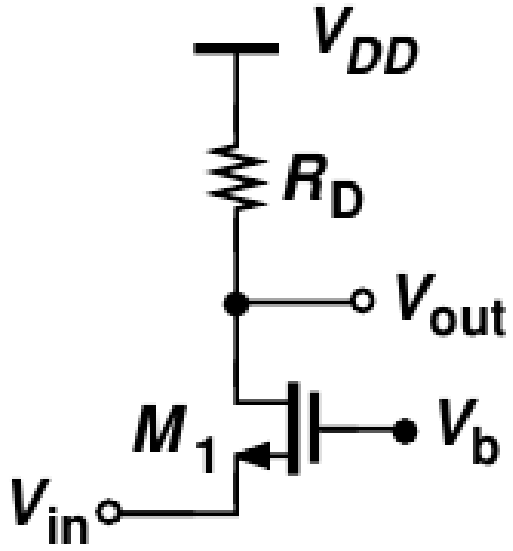
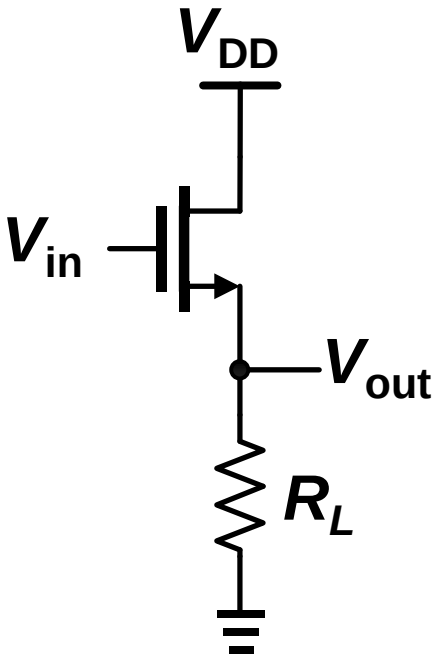
Frequency Response of CG Stage and Source Follower

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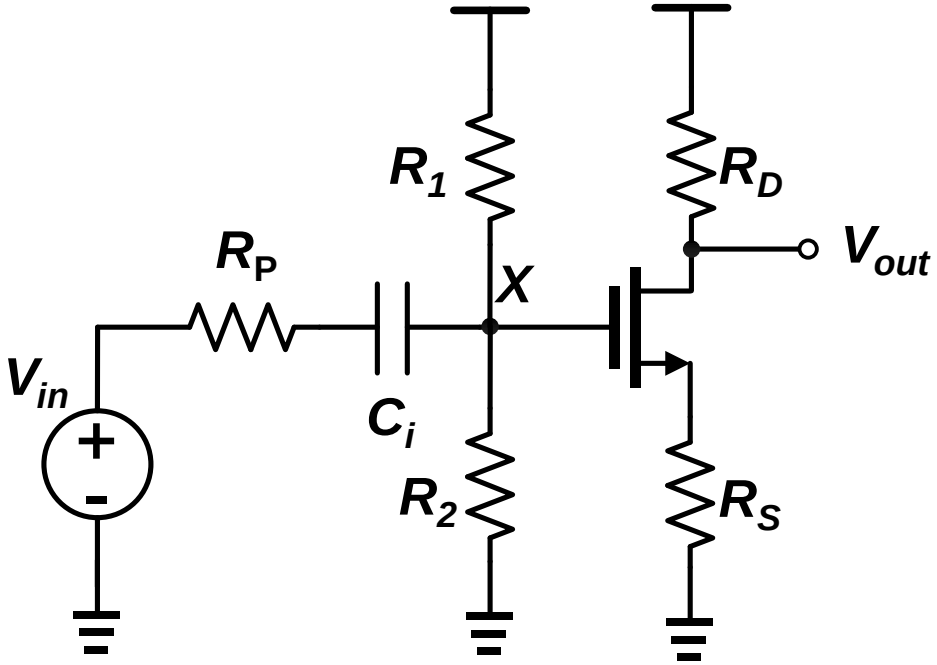
CG Stage & Source Follower





Frequency Response of CG Stage

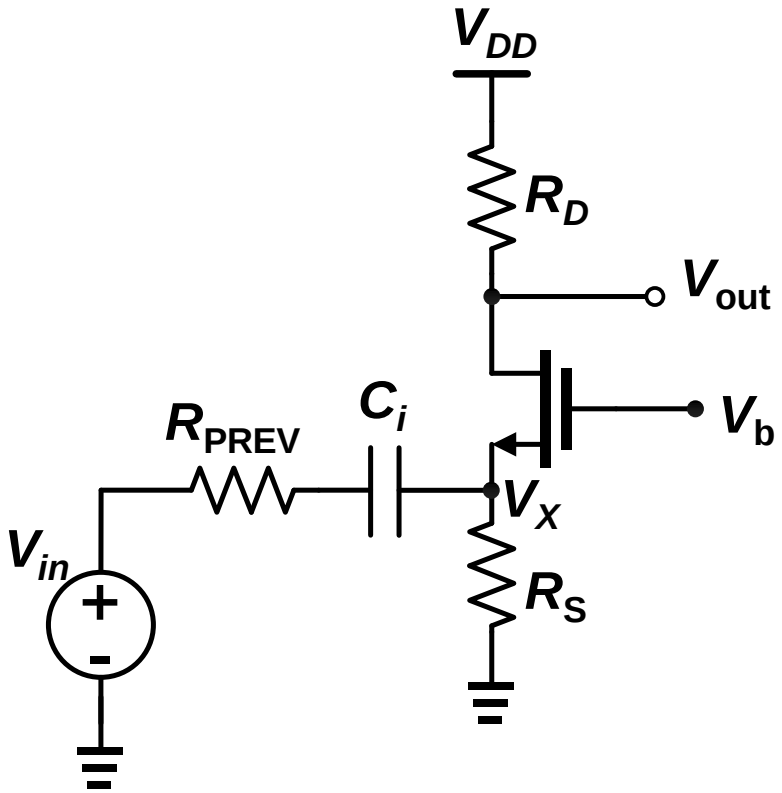
Revisit Effect of Coupling Capacitor in CS Stage



$$\frac{V_X}{V_{in}}(s) = \frac{R_1 \| R_2}{\frac{1}{sC_i} + R_{PREV} + R_1 \| R_2}$$

$$= \frac{s(R_1 \| R_2)C_i}{1 + s(R_{PREV} + R_1 \| R_2)C_i}$$

CG Stage



$$\frac{V_{out}}{V_{in}}(s) = \frac{V_X}{V_{in}}(s) \times \frac{V_{out}}{V_X}(s)$$

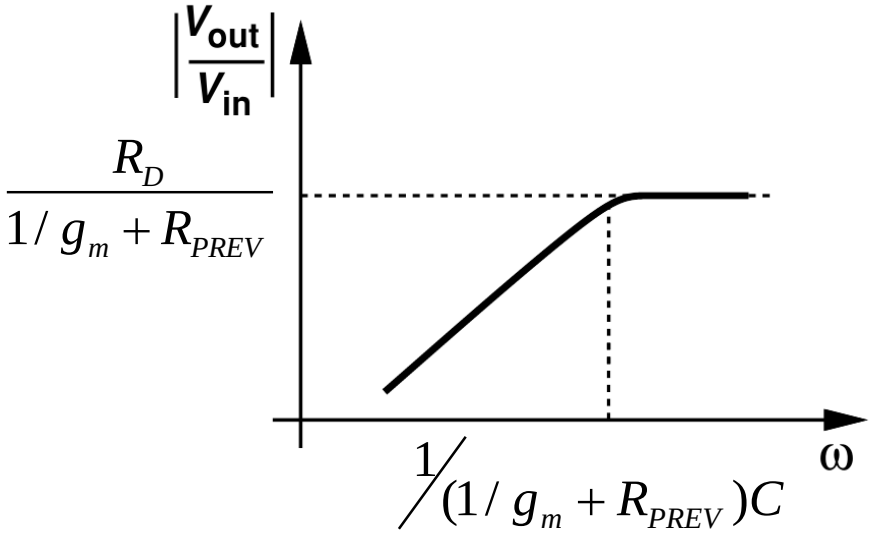
$$= \frac{R_S \parallel \frac{1}{g_m}}{\frac{1}{sC_i} + R_{PREV} + R_S \parallel \frac{1}{g_m}} \times g_m R_D$$

$$= \frac{sg_m R_D C_i}{g_m + 1/R_S + s(R_{PREV}(g_{mS} + 1/R_S) + 1)C_i}$$

$$\approx \frac{sg_m R_D C_i}{g_m + s(1 + g_m R_{PREV})C_i}$$ (When R_S is large)

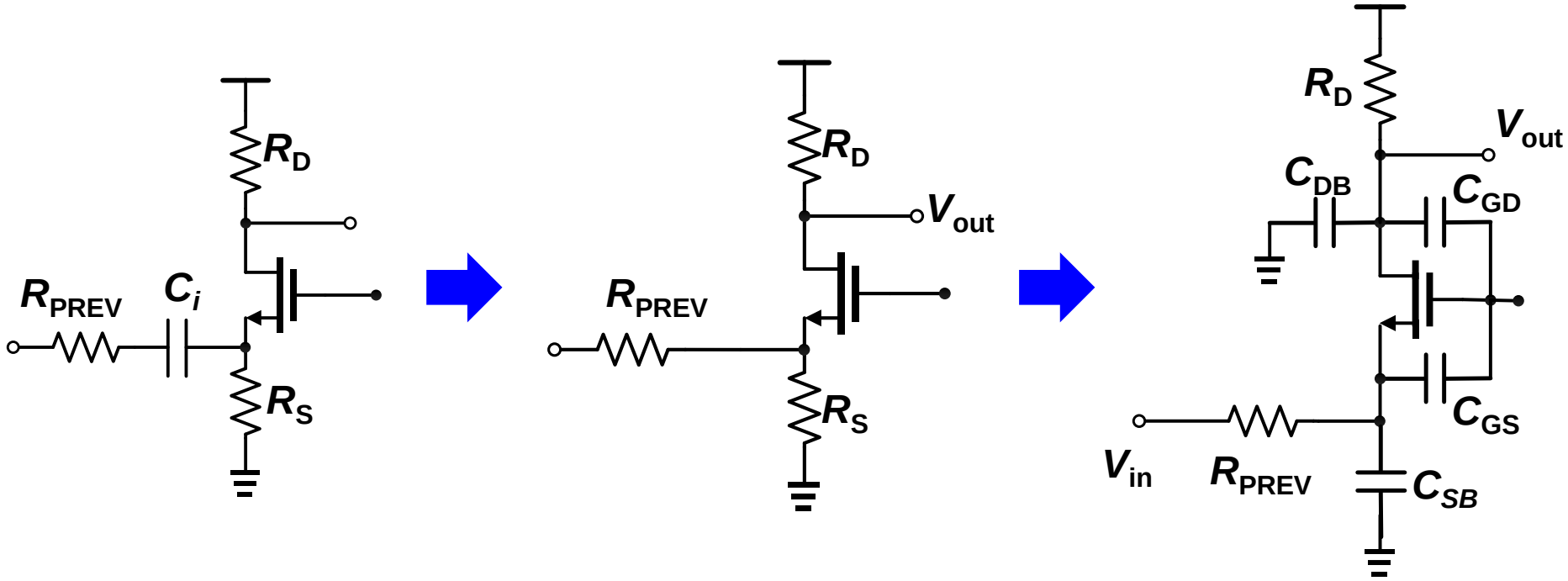
Low Frequency Response of CG Amp

$$\frac{sg_m R_D C_i}{g_m + s(1 + g_m R_{PREV})C_i}$$



With Higher Frequency

- Transistor cap should be considered.

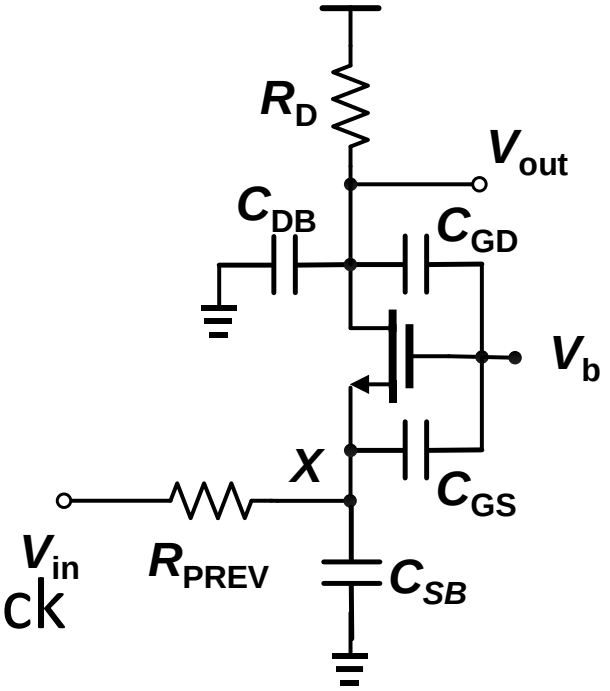


Poles At High Frequency

- Vb is ac ground (Why?)

$$\omega_{p,X} = \frac{1}{\left(R_{PREV} \parallel \frac{1}{g_m}\right)(C_{SB} + C_{GS})}$$

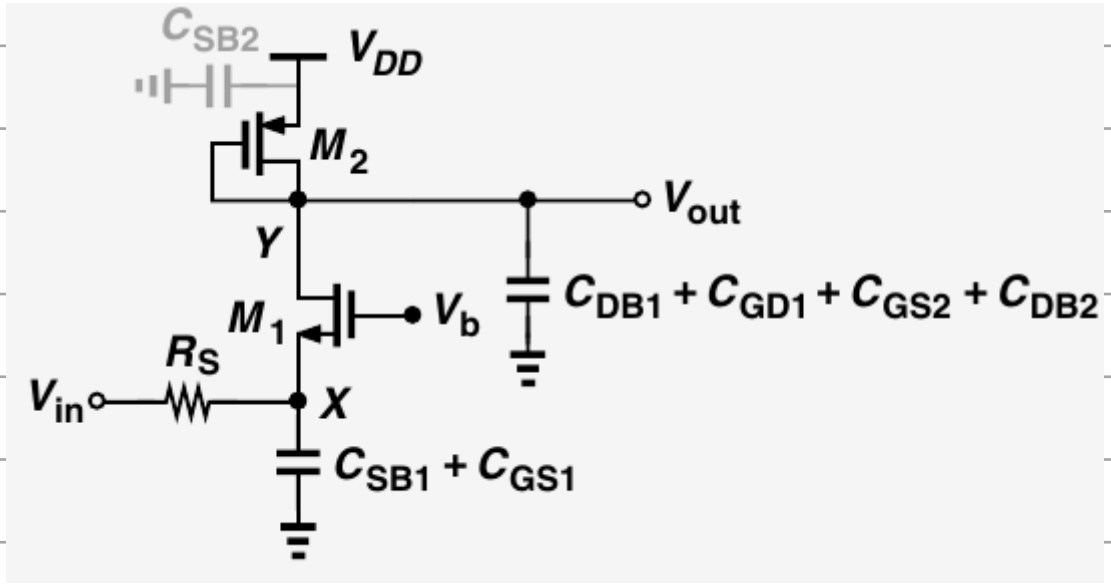
$$\omega_{p,out} = \frac{1}{R_D(C_{DB} + C_{GD})}$$

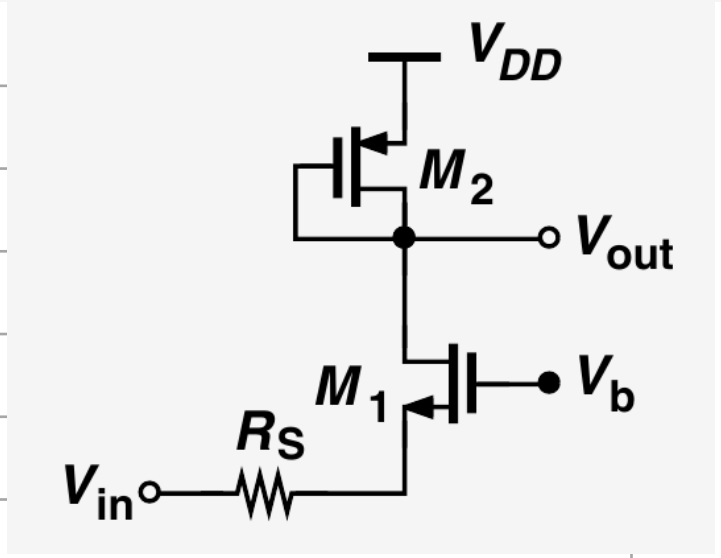


- No Miller effect
- Input pole rarely creates a speed bottleneck

Example 11.19

Compute the poles of the circuit shown in Fig. 11.36(a). Assume $\lambda = 0$.





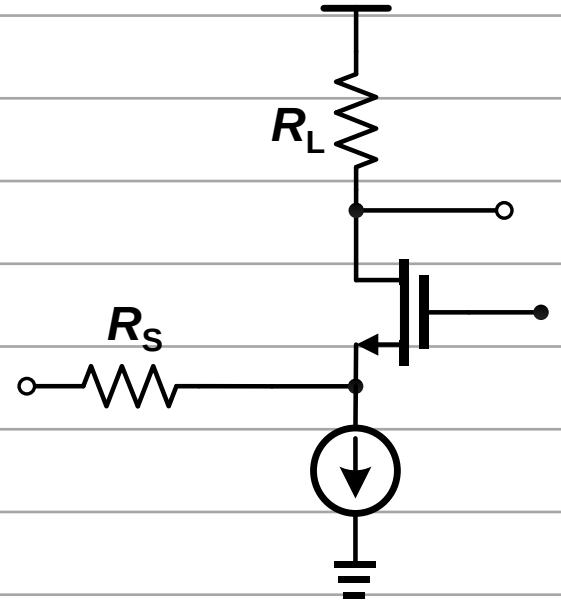
$$|\omega_{p,X}| = \frac{1}{\left(R_S \left\| \frac{1}{g_{m1}}\right.\right)(C_{SB1} + C_{GD1})}$$

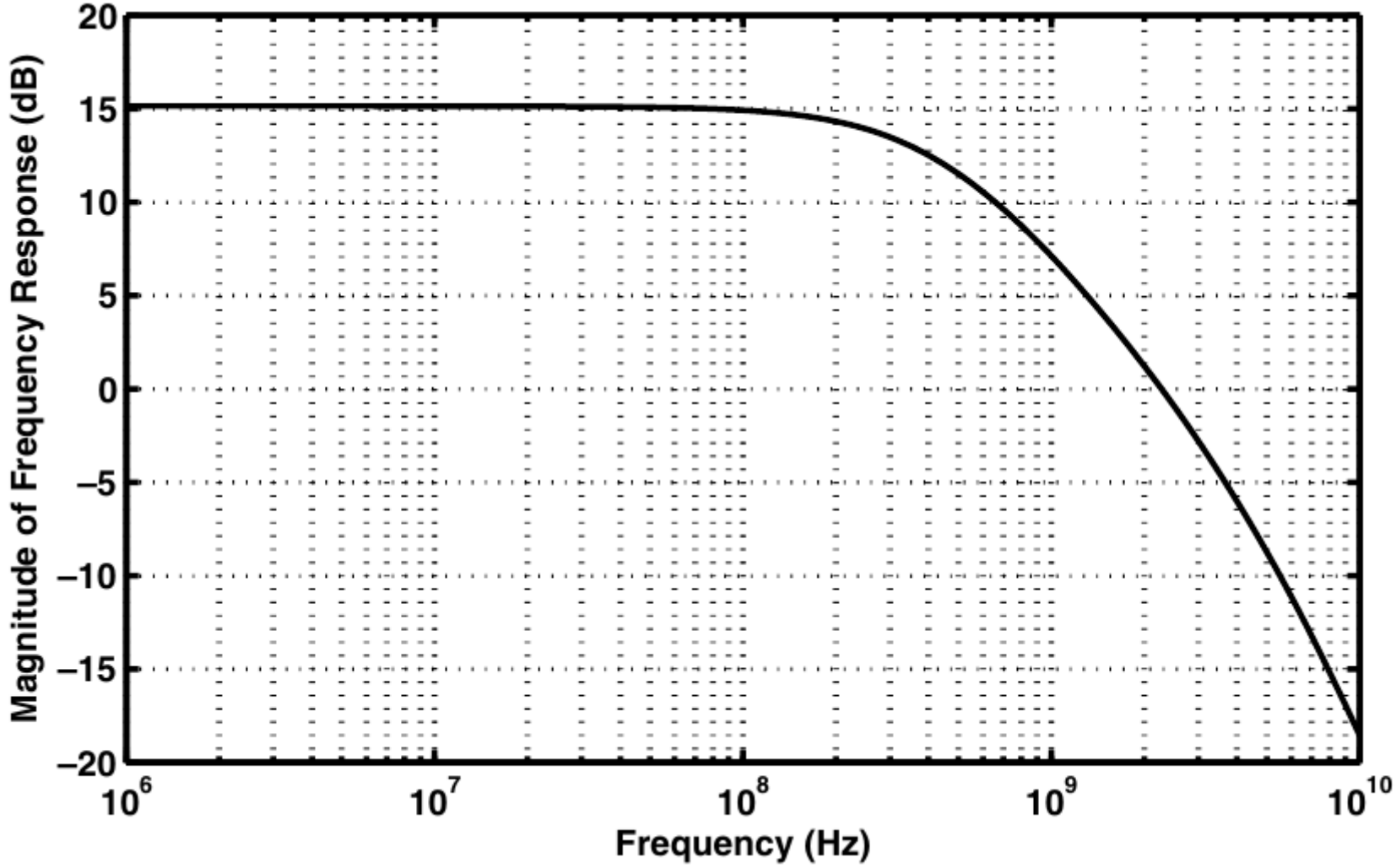
$$|\omega_{p,Y}| = \frac{1}{\frac{1}{g_{m2}}(C_{DB1} + C_{GD1} + C_{GS2} + C_{DB2})}$$

Example 11.20

In the CG stage of shown below, we have $R_S = 200\,\Omega, C_{GS} = 250$ fF, $C_{GD} = 80$ fF, $C_{DB} = 100$ fF, $g_m = (150\,\Omega)^{-1}$, $\lambda = 0$, and $R_L = 2\,\text{k}\Omega$. Plot the frequency response with the aid of (a) Miller's approximation, (b) the exact transfer function, (c) the dominant-pole approximation.

Assume C_{DB} and C_{SB} are equal.




Magnitude of Frequency Response (dB)
20
15
10
5
0
−5
−10
−15
−20
10^6
10^7
10^8
10^9
10^{10}
Frequency (Hz)

Frequency Response of Source Follower

Low Frequency Response of SF

- We already did!

Example 11.11

Figure 11.17 depicts a source follower used in a high-quality audio amplifier. Here, R_i establishes a gate bias voltage equal to V_{DD} for M_1, and I_1 defines the drain bias current. Assume $\lambda = 0$, $g_m = 1/(200\,\Omega)$, and $R_1 = 100$ kΩ. Determine the minimum required value of C_1 and the maximum tolerable value of C_L.

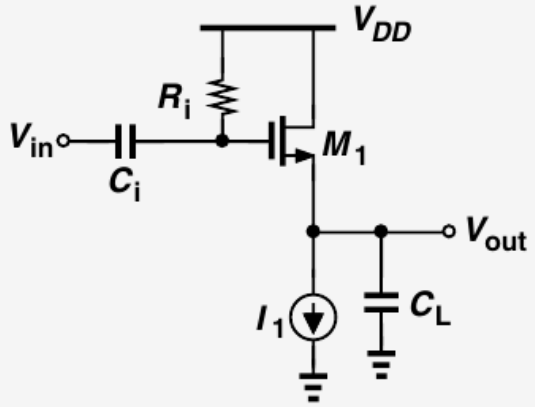
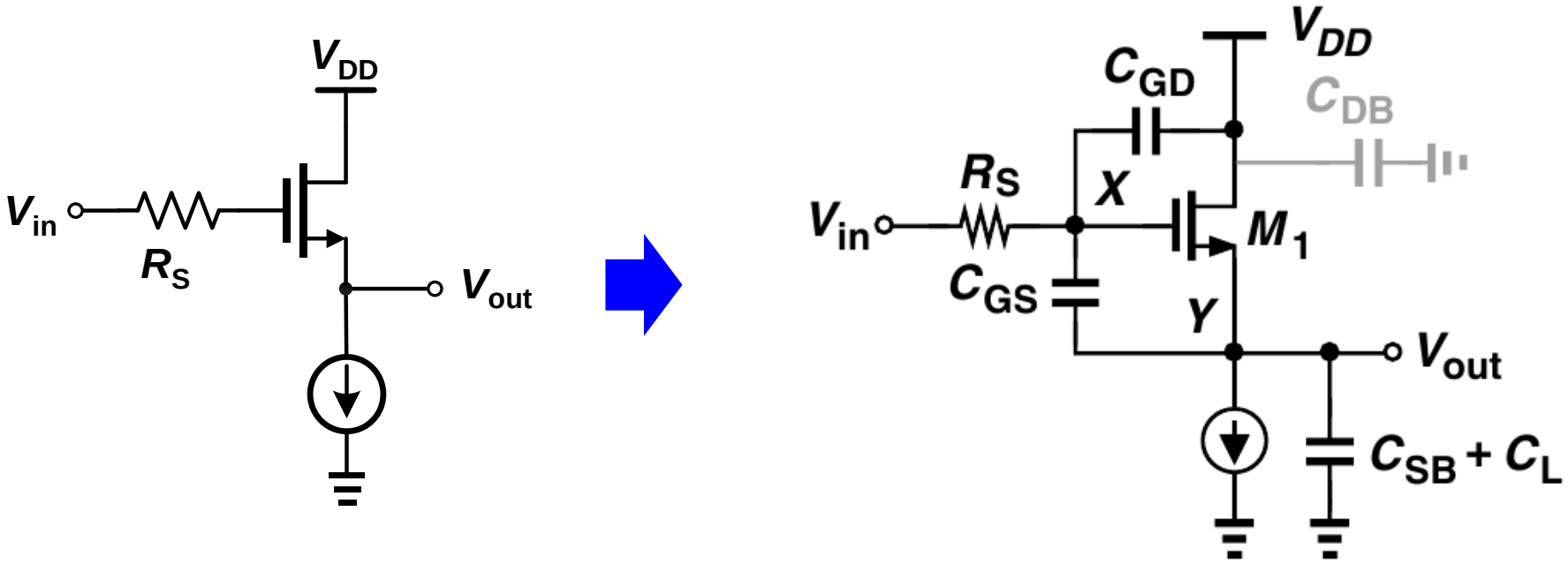


Figure 11.17

Capacitor Components for High Frequency Response of SF

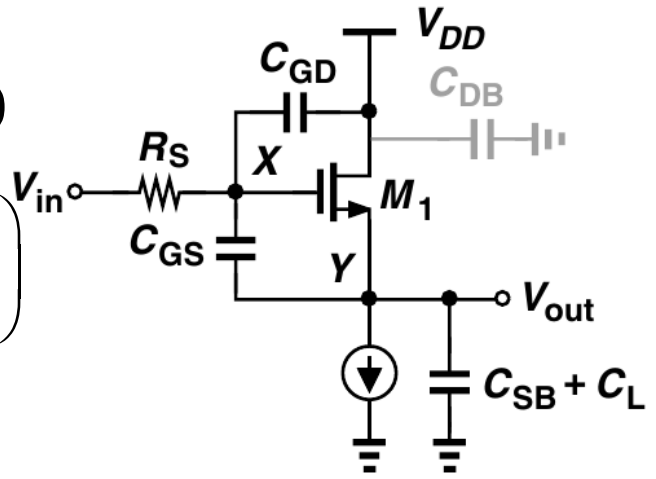


High Frequency Response of SF (cont'd)

- KCL can be used at the output node:

$$\frac{V_{in}-(V_{out}+v_{gs})}{R_S}-sC_{GD}(V_{out}+v_{gs})+g_m v_{gs}=sV_{out}(C_{SB}+C_L)$$

$$\frac{V_{in}}{R_S}+\left(g_m-\frac{1}{R_S}-sC_{GD}\right)v_{gs}=V_{out}\left(sC_{GD}+sC_{SB}+sC_L+\frac{1}{R_S}\right)$$

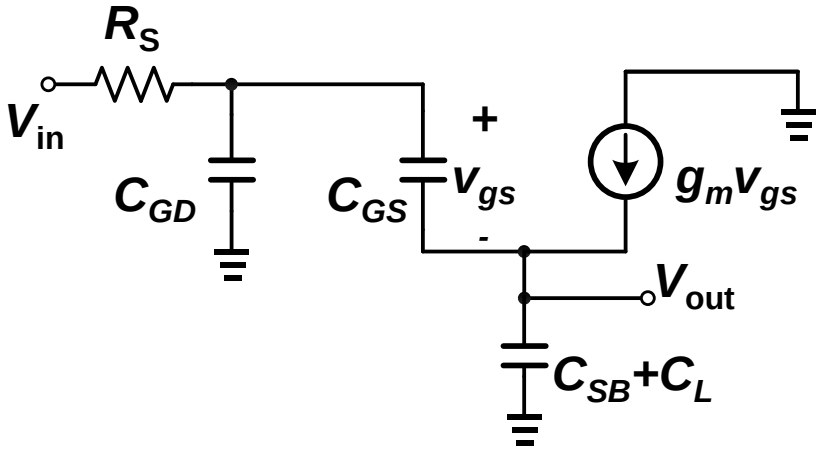


- Ohm's law across C_{GS} can eliminate v_{gs}:

$$v_{gs}=\frac{1}{sC_{GS}}\left\{\frac{V_{in}-(V_{out}+v_{gs})}{R_S}-sC_{GD}(V_{out}+v_{gs})\right\}$$

$$\left\{1+sR_S(C_{GS}+C_{GD})\right\}v_{gs}=V_{in}-V_{out}-sR_SC_{GD}V_{out}$$

$$v_{gs}=\frac{V_{in}-V_{out}-sR_SC_{GD}V_{out}}{1+sR_S(C_{GS}+C_{GD})}$$



High Frequency Response of SF (cont'd)

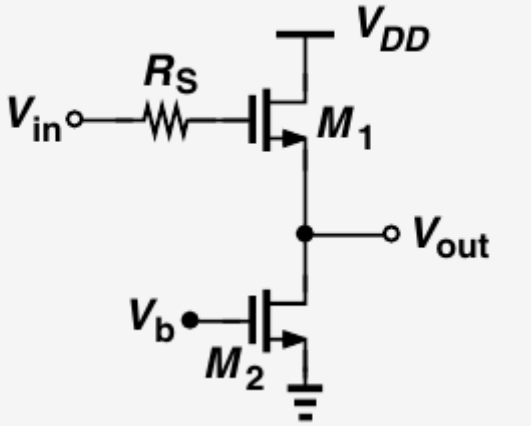
$$\frac{V_{in}}{R_S}+\left(g_m-\frac{1}{R_S}-sC_{GD}\right)\frac{V_{in}-V_{out}-sR_SC_{GD}V_{out}}{1+sR_S(C_{GS}+C_{GD})}=V_{out}\left(sC_{GD}+sC_{SB}+sC_L+\frac{1}{R_S}\right)$$

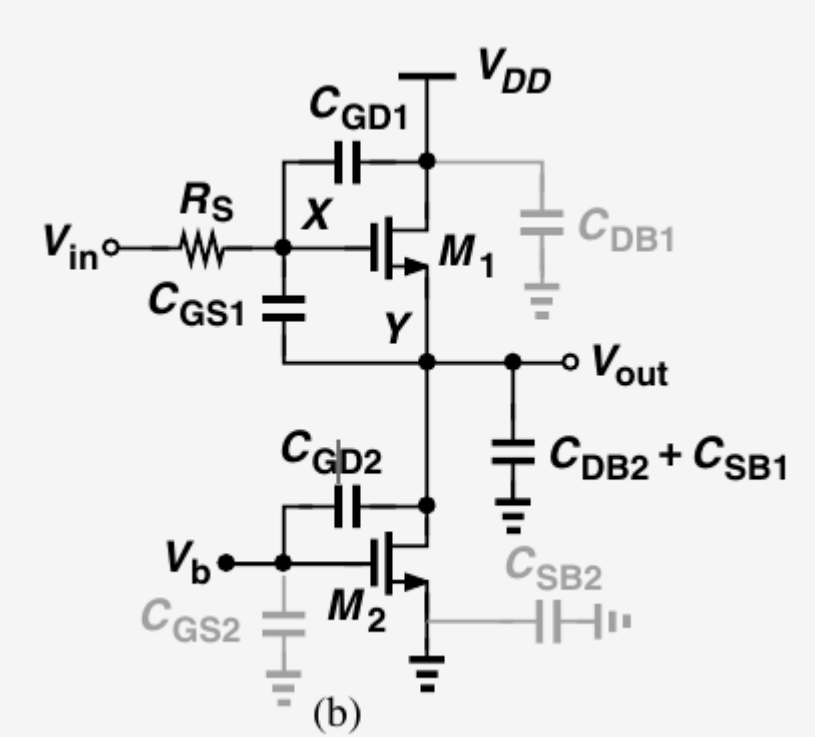
- This leads to

$$\frac{V_{out}}{V_{in}}=\frac{1+s\dfrac{C_{GS}}{g_m}}{1+s\left(R_SC_{GD}+\dfrac{C_{GD}+C_{SB}+C_L}{g_m}\right)+s^2\dfrac{R_S}{g_m}\left\{(C_{GS}+C_{GD})(C_{SB}+C_L)+C_{GD}C_{GS}\right\}}$$

Example 11.22

Determine the transfer function of the source follower shown in Fig. 11.41(a), where M_2 acts as a current source.



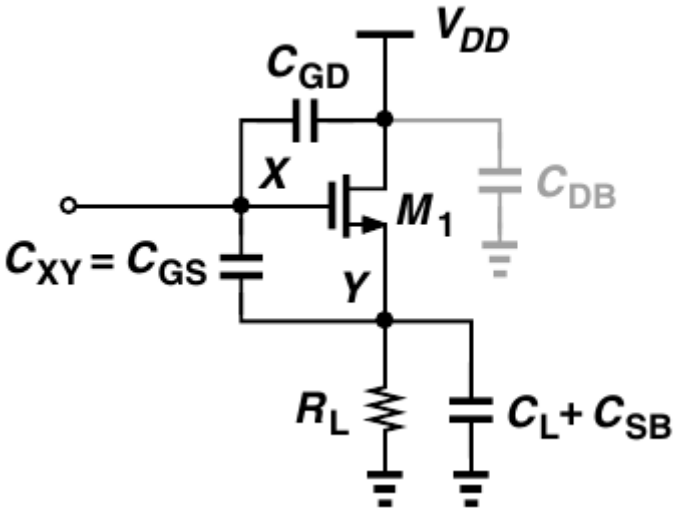


Input Impedance

- SF input resistance approaches infinity at low frequency.

$$A_v = \frac{R_L}{R_L + \dfrac{1}{g_m}}$$

$$C_X = (1 - A_v)C_{XY} = \frac{1}{1 + g_m R_L} C_{XY}$$

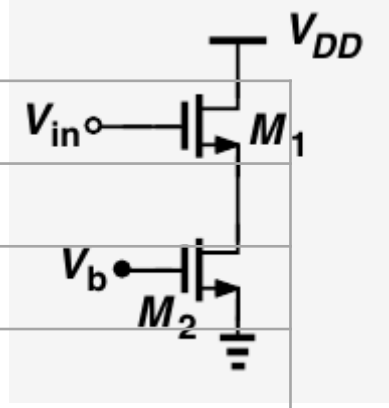


- Total input capacitance would be

$$C_{in} = \frac{1}{1 + g_m R_L} C_{GS} + C_{GD}$$

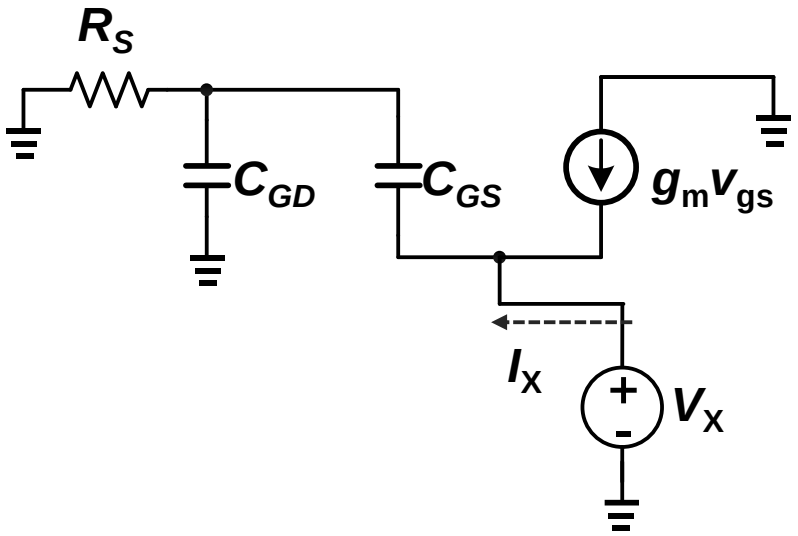
Example 11.23

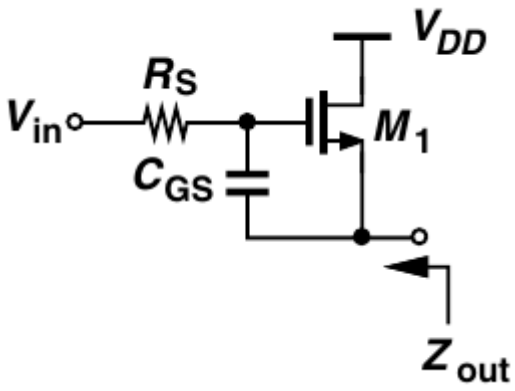
Estimate the input capacitance of the follower shown in Fig. 11.43. Assume $\lambda \neq 0$.



Output Impedance

- For simplicity, other R,C are neglected.



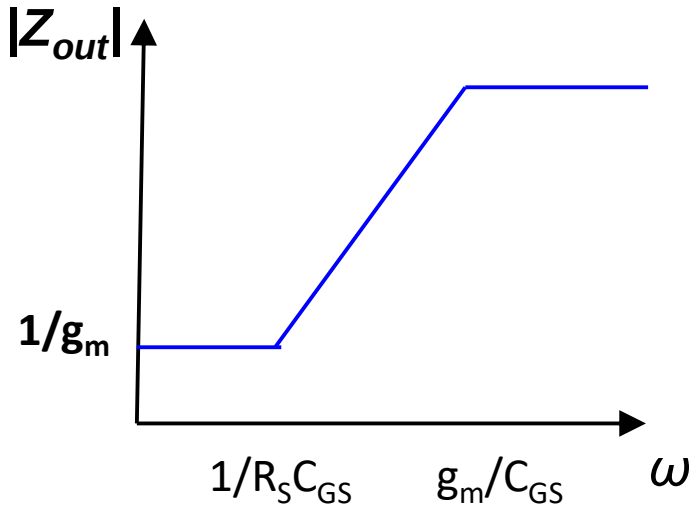


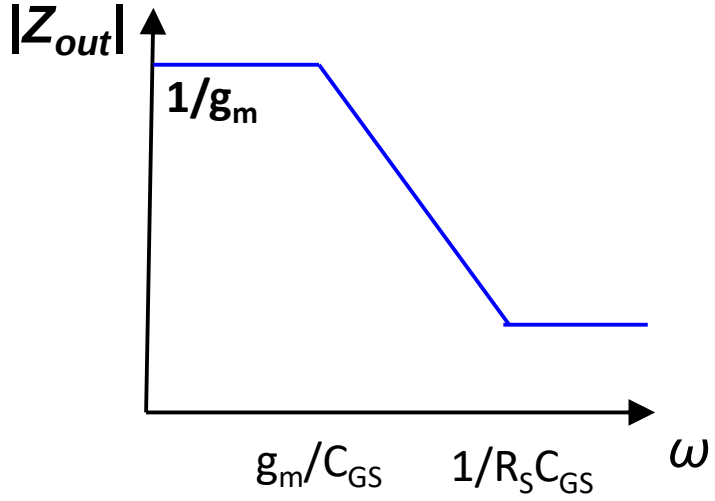
$$\frac{V_X}{I_X} = \frac{R_S C_{GS} s + 1}{C_{GS} s + g_m}$$

Output Impedance vs. Frequency

$$\frac{V_X}{I_X} = \frac{R_S C_{GS} s + 1}{C_{GS} s + g_m} = \frac{1/g_m \left(1 + s R_S C_{GS}\right)}{1 + s(C_{GS}/g_m)}$$

- That is $\omega_z = 1/R_S C_{GS}$ and $\omega_p = g_m/C_{GS}$.





Example 11.24

Figure 11.47 depicts a two-stage amplifier consisting of a CS circuit and a source follower. Assuming $\lambda \neq 0$ for M_1 and M_2 but $\lambda = 0$ for M_3, and neglecting all capacitances except C_{GS3}, compute the output impedance of the amplifier.

