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CMOS Inverters Formulas

Calculators! Examples! Conversions!

List of 16 CMOS Inverters Formulas

CMOS Inverters

1) Average Power Dissipation CMOS

Open Calculator

fx $P_{avg} = C_{load} \cdot (V_{DD})^2 \cdot f$

ex $0.404095\text{mW} = 0.93\text{fF} \cdot (3.3\text{V})^2 \cdot 39.9\text{GHz}$

2) Average Propagation Delay CMOS

Open Calculator

fx $\zeta_P = \frac{\zeta_{PHL} + \zeta_{PLH}}{2}$

ex $0.004236\text{ns} = \frac{0.00229\text{ns} + 0.006182\text{ns}}{2}$

3) Load Capacitance of Cascaded Inverter CMOS

Open Calculator

fx $C_{load} = C_{gd,p} + C_{gd,n} + C_{db,p} + C_{db,n} + C_{in} + C_g$

ex $0.93\text{fF} = 0.15\text{fF} + 0.1\text{fF} + 0.25\text{fF} + 0.2\text{fF} + 0.05\text{fF} + 0.18\text{fF}$

4) Maximum Input Voltage CMOS

Open Calculator

fx $V_{IL} = \frac{2 \cdot V_{output} + (V_{T0,p}) - V_{DD} + K_r \cdot V_{T0,n}}{1 + K_r}$

ex $1.08\text{V} = \frac{2 \cdot 3.14\text{V} + (-0.7\text{V}) - 3.3\text{V} + 2.5 \cdot 0.6\text{V}}{1 + 2.5}$

5) Maximum Input Voltage for Symmetric CMOS

Open Calculator

fx $V_{IL(sym)} = \frac{3 \cdot V_{DD} + 2 \cdot V_{T0,n}}{8}$

ex $1.3875\text{V} = \frac{3 \cdot 3.3\text{V} + 2 \cdot 0.6\text{V}}{8}$

6) Minimum Input Voltage CMOS

Open Calculator

fx $V_{IH} = \frac{V_{DD} + (V_{T0,p}) + K_r \cdot (2 \cdot V_{out} + V_{T0,n})}{1 + K_r}$

ex $1.557143\text{V} = \frac{3.3\text{V} + (-0.7\text{V}) + 2.5 \cdot (2 \cdot 0.27\text{V} + 0.6\text{V})}{1 + 2.5}$

7) Minimum Input Voltage for Symmetric CMOS

Open Calculator

fx $$V_{IH(sym)} = \frac{5 \cdot V_{DD} - 2 \cdot V_{T0,n}}{8}$$

ex $$1.9125V = \frac{5 \cdot 3.3V - 2 \cdot 0.6V}{8}$$

8) Noise Margin for High Signal CMOS

Open Calculator

fx $$N_{MH} = V_{OH} - V_{IH}$$

ex $$1.8V = 3.35V - 1.55V$$

9) Oscillation Period Ring Oscillator CMOS

Open Calculator

fx $$T_{osc} = 2 \cdot n \cdot \zeta_P$$

ex $$0.0252ns = 2 \cdot 3 \cdot 0.0042ns$$

10) Propagation Delay for High to Low Output Transition CMOS

Open Calculator

fx $$\zeta_{PHL} = \left(\frac{C_{load}}{K_n \cdot (V_{DD} - V_{T,n})}\right) \cdot \left(\left(2 \cdot \frac{V_{T,n}}{V_{DD} - V_{T,n}}\right) + \ln\left(\left(4 \cdot \frac{V_{DD} - V_{T,n}}{V_{DD}}\right) - 1\right)\right)$$

ex $$0.002508ns = \left(\frac{0.93fF}{200\mu A/V^2 \cdot (3.3V - 0.8V)}\right) \cdot \left(\left(2 \cdot \frac{0.8V}{3.3V - 0.8V}\right) + \ln\left(\left(4 \cdot \frac{3.3V - 0.8V}{3.3V}\right) - 1\right)\right)$$

11) Propagation Delay for Low to High Output Transition CMOS

Open Calculator

fx $$\zeta_{PLH} = \left(\frac{C_{load}}{K_p \cdot (V_{DD} - |V_{T,p}|)}\right) \cdot \left(\left(\frac{2 \cdot |V_{T,p}|}{V_{DD} - |V_{T,p}|}\right) + \ln\left(\left(4 \cdot \frac{V_{DD} - |V_{T,p}|}{V_{DD}}\right) - 1\right)\right)$$

ex $$0.006765ns = \left(\frac{0.93fF}{80\mu A/V^2 \cdot (3.3V - |-0.9V|)}\right) \cdot \left(\left(\frac{2 \cdot |-0.9V|}{3.3V - |-0.9V|}\right) + \ln\left(\left(4 \cdot \frac{3.3V - |-0.9V|}{3.3V}\right) - 1\right)\right)$$

12) Resistive Load Maximum Input Voltage CMOS

Open Calculator

fx $$V_{IL(RL)} = V_{T0} + \left(\frac{1}{K_n \cdot R_L}\right)$$

ex $$1.4025V = 1.4V + \left(\frac{1}{200\mu A/V^2 \cdot 2M\Omega}\right)$$

13) Resistive Load Minimum Input Voltage CMOS

Open Calculator

fx
$$V_{IH(RL)} = V_{T0} + \sqrt{\frac{8 \cdot V_{DD}}{3 \cdot K_n \cdot R_L}} - \left(\frac{1}{K_n \cdot R_L}\right)$$

ex
$$1.545824V = 1.4V + \sqrt{\frac{8 \cdot 3.3V}{3 \cdot 200\mu A/V^2 \cdot 2M\Omega}} - \left(\frac{1}{200\mu A/V^2 \cdot 2M\Omega}\right)$$

14) Resistive Load Minimum Output Voltage CMOS

Open Calculator

fx
$$V_{OL(RL)} = V_{DD} - V_{T0} + \left(\frac{1}{K_n \cdot R_L}\right) - \sqrt{\left(V_{DD} - V_{T0} + \left(\frac{1}{K_n \cdot R_L}\right)\right)^2 - \left(2 \cdot \frac{V_{DD}}{K_n \cdot R_L}\right)}$$

ex
$$0.004341V = 3.3V - 1.4V + \left(\frac{1}{200\mu A/V^2 \cdot 2M\Omega}\right) - \sqrt{\left(3.3V - 1.4V + \left(\frac{1}{200\mu A/V^2 \cdot 2M\Omega}\right)\right)^2 - \left(2 \cdot \frac{\ldots}{200 \ldots}\right.}$$

15) Threshold Voltage CMOS

Open Calculator

fx
$$V_{th} = \frac{V_{T0,n} + \sqrt{\frac{1}{K_r}} \cdot (V_{DD} + (V_{T0,p}))}{1 + \sqrt{\frac{1}{K_r}}}$$

ex
$$1.374852V = \frac{0.6V + \sqrt{\frac{1}{2.5}} \cdot (3.3V + (-0.7V))}{1 + \sqrt{\frac{1}{2.5}}}$$

16) Transconductance Ratio CMOS

Open Calculator

fx
$$K_r = \frac{K_n}{K_p}$$

ex
$$2.5 = \frac{200\mu A/V^2}{80\mu A/V^2}$$

Variables Used

- $C_{db,n}$ NMOS Drain Bulk Capacitance *(Femtofarad)*
- $C_{db,p}$ PMOS Drain Bulk Capacitance *(Femtofarad)*
- C_g Inverter CMOS Gate Capacitance *(Femtofarad)*
- $C_{gd,n}$ NMOS Gate Drain Capacitance *(Femtofarad)*
- $C_{gd,p}$ PMOS Gate Drain Capacitance *(Femtofarad)*
- C_{in} Inverter CMOS Internal Capacitance *(Femtofarad)*
- C_{load} Inverter CMOS Load Capacitance *(Femtofarad)*
- f Frequency *(Gigahertz)*
- K_n Transconductance of NMOS *(Microampere per Square Volt)*
- K_p Transconductance of PMOS *(Microampere per Square Volt)*
- K_r Transconductance Ratio
- n Number of Stages Ring Oscillator
- N_{MH} Noise Margin for High Signal *(Volt)*
- P_{avg} Average Power Dissipation *(Milliwatt)*
- R_L Load Resistance *(Megohm)*
- T_{osc} Oscillation Period *(Nanosecond)*
- V_{DD} Supply Voltage *(Volt)*
- V_{IH} Minimum Input Voltage *(Volt)*
- $V_{IH(RL)}$ Resistive Load Minimum Input Voltage *(Volt)*
- $V_{IH(sym)}$ Minimum Input Voltage Symmetric CMOS *(Volt)*
- V_{IL} Maximum Input Voltage CMOS *(Volt)*
- $V_{IL(RL)}$ Resistive Load Maximum Input Voltage CMOS *(Volt)*
- $V_{IL(sym)}$ Maximum Input Voltage Symmetric CMOS *(Volt)*
- V_{OH} Maximum Output Voltage *(Volt)*
- $V_{OL(RL)}$ Resistive Load Minimum Output Voltage *(Volt)*
- V_{out} Output Voltage *(Volt)*
- V_{output} Output Voltage for Max Input *(Volt)*
- $V_{T,n}$ Threshold Voltage of NMOS with Body Bias *(Volt)*
- $V_{T,p}$ Threshold Voltage of PMOS with Body Bias *(Volt)*
- V_{T0} Zero Bias Threshold Voltage *(Volt)*
- $V_{T0,n}$ Threshold Voltage of NMOS Without Body Bias *(Volt)*
- $V_{T0,p}$ Threshold Voltage of PMOS Without Body Bias *(Volt)*

- V_{th} Threshold Voltage *(Volt)*
- $ζ_P$ Average Propagation Delay *(Nanosecond)*
- $ζ_{PHL}$ Time for High to Low Transition of Output *(Nanosecond)*
- $ζ_{PLH}$ Time for Low to High Transition of Output *(Nanosecond)*

Constants, Functions, Measurements used

- Function: **abs**, abs(Number)
  The absolute value of a number is its distance from zero on the number line. It's always a positive value, as it represents the magnitude of a number without considering its direction.
- Function: **ln**, ln(Number)
  The natural logarithm, also known as the logarithm to the base e, is the inverse function of the natural exponential function.
- Function: **sqrt**, sqrt(Number)
  A square root function is a function that takes a non-negative number as an input and returns the square root of the given input number.
- Measurement: **Time** in Nanosecond (ns)
  Time Unit Conversion
- Measurement: **Power** in Milliwatt (mW)
  Power Unit Conversion
- Measurement: **Frequency** in Gigahertz (GHz)
  Frequency Unit Conversion
- Measurement: **Capacitance** in Femtofarad (fF)
  Capacitance Unit Conversion
- Measurement: **Electric Resistance** in Megohm (MΩ)
  Electric Resistance Unit Conversion
- Measurement: **Electric Potential** in Volt (V)
  Electric Potential Unit Conversion
- Measurement: **Transconductance Parameter** in Microampere per Square Volt (μA/V²)
  Transconductance Parameter Unit Conversion

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- Array Datapath Subsystem Formulas
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