The Cascode Configuration

Common source / common gate cascade is one version of a cascode (all have shared supplies)

DC bias:

Two-port model: first stage has no current supply of its own
Cascode Two-Port Model

Output resistance of first stage = \( R_{\text{out,CS}} = r_{01} \)

\[
R_{\text{out}} = r_{oc2} \parallel (1 + g_m r_{01}) r_{02}
\]

\( G_m = g_{m1} \)

\( R_{in} = \infty \)

Why is the cascode such an important configuration?

Miller Capacitance of Input Stage

Find the Miller capacitance for \( C_{gd1} \)

Input resistance to common-gate second stage is low
\( \rightarrow \) gain across \( C_{gd1} \) is small.
Two-Port Model with Capacitors

Miller capacitance: \[ C_M = (1 - A_{VC_{gd1}})C_{gd1} \]

\[ A_{VC_{gd1}} = -g_m \left( \frac{1}{g_{m2} || r_o} \right) \approx - \frac{g_{m1}}{g_{m2}} = -1 \]

\[ C_M = 2C_{gd1} \]
Complete Amplifier Schematic

Goals: \( g_{m1} = 1 \text{ mS}, \quad R_{out} = 10 \text{ M} \Omega \)

Device Sizes

\( M_1 \): select \((W/L)_1 = 200/2\) to meet specified \( g_{m1} = 1 \text{ mS}\)
\[ \rightarrow \text{ find } V_{\text{BIAS}} = 1.2 \text{ V} \]

Cascode current supply devices: select \( V_{SG} = 1.5 \text{ V}\)
\[ (W/L)_4 = (W/L)_4B = (W/L)_3 = (W/L)_3B = 64/2 \]

\( M_2 \): select \((W/L)_2 = 50/2\) to meet specified \( R_{out} = 10 \text{ M} \Omega \)
\[ \rightarrow \text{ find } V_{GS2} = 1.4 \text{ V} \]

Match \( M_2 \) with diode-connected device \( M_{2B} \).

Assuming perfect matching and zero input voltage, what is \( V_{OUT} \)?
Output (Voltage) Swing

Maximum $V_{OUT}$  
Minimum $V_{OUT}$

$V_{REF} = 100 \, \mu A$

Two-Port Model

Find output resistance $R_{out}$

$\lambda_n = \frac{1}{20} \, V^{-1}$, $\lambda_p = \frac{1}{50} \, V^{-1}$ at $L = 2 \, \mu m$  
$r_{on} = (100 \, \mu A / 20 \, V^{-1})^{-1} = 200 \, k\Omega$, $r_{op} = 500 \, k\Omega$

$g_{m2} = \frac{2I_D2}{V_{GS2} - V_{Th}} = \frac{2(100 \, \mu A)}{1.4V - 1V} = 500 \, \mu S$

$g_{m3} = \frac{2(-I_D3)}{V_{SG3} + V_{Tp}} = \frac{2(100 \, \mu A)}{1.5V - 1V} = 400 \, \mu S$

$R_{out} = r_{oc} \parallel r_{o2}(1+g_{m2}R_{S2}) = r_{o3}(1+g_{m3}R_{S3}) \parallel r_{o2}(1+g_{m2}r_{o1})$