6장 SINGLE-STAGE INTEGRATED-CIRCUIT AMPLIFIERS,
전자회로

5차시

캐스코드 증폭기

캐스코드 증폭기

- CS(CE)+CG(CB) → 큰 trans-conductance, 높은 입력저항, 넓은 대역폭

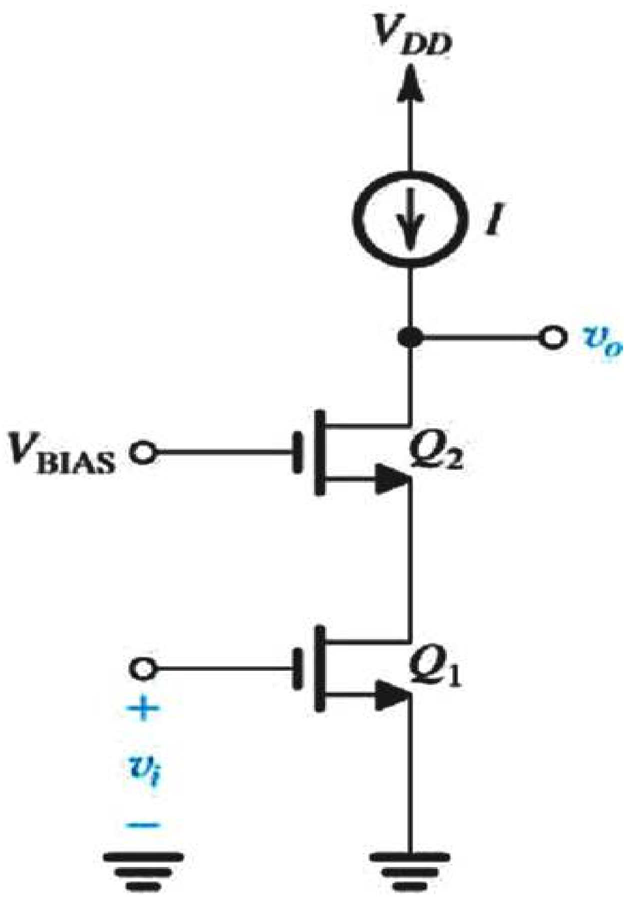
MOS 캐스코드

- 입력저항

$$R_{in} = \infty$$

$$R_{in2} = \frac{1}{g_{m2} + g_{mb2}} + \frac{R_L}{A_{vo2}}$$

$$A_{vo2} = 1 + \left(g_{m2} + g_{mb2}\right) r_{o2}$$



(a)

캐스코드 증폭기

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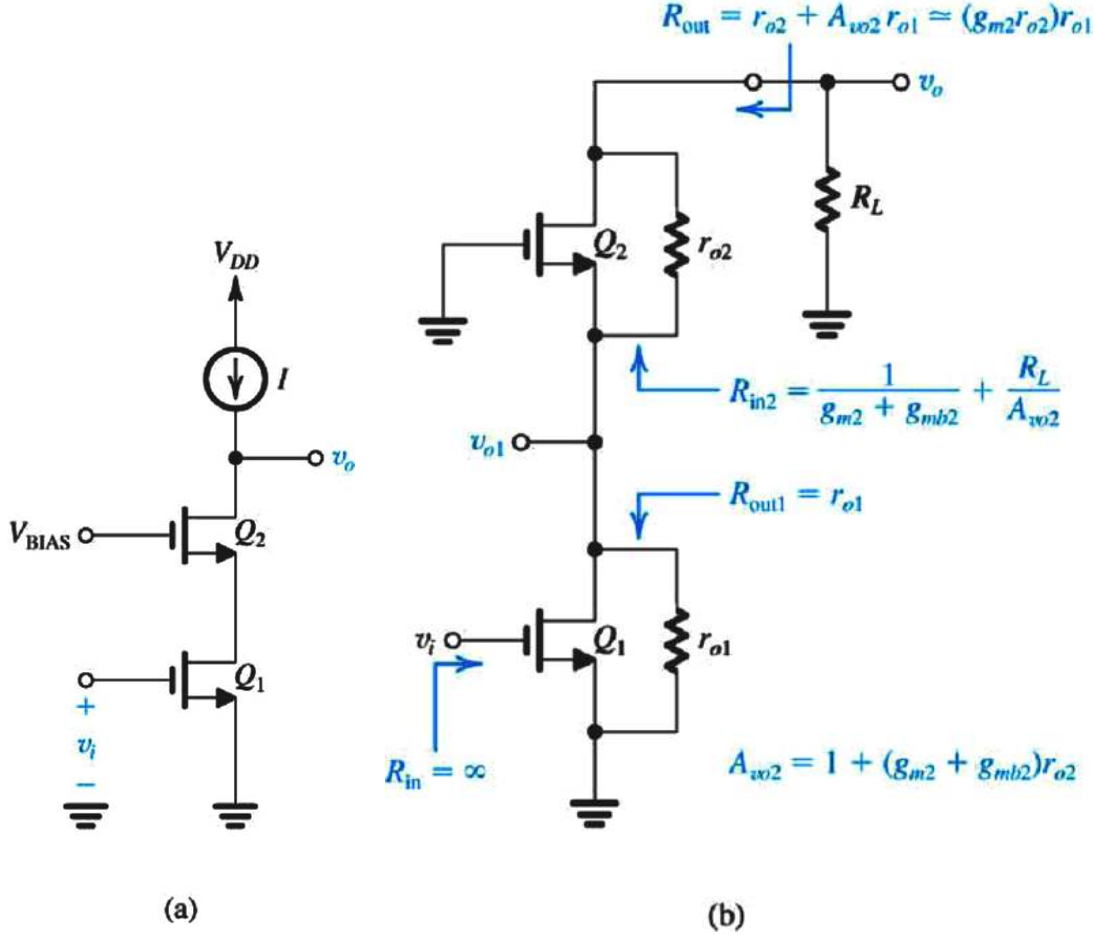


캐스코드 증폭기

- CS(CE)+CG(CB) → 큰 trans-conductance, 높은 입력저항, 넓은 대역폭

MOS 캐스코드

- Q1 드레인과 접지사이 저항

$$R_{d1} = r_{o1} \| \left[\frac{1}{g_{m2} + g_{mb2}} + \frac{R_L}{A_{vo2}} \right]$$

- 출력저항

$$R_{out1} = r_{o1}$$

$$R_{out} = r_{o2} + A_{vo2} r_{o1}$$

$$R_{out} = r_{o2} + \left[1 + \left(g_{m2} + g_{mb2} \right) r_{o2} \right] r_{o1}$$

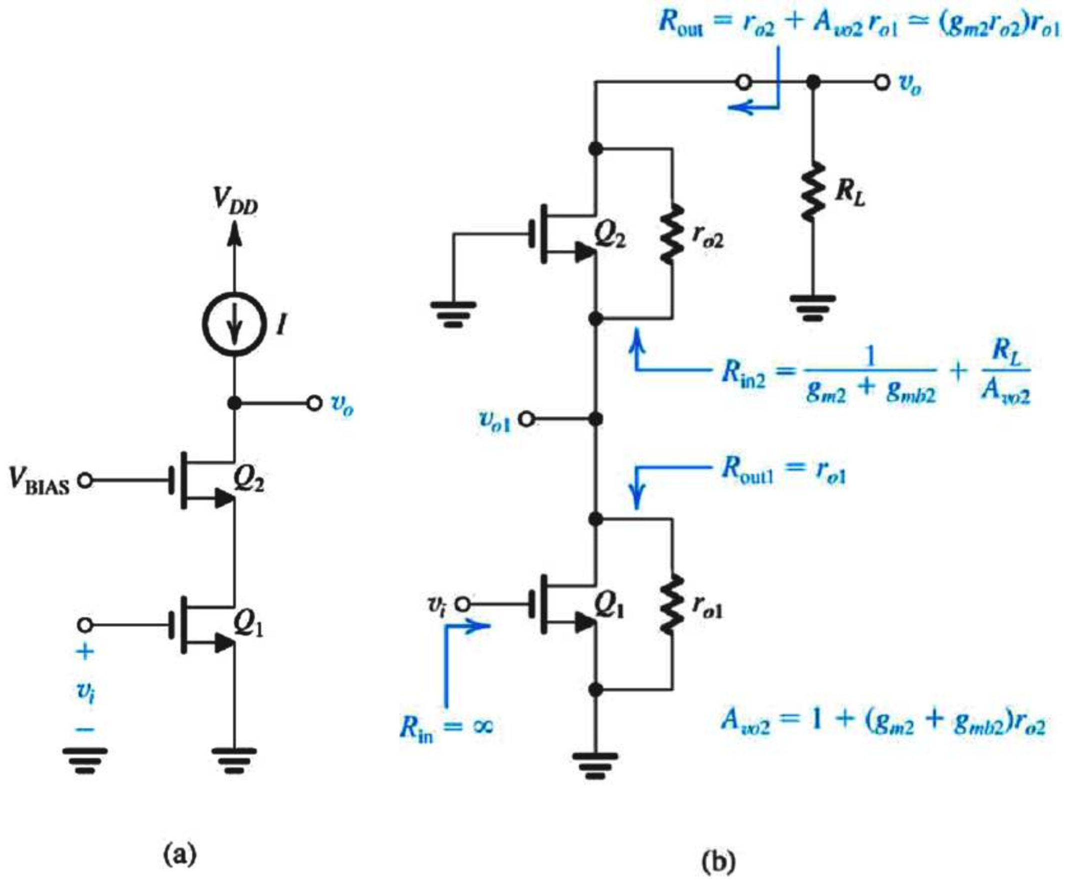
$$R_{out} \cong \left(g_{m2} r_{o2} \right) r_{o1} = A_0 r_{o1}$$

- 그림 (b) 에서

$$v_i = v_{sig}$$

$$G_v = A_v$$

$$R_o = R_{out}$$



캐스코드 증폭기

- CS(CE)+CG(CB) → 큰 trans-conductance, 높은 입력저항, 넓은 대역폭

<u>MOS 캐스코드</u>

- 입력저항

$$R_{in} = \infty$$

$$R_{in2} = \frac{1}{g_{m2} + g_{mb2}} + \frac{R_L}{A_{\upsilon o2}}$$

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- Q1 드레인과 접지사이 저항

$$R_{d1} = r_{o1} \| \left[\frac{1}{g_{m2} + g_{mb2}} + \frac{R_L}{A_{\upsilon o2}} \right]$$

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$$R_{out1} = r_{o1}$$

$$R_{out} = r_{o2} + A_{\upsilon o2} r_{o1}$$

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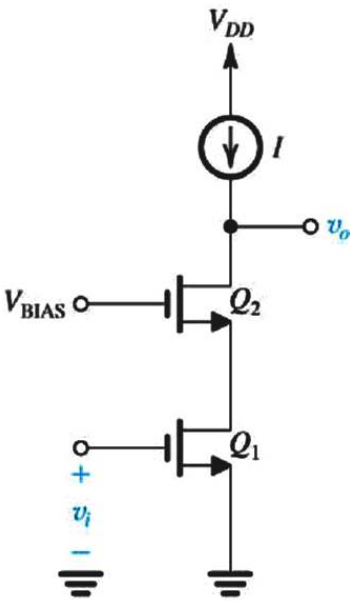
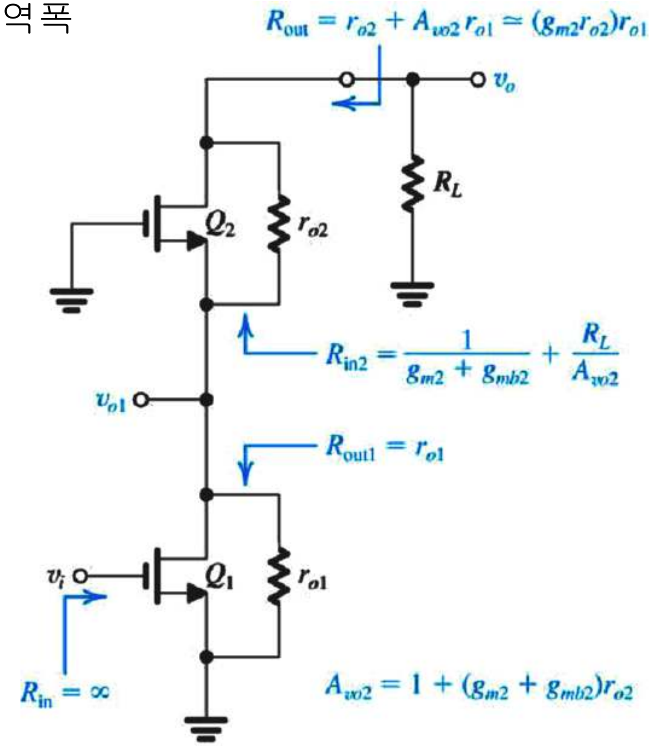
$$R_{out} \cong \left(g_{m2} r_{o2}\right) r_{o1} = A_0 r_{o1}$$



(a)



(b)

- 그림 (b) 에서

$$\upsilon_i = \upsilon_{sig}$$

$$G_\upsilon = A_\upsilon$$

$$R_o = R_{out}$$

캐스코드 증폭기

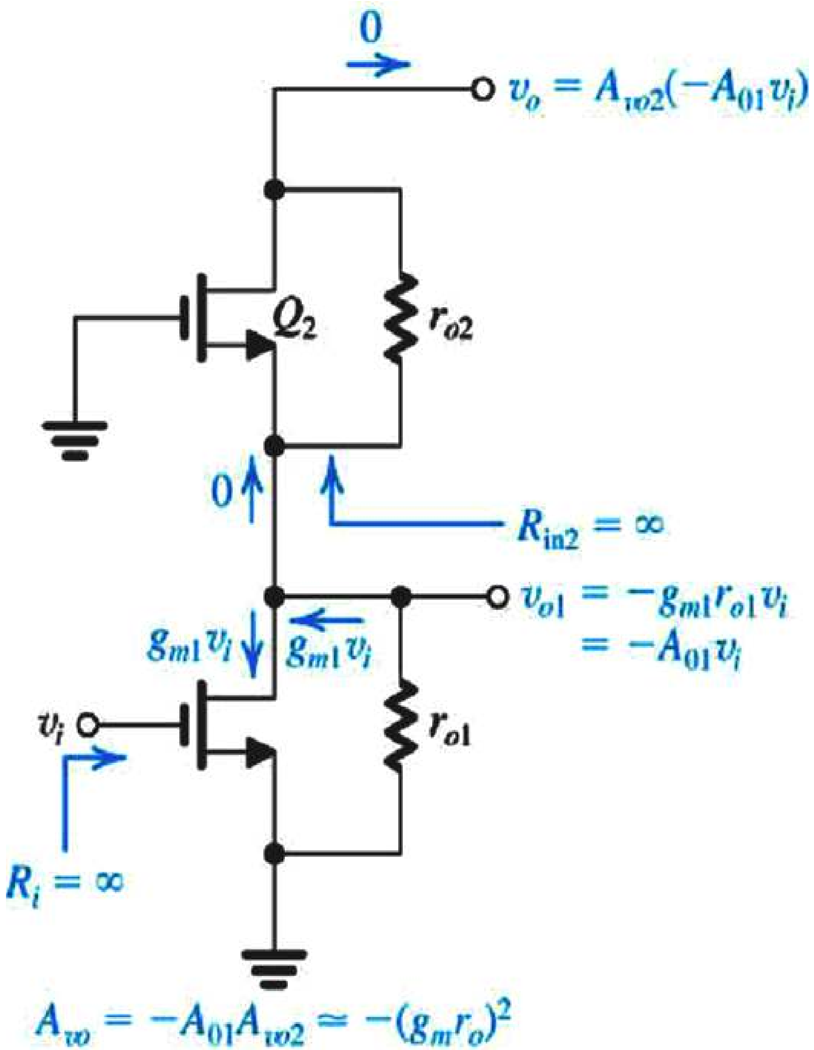
- 개방회로 전압이득

$$A_{vo1} = \frac{\upsilon_{o1}}{\upsilon_i} = -g_{m1} r_{o1} = -A_{01}$$

$$\upsilon_o = A_{\upsilon o2} \upsilon_{o1}$$

$$A_{\upsilon o} = -A_{01} A_{\upsilon o2} \cong -A_{01} A_{02}$$

$$A_{\upsilon o} = -A_0^2 = -\left(g_m r_o\right)^2$$



(c)

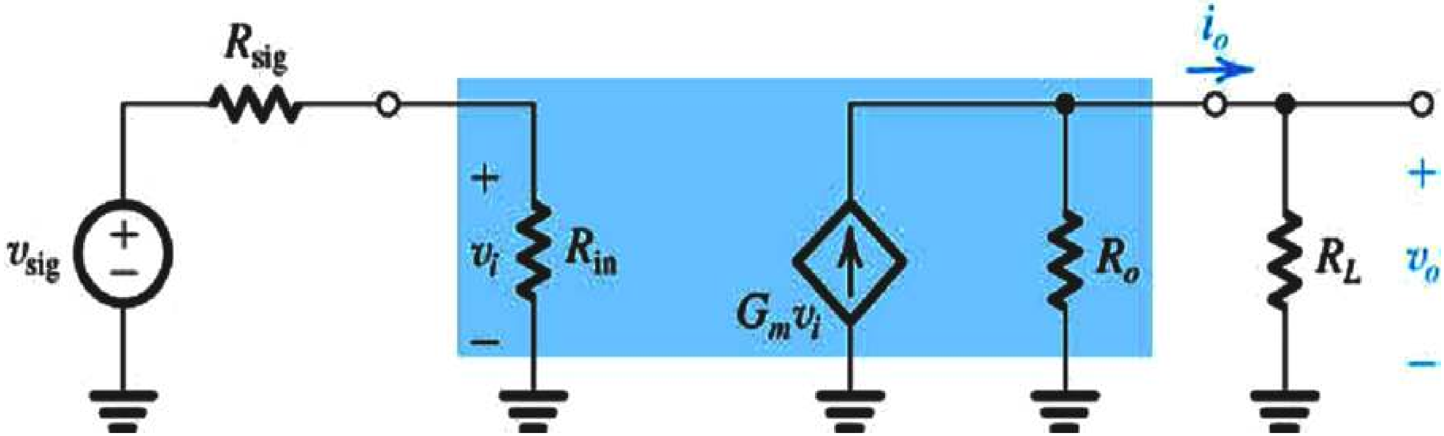
캐스코드 증폭기

- 단락회로 trans-conductance

$$A_{vo} = G_m R_o$$

$$G_m = -\frac{A_{01}A_{vo2}}{r_{o2} + A_{vo2}r_{o1}} = -\frac{g_{m1}r_{o1}\left[1+\left(g_{m2}+g_{mb2}\right)r_{o2}\right]}{r_{o2}+\left[1+\left(g_{m2}+g_{mb2}\right)r_{o2}\right]r_{o1}}$$

$$\cong -g_{m1}$$



캐스코드 증폭기

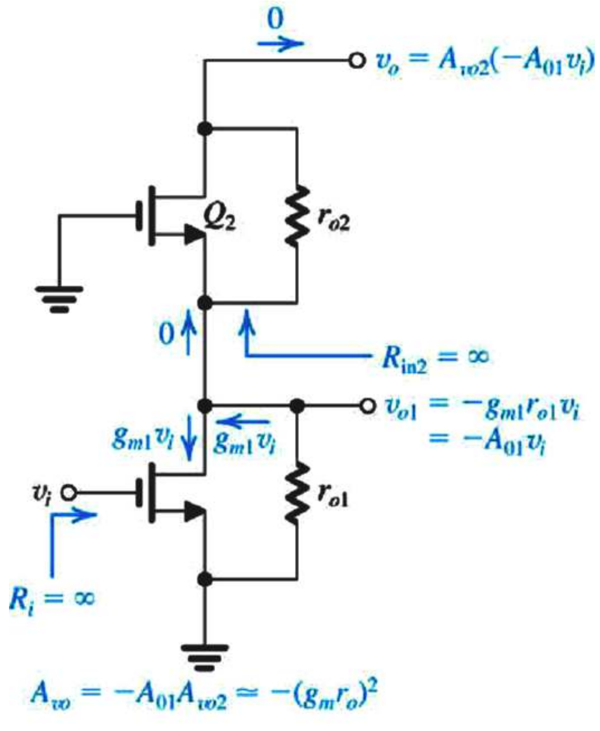
- 개방회로 전압이득

$$A_{vo1} = \frac{v_{o1}}{v_i} = -g_{m1} r_{o1} = -A_{01}$$

$$v_o = A_{vo2} v_{o1}$$

$$A_{vo} = -A_{01} A_{vo2} \cong -A_{01} A_{02}$$

$$A_{vo} = -A_0^2 = -\left(g_m r_o\right)^2$$



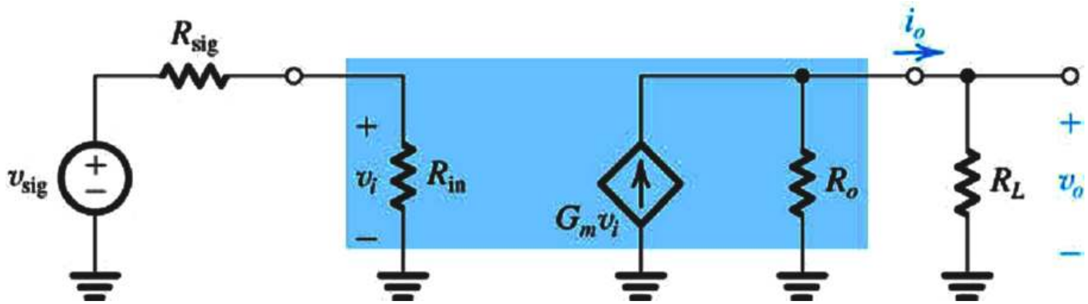
(c)

- 단락회로 trans-conductance

$$A_{vo} = G_m R_o$$

$$G_m = -\frac{A_{01} A_{vo2}}{r_{o2} + A_{vo2} r_{o1}} = -\frac{g_{m1} r_{o1}\left[1 + \left(g_{m2} + g_{mb2}\right) r_{o2}\right]}{r_{o2} + \left[1 + \left(g_{m2} + g_{mb2}\right) r_{o2}\right] r_{o1}}$$

$$\cong -g_{m1}$$

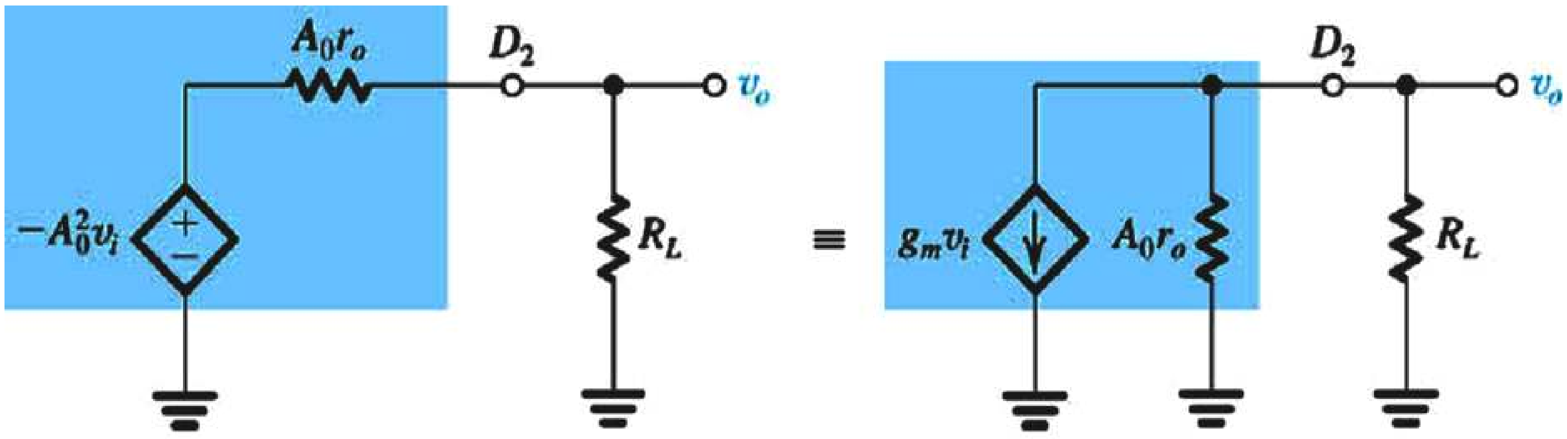


캐스코드 증폭기

- 전압이득

$$A_v = -A_0^2 \frac{R_L}{R_L + A_0 r_o}$$

→ R_L이 클수록 큰 A_v
($R_L = A_0 ro$, $A_v = -A_0^2/2$)



(a) (b)

캐스코드 증폭기

- 전압이득

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$\rightarrow R_L$이 클수록 큰 A_v
($R_L = A_0 ro$, $A_v = -A_0^2/2$)

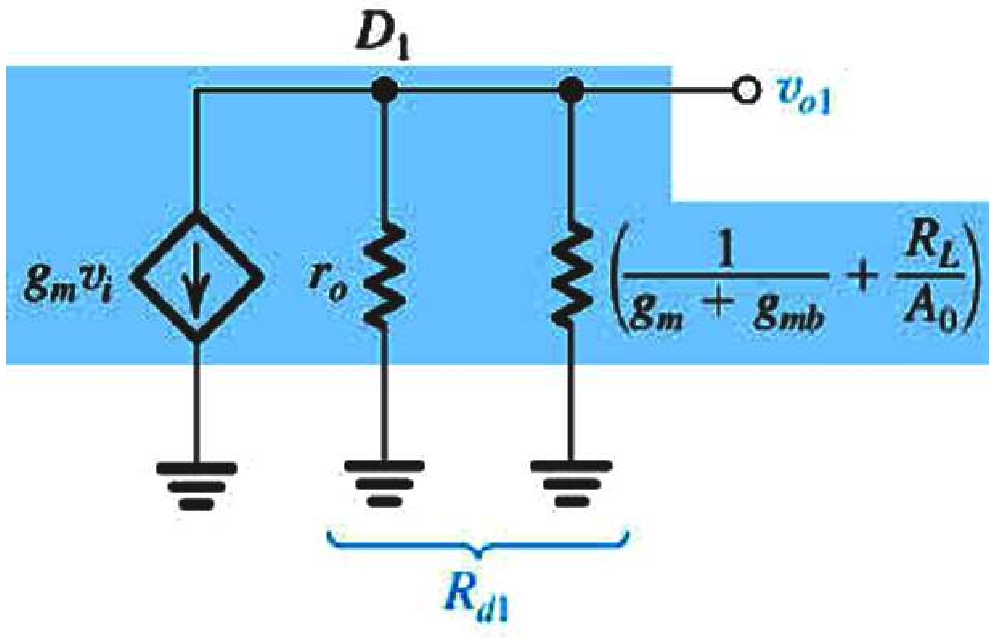
- CS단의 전압이득

$$\frac{v_{o1}}{v_i} = -g_m \left[r_o \parallel \left(\frac{1}{g_m} + \frac{R_L}{A_0} \right) \right]$$

$R_L = A_0 ro$이면

$$\frac{v_{o1}}{v_i} = -g_m \left[r_o \parallel \left(\frac{1}{g_m} + r_o \right) \right]$$

$$\cong -\frac{1}{2} g_m r_o = -\frac{1}{2} A_0$$



캐스코드 증폭기

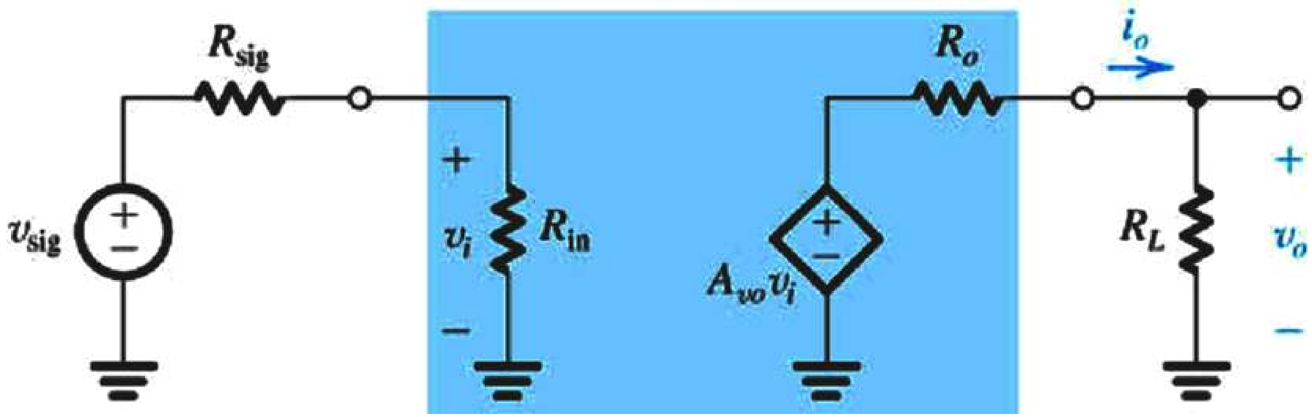
- 전압이득

- R_L이 크고, 캐스코드 증폭기가 큰 이득을 가질 때, CS 단이 큰 영향.

CS 단의 이득을 작게 하는 경우, 예를 들어 $R_L = ro$이면

$$\frac{v_{o1}}{v_i} = -g_m \left[r_{o1} \parallel \left(\frac{1}{g_m} + \frac{1}{g_m} \right) \right] \cong -2\,\mathrm{V/V}$$

$$A_v = -A_0^2 \frac{r_o}{r_o + A_0 r_o} \cong -A_0$$



캐스코드 증폭기

- 전압이득

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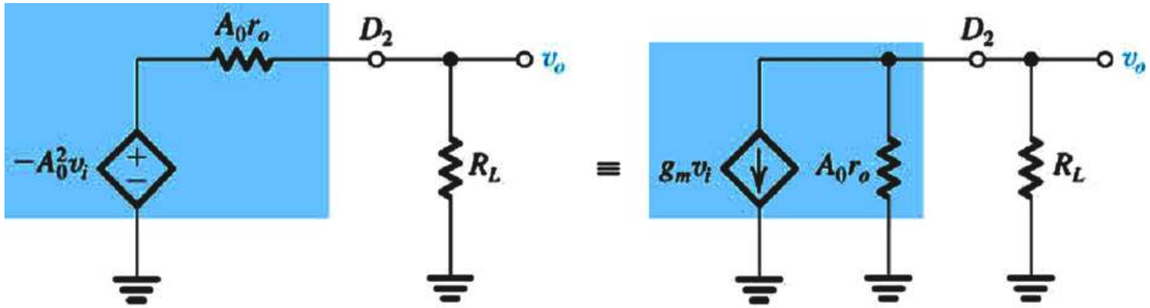
($R_L = A_0 ro$, $A_v = -A_0^2/2$)



- CS단의 전압이득

$$\frac{v_{o1}}{v_i} = -g_m \left[r_o \| \left(\frac{1}{g_m} + \frac{R_L}{A_0} \right) \right]$$

$R_L = A_0 ro$이면

$$\frac{v_{o1}}{v_i} = -g_m \left[r_o \| \left(\frac{1}{g_m} + r_o \right) \right]$$

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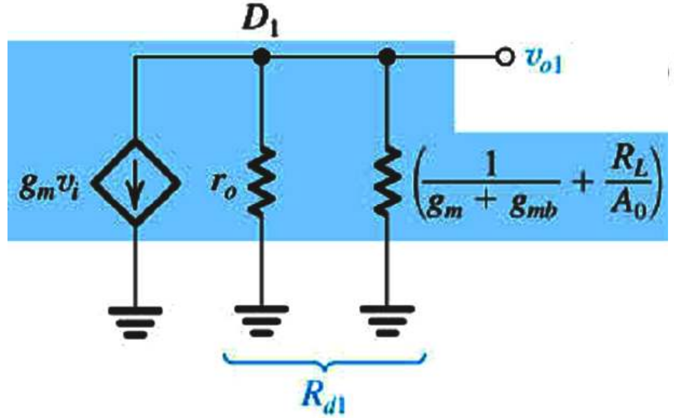

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$$\frac{v_{o1}}{v_i} = -g_m \left[r_{o1} \| \left(\frac{1}{g_m} + \frac{1}{g_m} \right) \right] \cong -2\,\mathrm{V/V}$$

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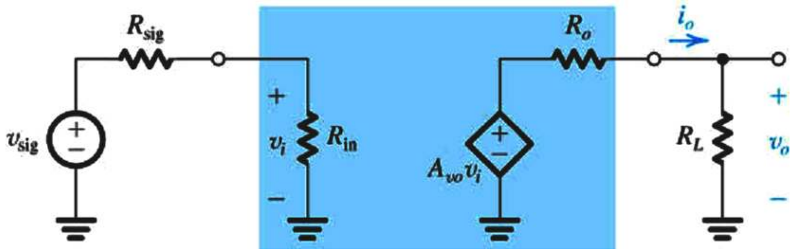

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HANKYONG NATIONAL UNIV.

캐스코드 증폭기

MOS 캐스코드의 주파수 응답

- 개방회로 시정수를 이용하면

$$R_{gs1} = R_{sig}$$

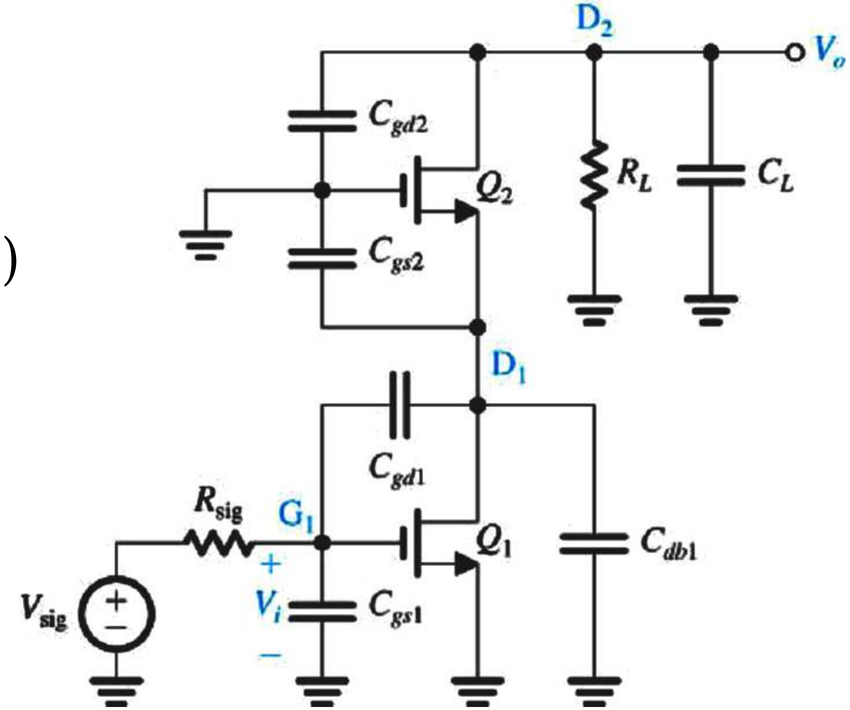
$$R_{gd1} = \left(1 + g_{m1}R_{d1}\right)R_{sig} + R_{d1}$$

$$R_{gs2,db1} = R_{d1}$$

$$R_{gd2,L} = R_L \,//\, R_{out}$$

$$\tau_H = C_{gs1}R_{sig} + C_{gd1}\left[\left(1 + g_{m1}R_{d1}\right)R_{sig} + R_{d1}\right] + \left(C_{db1} + C_{gs2}\right)R_{d1} + \left(C_L + C_{gd2}\right)\left(R_L \parallel R_{out}\right)$$

$$f_H \cong \frac{1}{2\pi\tau_H}$$



캐스코드 증폭기

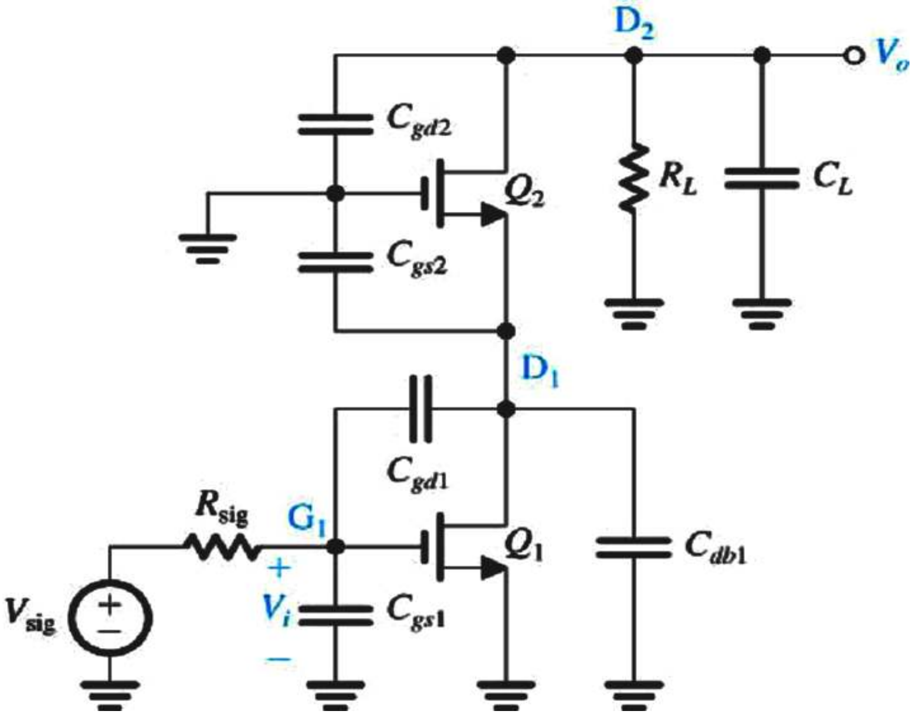
MOS 캐스코드의 주파수 응답

- 다음과 같이 정리하면, R_{sig}, $1+g_{m1}R_{d1}$이 큰 경우- 첫째 항이 중요.

$$\tau_H = R_{sig}\left[C_{gs1} + C_{gd1}\left(1 + g_{m1}R_{d1}\right)\right] + R_{d1}\left(C_{gd1} + C_{db1} + C_{gs2}\right)$$
$$+\left(R_L \parallel R_{out}\right)\left(C_L + C_{gd2}\right)$$

- R_{sig}이 작은 경우- 셋째 항이 중요. R_{sig}=0이고, 둘째 항이 작으면

$$\tau_H \cong \left(C_L + C_{gd2}\right)\left(R_L \parallel R_{out}\right)$$



캐스코드 증폭기

<u>MOS 캐스코드의 주파수 응답</u>

- 개방회로 시정수를 이용하면

$$R_{gs1} = R_{sig}$$

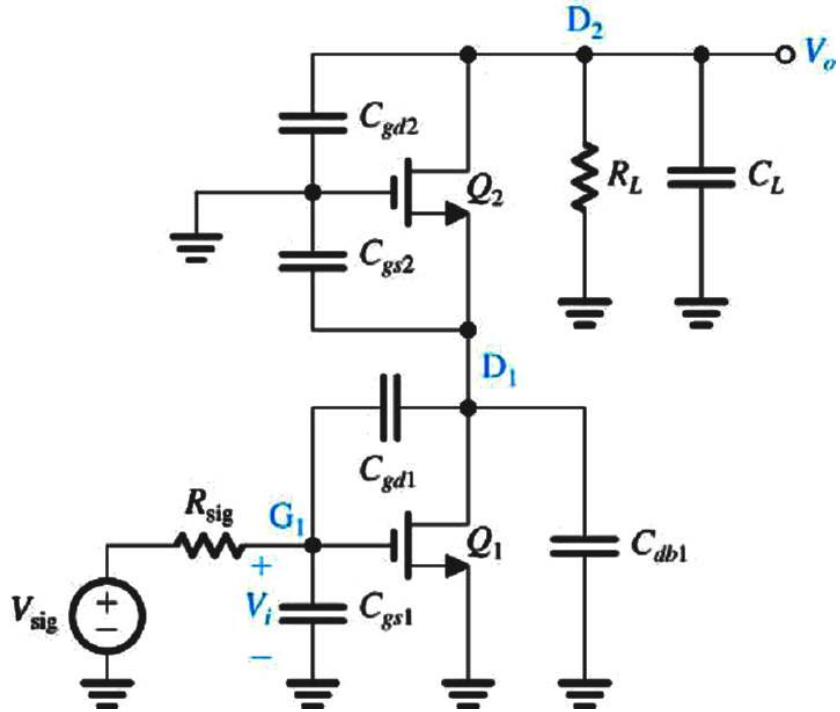
$$R_{gd1} = (1 + g_{m1}R_{d1})R_{sig} + R_{d1}$$

$$R_{gs2,db1} = R_{d1}$$

$$R_{gd2,L} = R_L \,//\, R_{out}$$

$$\tau_H = C_{gs1}R_{sig} + C_{gd1}\left[(1 + g_{m1}R_{d1})R_{sig} + R_{d1}\right] + (C_{db1} + C_{gs2})R_{d1} + (C_L + C_{gd2})(R_L \parallel R_{out})$$

$$f_H \cong \frac{1}{2\pi\tau_H}$$



- 다음과 같이 정리하면, R_{sig}, $1+g_{m1}R_{d1}$이 큰 경우- 첫째 항이 중요.

$$\tau_H = R_{sig}\left[C_{gs1} + C_{gd1}(1 + g_{m1}R_{d1})\right] + R_{d1}(C_{gd1} + C_{db1} + C_{gs2}) + (R_L \parallel R_{out})(C_L + C_{gd2})$$

- R_{sig}이 작은 경우- 셋째 항이 중요. $R_{sig}=0$이고, 둘째 항이 작으면

$$\tau_H \cong (C_L + C_{gd2})(R_L \parallel R_{out})$$

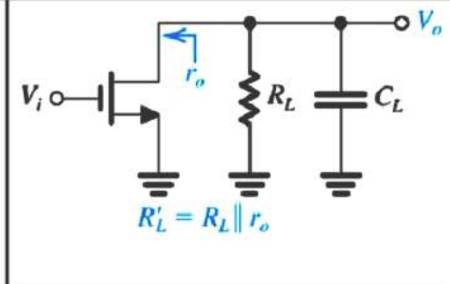
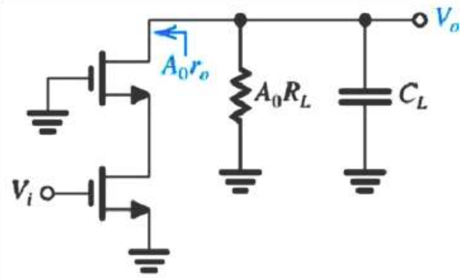
캐스코드 증폭기

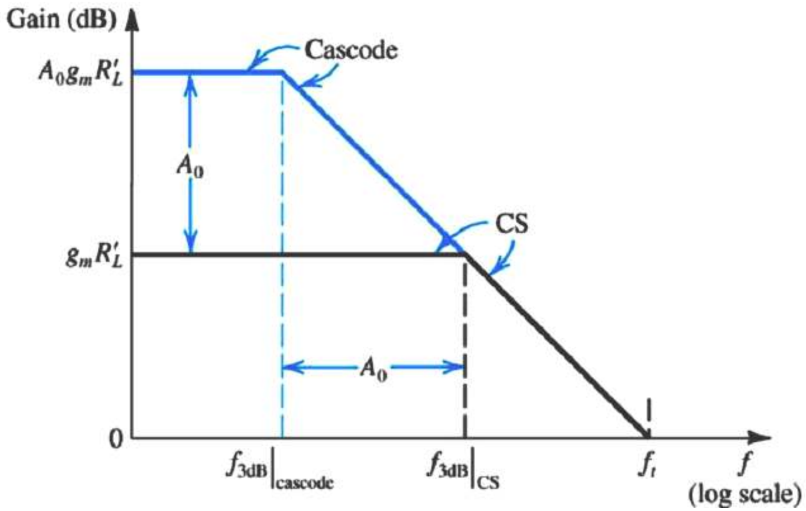
$$f_H = \frac{1}{2\pi\left(C_L + C_{gd2}\right)\left(R_L \parallel R_{out}\right)}$$

→ R_{sig}=0인 CS 증폭기와 같은 식.
단, CS 보다 A_0만큼 큰 부하저항.
(f_H 감소)

- R_{sig}=0인 경우, 단위이득 주파수, f_t 동일하면, 이득은 A_0만큼 증가.

$$f_t \cong \frac{1}{2\pi}\frac{g_m}{C_L + C_{gd2}}$$

	Common Source	Cascode
Circuit		
DC Gain	$-g_m R'_L$	$-A_0 g_m R'_L$
f_{3dB}	$\frac{1}{2\pi(C_L + C_{gd})R'_L}$	$\frac{1}{2\pi(C_L + C_{gd})A_0 R'_L}$
f_t	$\frac{g_m}{2\pi(C_L + C_{gd})}$	$\frac{g_m}{2\pi(C_L + C_{gd})}$



캐스코드 증폭기

Ex 6.12 캐스코드 와 CS 증폭기 비교

W/L=7.2μm/0.36μm, I_D=100μA, g_m=1.25mA/V, χ=0.2, r_o= 20kΩ, C_{gs}=20fF, C_{gd}=5fF, C_{db}=5fF, C_L= 5fF.
A_v, f_H, f_t=?

(a) R_{sig}=10kΩ, CS 증폭기의 R_L= r_o= 20kΩ, 캐스코드 증폭기의 R_L= 20kΩ .

- CS 증폭기

$$A_0 = g_m r_o = 1.25\times 20 = 25\,\text{V/V}$$

$$A_v = -g_m\left(R_L \parallel r_o\right) = -g_m\left(r_o \parallel r_o\right) = -\frac{1}{2}A_0 = -12.5\,\text{V/V}$$

$$\tau_H = C_{gs}R_{sig} + C_{gd}\left[\left(1+g_m R'_L\right)R_{sig} + R'_L\right] + \left(C_L + C_{db}\right)R'_L$$

$$R'_L = r_o \parallel R_L = \left(r_o \parallel r_o\right) = 10\,\text{k}\Omega$$

$$\tau_H = 20\times 10 + 5\left[\left(1+12.5\right)10 + 10\right] + \left(5+5\right)10$$

$$= 200 + 725 + 100 = 1025\,\text{ps}$$

$$f_H = \frac{1}{2\pi\times 1025\times 10^{-12}} = 155\,\text{MHz}$$

$$f_t = \left|A_v\right| f_H = 12.5\times 155 = 1.94\,\text{GHz}$$

캐스코드 증폭기

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W/L=7.2μm/0.36μm, I_D=100μA, g_m=1.25mA/V, χ=0.2, r_o= 20kΩ, C_{gs}=20fF, C_{gd}=5fF, C_{db}=5fF, C_L= 5fF.
A_v, f_H , f_t=?

(a) R_{sig}=10kΩ, CS 증폭기의 R_L= r_o= 20kΩ, 캐스코드 증폭기의 R_L= 20kΩ .

- 캐스코드 증폭기

$$A_{01} = g_{m1} r_{o1} = 1.25 \times 20 = 25\,\text{V/V}$$

$$A_{\upsilon o2} = 1 + \left(g_{m2} + g_{mb2}\right) r_{o2} = 1 + \left(1.25 + 0.2 \times 1.25\right) \times 20$$

$$= 1 + 1.5 \times 20 = 31\,\text{V/V}$$

$$R_{out1} = r_{o1} = 20\,\text{k}\Omega$$

$$R_{in2} = \frac{1}{g_{m2} + g_{mb2}} + \frac{R_L}{A_{\upsilon o2}} = \frac{1}{1.5} + \frac{20}{31} = 1.3\,\text{k}\Omega$$

$$R_{d1} = R_{out} \parallel R_{in2} = 20 \parallel 1.3 = 1.22\,\text{k}\Omega$$

$$R_{out} = r_{o2} + A_{\upsilon o2} r_{o1} = 20 + 31 \times 20 = 640\,\text{k}\Omega$$

$$\frac{\upsilon_{o1}}{\upsilon_i} = -g_{m1} R_{d1} = -1.25 \times 1.22 = -1.5\,\text{V/V}$$

$$A_\upsilon = A_{\upsilon o} \frac{R_L}{R_L + R_{out}} = -25 \times 31 \times \frac{20}{640 + 20} = -23.5\,\text{V/V}$$

$$\tau_H = R_{sig}\left[C_{gs1} + C_{gd1}\left(1 + g_{m1} R_{d1}\right)\right] + R_{d1}\left(C_{gd1} + C_{db1} + C_{gs2}\right)$$

$$+ \left(R_L \parallel R_{out}\right)\left(C_L + C_{db2} + C_{gd2}\right)$$

$$\tau_H = 10\left[20 + 5\left(1 + 1.5\right)\right] + 1.22\left(5 + 5 + 20\right)$$

$$+ \left(20 \parallel 640\right)\left(5 + 5 + 5\right)$$

$$= 325 + 36.6 + 290.9 = 653\,\text{ps}$$

캐스코드 증폭기

Ex 6.12 캐스코드 와 CS 증폭기 비교

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A_v, f_H , f_t=?

(a) R_{sig}=10kΩ, CS 증폭기의 R_L= r_o= 20kΩ, 캐스코드 증폭기의 R_L= 20kΩ .

- CS 증폭기

$$A_0 = g_m r_o = 1.25 \times 20 = 25\,\text{V/V}$$

$$A_\upsilon = -g_m\left(R_L \| r_o\right) = -g_m\left(r_o \| r_o\right) = -\frac{1}{2}A_0 = -12.5\,\text{V/V}$$

$$\tau_H = C_{gs}R_{sig} + C_{gd}\left[\left(1+g_m R_L'\right)R_{sig} + R_L'\right] + \left(C_L + C_{db}\right)R_L'$$

$$R_L' = r_o \| R_L = \left(r_o \| r_o\right) = 10\,\text{k}\Omega$$

$$\tau_H = 20\times 10 + 5\left[\left(1+12.5\right)10 + 10\right] + \left(5+5\right)10$$

$$= 200 + 725 + 100 = 1025\,\text{ps}$$

$$f_H = \frac{1}{2\pi \times 1025 \times 10^{-12}} = 155\,\text{MHz}$$

$$f_t = \left|A_\upsilon\right| f_H = 12.5 \times 155 = 1.94\,\text{GHz}$$

- 캐스코드 증폭기

$$A_{01} = g_{m1} r_{o1} = 1.25 \times 20 = 25\,\text{V/V}$$

$$A_{\upsilon o2} = 1 + \left(g_{m2} + g_{mb2}\right) r_{o2} = 1 + \left(1.25 + 0.2\times 1.25\right)\times 20$$

$$= 1 + 1.5 \times 20 = 31\,\text{V/V}$$

$$R_{out1} = r_{o1} = 20\,\text{k}\Omega$$

$$R_{in2} = \frac{1}{g_{m2} + g_{mb2}} + \frac{R_L}{A_{\upsilon o2}} = \frac{1}{1.5} + \frac{20}{31} = 1.3\,\text{k}\Omega$$

$$R_{d1} = R_{out} \| R_{in2} = 20 \| 1.3 = 1.22\,\text{k}\Omega$$

$$R_{out} = r_{o2} + A_{\upsilon o2} r_{o1} = 20 + 31 \times 20 = 640\,\text{k}\Omega$$

$$\frac{\upsilon_{o1}}{\upsilon_i} = -g_{m1} R_{d1} = -1.25 \times 1.22 = -1.5\,\text{V/V}$$

$$A_\upsilon = A_{\upsilon o}\frac{R_L}{R_L + R_{out}} = -25 \times 31 \times \frac{20}{640 + 20} = -23.5\,\text{V/V}$$

$$\tau_H = R_{sig}\left[C_{gs1} + C_{gd1}\left(1 + g_{m1}R_{d1}\right)\right] + R_{d1}\left(C_{gd1} + C_{db1} + C_{gs2}\right)$$
$$+ \left(R_L \| R_{out}\right)\left(C_L + C_{db2} + C_{gd2}\right)$$

$$\tau_H = 10\left[20 + 5\left(1 + 1.5\right)\right] + 1.22\left(5 + 5 + 20\right)$$
$$+ \left(20 \| 640\right)\left(5 + 5 + 5\right)$$
$$= 325 + 36.6 + 290.9 = 653\,\text{ps}$$

캐스코드 증폭기

$$f_H = \frac{1}{2\pi \times 653 \times 10^{-12}} = 244\,\text{MHz}$$

$f_t = 23.5 \times 244 = 5.73\,\text{GHz}$ → 캐스코딩은 f_t를 3배 증가

(b) R_{sig}=0kΩ, 단, CS 보다 A_0만큼 큰 부하저항.

- CS 증폭기

$$A_v = -12.5\,\text{V/V}$$

$$\tau_H = \left(C_{gd} + C_L + C_{db}\right) R_L'$$

$$= \left(5 + 5 + 5\right) 10 = 150\,\text{ps}$$

$$f_H = \frac{1}{2\pi \times 150 \times 10^{-12}} = 1.06\,\text{GHz}$$

$$f_t = 12.5 \times 1.06 = 13.3\,\text{GHz}$$

캐스코드 증폭기

$$f_H = \frac{1}{2\pi \times 653 \times 10^{-12}} = 244\,\text{MHz}$$

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- CS 증폭기

$$A_v = -12.5\,\text{V/V}$$

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$$f_H = \frac{1}{2\pi \times 150 \times 10^{-12}} = 1.06\,\text{GHz}$$

$$f_t = 12.5 \times 1.06 = 13.3\,\text{GHz}$$

- 캐스코드 증폭기

$$A_v = A_{vo} \frac{R_L}{R_L + R_{out}}$$

$$= -25 \times 31 \times \frac{640}{640 + 640} = -388\,\text{V/V}$$

$$R_{in2} = \frac{1}{g_{m2} + g_{mb2}} + \frac{R_L}{A_{vo2}} = \frac{1}{1.5} + \frac{640}{31} = 21.3\,\text{k}\Omega$$

$$R_{d1} = 21.3 \parallel 20 = 10.3\,\text{k}\Omega$$

$$\tau_H = R_{d1}\left(C_{gd1} + C_{db1} + C_{gs2}\right) + \left(R_L \parallel R_{out}\right)\left(C_L + C_{gd2} + C_{db2}\right)$$

$$= 10.3\left(5 + 5 + 20\right) + \left(640 \parallel 640\right)\left(5 + 5 + 5\right)$$

$$= 309 + 4800 = 5109\,\text{ps}$$

$$f_H = \frac{1}{2\pi \times 5109 \times 10^{-12}} = 31.2\,\text{MHz}$$

$$f_t = 388 \times 31.2 = 12.1\,\text{GHz}$$

→ 캐스코딩은 dc 이득 증가. f_t 일정.

소스(이미터)저항이 있는 CS/CE 증폭기

소스저항이 있는 CS 증폭기

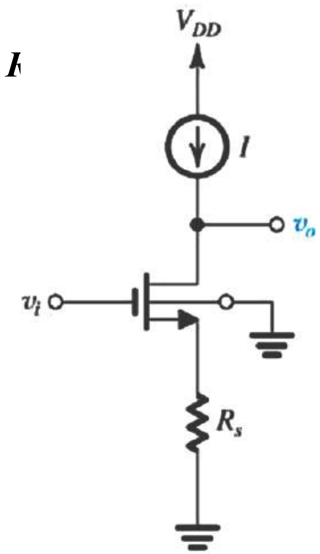
- 출력저항

$$R_{out} = r_o + \left[1+\left(g_m + g_{mb}\right)r_o\right]R_s$$

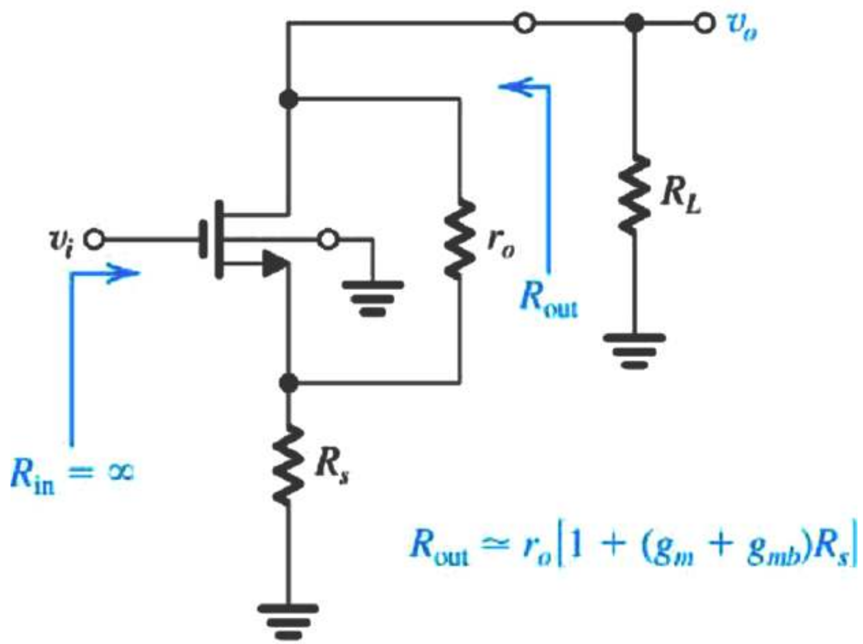
$(g_m+g_{mb})r_o \gg 1$이므로

$$R_{out} \cong r_o\left[1+\left(g_m + g_{mb}\right)R\right.$$

→ R_s는 R_{out} 증가



(a)



소스(이미터)저항이 있는 CS/CE 증폭기

소스저항이 있는 CS 증폭기

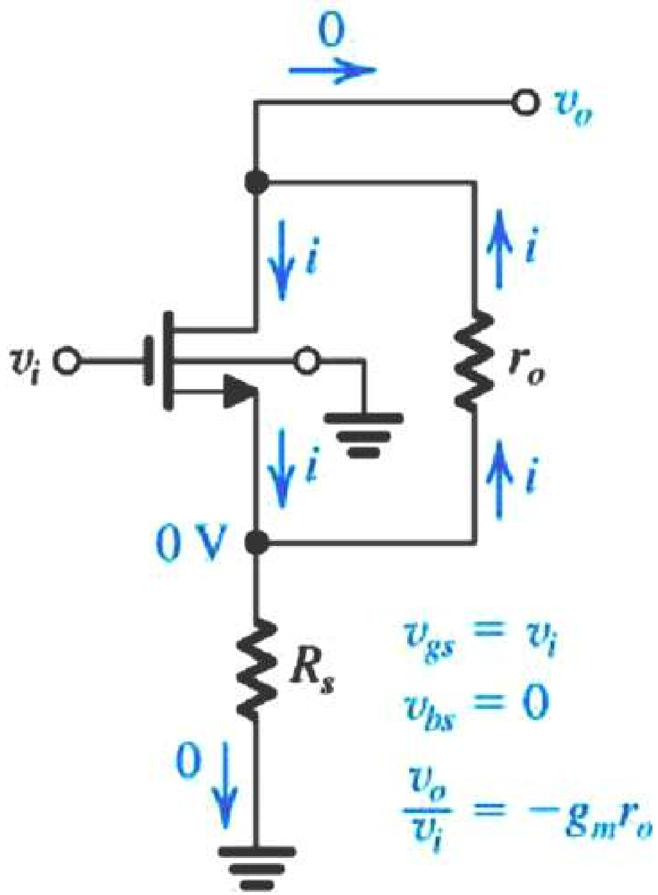
- 개방회로 전압이득

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

$$\upsilon_o = -ir_o = -g_m r_o \upsilon_{gs} = -g_m r_o \upsilon_i$$

$$A_{\upsilon o} = -g_m r_o = -A_0$$

→ R_s는 A_{vo}에 영향주지 않음.



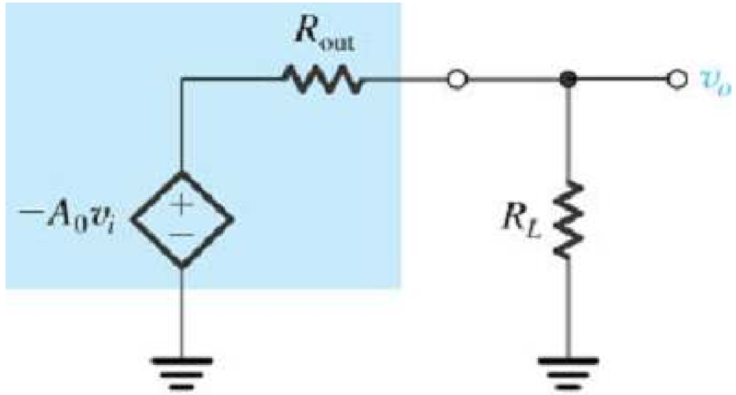
소스(이미터)저항이 있는 CS/CE 증폭기

- 단락회로 트랜스컨덕턴스

$$G_m = \frac{|A_{vo}|}{R_{out}} = \frac{g_m r_o}{r_o\left[1+\left(g_m+g_{mb}\right)R_s\right]}$$

$$G_m = \frac{g_m}{1+\left(g_m+g_{mb}\right)R_s}$$

→ R_s는 G_m 감소.



- 전압이득

$$A_v = A_{vo}\frac{R_L}{R_L+R_{out}} = -A_0\frac{R_L}{R_L+R_{out}}$$

→ R_s는 R_{out} 증가시키고 A_V 감소.

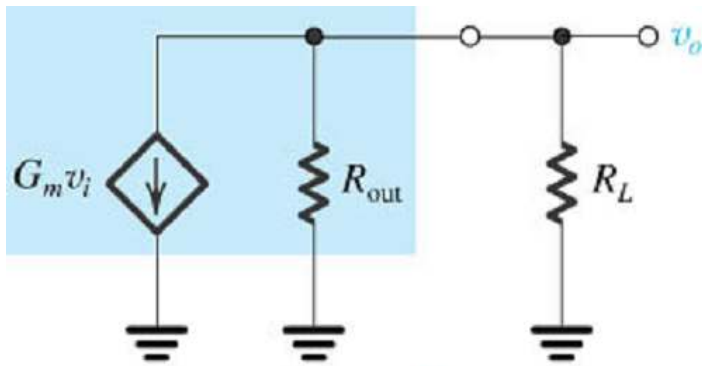
- 증폭기의 선형성($v_{gs} \ll 2V_{OV}$일 때)

$$\frac{v_{gs}}{v_i} \cong \frac{1}{1+\left(g_m+g_{mb}\right)R_s}\,\frac{R_L \parallel R_{out}}{R_L \parallel r_o}\ ^{**}$$

$r_o \gg R_L$일 때

$$\frac{v_{gs}}{v_i} \cong \frac{1}{1+\left(g_m+g_{mb}\right)R_s}$$

→ R_s는 v_{gs} 조절하여 선형성 증가.



$$G_m \simeq \frac{g_m}{[1+(g_m+g_{mb})R_s]}$$

소스(이미터)저항이 있는 CS/CE 증폭기

주파수 응답

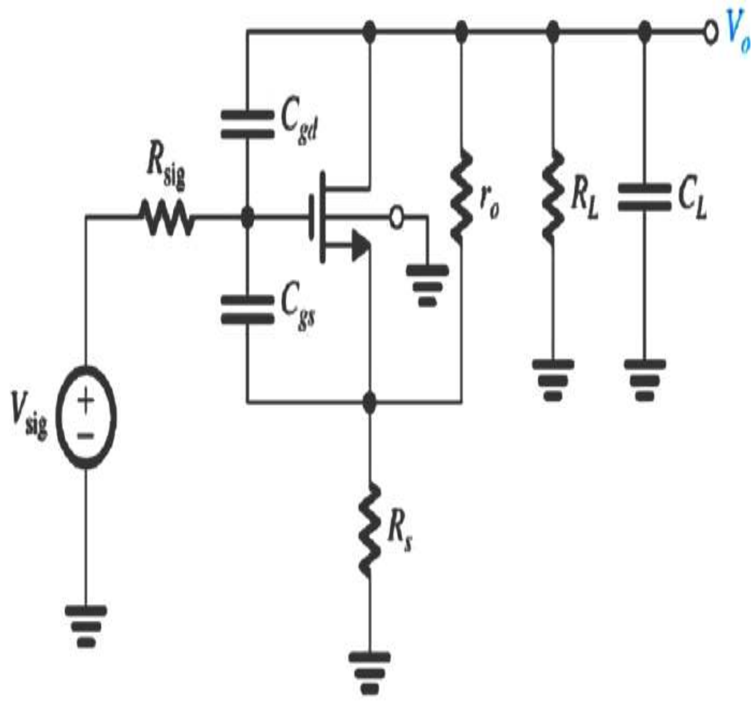
- R_s는 대역폭 증가

$$R_{gd} = R_{sig}\left(1+G_m R_L^{'}\right)+R_L^{'} \ ,R_L^{'} = R_L \parallel R_{out}$$

$$R_{C_L} = R_L \parallel R_{out} = R_L^{'}$$

$$R_{gs} \cong \frac{R_{sig}+R_s}{1+\left(g_m+g_{mb}\right)R_s\left(\dfrac{r_o}{r_o+R_L}\right)} \quad {}^{**}$$

$$\tau_H = C_{gs}R_{gs} + C_{gd}R_{gd} + C_L R_{C_L}$$



(a)

소스(이미터)저항이 있는 CS/CE 증폭기

주파수 응답

- R_{sig}가 클 경우, 밀러 효과에 의해 $C_{gd}R_{gd}$가 dominant

$$\tau_H \cong C_{gd} R_{gd}$$

$$f_H \cong \frac{1}{2\pi C_{gd} R_{gd}}$$

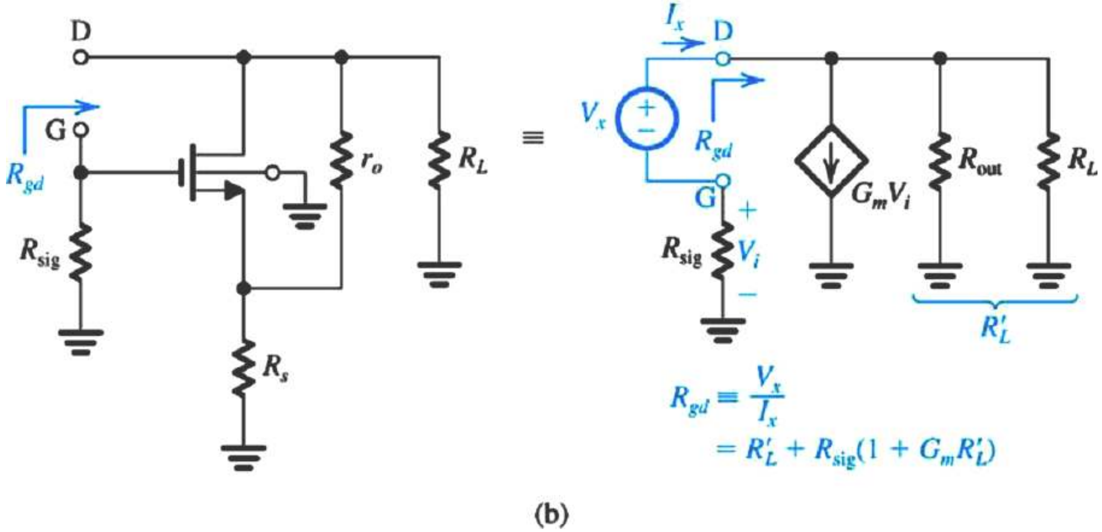
R_s증가 → R_{gd} 감소, f_H 증가, A_M감소

- $G_m R'_L \gg 1$, $G_m R_{sig} \gg 1$로 가정하면

$$R_{gd} \cong G_m R'_L R_{sig} = |A_M| R_{sig}$$

$$f_H = \frac{1}{2\pi C_{gd} R_{sig} |A_M|}$$

$$f_t = |A_M| f_H = \frac{1}{2\pi C_{gd} R_{sig}}$$



소스(이미터)저항이 있는 CS/CE 증폭기

주파수 응답

- R_s는 대역폭 증가

$$R_{gd} = R_{sig}\left(1+G_m R_L^{'}\right)+R_L^{'}\ ,\qquad R_L^{'} = R_L \parallel R_{out}$$

$$R_{C_L} = R_L \parallel R_{out} = R_L^{'}$$

$$R_{gs} \cong \frac{R_{sig}+R_s}{1+\left(g_m+g_{mb}\right)R_s\left(\dfrac{r_o}{r_o+R_L}\right)} \quad {}^{**}$$

$$\tau_H = C_{gs}R_{gs} + C_{gd}R_{gd} + C_L R_{C_L}$$

- R_{sig}가 클 경우, 밀러 효과에 의해 $C_{gd}R_{gd}$가 dominant

$$\tau_H \cong C_{gd}R_{gd}$$

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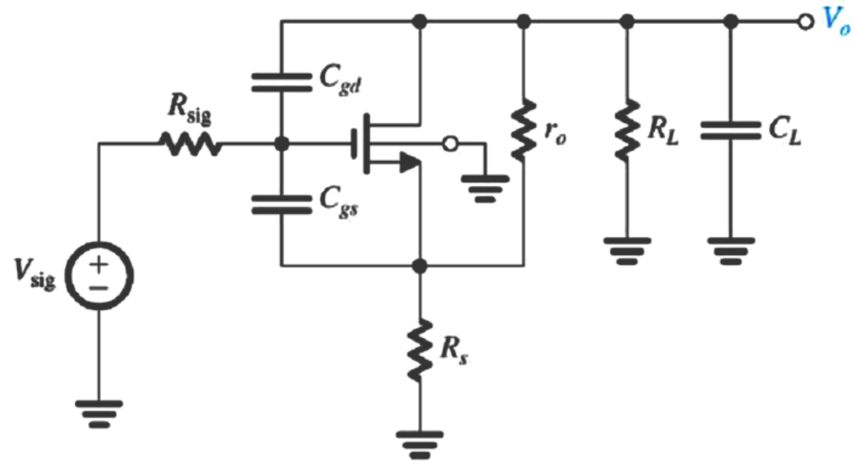
R_s증가 → R_{gd} 감소, f_H 증가, A_M감소

- $G_m R'_L \gg 1$, $G_m R_{sig} \gg 1$로 가정하면

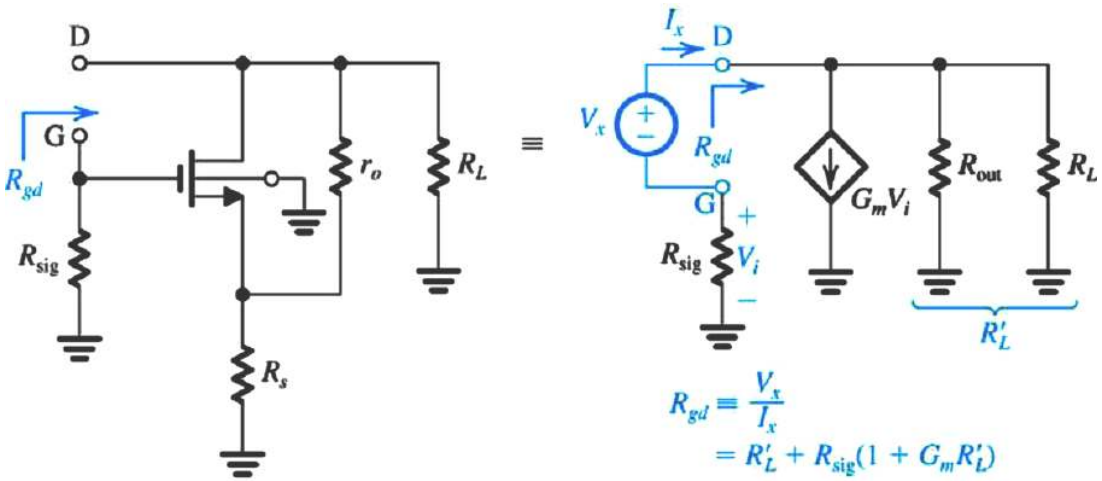
$$R_{gd} \cong G_m R_L^{'} R_{sig} = \left|A_M\right| R_{sig}$$

$$f_H = \frac{1}{2\pi C_{gd}R_{sig}\left|A_M\right|}$$

$$f_t = \left|A_M\right| f_H = \frac{1}{2\pi C_{gd}R_{sig}}$$



(a)



(b)

소스(이미터)저항이 있는 CS/CE 증폭기

이미터저항이 있는 CE 증폭기

- 출력전압

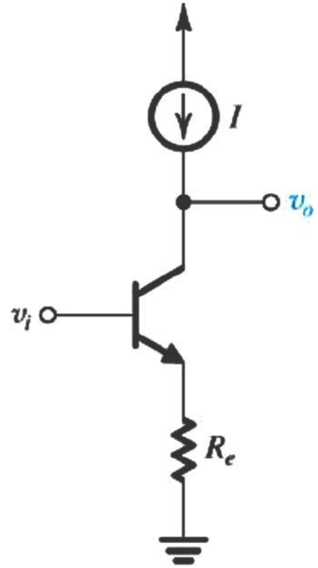
$$\upsilon_o = \left[(1-\alpha)i - \frac{\upsilon_i - ir_e}{R_e} \right] R_L$$

$$\upsilon_o = (\upsilon_i - ir_e) - r_o \left[i - \frac{\upsilon_i - ir_e}{R_e} \right]$$

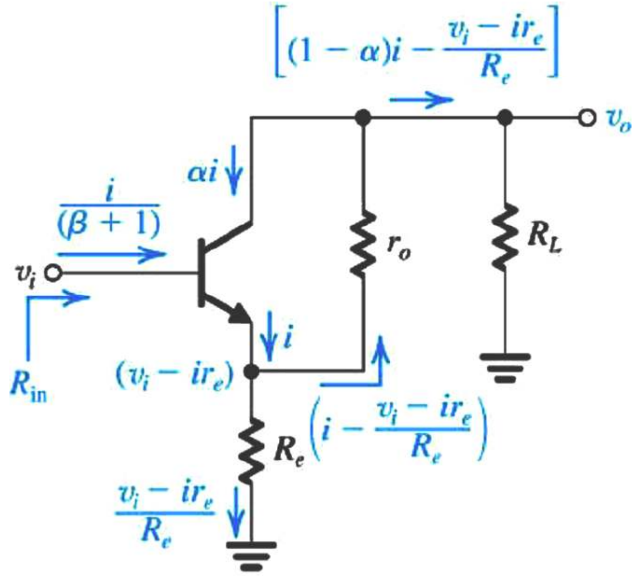
- 입력저항

$$R_{in} = \frac{\upsilon_i}{i/(\beta+1)}$$

$$= (\beta+1) r_e + (\beta+1) R_e \frac{r_o + R_L/(\beta+1)}{r_o + R_L + R_e}$$



(a)



(b)

소스(이미터)저항이 있는 CS/CE 증폭기

이미터저항이 있는 CE 증폭기

- $R_L/(1+\beta) \ll r_o$, $R_e \ll r_o$ 이므로,

$$R_{in} \cong (\beta+1) r_e + (\beta+1) R_e \frac{1}{1+R_L/r_o}$$

→ r_o 가 존재하면 R_L이 증가함에 따라 R_e 의 영향 감소

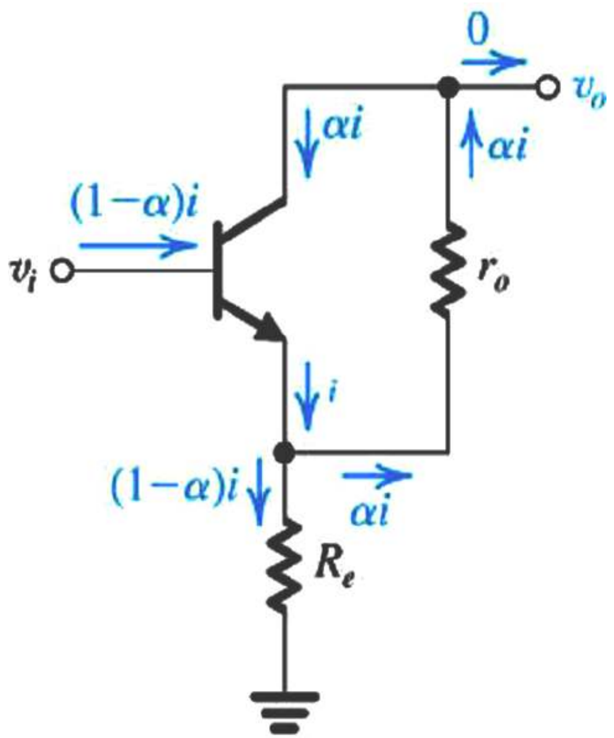
- 개방회로 전압이득

$$A_{vo} \cong -g_m r_o$$

- 출력저항

$$R_o \cong r_o \left(1 + g_m R_e'\right) \;, \quad R_e' = R_e \,//\, r_\pi$$

$$R_o \cong r_o \left(1 + g_m R_e\right)$$



- 단락회로 트랜스컨덕턴스

$$G_m = -\frac{A_{vo}}{R_o}$$

$$G_m = \frac{g_m}{1+g_m R_e}$$

* R_e → 밀러 효과의 영향 감소. 대역폭 증가. 선형성 증가

소스(이미터)저항이 있는 CS/CE 증폭기

이미터저항이 있는 CE 증폭기

- 출력전압

$$\upsilon_o = \left[(1-\alpha) i - \frac{\upsilon_i - i r_e}{R_e} \right] R_L$$

$$\upsilon_o = (\upsilon_i - i r_e) - r_o \left[i - \frac{\upsilon_i - i r_e}{R_e} \right]$$

- 입력저항

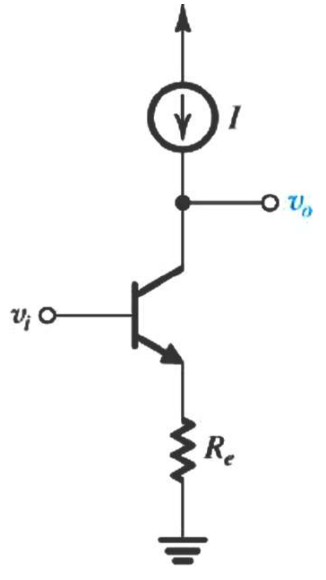
$$R_{in} = \frac{\upsilon_i}{i/(\beta+1)}$$

$$= (\beta+1) r_e + (\beta+1) R_e \frac{r_o + R_L/(\beta+1)}{r_o + R_L + R_e}$$

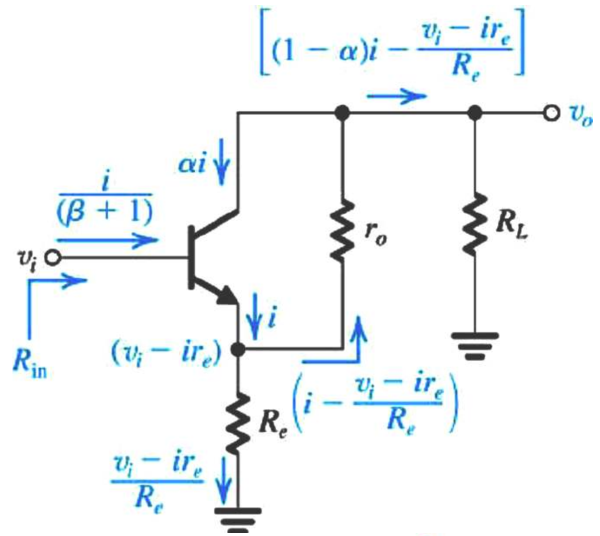
- $R_L/(1+\beta) \ll r_o$, $R_e \ll r_o$ 이므로,

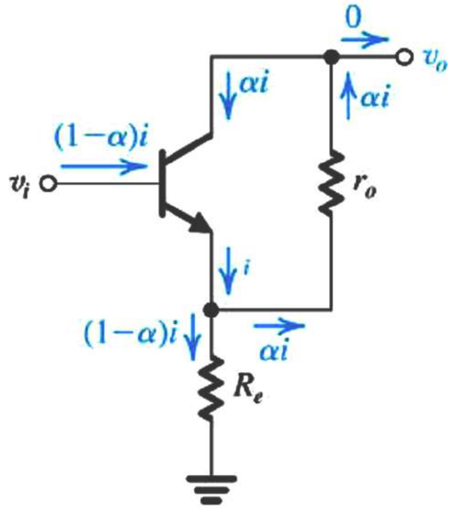
$$R_{in} \cong (\beta+1) r_e + (\beta+1) R_e \frac{1}{1 + R_L / r_o}$$

→ r_o 가 존재하면 R_L이 증가함에 따라 R_e 의 영향 감소



(a)





- 개방회로 전압이득

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$$R_o \cong r_o (1 + g_m R_e)$$

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$$G_m = \frac{g_m}{1 + g_m R_e}$$

* R_e → 밀러 효과의 영향 감소. 대역폭 증가. 선형성 증가