"Nothing but NANDs."

\[ \overline{AA} = \overline{A} \quad \text{not (A and A)} \]

Inverter

\[ \overline{AB} = A + B \]

\[ \text{not(\text{not}(A \text{ and } \text{not}(B)))} = (A \text{ or } B) \]

\[ \text{not (\text{not} (A \text{ and } B)}) = (A \text{ and } B) \]

\text{Nors}

\[ \overline{A} \quad A + B \quad A \text{ or } B \]

\[ A \quad B \quad A \times B \]
Electrical Issues

Diode Logic

RTL  Resistor-Transistor logic

TTL  Transistor-Transistor

High is true

Noise Tolerance

[Diagram of electrical circuit with labels and waveforms]

Some input

Error

Out of SPEC but OK
Gate C is fF
Total Load often PF

\[ Q = C_L V_{DD} \]

Energy
\[ Q V_{DD} \]

Power
\[ f Q V_{DD} = f C_L V_{DD}^2 \]

Frequency
\[ \frac{N^2}{3} \times 10^{12} \times 25 \text{ V}^2 \]

10^{-2} to 10^{-1} W/unit

Timing rise time
input \[ \text{V}_{OH} \]
output \[ \text{V}_{OL} \]

Propagation Times

\[ T_{PHL}, T_{PLH} \]
Inverter AND

$A \times \overline{A} = C$

Don't look at the output too quickly.

\[ R_D = 904k \Omega \]

\[ \frac{5V}{R_{ON}} + \frac{5V}{R_{ON} + R_D} \]
\[ i_D = k \left[ 2(V_{GS} - V_{TO}) V_{DS} - V_{DS}^2 \right] \]

\[ i_D \approx k_2 (V_{GS} - V_{TO}) V_{DS} \]

\[ R_{on} = \frac{V_{DS}}{i_D} = \frac{V_{DS}}{2k(V_{GS} - V_{TO}) V_{DS}} \]

\[ k = \frac{k_0}{2} \frac{W}{L} \]