**Common Source / Source Resistance**

![Schematic Diagram]

*Why $R_S = R_{S1} + R_{S2}$?*

The source resistor provides a DC bias point more robust to variations ($K_P$, $V_T$, temperature). This comes at the cost of reduced gain.

**DC Biasing**

![Schematic Diagram]

$$V_G = V_{DD} \left( \frac{R_{S2}}{R_{S1} + R_{S2}} \right)$$

$$I_D = \frac{1}{2} K P N \frac{W}{L} \left[ V_G - I_D R_S - V_{TN} \right]^2$$

⇒ Must solve quadratic equation for $I_D$

After some algebra...

$$I_D^2 R_S^2 = I_D \left[ 2 (V_G - V_{TN}) R_S + \frac{2}{K P N \frac{W}{L}} \right] + (V_G - V_{TN})^2 = 0$$

⇒ Get 2 solutions, choose the one consistent with saturation (probably smaller value)
AC Equivalent Model (V/V model)

Neglecting $v_0$ to simplify analysis

$$v_0 = -i \left( R_0 || R_L \right)$$

$$i = \frac{v_i}{g_m + R_s}$$

$$v_0 = -\frac{v_i (R_0 || R_L)}{g_m + R_s} = -\frac{g_m (R_0 || R_L)}{1 + g_m R_s} v_i$$

$$A_v = \frac{v_0}{v_i} = -\frac{g_m (R_0 || R_L)}{1 + g_m R_s}$$

If $g_m R_s \gg 1 \Rightarrow$ gain approaches $- \frac{R_0}{R_s}$

(and $R_L$ big)

Source cap allows for both stable DC bias and high AC gain.

* For $R_{in}$, since $i_a = 0$

* For $R_{out}$: $\frac{v_o}{v_i} = 0, i = 0$

$$R_{in} = \frac{v_i}{i} = R_a \quad (mattered)$$

$$R_{out} = R_0 \quad (mattered by R_s)$$
Common Drain

\[ VDD \]
\[ V_i \]
\[ V_o \]
\[ R_s \]
\[ R_{a1} \]
\[ R_{a2} \]
\[ R_L \]
\[ R_{out} \]

AC Equivalent Circuit (neglecting \( R_o \))

\[ V_o = i (R_s \parallel R_L) \]

\[ = \frac{V_i (R_s \parallel R_L)}{\frac{1}{g_m} + (R_s \parallel R_L)} \]

\[
A_V = \frac{V_o}{V_i} = \frac{g_m (R_s \parallel R_L)}{1 + g_m (R_s \parallel R_L)}
\]

\[ R_{in} = \frac{V_i}{i_i} = R_a \quad \text{(same as CS)} \]

For \( R_{out} \):

\[ R_{out} = R_s \parallel \frac{1}{g_m} \quad \text{(low)} \]
**Common Gate**

\[ V_{PD} \]

\[ R_{a1} \]

\[ R_{a2} \]

\[ V_{in} \]

AC Equivalent Circuit (Neglecting \( R_o \))

\[ V_i \]

\[ R_s \]

\[ \frac{1}{g_m} \]

\[ i \]

\[ V_o = -i \left( R_p || R_L \right) \]

\[ i = -\frac{V_i}{V_{in}} \]

\[ A_v = \frac{V_o}{V_i} = g_m \left( R_p || R_L \right) \]

(Medium Gain) (Non-Inv)

\[ R_{in} = R_s \parallel \frac{1}{g_m} = \frac{1}{g_m} \]

(10x)

For \( R_{out} \):

\[ R_o \]

\[ V_{out} \]

\[ R_{out} = R_o \] (High)