Inverter Schematic

Digital:
Input = "0" → output = "1"
Input = "1" → output = "0"

Can be used as amplifier for if biased correctly!
ALD1105 Internal Diagram
Transfer Characteristics

- Gain in linear region ~ \(-18.8\) V/V

\[ y = -18.829x + 89.461 \]
Inverter Gain

- Two common source stages
  - Can find the gain using superposition

NMOS common-source

\[
\frac{V_{out}}{V_{in}} = -g_{mn} (r_{on} \parallel r_{op})
\]

PMOS common-source

\[
\frac{V_{out}}{V_{in}} = -g_{mp} (r_{on} \parallel r_{op})
\]

Total gain: \[
\frac{V_{out}}{V_{in}} = -(g_{mn} + g_{mp}) (r_{on} \parallel r_{op})
\]

Find device parameters using measurements
Transistor Small signal Parameter

\[ g_m = \frac{2I_0}{V_{ov}} = M_n \cdot Cox \cdot \frac{W}{L} \cdot V_{ov} = \sqrt{2M_nCox} \cdot \frac{W}{L} \cdot I_0 \]

\[ r_0 = \frac{1}{\lambda I_0} \]
Measured IV Curves (IDS vs VDS)

**NMOS**

**PMOS**

- **IDS (mA)**
- **VDS (V)**
- **10 - |VDS| (V)**
Finding Rout

- For the inverter $V_{out} = 4.5V$ (As shown earlier)
  - NMOS: $V_{GS} = 4.5V$, PMOS: $V_{SG} = 5.5V$

Right in the middle of the linear region

$\lambda = \frac{1}{\lambda I_D}$

\[ V_{SG} = 5.5V \]
\[ V_{GS} = 4.5V \]

$r_{on} = 14.1 \text{ K}\Omega$

$r_{op} = 12.5 \text{ K}\Omega$

NMOS: $V_{DS}$, PMOS: $10-|V_{DS}|$ (V)
Finding Transconductance (gm)

- Linearize the transistor around the operating point.
- \( \frac{1}{\text{slope}} \) will give us transconductance.

\[
\begin{align*}
\text{IDS} \text{(mA)} & \quad \text{gm} \text{ (mS)} \\
\\text{IDS} \quad |\text{IDS}| & \quad \text{gm} \text{ (mS)} \\
0 & \quad 0 \quad 2 \quad 10 \quad 0 \quad 10 \quad 20 \quad 15 \quad 10 \quad 5 \quad 0 \\
0 & \quad 0 \quad 2 \quad 4 \quad 6 \quad 8 \quad 10 \\
\quad \text{IDS (mA)} & \quad \text{IDS (mA)} \\
\quad |\text{IDS}| & \quad |\text{IDS}| \\
\text{gm}_n = 1.69 \text{ mS} & \quad \text{gm}_p = 1.13 \text{ mS}
\end{align*}
\]

\[
\begin{align*}
\text{gm}_n = \frac{2|I_D|}{V_{DS}} = \mu_n(C_o \times \frac{W}{L})V_{DS} = \sqrt{2\mu_n(C_o \times \frac{W}{L})I_D}
\end{align*}
\]
Calculating Gain (From measured device parameters)

- Gain from measured transfer characteristic: \(-18.8\, \text{V/V}\)

- Gain using small-signal models and measured device parameters

\[
\frac{V_{\text{out}}}{V_{\text{in}}} = -(g_{m_n} + g_{m_p})(r_{on} \!//\! r_{op})
\]

\[
= -\left(1.69\, \text{mS} + 1.12\, \text{mS}\right)\left(14.1\, \text{k}\Omega // 12.5\, \text{k}\Omega\right)
\]

\[
\approx -(2.81\, \text{mS})\left(6.63\, \text{k}\Omega\right)
\]

\[
\frac{V_{\text{out}}}{V_{\text{in}}} = -18.6\, \text{V/V}
\]
Transimpedance Amplifier

- Convert an input current to a voltage

\[
\frac{V_{out}}{I_{in}} = R_F
\]

Now there is feedback, \( R_F \) will affect our gain.
Finding TIA Gain

Break the feedback to find gain (consider loading effect of $RF$)

$$A_{CL} = \frac{A_{OL}}{1 + BA_{OL}}$$

Shunt-Shunt Feedback:

$$A_{OL} = R_F \times \left( g_{mn} + g_{mp} \right) \left( \frac{\text{Ron} \parallel \text{Rop} \parallel R_F}{} \right)$$

Using $R_F = 30 \Omega$

$$15.25 \text{ V/V}$$
Finding TIA Gain

Finding $B$: $\frac{I_{fb}}{V_{out}} = -\frac{1}{RF} - B$

$A_{cl} = \frac{A_{ol}}{1 + B A_{ol}}$

If $A_{ol}$ is large

$A_{cl} = \frac{1}{B} = -RF$

$A_{cl} = 28.14 \, \text{kV/A} \quad \text{close to } RF = 30 \, \text{kV}$

Gain is slightly less than using a resistor!

Why would we do this?!
Bandwidth Extension

\[ \frac{\text{Nout}}{\text{Iin}} = R_F \]

Now there is feedback, \( R_F \) will affect our gain.