Chapter 3

$$g_m = \mu_n C_{ox} \frac{W}{L} V_{eff}$$

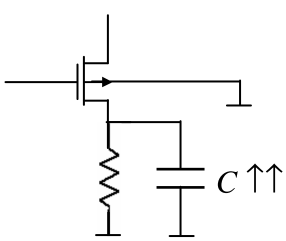
$$g_m = \sqrt{2\mu_n C_{ox} \frac{W}{L} I_D}$$

If source is at a different potential than body contact, you have body effect.

$$V_{t_n} = V_{t_{n0}} + \gamma(\sqrt{V_{SB} + |2\Phi_f|} - \sqrt{2\Phi_f})$$

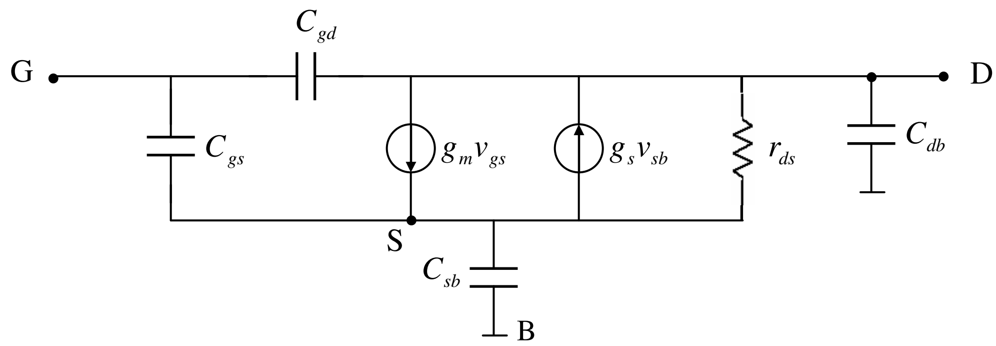
You also introduce an additional trans-conductance known as body effect trans-conductance g_s.

g_s exists only when $V_{SB} \neq 0$ $\rightarrow$ at ac



→ in this case although you have body effect changing your V_{t_n}, but it does not effect your overall trans-conductance $(v_s = 0)$

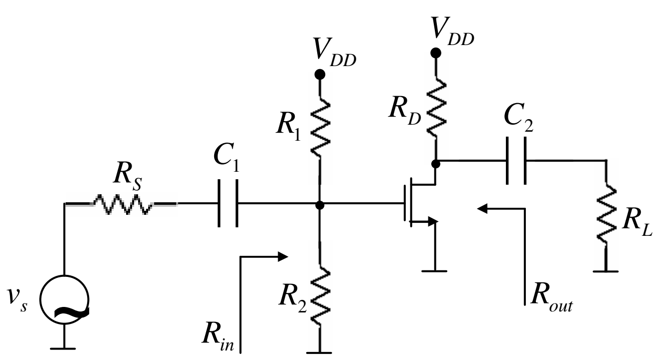
Equivalent circuit is modified:



$$g_s = \frac{\gamma g_m}{2\sqrt{V_{SB} + |2\Phi_f|}}$$

Common Source Amplifier

Non-integrated form



$$V_{GS} = \frac{R_2}{R_1 + R_2} V_{DD}$$

Ideal MOS equation valid only

$$I_D = \frac{\mu C_{ox} W}{2L}(V_{GS} - V_{t_n})^2$$

$$V_{DS} > V_{GS} - V_{t_n}$$

$$V_{DS} = V_{DD} - R_D I_D$$

$$A_v = -g_m \frac{(R_D \| R_L \| r_{ds})(R_2 \| R_1)}{R_2 \| R_1 + R_S}$$

$$R_{in} = R_1 \| R_2$$

$$R_{out} = R_D \| r_{ds}$$

- R_1, R_2 and R_D are set by biasing condition

- R_S and R_L are not part of the circuit and are given based on the design specifications

-in mid-range frequencies, assume:

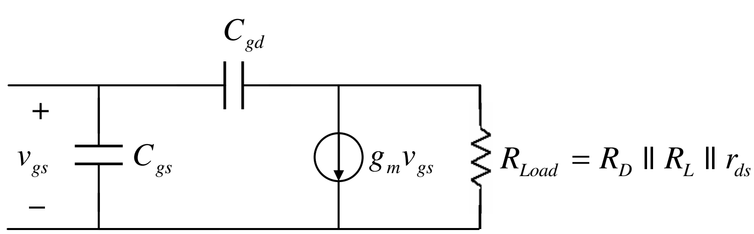
C_1 , $C_2 = \infty$

C_{gs} , $C_{gd} = 0$

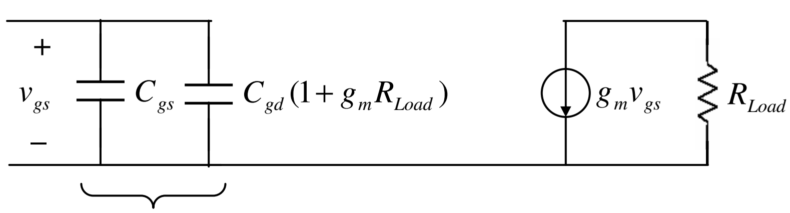
Calculate high frequency bandwidth of common source amplifier.

→ use either miller effect or method of open circuit time constants $OC\tau$.

Miller effect



$$\equiv$$



$$C_{gs} + C_{Miller} = C_{gs} + C_{gd}(1+g_m R_{Load})$$

You can now calculate the transfer function of a one-pole system.

$$\left.\begin{aligned} V_{out} &= -g_m R_{Load} V_{gs} \\ V_{gs} &= V_{in} \frac{Z_1}{Z_1 + R_S} \\ Z_1 &= \frac{1}{j\omega(C_{Miller} + C_{gs})} \parallel R_1 \parallel R_2 \end{aligned}\right\} \rightarrow \; A_v(f) = \frac{g_m R_{Load} \cdot \dfrac{R_1 R_2}{R_1 R_2 + R_S R_1 + R_S R_2}}{1 + j\omega C_{Miller} \cdot \dfrac{R_1 R_2 R_S}{R_1 R_2 + R_S R_1 + R_S R_2}}$$

$$\rightarrow \quad A_v(f) = \frac{A_v}{1 + j\omega(C_{Miller} + C_{gs})(R_1 \parallel R_2 \parallel R_S)}$$

$$\omega_h = \frac{1}{(R_1 \parallel R_2 \parallel R_S)(C_{gs} + C_{gd}(1 + g_m(R_L \parallel R_D \parallel r_{ds})))}$$

Using OCT

Steps to find ω_h:

1- find simplified equivalent circuit

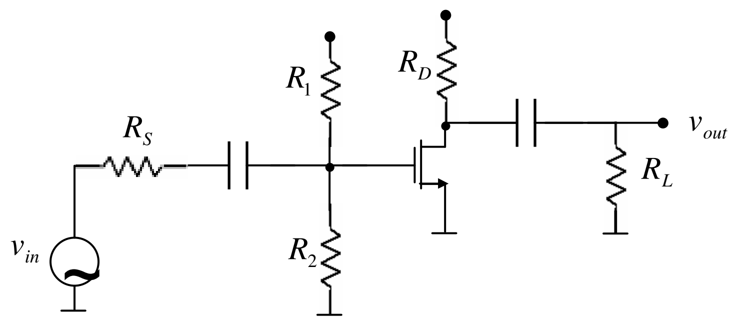
2- get rid of capacitors that are not gain limiting at high frequency (typically coupling and bypass capacitors)

3- for each remaining capacitor, calculate the effective resistance facing the capacitor while the rest of capacitors are open-circuit (R_{jo})

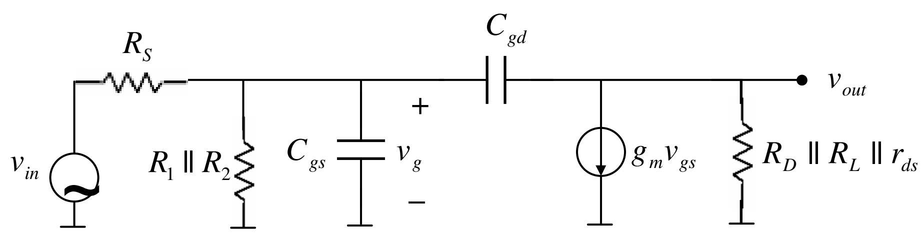
4- calculate $\omega_h = \dfrac{1}{R_{1o} C_1 + R_{2o} C_2 + \ldots}$

do it for:

<u>Common Source Amplifier</u>

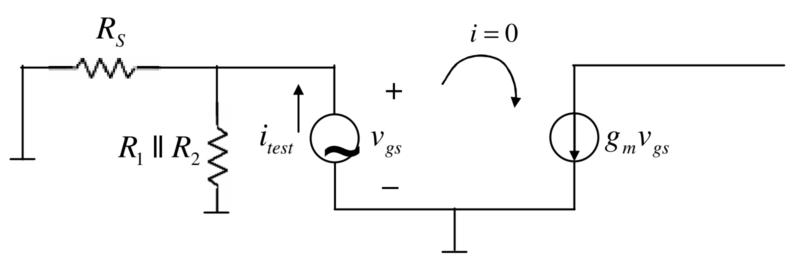


<u>Step1, 2</u>



<u>Step3</u>

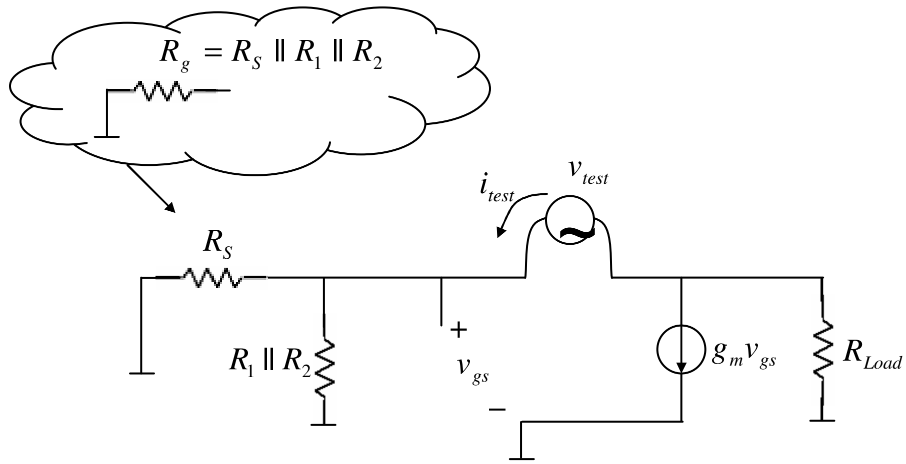
For C_{gs}:



$$i_{test} = \frac{v_{test}}{R_1 \parallel R_2 \parallel R_S} \quad \rightarrow \quad R_{1o} = R_1 \parallel R_2 \parallel R_S$$

$$\tau_1 = C_{gs}(R_1 \parallel R_2 \parallel R_S)$$

For C_{gd}:



$$\left.\begin{array}{l} v_{test} = i_{test}(R_g) + (i_{test} + g_m v_{gs})R_{Load} \\ \\ v_{gs} = i_{test} \cdot R_g \end{array}\right\} \rightarrow \; v_{test} = i_{test}(R_g + R_{Load} + g_m R_g R_{Load})$$

$$R_{o2} = \frac{v_{test}}{i_{test}} = R_g + R_{Load} + g_m R_g R_{Load}$$

$$\rightarrow \quad R_{o2} = R_1 \parallel R_2 \parallel R_S + (R_L \parallel R_D \parallel r_{ds})(1 + g_m(R_1 \parallel R_2 \parallel R_S))$$

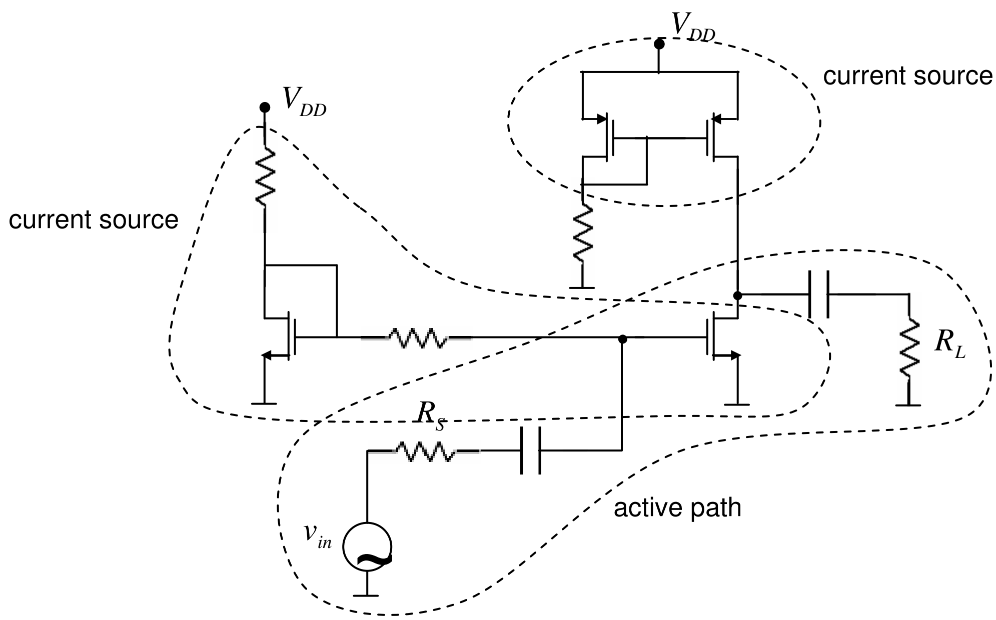
$$\tau_2 = C_{gd} R_{02}$$

For C_{ds} $\rightarrow$ $R_{o3} = R_{Load}$, $\tau_3 = C_{ds}(R_L \parallel R_D \parallel r_{ds})$

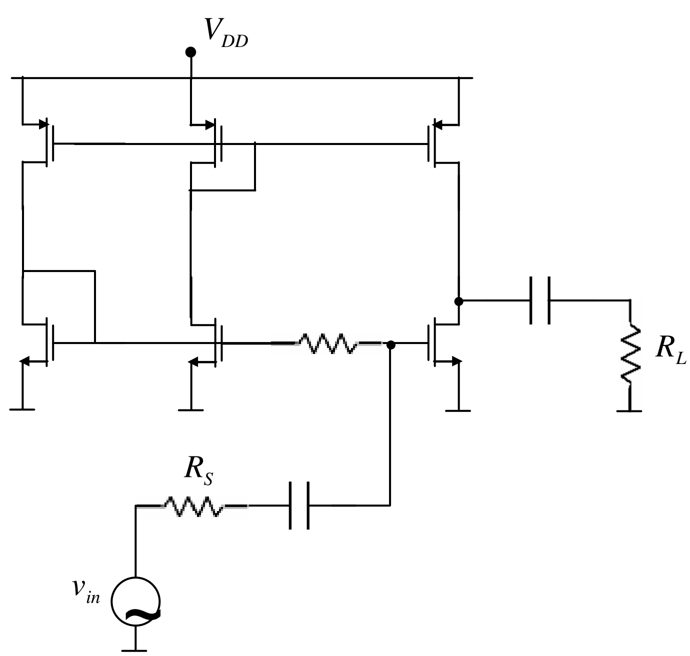
$$\omega_h = \frac{1}{\underbrace{\tau_1 + \tau_2 + \tau_3}}$$

should be very close to what Miller solution gave us.

Now consider an integrated version of common source amplifier:

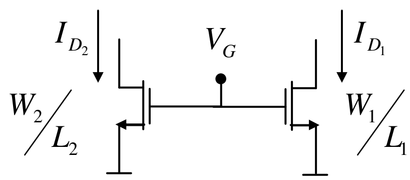


Or you can combine the two current sources:



But how a current source works?

First consider two gate-coupled transistors:



Assuming $V_G > V_{t_n}$ and ideal MOS operation:

$$I_{D_1} = \mu_n C_{ox} \frac{W_1}{2L_1}(V_G - V_{t_{n1}})^2$$

$$I_{D_2} = \mu_n C_{ox} \frac{W_2}{2L_2}(V_G - V_{t_{n2}})^2$$

If $V_{t_{n1}} = V_{t_{n2}}$ → $\boxed{\dfrac{I_{D_1}}{I_{D_2}} = \dfrac{W_1/L_1}{W_2/L_2}}$

So if you set the current in one branch you can set the other one.