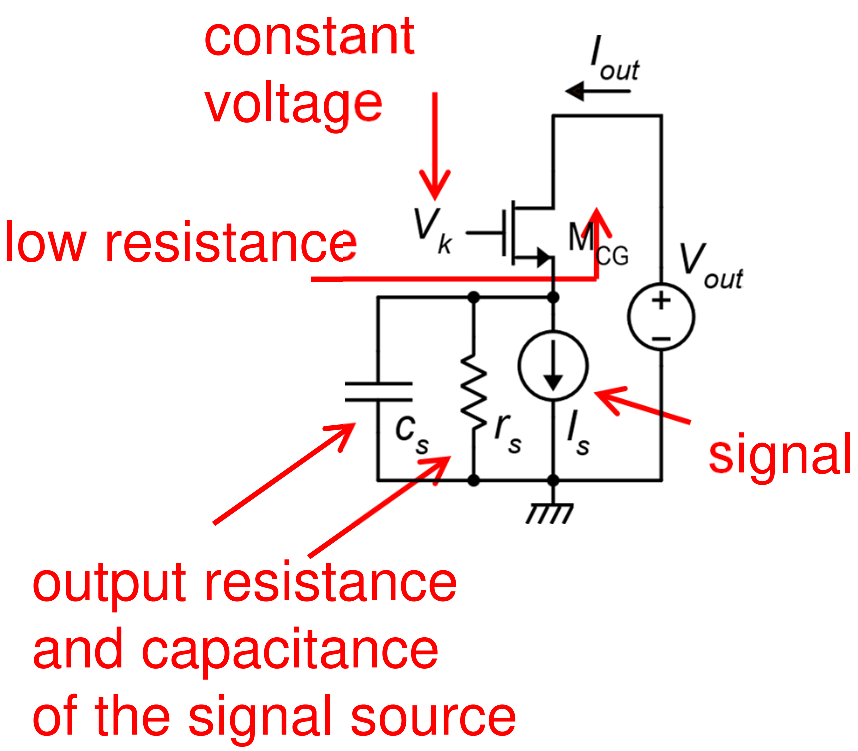
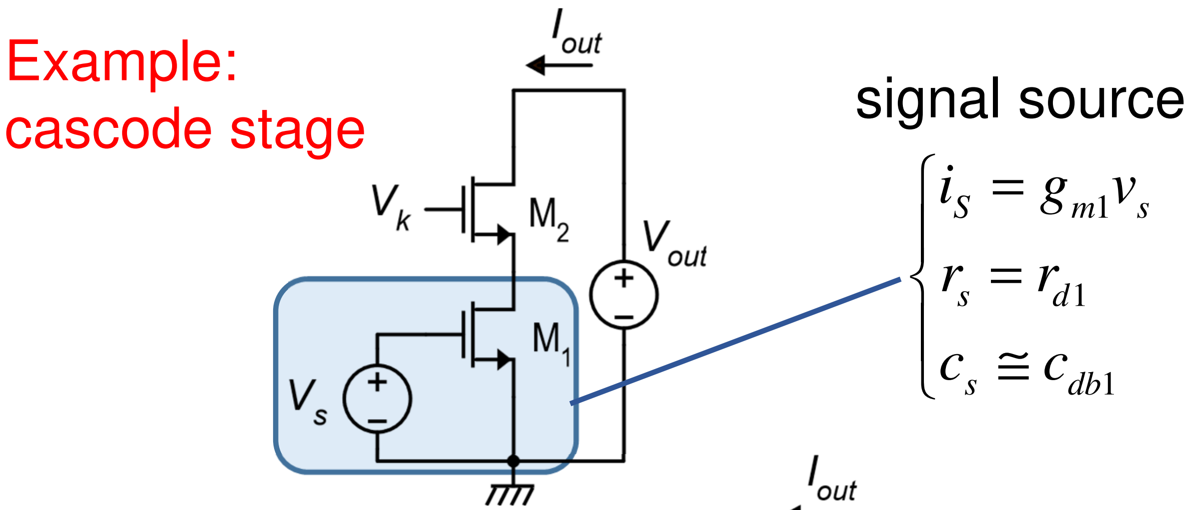
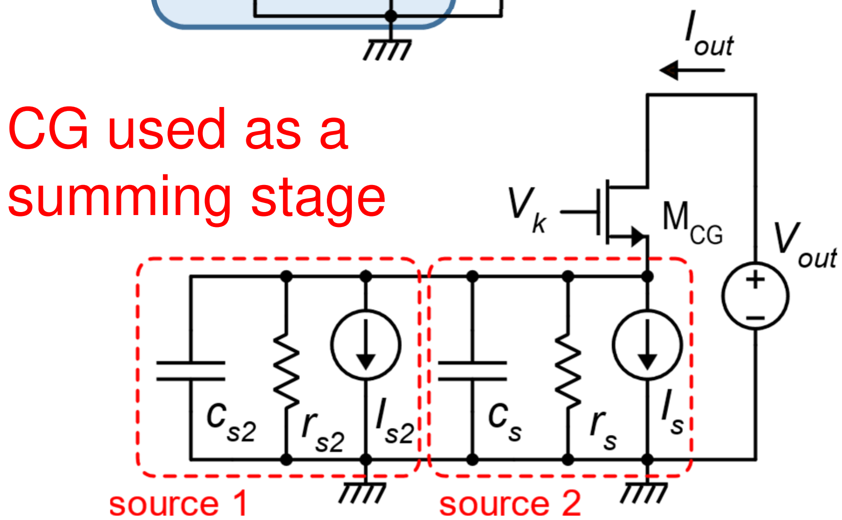
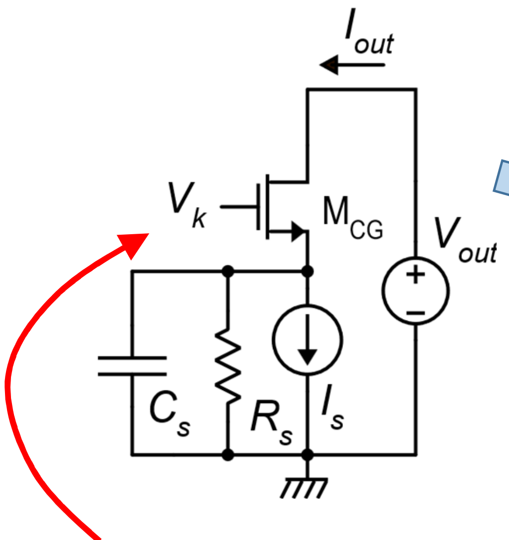
The common gate (CG) stage



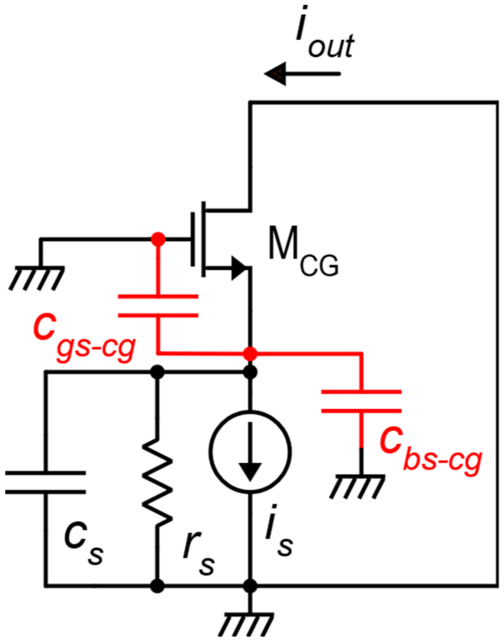




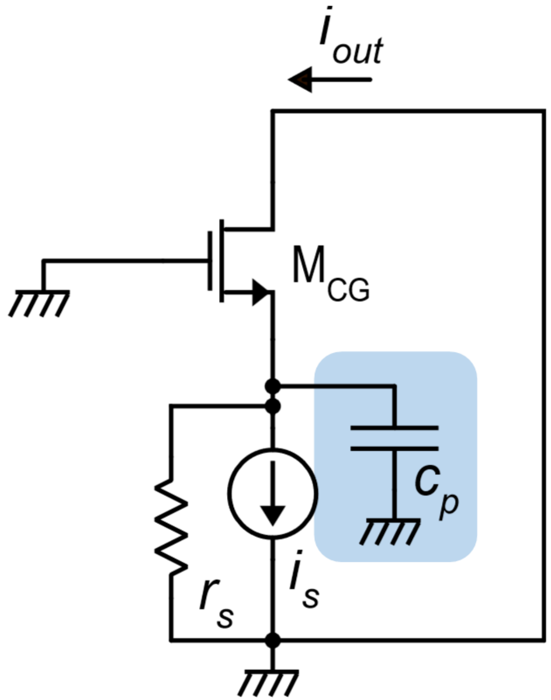
Frequency response of the common gate stage



Hypothesis: V_k is at *gnd* in the small signal circuit. For example, it is provided by an ideal voltage source

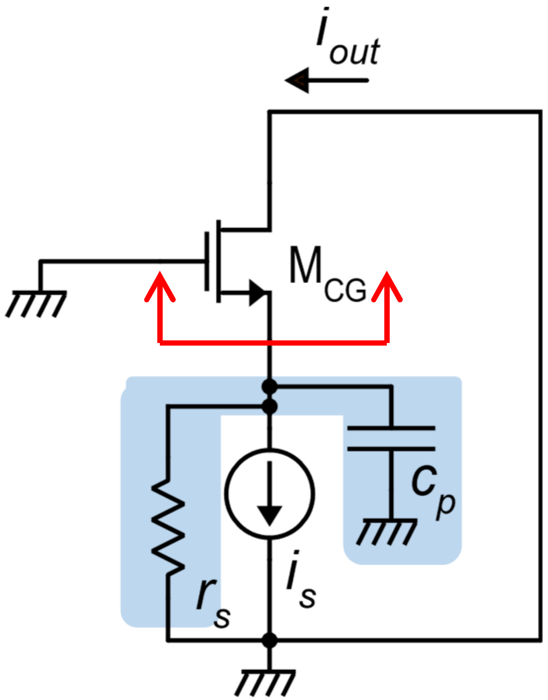


small-signal circuit
with parasitic capacitances



$$c_p = c_{gs-cg} + c_{bs-cg} + c_s$$

Frequency response of the common gate stage



$$R_{in} = \frac{1}{g_{mb-cg} + g_{m-cg}} \cong \frac{1}{g_{m-cg}}$$

current division between R_{in} and z_s

$$i_{out} = i_s \frac{z_s}{z_s + \frac{1}{g_{m-cg}}} = i_s \frac{1}{1 + \frac{1}{g_{m-cg} z_s}}$$

$$\frac{1}{z_s} = \frac{1}{r_s} + sc_p$$

$$i_{out} = i_s \frac{1}{1 + \frac{1}{g_{m-cg}}\left(\frac{1}{r_s} + sc_p\right)}$$

$$i_{out} = i_s \frac{1}{1 + \frac{1}{g_{m-cg} r_s} + \frac{sc_p}{g_{m-cg}}}$$

Frequency response of the common gate stage

$$i_{out} = i_s \frac{1}{1+\frac{1}{g_{m-cg} r_s}+\frac{s c_p}{g_{m-cg}}}$$

$$\frac{i_{out}}{i_s} = A_I(s) = \frac{1}{1+\frac{1}{g_{m-cg} r_s}} \cdot \frac{1}{1+s\frac{c_p}{g_{m-cg}}\left(1+\frac{1}{g_{m-cg} r_s}\right)^{-1}}$$

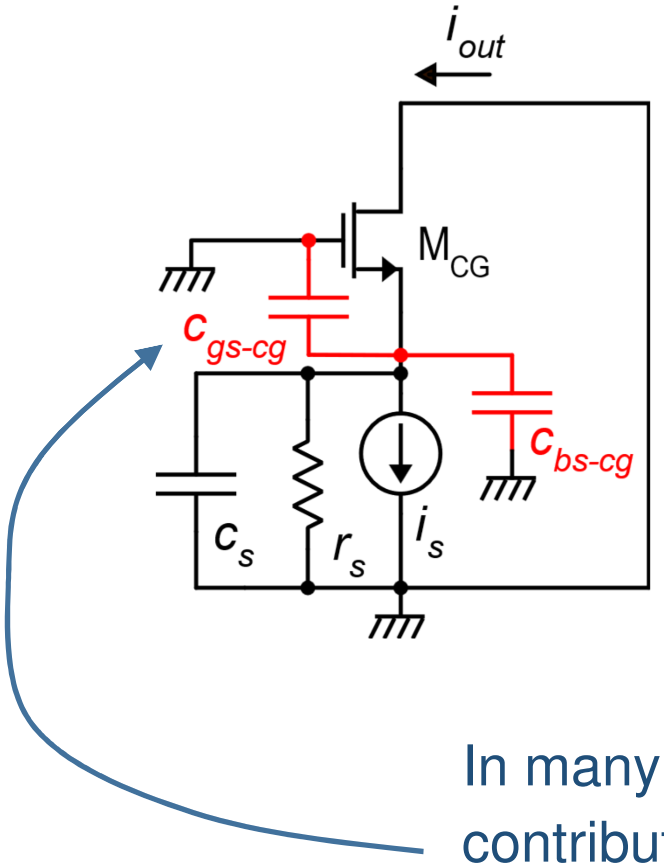
$A_{I-CG}(0)$

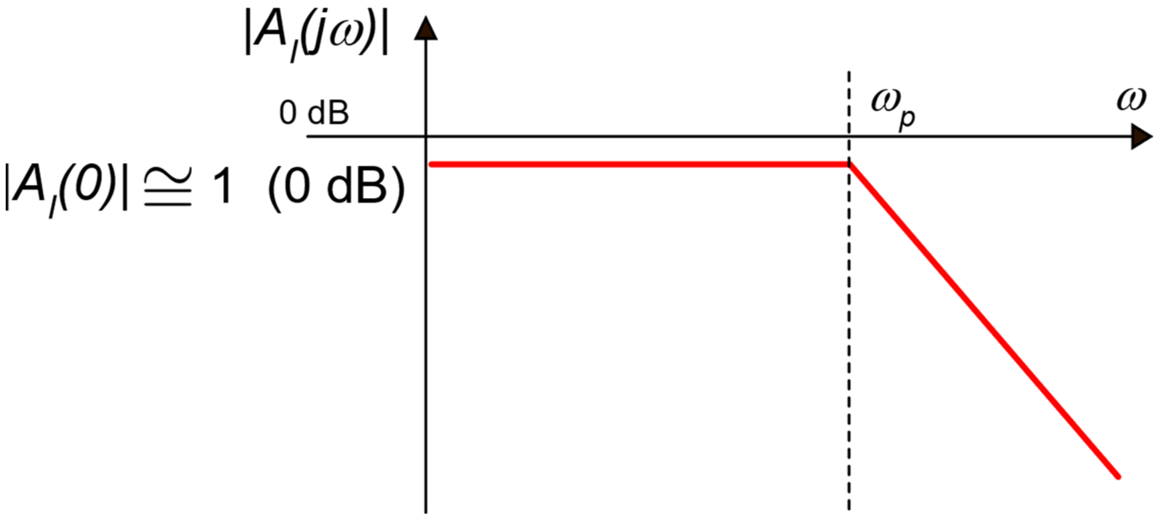
$$A_{I-CG}(s) = A_{I-CG}(0)\frac{1}{1+\frac{s}{\omega_p}}$$

Typical case: $r_s \gg \frac{1}{g_{m-cg}} \Rightarrow g_{m-cg} r_s \gg 1$

$$A_{I-CG}(0) = \frac{1}{1+\frac{1}{g_{m-cg} r_s}} \cong 1 \qquad \omega_p \cong \frac{g_{m-cg}}{c_p}$$

Frequency response of the common gate stage



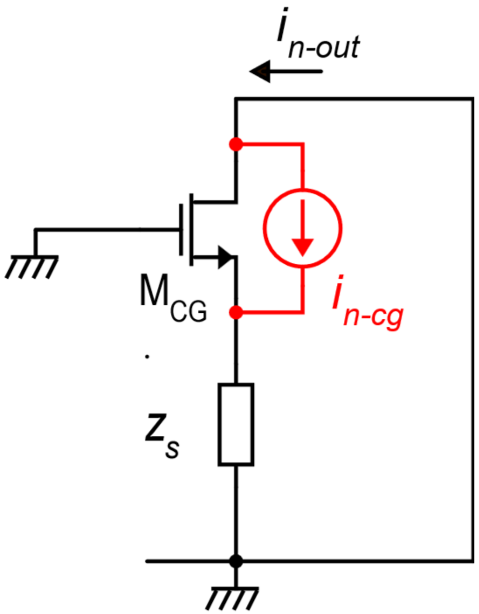


$$\omega_p \cong \frac{g_{m-cg}}{c_p}$$

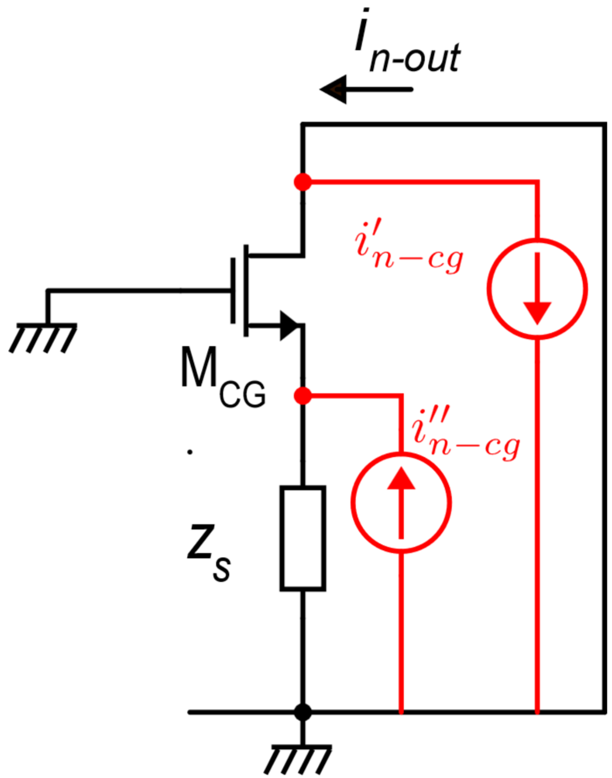
$$f_p \cong \frac{1}{2\pi}\frac{g_{m-cg}}{c_{gs-cg}} \cong f_{T-CG}$$

In many cases, the main contribution to $\boldsymbol{c_p}$ is the $\mathbf{c_{gs}}$ of the CG MOSFET

Noise contribution of a CG stage



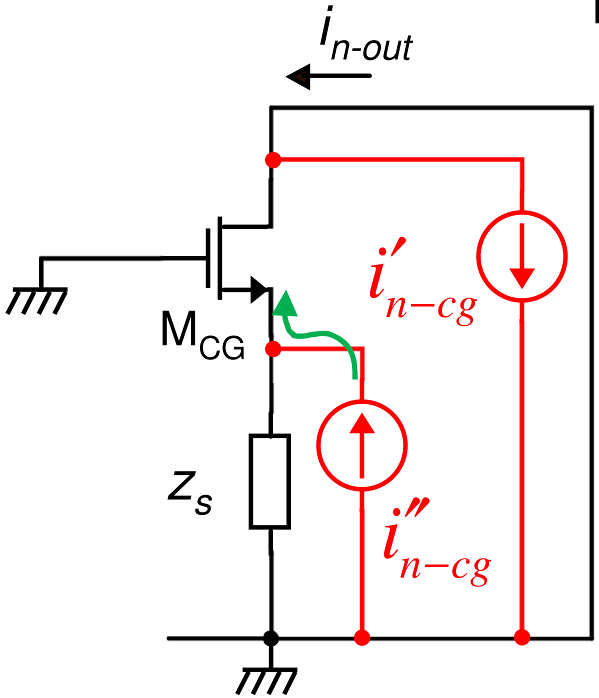
$$z_s = c_p // r_s$$



Every time we have a floating current source, we can split it into two sources with one terminal at ground

$$i'_{n-cg} = i''_{n-cg} = i_{n-cg}$$

Noise contribution of a CG stage



$$i_{n-out} = i'_{n-cg} - i''_{n-cg} A_I(s) = i_{n-cg}\left[1 - A_I(s)\right]$$

$$i'_{n-cg} = i''_{n-cg} = i_{n-cg}$$

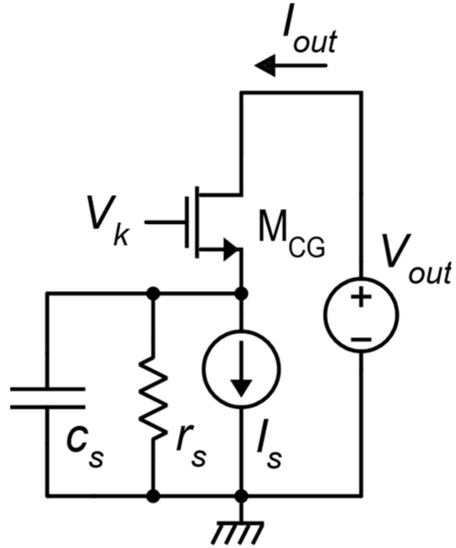
In DC: $$A_I = A_{I-CG}(0) = \frac{1}{1+\dfrac{1}{g_{m-cg} r_s}} = \frac{g_{m-cg} r_s}{1+g_{m-cg} r_s}$$

$$1 - A(0) = 1 - \frac{g_{m-cg} r_s}{1+g_{m-cg} r_s} = \frac{1}{1+g_{m-cg} r_s}$$

$$\frac{i_{n-out}}{i_{n-cg}} \cong \frac{1}{1+g_{m-cg} r_s}$$

Summary of properties of a CG stage in typical cases

$$r_s >> \frac{1}{g_{m-cg}} \Rightarrow g_{m-cg} r_s >> 1$$



1. $$A_{I-CG}(0) = \frac{g_{m-cg} r_s}{1+g_{m-cg} r_s} \cong 1$$

2. $$\omega_p \cong \frac{g_{m-cg}}{c_p} \qquad c_p \cong c_{gs-cg}$$

3. $$\frac{i_{n-out}}{i_{n-cg}} = |1 - A(j\omega)|$$ ← Usually, this factor is << 1 for $f << f_p = \frac{\omega_p}{2\pi}$

In DC: $$\frac{i_{n-out}}{i_{n-cg}} = \frac{1}{1+g_{m-cg} r_s} \cong \frac{1}{g_{m-cg} r_s} << 1$$