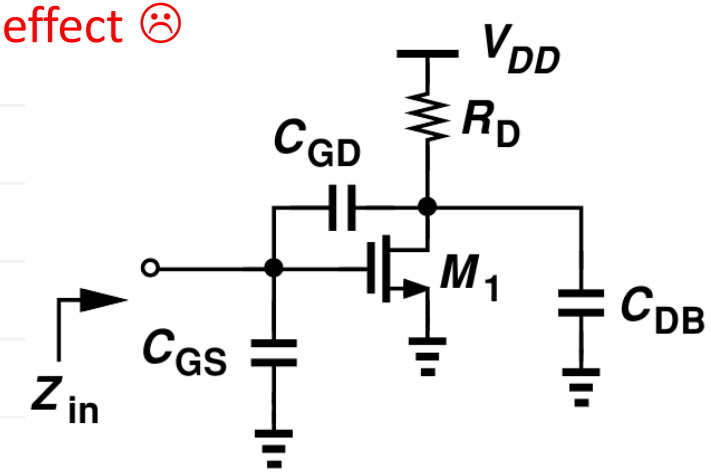
Frequency Response of Cascode Stage & Differential Pairs

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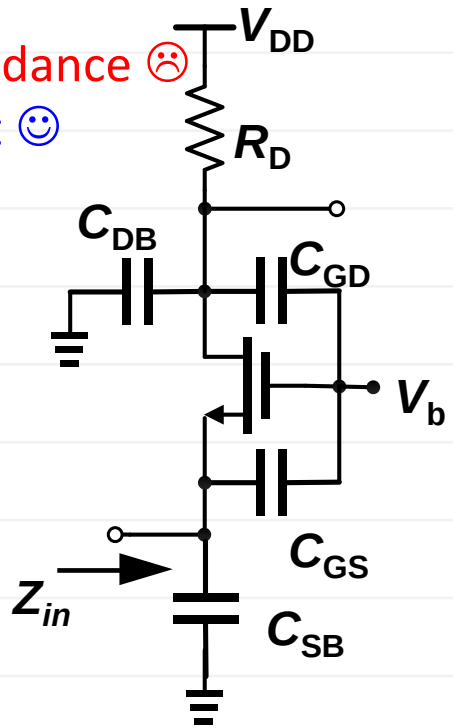
Input Impedance in CS vs. CG

High input impedance ☺
Miller effect ☹



$$Z_{in} \approx \frac{1}{[C_{GS} + (1 + g_m R_D) C_{GD}]s}$$

Low input impedance ☹
No Miller effect ☺



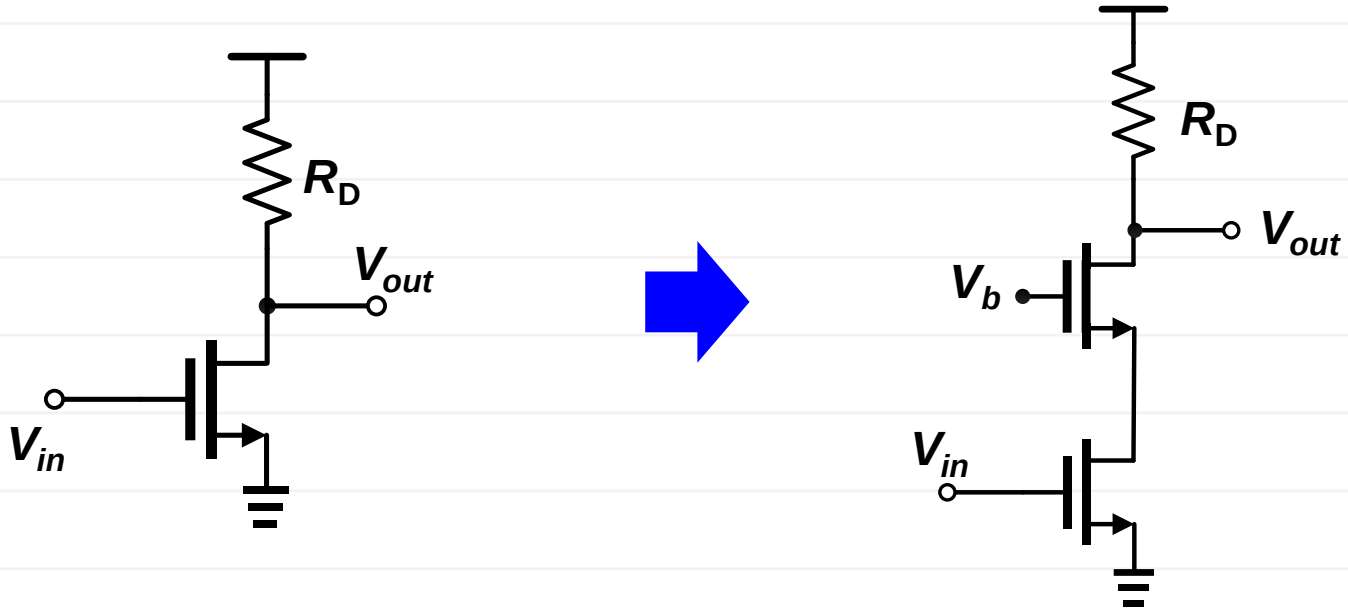
$$Z_{in} \approx \frac{1}{g_m} \| \frac{1}{s(C_{GS} + C_{SB})}$$

➔ Is there any way to combine the two desirable properties?

Frequency Response of Cascode Stage

At Low Frequency,

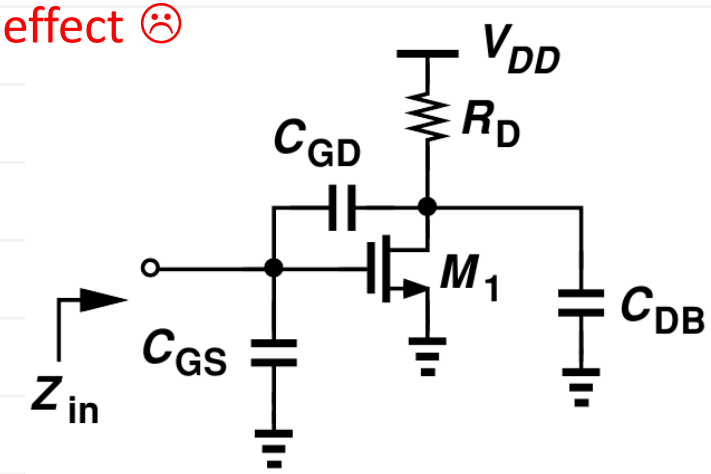
- Assume $R_D << r_o$. Is it beneficial?



Where Does Miller Effect Come From?

High input impedance ☺

Miller effect ☹



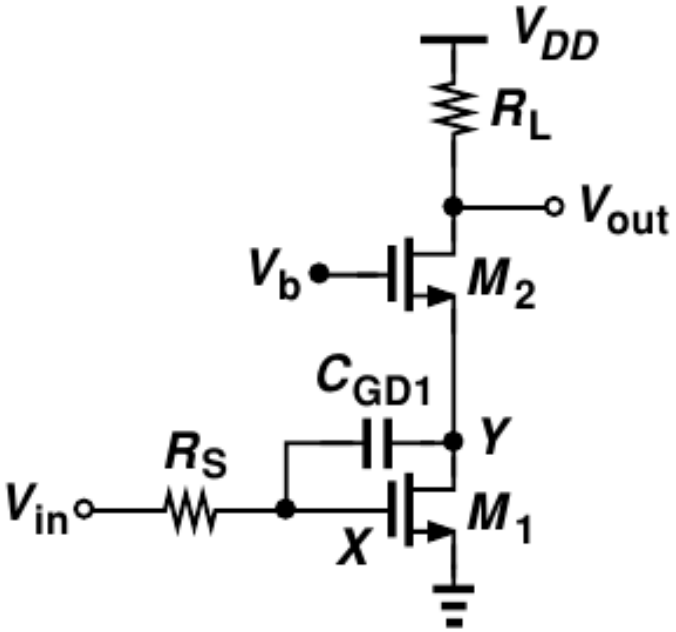
$$Z_{in} \approx \frac{1}{[C_{GS} + (1 + g_m R_D) C_{GD}]s}$$

It is from high gain!

➔ We can reduce Miller Effect by reducing $g_m R_D$

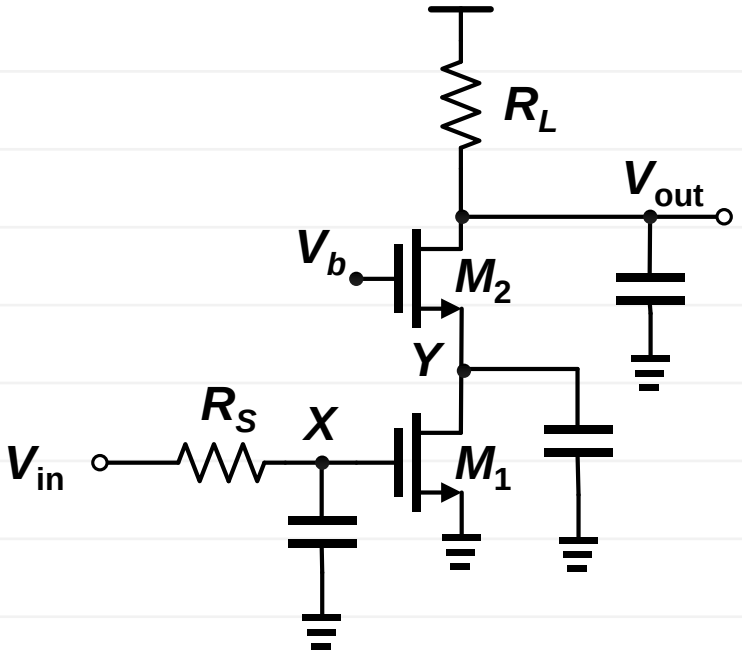
Cascode is Formed

- Can you find the capacitance at the X node being reduced?



Poles of Cascode Stage

- Assuming λ = 0,



$$|\omega_{p,X}| = \frac{1}{R_S\left[C_{GS1} + \left(1 + \frac{g_{m1}}{g_{m2}}\right)C_{GD1}\right]}$$

$$|\omega_{p,Y}| = \frac{1}{\frac{1}{g_{m2}}\left[C_{DB1} + C_{GS2} + \left(1 + \frac{g_{m2}}{g_{m1}}\right)C_{GD1} + C_{SB2}\right]}$$

$$|\omega_{p,out}| = \frac{1}{R_L(C_{DB2} + C_{GD2})}$$

Example 11.25

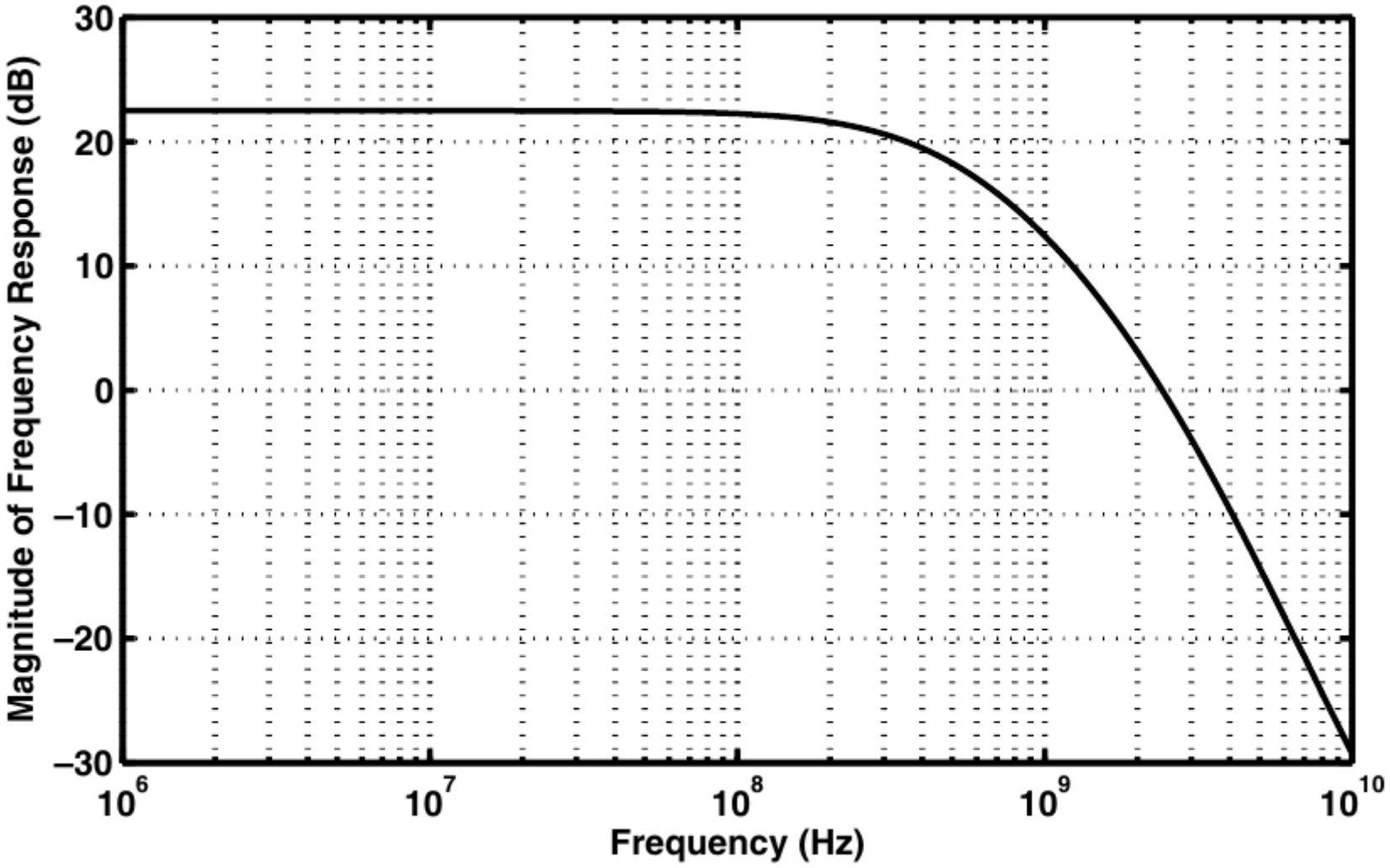
The CS stage studied in Example 11.18 is converted to a cascode topology. Assuming the two transistors are identical, estimate the poles, plot the frequency response, and compare the results with those of Example 11.18. Assume $C_{DB} = C_{SB}$.

- $R_S = 200\Omega$, $C_{GS} = 250$ fF, $C_{GD} = 80$ fF, $C_{DB} = 100$ fF,
- $g_m = (150\Omega)^{-1}$, $\lambda = 0$, and $R_L = 2k\Omega$

$$|\omega_{p,X}| = 2\pi \times (1.95\,\text{GHz})$$

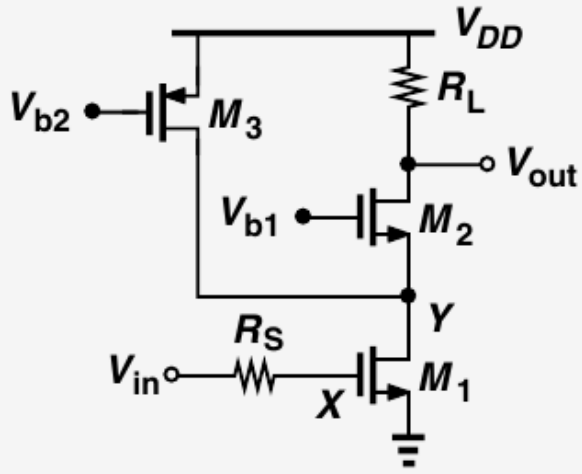
$$|\omega_{p,Y}| = 2\pi \times (1.73\,\text{GHz})$$

$$|\omega_{p,out}| = 2\pi \times (442\,\text{MHz}).$$


Magnitude of Frequency Response (dB)
30
20
10
0
−10
−20
−30
10^6
10^7
10^8
10^9
10^{10}
Frequency (Hz)

Example 11.26

In the cascode shown in Fig. 11.52, transistor M_3 serves as a constant current source, allowing M_1 to carry a larger current than M_2. Estimate the poles of the circuit, assuming $\lambda = 0$.

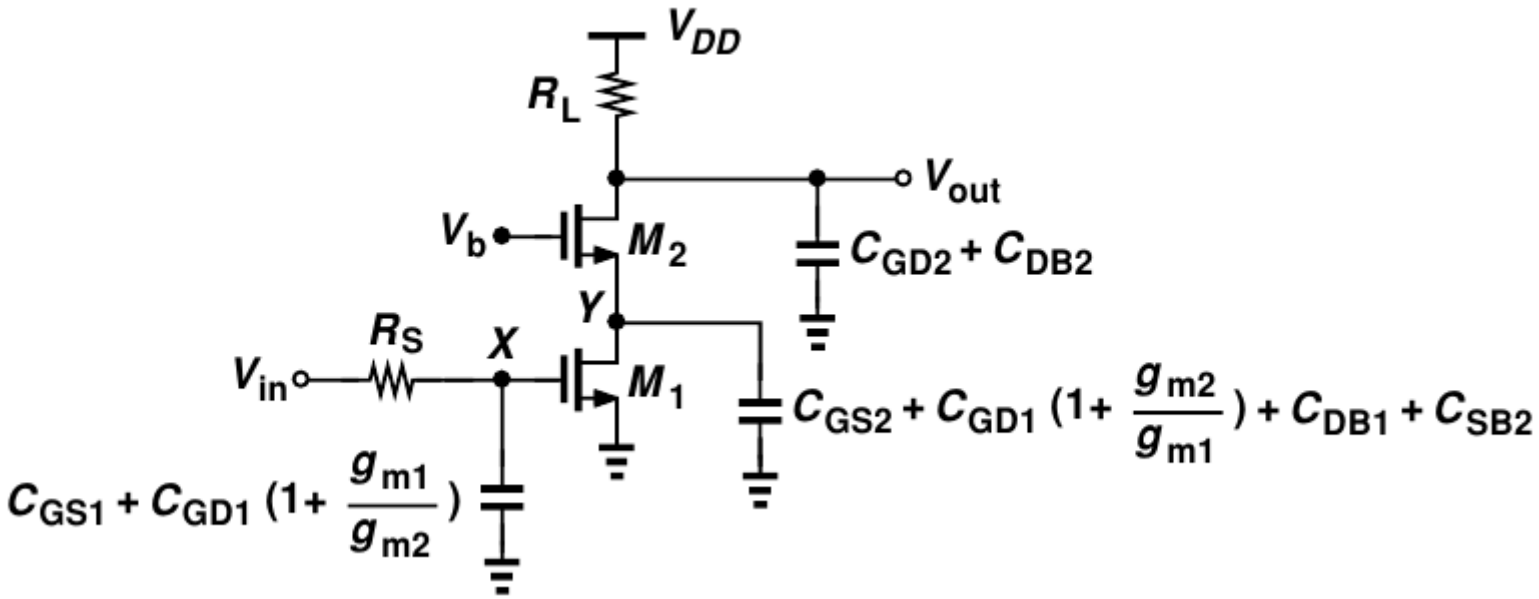


$$|\omega_{p,X}| = \frac{1}{R_S\left[C_{GS1} + \left(1 + \frac{g_{m1}}{g_{m2}}\right)C_{GD1}\right]}$$

$$|\omega_{p,Y}| = \frac{1}{\frac{1}{g_{m2}}\left[C_{DB1} + C_{GS2} + \left(1 + \frac{g_{m2}}{g_{m1}}\right)C_{GD1} + C_{GD3} + C_{DB3} + C_{SB2}\right]}$$

$$|\omega_{p,out}| = \frac{1}{R_L(C_{DB2} + C_{GD2})}.$$

Input & Output Impedance

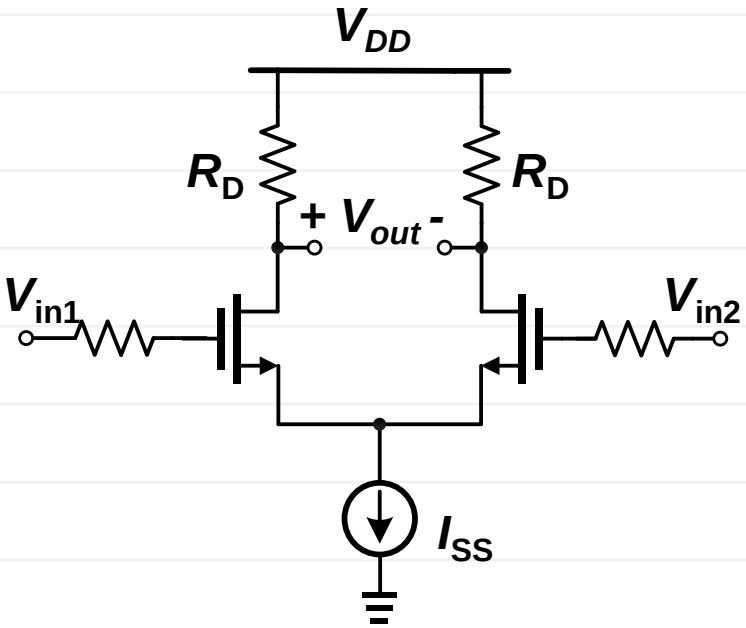


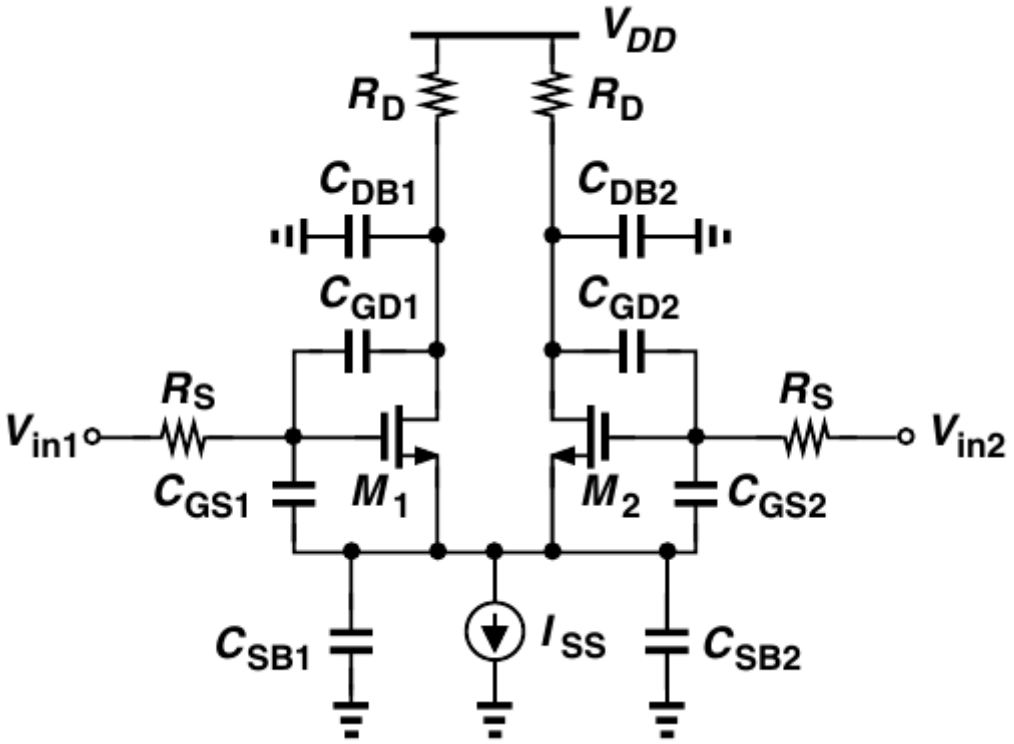
$$Z_{in} = \frac{1}{\left[C_{GS1} + \left(1 + \frac{g_{m1}}{g_{m2}}\right)C_{GD1}\right]s}$$

$$Z_{out} = \frac{1}{R_L(C_{GD2} + C_{DB2})}$$

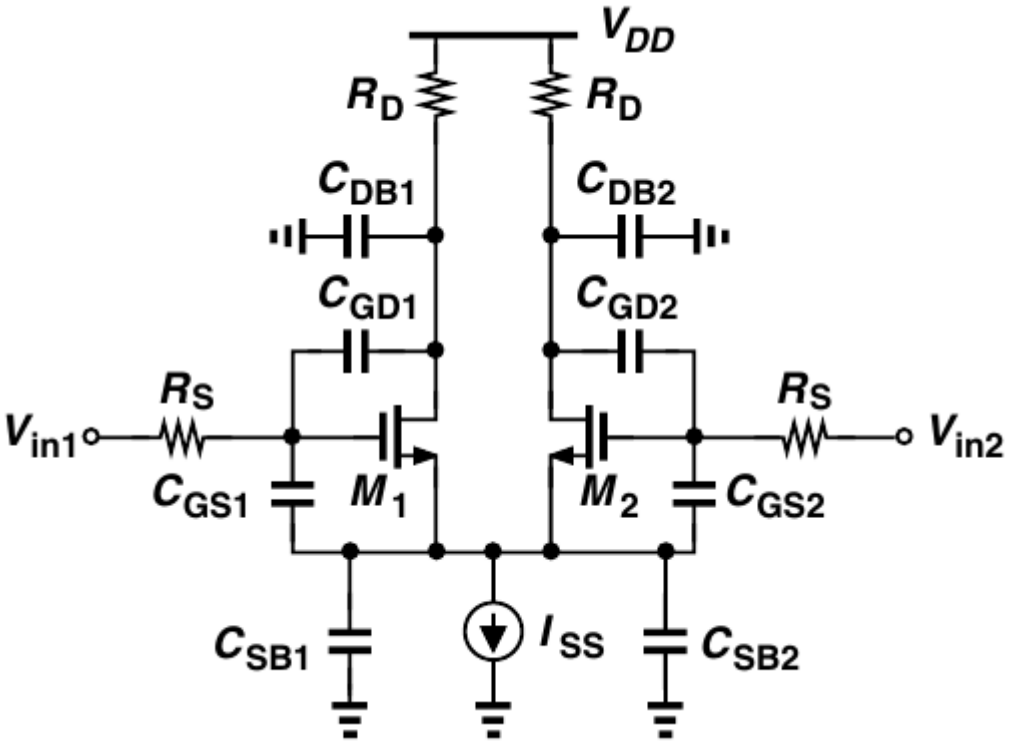
Frequency Response of Differential Pairs

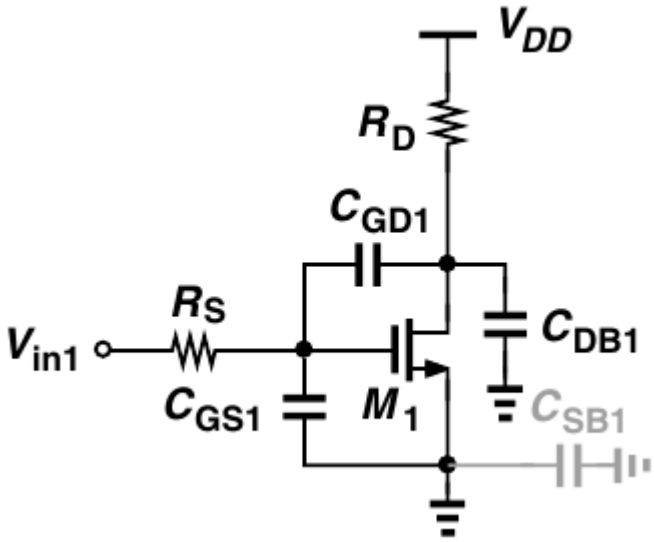
Capacitances in MOSFET Differential Pairs



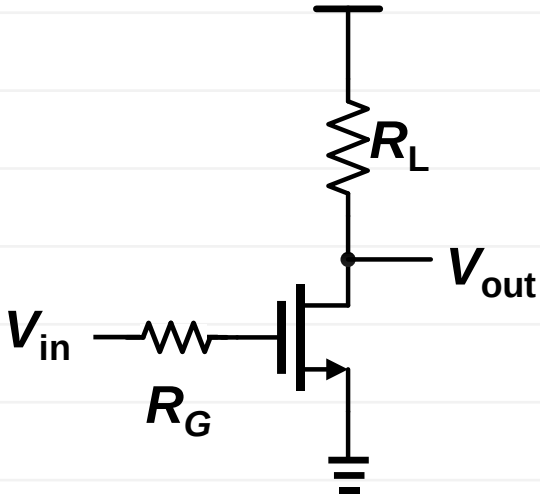


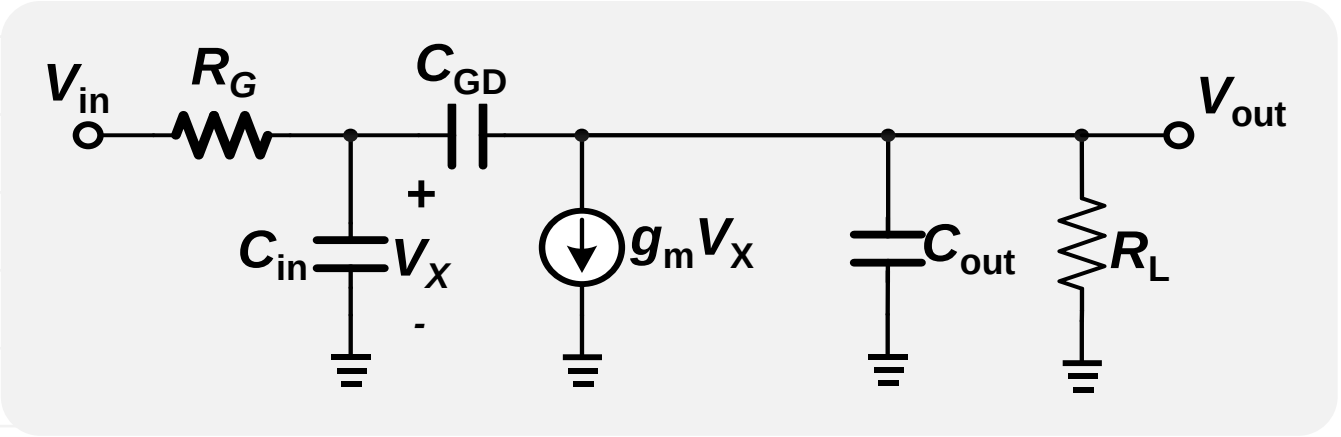
Half Circuit





Revisit CS Stage H(s)

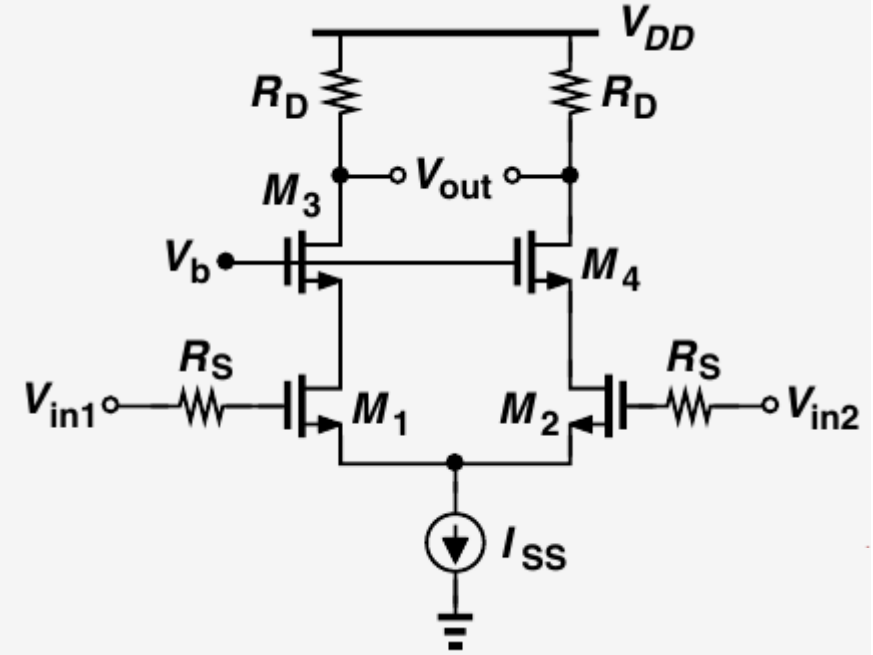




$$\frac{V_{out}}{V_{in}}(s) = \frac{R_L(sC_{GD} - g_m)}{R_L R_G(C_{GD}C_{out} + C_{in}C_{out} + C_{in}C_{GD})s^2 + (g_m R_L R_G C_{GD} + R_G C_{in} + R_G C_{GD} + R_L C_{GD} + R_L C_{out})s + 1}$$

Example 11.27

A differential pair employs cascode devices to lower the Miller effect [Fig. 11.54(a)]. Estimate the poles of the circuit.



$$|\omega_{p,X}| = \frac{1}{R_S\left[C_{GS1} + \left(1 + \frac{g_{m1}}{g_{m3}}\right)C_{GD1}\right]}$$

$$|\omega_{p,out}| = \frac{1}{R_L(C_{DB3} + C_{GD3})}$$

$$|\omega_{p,Y}| = \frac{1}{\frac{1}{g_{m3}}\left[C_{DB1} + C_{GS3} + \left(1 + \frac{g_{m3}}{g_{m1}}\right)C_{GD1} + C_{SB3}\right]}$$