Source Followers & Summary

zrrraa

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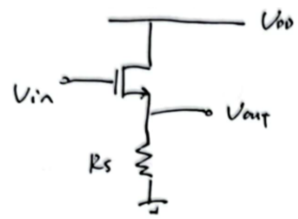
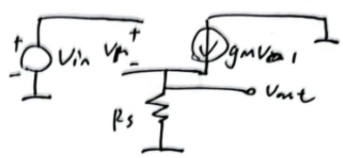
Source Followers



Draw the small signal model.



We get:

$$\begin{cases} v_{in} = v_1 + v_{out} \\ \frac{v_{out}}{R_s} = g_m v_1 \end{cases}$$

So:

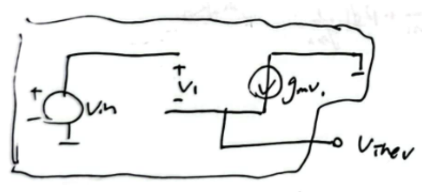
$$A_v = \frac{R_s}{\frac{1}{g_m} + R_s}$$

In other words, $A_v = \frac{Resistance\ tied\ between\ S\ and\ GND}{\frac{1}{g_m}+Resistance\ tied\ between\ S\ and\ GND}$.

Alternative Analysis

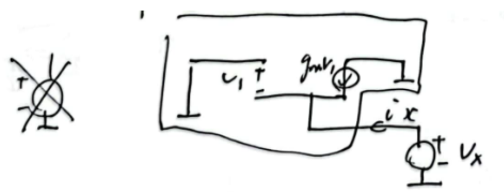
We can also use Thevenin Equivalent to analyze the source follower.

First, let's think of the source follower as a voltage source.



$$g_m v_1 = 0 \Longrightarrow v_1 = 0 \Longrightarrow v_{in} = v_{Thevenin}$$

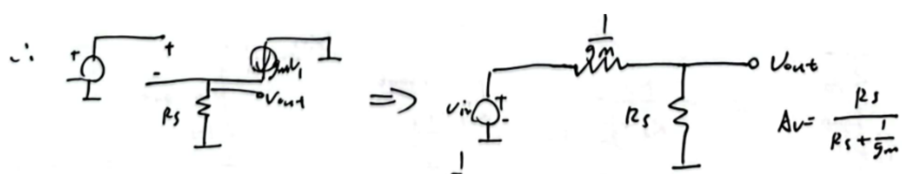
Then let's kill the independent voltage source.



$$\begin{cases} i_x = -g_m v_1 \\ v_1 = -v_x \end{cases}$$

$$\Longrightarrow R_x = \frac{v_x}{i_x} = \frac{-v_1}{-g_m v_1} = \frac{1}{g_m}$$

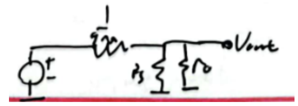
So we can get the simple model:



$$A_v = \frac{R_s}{R_s + \frac{1}{g_m}}$$

The same as we derive just now.
If $\lambda \neq 0$:

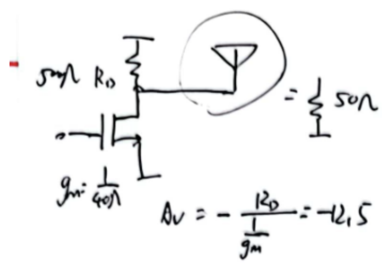
$$A_v = \frac{R_s || r_o}{R_s || r_o + \frac{1}{g_m}}$$



$$R_{out} = \frac{1}{g_m}||R_s||r_o$$

Application of Source Follower

If we want to radiate the amplified signal through the antenna, we can use a CS Stage.



For the CS Stage,

$$A_v = -\frac{R_D}{\frac{1}{g_m}} = 12.5$$

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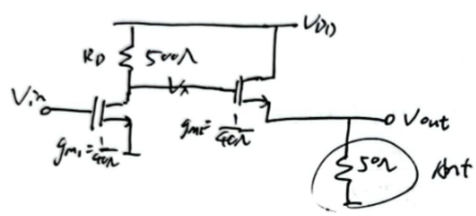
The resistance of antenna is usually very small, such as, 50Ω. The gain decrease a lot because of this.

$$A_v = -\frac{R_D||R_{ant}}{\frac{1}{g_m}} = -1.14$$

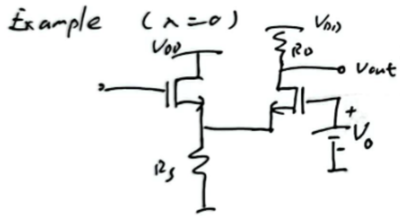
In this way we can use a source follower.



$$A_v = \frac{v_{out}}{v_{in}} = \frac{v_x}{v_{in}\frac{v_{out}}{v_x}} = -g_{m1}R_D * \frac{R_s}{\frac{1}{g_{m2}} + R_s} = -6.9$$

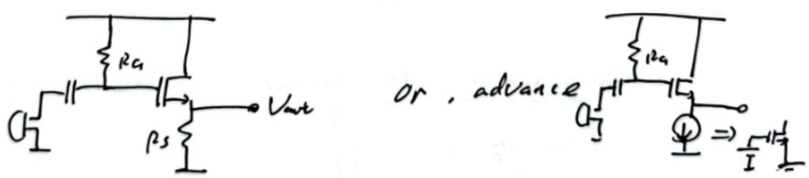
Source follower suppresses gain reduction.

Example



$$A_v = \frac{R_s||\frac{1}{g_{m1}}}{\frac{1}{g_{m1}} + R_s||\frac{1}{g_{m2}}} * g_{m2}R_D$$

Bias Design



We can create bias by adding a resistor between gate and V_{DD}.

In order to reduce the loss of gain caused by the source follower, a current source can be used instead of the source resistor.

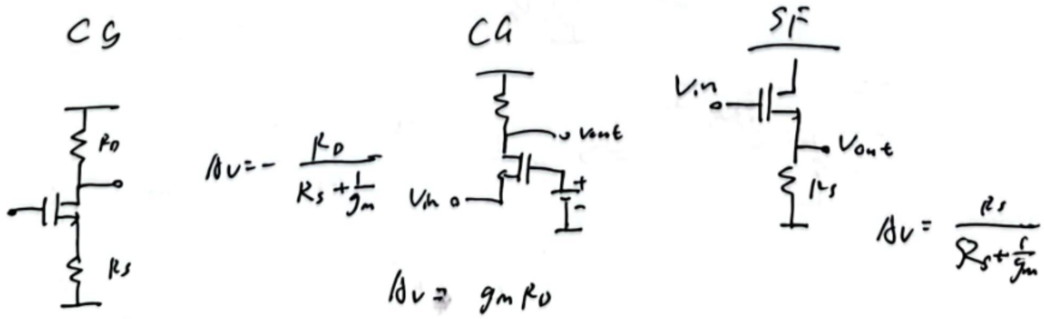
Summary

The three structures show different situations when the input and output are at the source, drain and gate of the MOSFET respectively.

For $\lambda = 0$

CS Stage

$$A_v = -\frac{R_D}{R_s + \frac{1}{g_m}}$$



CG Stage

$$A_v = g_m R_D$$

SF

$$A_v = \frac{R_s}{R_s + \frac{1}{g_m}}$$

Link

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