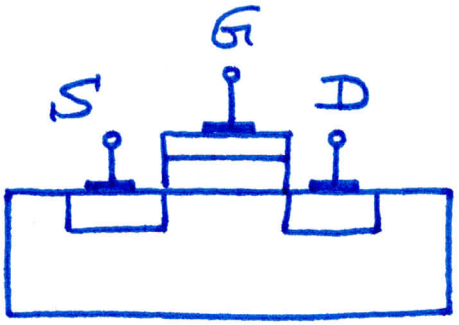
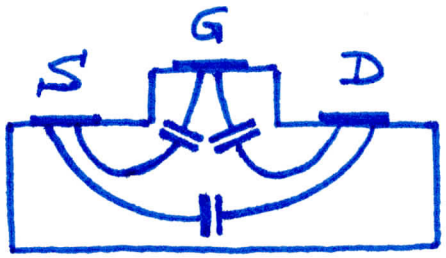
Miller capacitance

⇒ Frequency response of FET

FET



Capacitances ? Parasitic capacitances ?



C_{GS}

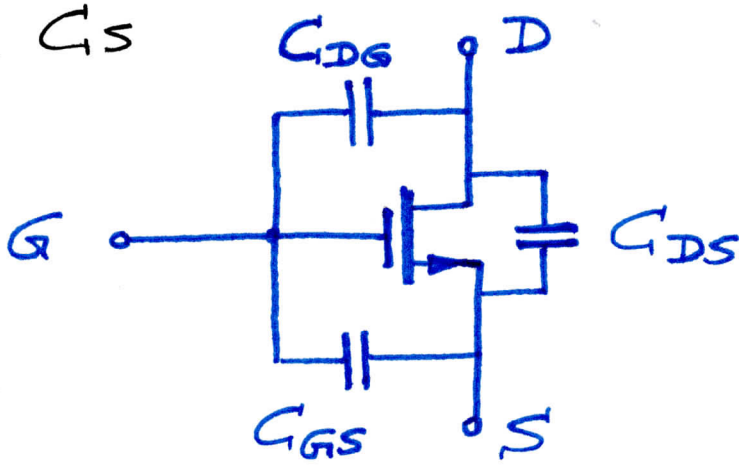
C_{DG}

C_{DS}

Q: Do we need to consider all three C_s ?

Q: Is it sufficient to consider only the most relevant C ?

FET with Cs



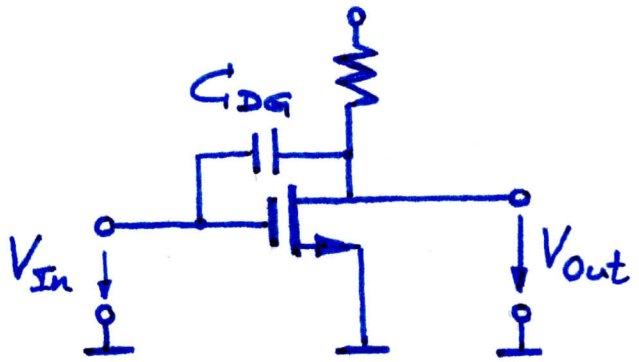
Q: Which C is most important ?

Q: Which C is least important ?

Q: Can we neglect two of the three Cs ?

⇒ Explain your reasoning.

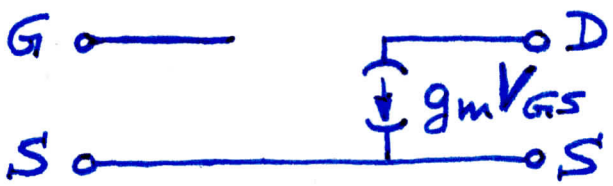
Consider common-S circuit



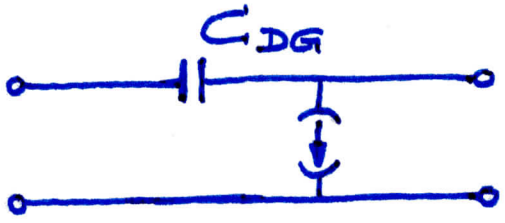
C_{DG} is most important

Equivalent circuit

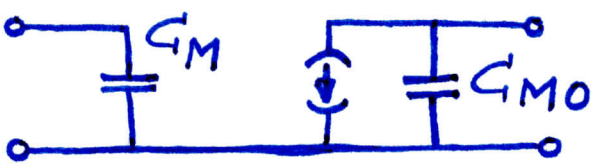
Recall



Now



Modification



$C_M = C_{Miller}$ $C_{MO} = C_{Miller,\,Output}$

Let us calculate C_M

Requirement : C_M and C_{DG} should carry the same charge (same current)

$$I_{In} = V_{DG}\, j\omega C_{DG} = (V_{In} - V_{out})\, j\omega C_{DG}$$

$$= V_{In}(1 + A_{Voc})\, j\omega C_{DG}$$

$$Z_{In} = \frac{V_{In}}{I_{In}} = \frac{V_{In}}{V_{In}(1+A_{Voc})\, j\omega C_{DG}} = \frac{1}{j\omega C_M}$$

where

$$C_{Miller} = (1 + A_{Voc})\, C_{DG} \quad \text{For } R_L = \infty$$

$$C_{Miller} = (1 + A_V)\, C_{DG} \quad \text{For } R_L < \infty \ (R_{Load} = \text{finite})$$

Let us calculate C_{MO} → on output side

$$I_{out} = (V_{out} - V_{In})\, j\omega C_{DG} = V_{out}\left(1 + \frac{1}{A_{Voc}}\right) j\omega C_{DG}$$

$$Z_{out} = \frac{V_{out}}{I_{out}} = \frac{V_{out}}{V_{out}\left(1 + \frac{1}{A_{Voc}}\right) j\omega C_{DG}} = \frac{1}{j\omega C_{MO}}$$

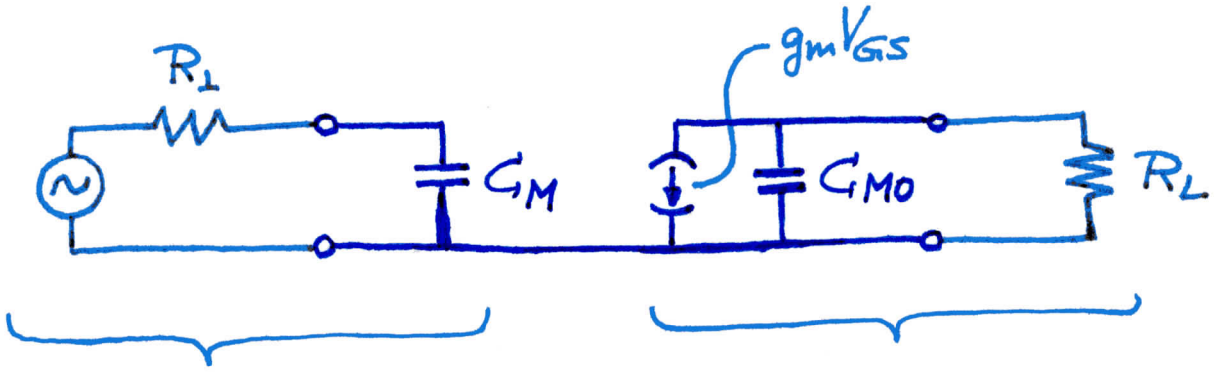
where

$$C_{MO} = (1 + A_{Voc}^{-1})\, C_{DG} \approx C_{DG}$$

Note: $C_M \gg C_{DG} \Rightarrow$ FET amplifies effect of C_{DG}.

$C_{MO} \approx C_{DG}$

Inclusion of C_M and C_{MO} in equivalent circuit



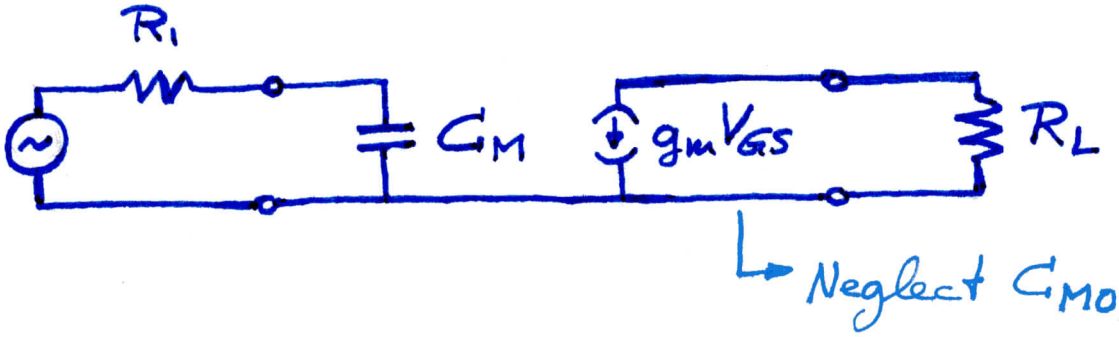
$\tau_{In} = R_1 C_M$ $\qquad$ $\tau_{out} = R_L C_{MO}$

Q: Which one is smaller τ_{In} OR τ_{out} ?

$\Rightarrow \tau_{out}$ is smaller ($C_{MO} \ll C_M$ & $R_L < R_1$)

Q: Neglect C_{MO} ? $\Rightarrow$ Yes.

Simplified equivalent circuit



⇒ Longest time constant is the limiting time constant.

⇒ Relevant time constant:

$$\tau = RC = R_1 C_{Miller} = R_1 C_M$$

⇒ Frequency response

$$\omega_{knee} = \frac{1}{RC} = \frac{1}{R_1 C_M}$$

Q: How can frequency response be improved?

⇒ Reduce R_1

Q: How can R_1 be reduced?

⇒ Use low-output-impedance pre-amplifier (e.g. source follower).