac{R_G}{R_G + R_{sig}} g_m (r_o \parallel R_D \parallel R_L)$$

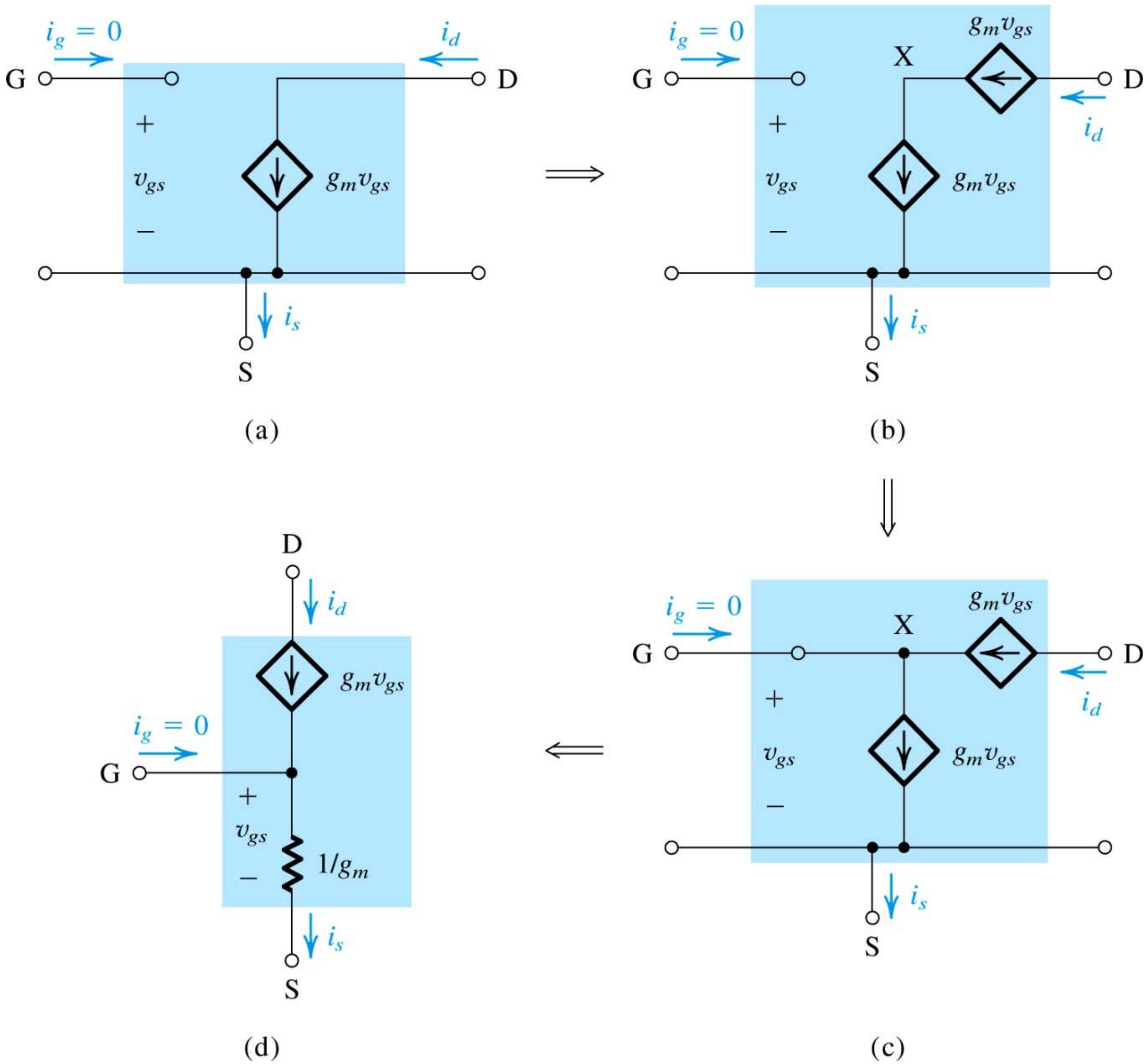
$$R_{out} = r_o \parallel R_D$$ (by assuming $v_{sig} = 0$)

CS 증폭기:

-매우 높은 입력 전압, 적당히 높은 전압 이득, 상대적으로 높은 출력 저항.

-일반적으로 다단 증폭기의 첫 번째 단으로 활용되며, 필요한 이득의 대부분을 얻는 데 가장 적합.

Small signal equivalent circuit of n-MOSFET (T 모델)



Small signal equivalent circuit of n-MOSFET (T 모델)

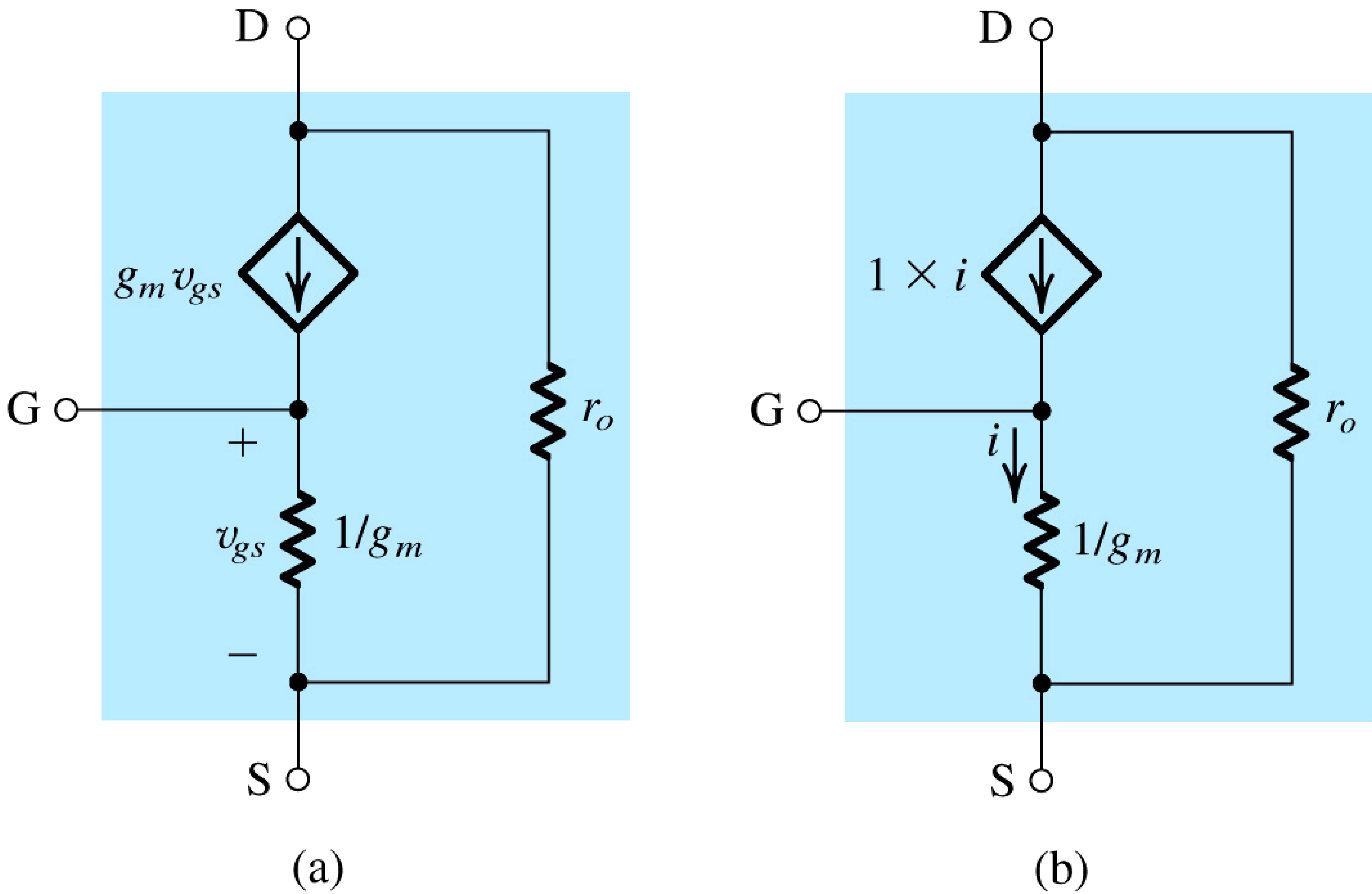
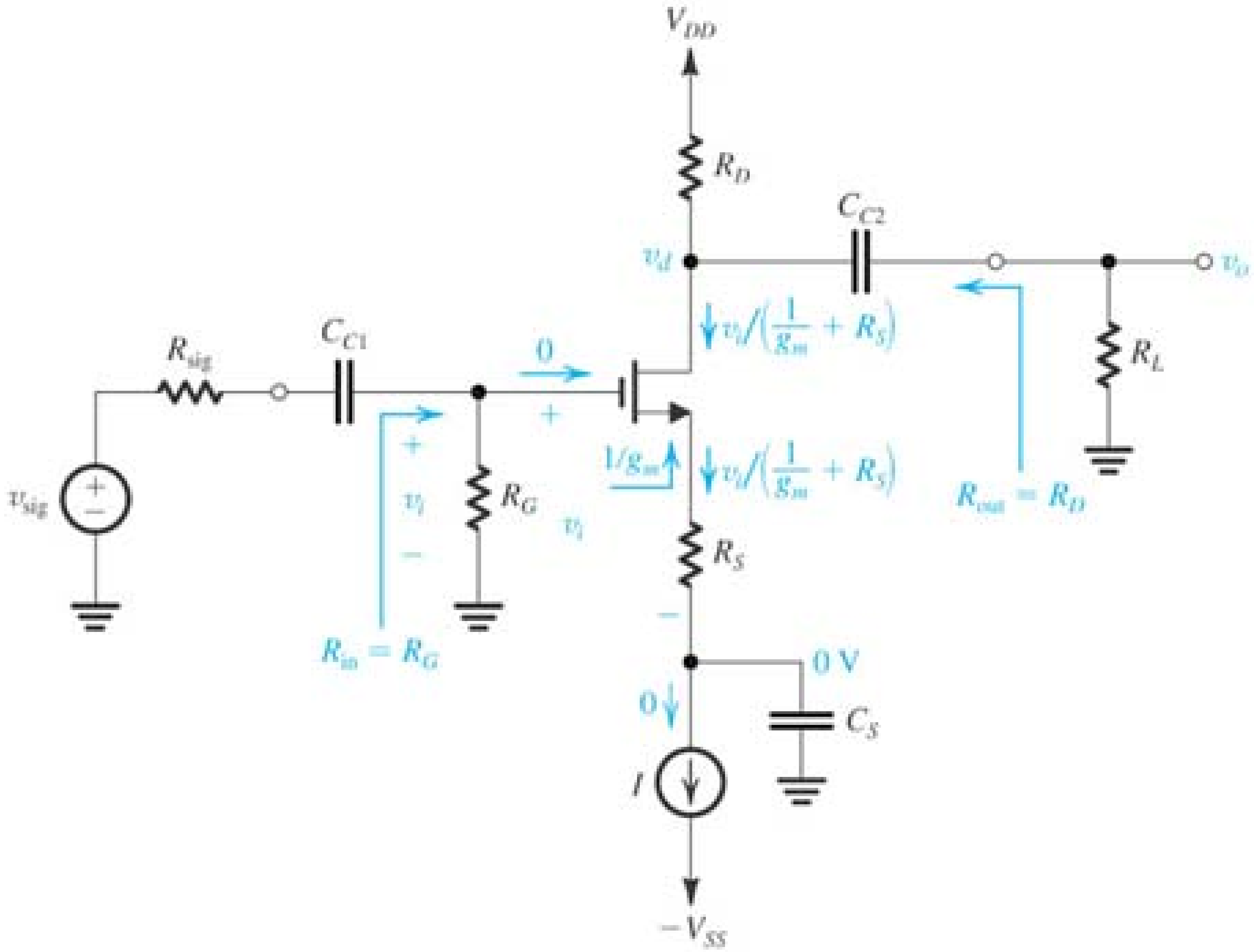
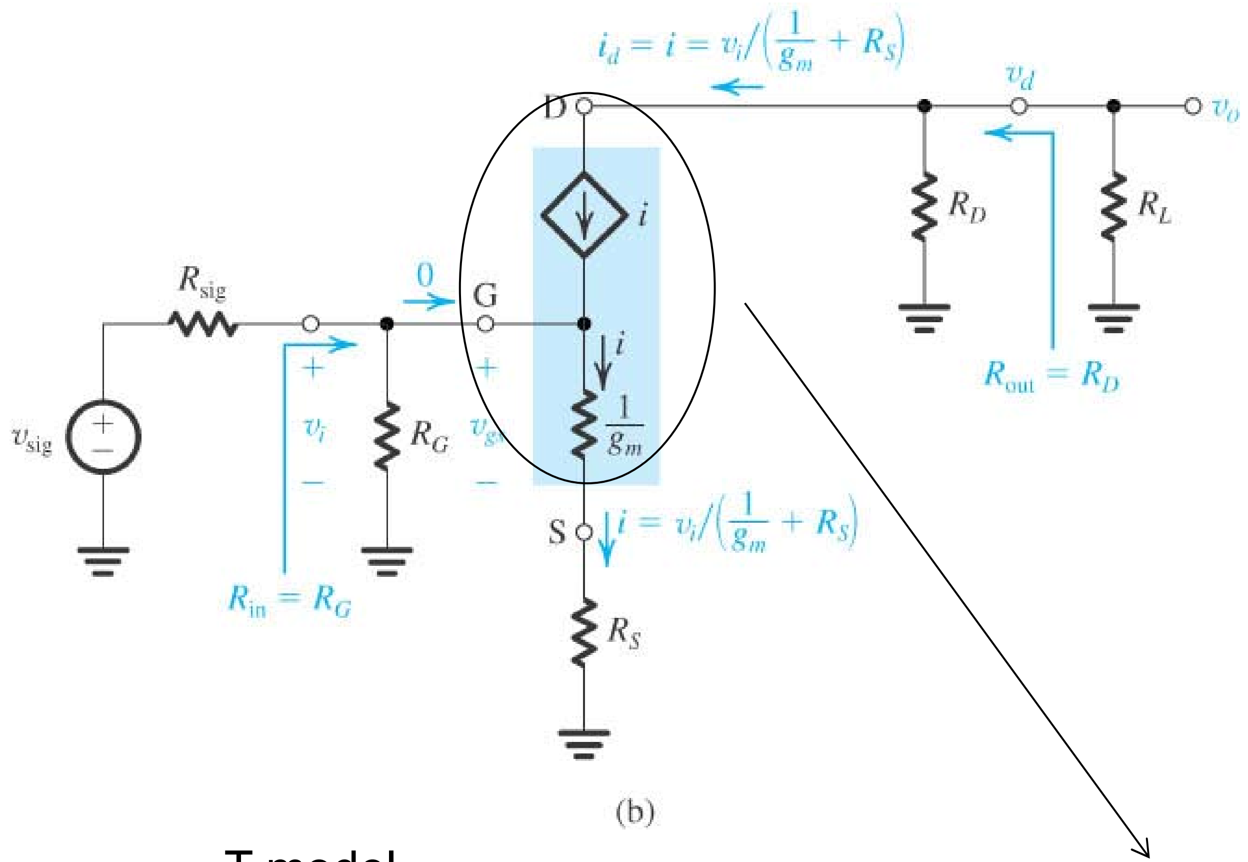


Figure 5.41 (a) The T model of the MOSFET augmented with the drain-to-source resistance r_o. (b) An alternative representation of the T model.

◆ Common Source Amplifier w/ source resistance



◆ Common Source Amplifier w/ source resistance



(b)

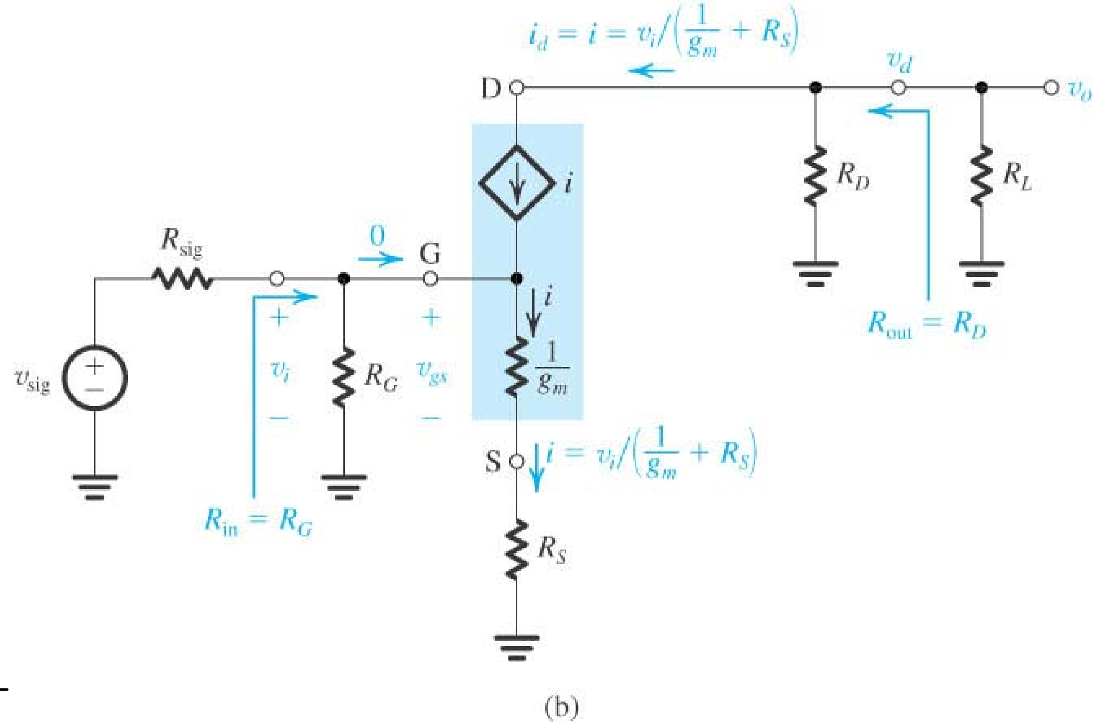
T model,
Source단이 저항과 직렬 연결된 경우, 일반적으로 사용

$$R_{in} = R_i = R_G$$

$$\upsilon_i = \upsilon_{sig} \frac{R_G}{R_G + R_{sig}}$$

$$\upsilon_{gs} = \upsilon_i \frac{\frac{1}{g_m}}{\frac{1}{g_m} + R_S} = \frac{\upsilon_i}{1 + g_m R_S}$$

$$i_d = i = \frac{\upsilon_i}{\frac{1}{g_m} + R_S} = \frac{g_m \upsilon_i}{1 + g_m R_S}$$



(b)

We can reduce the input signal by increasing the magnitude of R_S

Bandwidth is increased. (next chapter)

Output resistance is decreased. (next chapter)

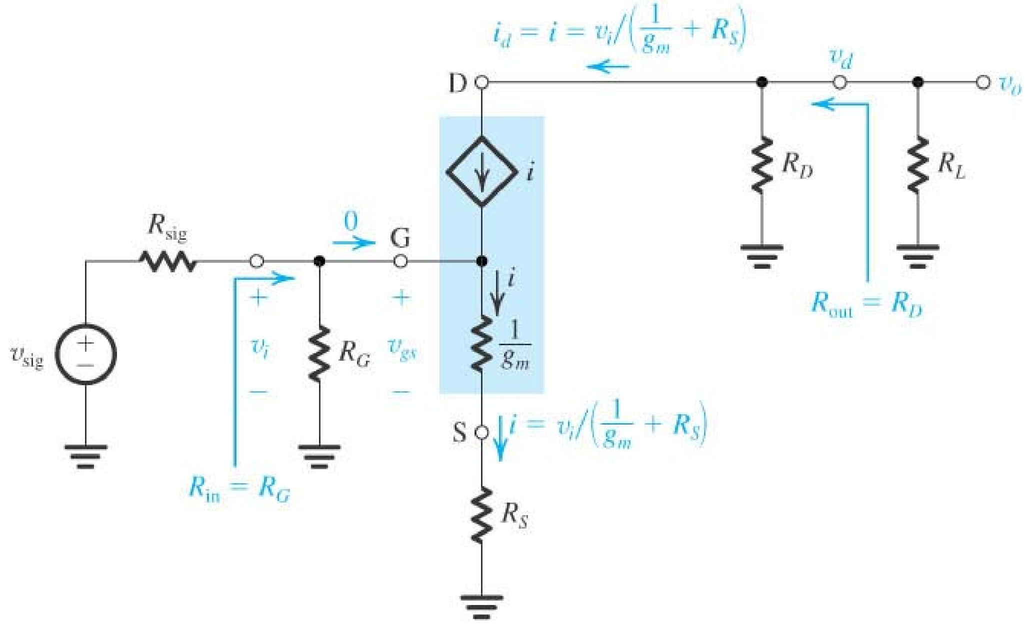
$$V_o = -i_d(R_D \parallel R_L)$$

$$= -\frac{g_m(R_D \parallel R_L)}{1+g_m R_S}\upsilon_i$$

$$A_\upsilon = -\frac{g_m(R_D \parallel R_L)}{1+g_m R_S}$$

$$A_{\upsilon o} = -\frac{g_m R_D}{1+g_m R_S}$$

Voltage gain is reduced compared w/ CS without source resistance

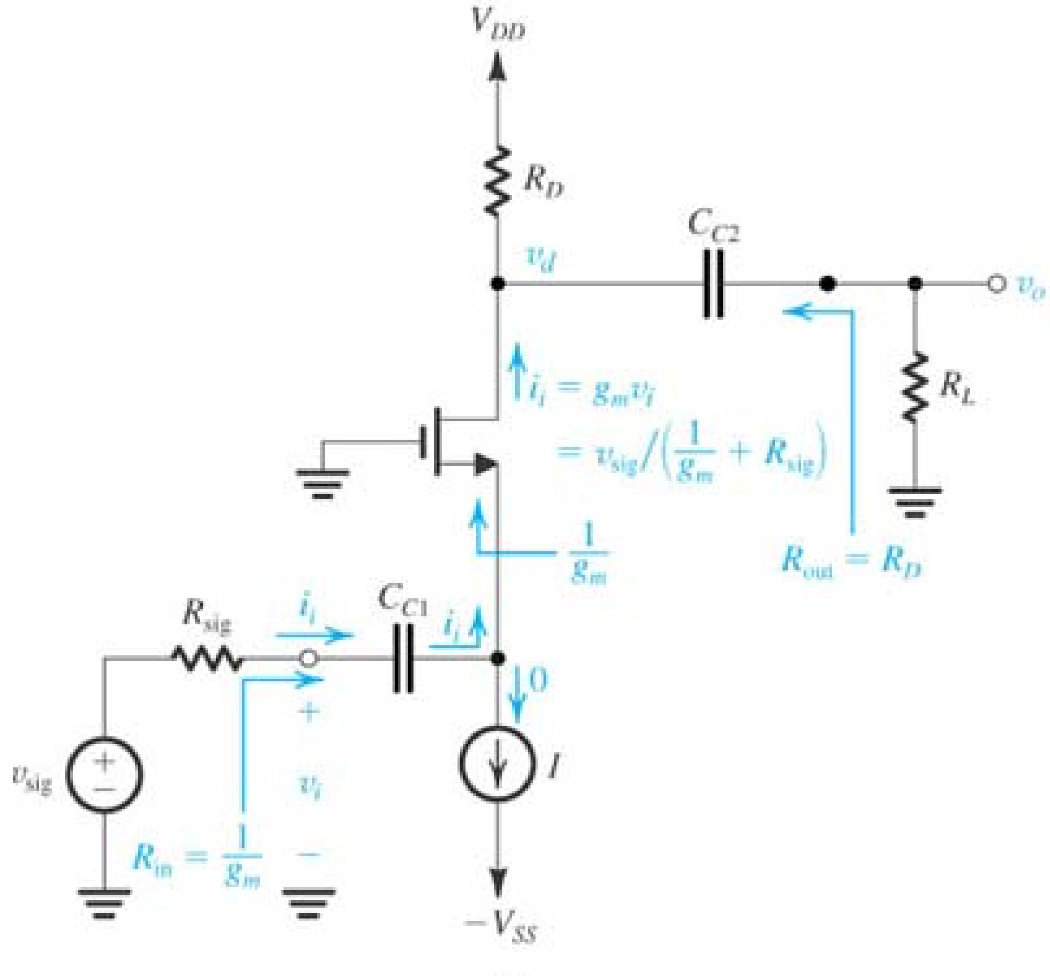


(b)

$$G_\upsilon = \frac{R_G}{R_G + R_{sig}}\frac{g_m(R_D \parallel R_L)}{1+g_m R_S}$$

Single-Stage MOS Amplifiers

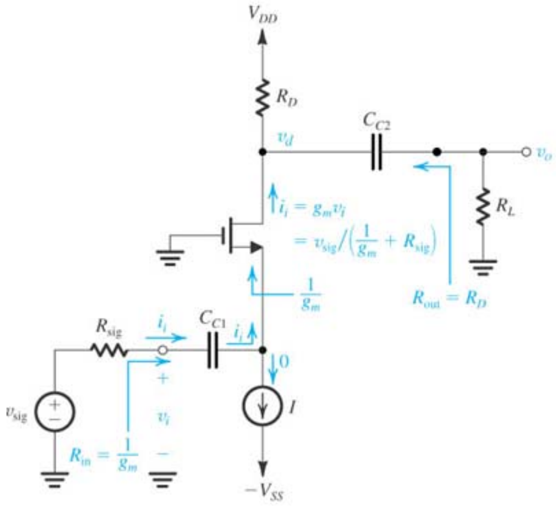
◆ Common Gate Amplifier (biasing w/ current source)



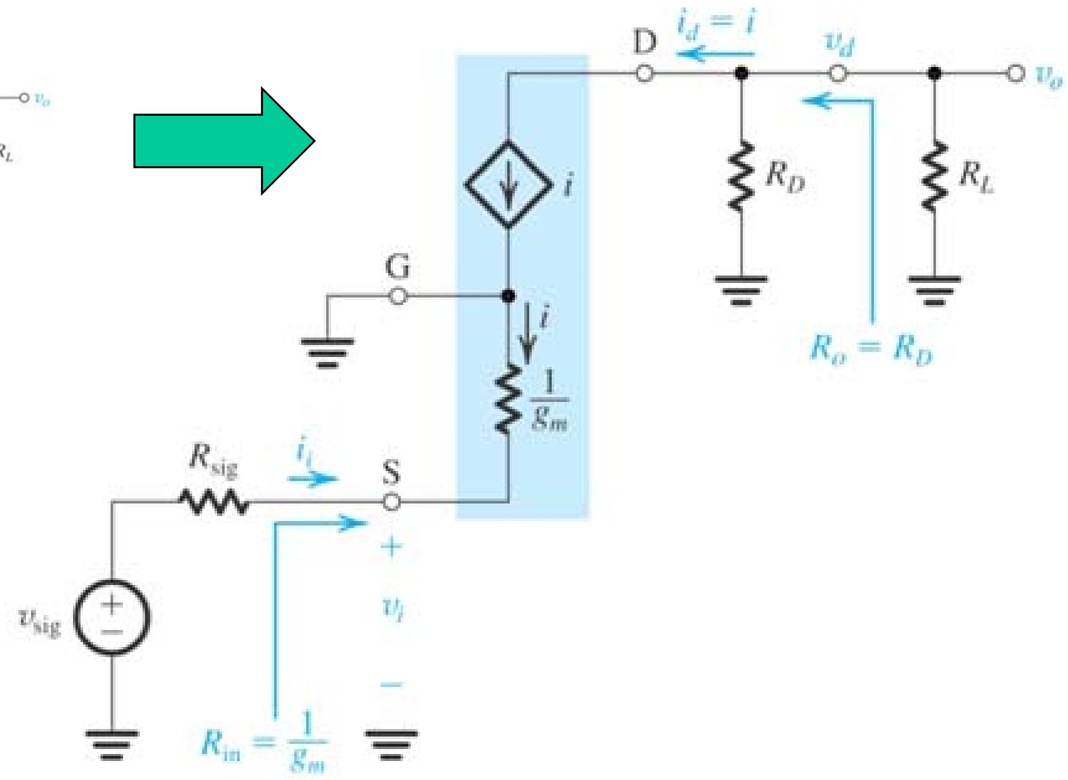
(a)

Single-Stage MOS Amplifiers

- Common Gate Amplifier



(a)



Equivalent circuit of the amplifier for small-signal analysis.

$$R_{\text{in}} = \frac{1}{g_m}$$

Low input resistance

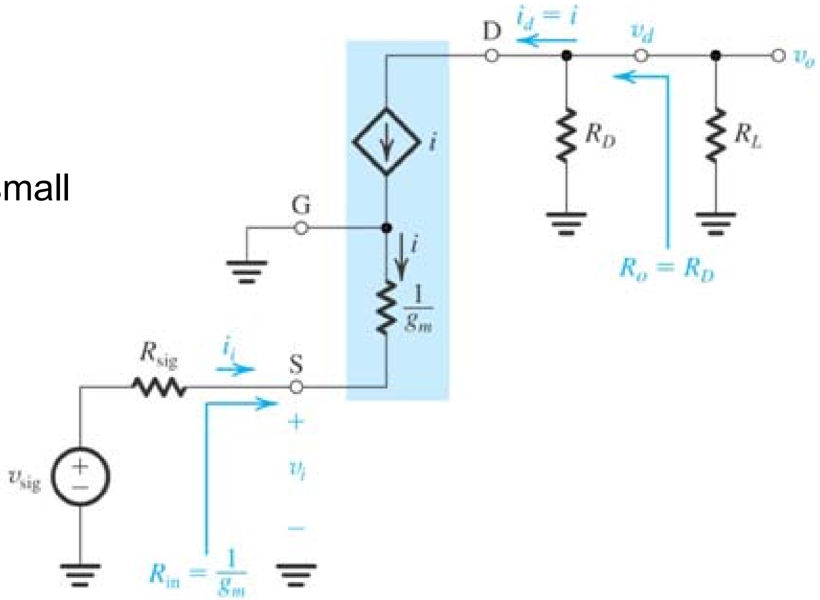
$$v_i = v_{\text{sig}} \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}}$$

$$v_i = v_{\text{sig}} \frac{\frac{1}{g_m}}{\frac{1}{g_m} + R_{\text{sig}}} = v_{\text{sig}} \frac{1}{1 + g_m R_{\text{sig}}}$$

$$R_{\text{sig}} \ll \frac{1}{g_m}$$

:to keep the loss in signal strength small

$$i_i = \frac{v_i}{R_{\text{in}}} = \frac{v_i}{1/g_m} = g_m v_i$$

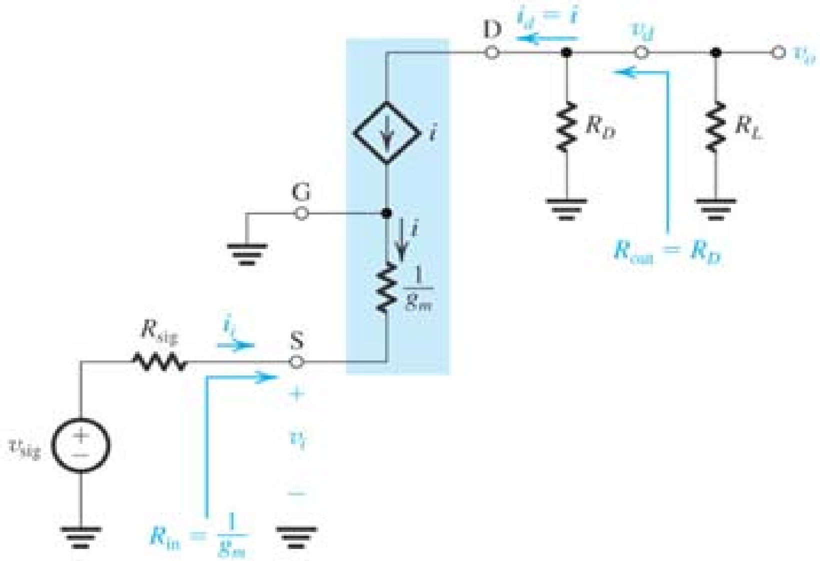


$$i_d = i = -i_i = -g_m \upsilon_i$$

$$\upsilon_o = \upsilon_d = -i_d (R_D \parallel R_L) = g_m (R_D \parallel R_L) \upsilon_i$$

$$A_\upsilon = g_m (R_D \parallel R_L)$$

$$A_{\upsilon o} = g_m R_D$$



$$G_\upsilon = \frac{R_{in}}{R_{in} + R_{sig}} A_\upsilon = \frac{\frac{1}{g_m}}{\frac{1}{g_m} + R_{sig}} A_\upsilon = \frac{A_\upsilon}{1 + g_m R_{sig}}$$

Relatively low gain compared to CS

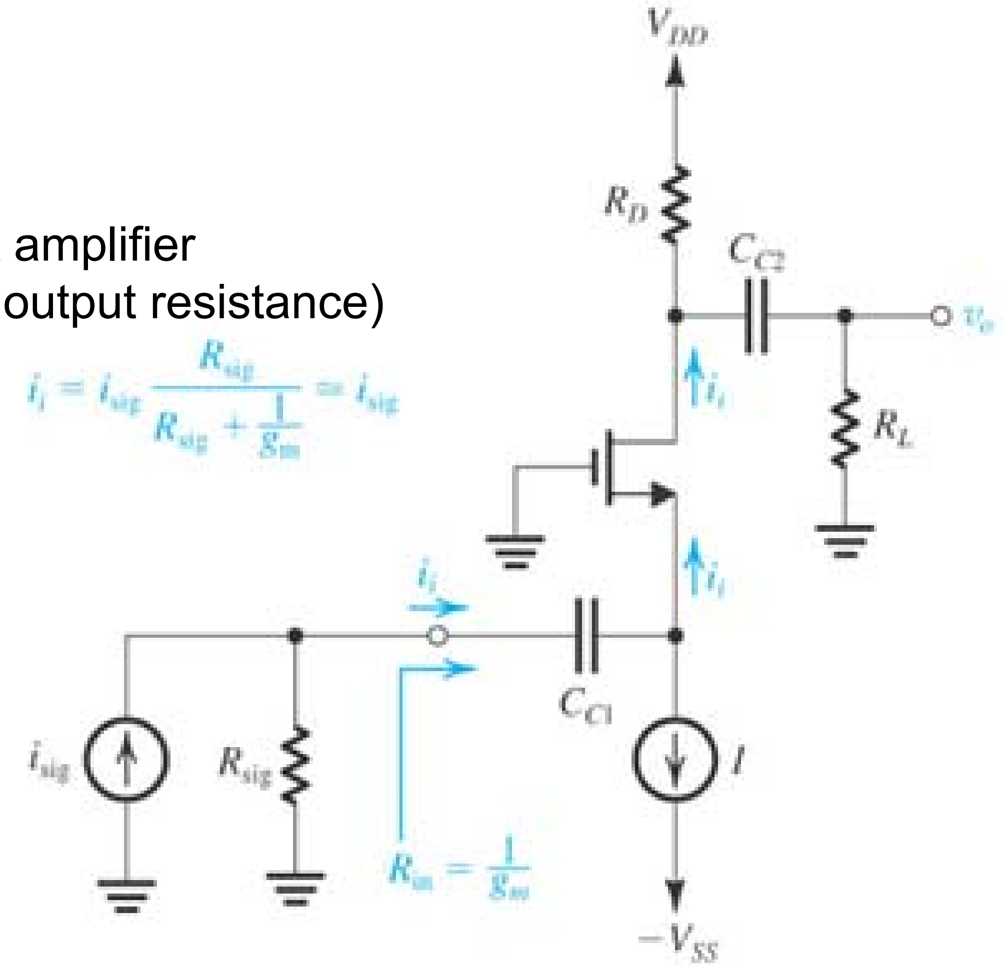
$$G_\upsilon = \frac{g_m (R_D \parallel R_L)}{1 + g_m R_{sig}}$$

$$R_{out} = R_o = R_D$$ (by assuming $v_{sig} = 0$)

$$i_i = i_{\text{sig}} \frac{R_{\text{sig}}}{R_{\text{in}} + R_{\text{sig}}} = i_{\text{sig}} \frac{R_{\text{sig}}}{R_{\text{sig}} + \dfrac{1}{g_m}} \qquad \text{when} \quad R_{\text{sig}} > \frac{1}{g_m}$$

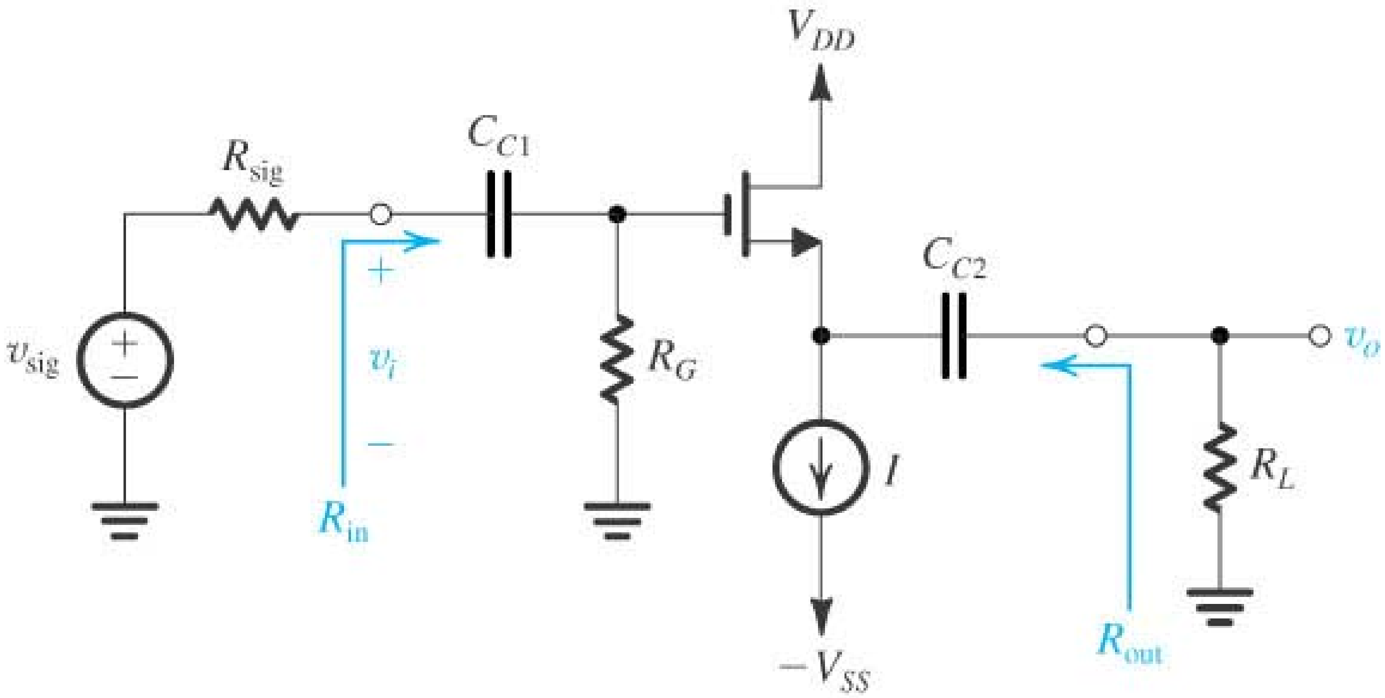
$$i_i \cong i_{\text{sig}}$$

Useful as a unity gain current amplifier
(small input resistance, large output resistance)



Single-Stage MOS Amplifiers

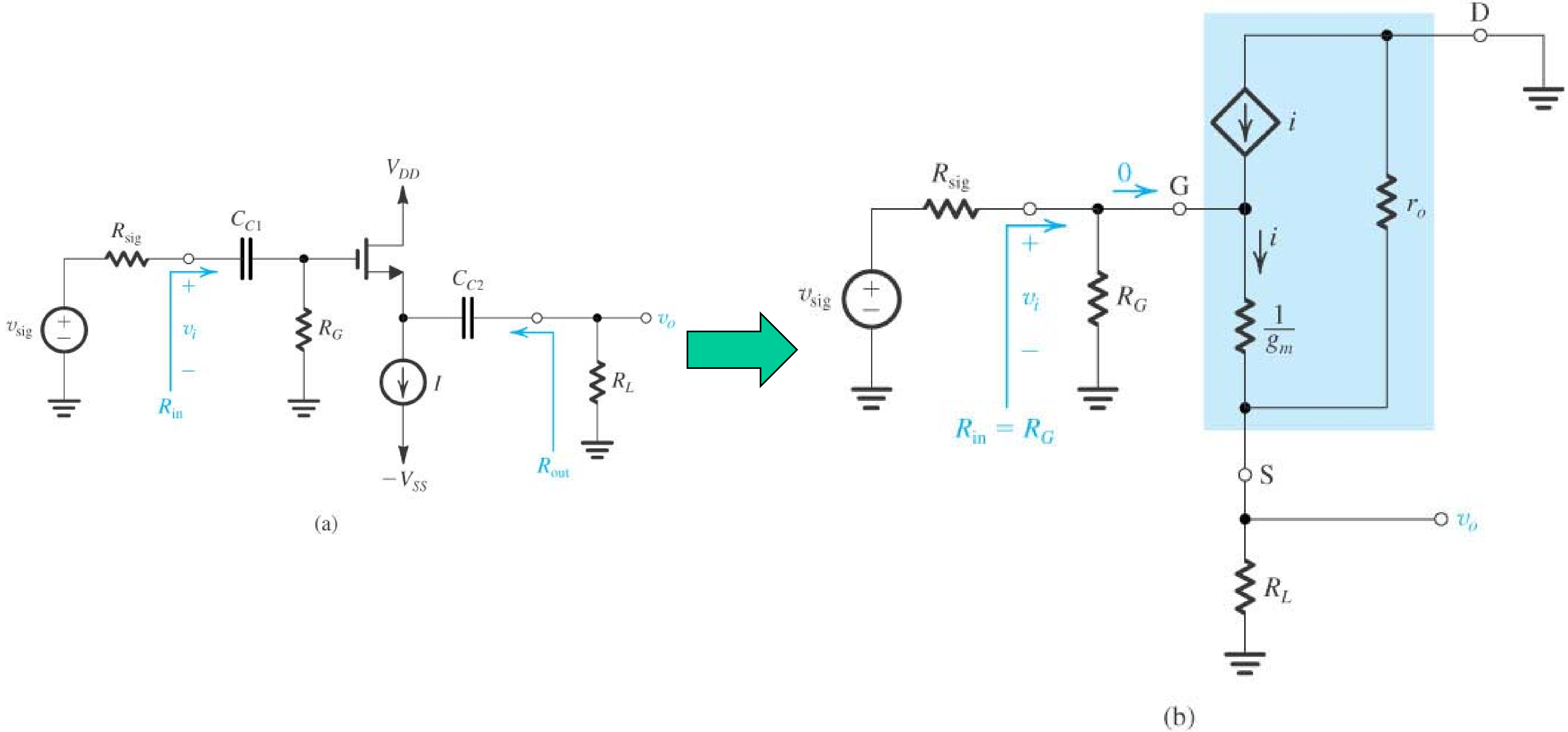
◆ Common Drain Amplifier (Source Follower)



(a)

Single-Stage MOS Amplifiers

◆ Source Follower



Equivalent circuit of the amplifier for small-signal analysis.

$$R_{in} = R_G$$

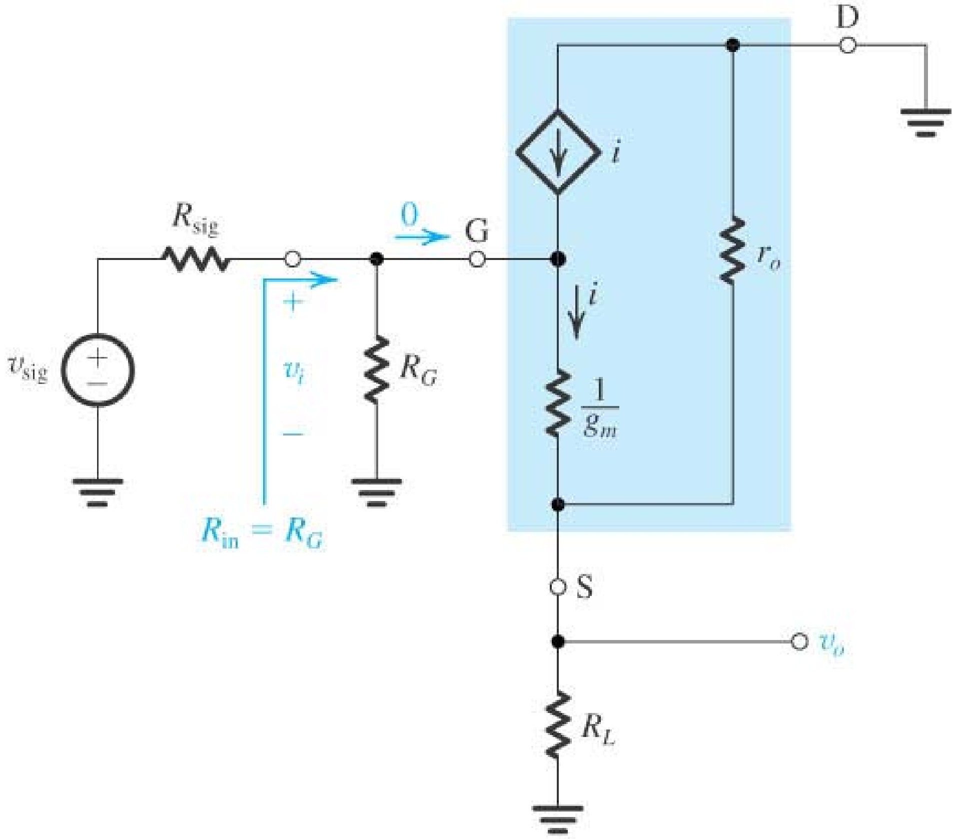
$$\upsilon_i = \upsilon_{sig} \frac{R_{in}}{R_{in} + R_{sig}} = \upsilon_{sig} \frac{R_G}{R_G + R_{sig}}$$

$$\upsilon_i \cong \upsilon_{sig}$$

$$\upsilon_o = \upsilon_i \frac{R_L \parallel r_o}{(R_L \parallel r_o) + \frac{1}{g_m}}$$

$$A_\upsilon = \frac{R_L \parallel r_o}{(R_L \parallel r_o) + \frac{1}{g_m}}$$

$$A_{\upsilon o} = \frac{r_o}{r_o + \frac{1}{g_m}} \quad \sim 1$$



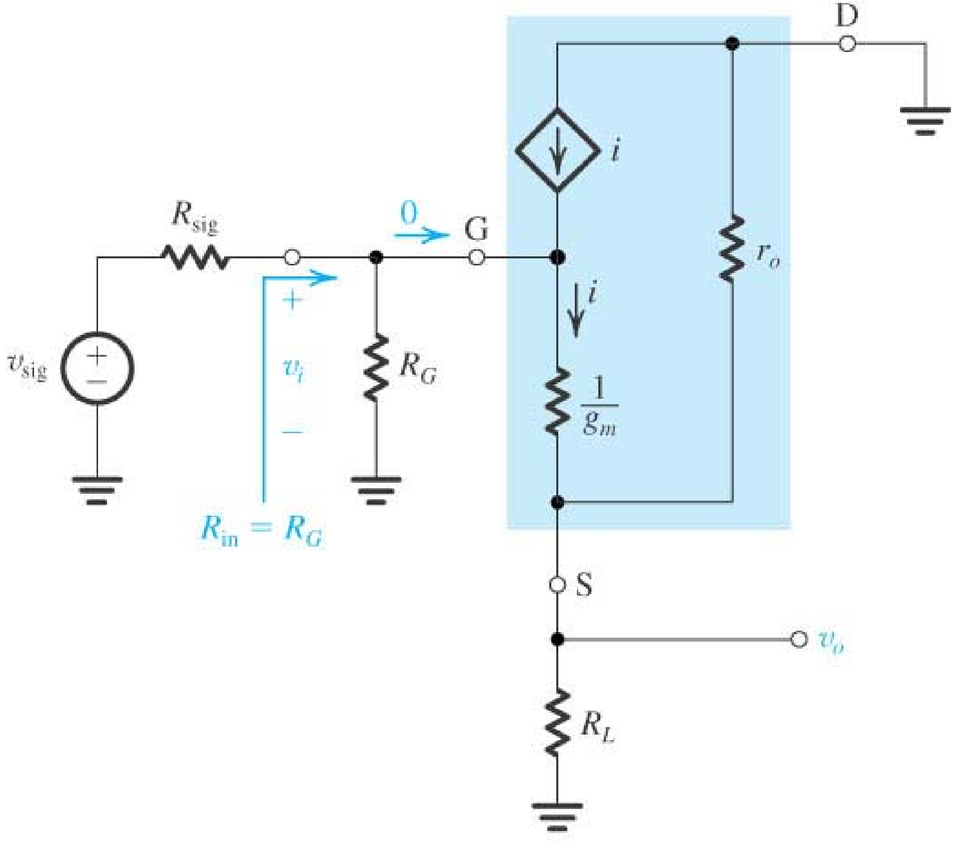
(b)

$$A_\upsilon \cong \frac{R_L}{R_L + \frac{1}{g_m}}$$ When $r_o >> R_L$

$$G_\upsilon = \frac{R_G}{R_G + R_{sig}} \frac{R_L \| r_o}{(R_L \| r_o) + \frac{1}{g_m}}$$

$$R_{out} = \frac{1}{g_m} \| r_o$$ (by assuming $v_{sig} = 0$)

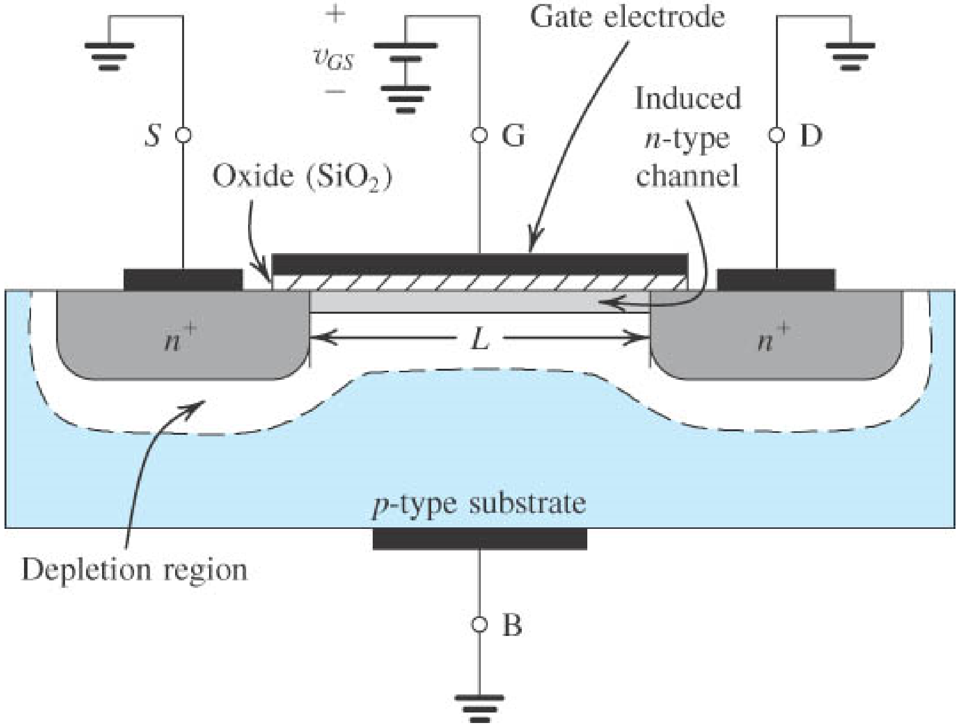
$$R_{out} \cong \frac{1}{g_m}$$ Gain: ~1, high input resistance, low output resistance, voltage buffer

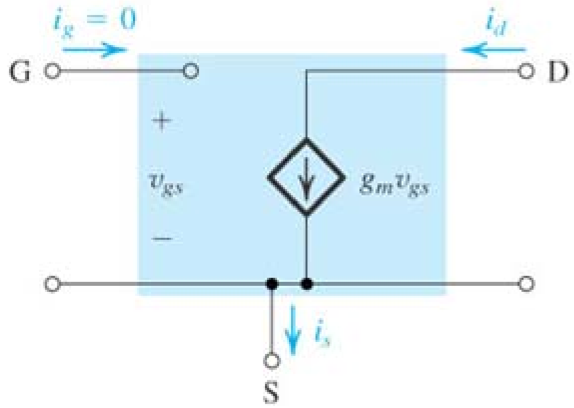


(b)

The MOSFET Internal Capacitance and High-Frequency Model

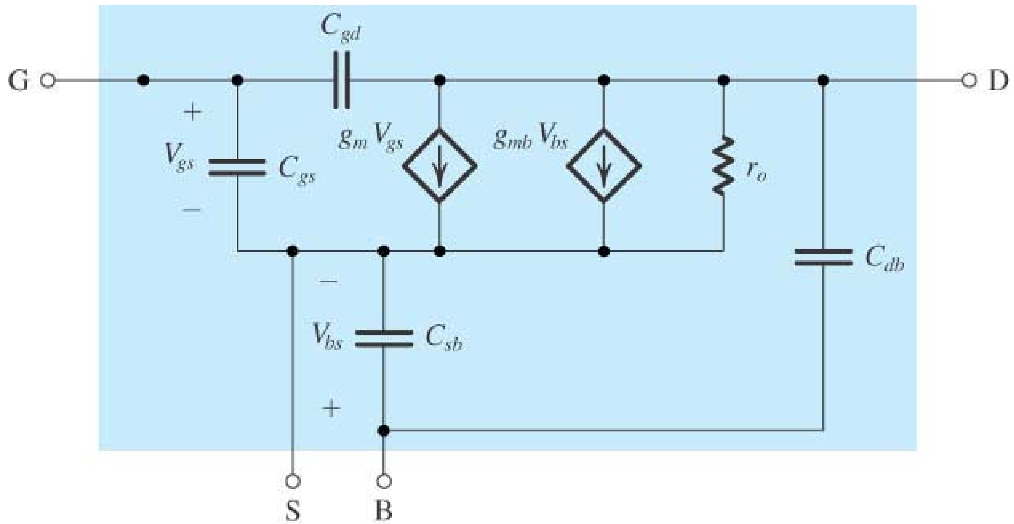
◆ MOSFET internal capacitance



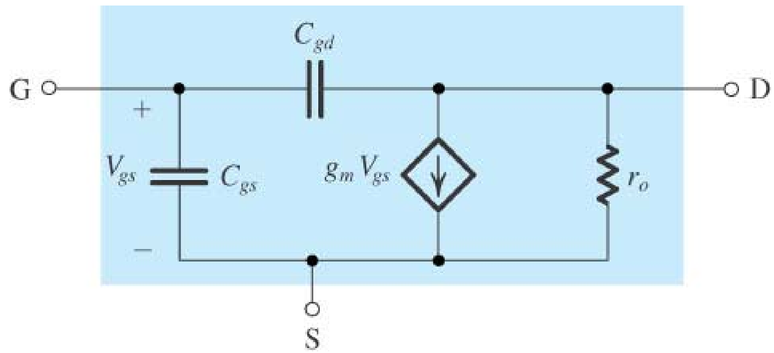


Why did we neglect the effect of internal capacitance in MOSFET until yet ?

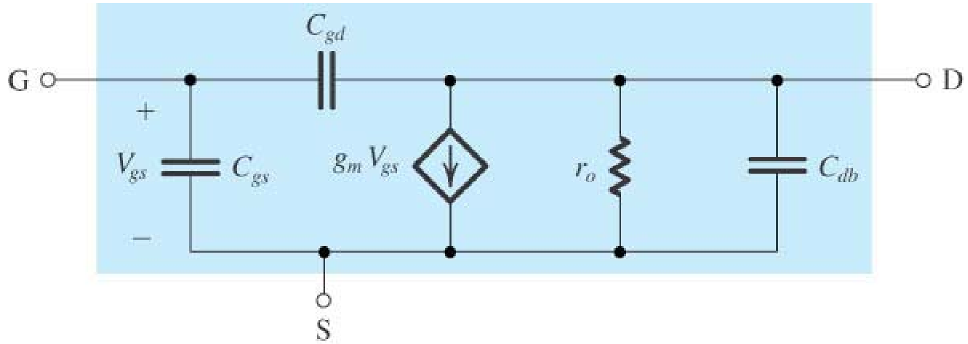
◆ High-frequency equivalent circuit model for MOSFET



(a)



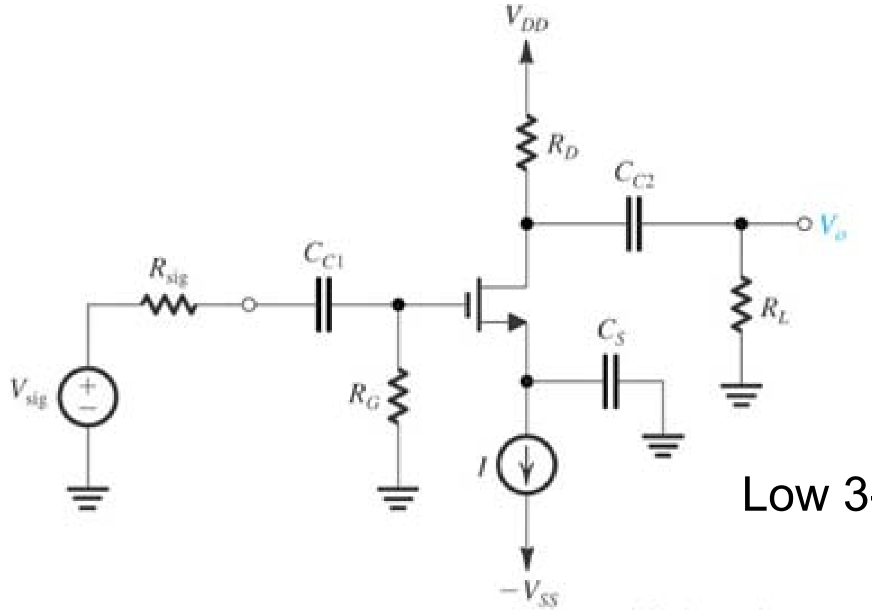
(c)



(b)

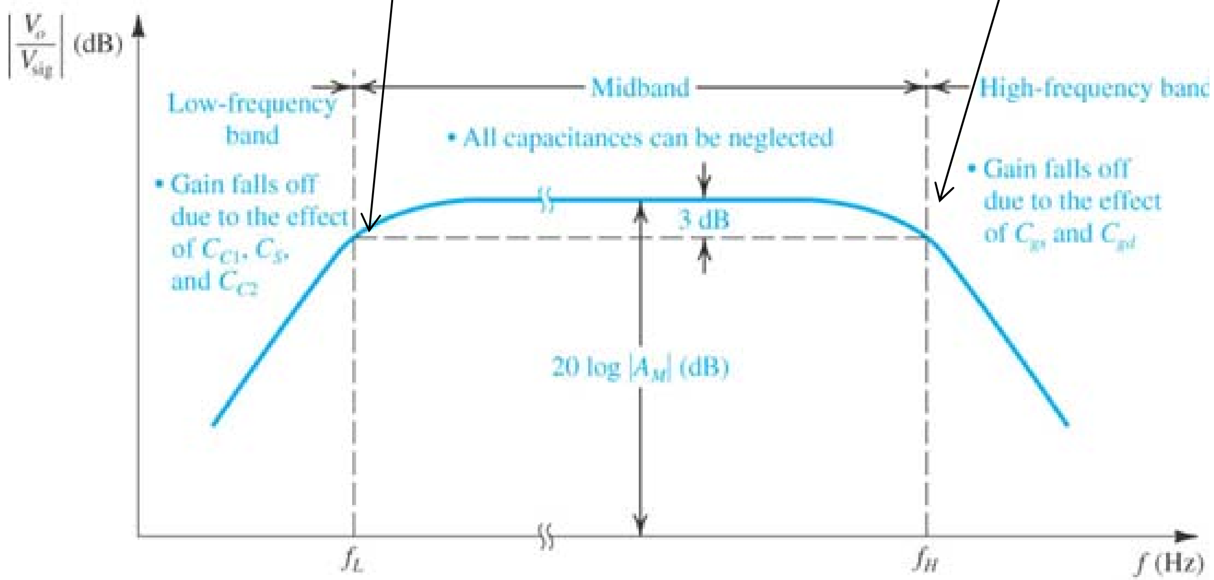
(a) High-frequency equivalent circuit model for the MOSFET. **(b)** The equivalent circuit for the case in which the source is connected to the substrate (body). **(c)** The equivalent circuit model of (b) with C_{db} neglected (to simplify analysis).

Frequency Response of the CS Amplifier



Low 3-dB frequency

High 3-dB frequency



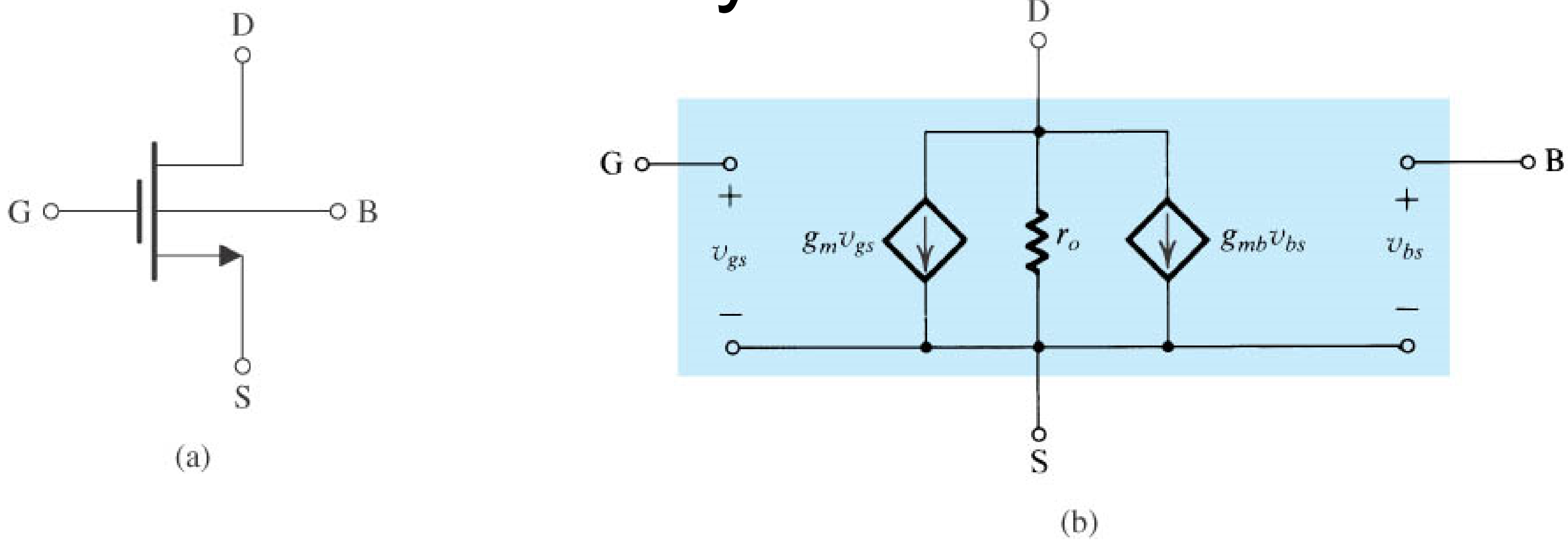
$$\mathbf{A}_M \equiv \frac{\mathbf{V}_o}{\mathbf{V}_{\text{sig}}} = \frac{R_G}{R_G + R_{\text{sig}}} g_m (r_o \parallel R_D \parallel R_L)$$

$$BW \equiv f_H - f_L$$

$$BW \cong f_H$$

$$GB \equiv \left|\mathbf{A}_M\right| BW$$ Gain-Bandwidth product

Body Effect



chi

$$g_{mb} \equiv \left. \frac{\partial i_D}{\partial v_{BS}} \right|_{\substack{v_{GS} = \text{constant} \\ v_{DS} = \text{constant}}} \quad (4.75)$$

$$g_{mb} \equiv \chi g_m \quad (4.76)$$

$$\chi \equiv \frac{\partial V_t}{\partial V_{SB}} = \frac{\gamma}{2\sqrt{2\phi_f + V_{SB}}} \quad (4.77)$$

Figure 4.41 Small-signal equivalent-circuit model of a MOSFET in which the source is not connected to the body.

