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CMOS Design Characteristics Formulas

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List of 24 CMOS Design Characteristics Formulas

CMOS Design Characteristics

1) Adjacent Capacitance

$$fx \quad C_{adj} = \frac{V_{tm} \cdot C_{gnd}}{V_{agr} - V_{tm}}$$

Open Calculator 

$$ex \quad 7.998947pF = \frac{12.75V \cdot 2.98pF}{17.5V - 12.75V}$$

2) Agression Driver

$$fx \quad R_{agr} = \frac{R_{vi} \cdot k \cdot (C_{adj} + C_{gnd})}{C_{ga} + C_{adj}}$$

Open Calculator 

$$ex \quad 1.123254 = \frac{1.98 \cdot 0.62 \cdot (8pF + 2.98pF)}{4pF + 8pF}$$

3) Agression Time Constant

$$fx \quad \tau_{agr} = k \cdot \tau_{vi}$$

Open Calculator 

$$ex \quad 1.2462 = 0.62 \cdot 2.01$$



4) Agressor Voltage

$$\text{fx } V_{\text{agr}} = \frac{V_{\text{tm}} \cdot (C_{\text{gnd}} + C_{\text{adj}})}{C_{\text{adj}}}$$

[Open Calculator !\[\]\(cbe80b694ebd74fcfe136a095b608235_img.jpg\)](#)

$$\text{ex } 17.49938\text{V} = \frac{12.75\text{V} \cdot (2.98\text{pF} + 8\text{pF})}{8\text{pF}}$$

5) Branching Effort

$$\text{fx } b = \frac{C_{\text{onpath}} + C_{\text{offpath}}}{C_{\text{onpath}}}$$

[Open Calculator !\[\]\(3e2231b1ad3ca8da8658228c00dd08e0_img.jpg\)](#)

$$\text{ex } 3.8125 = \frac{3.2\text{pF} + 9\text{pF}}{3.2\text{pF}}$$

6) Built-in Potential

$$\text{fx } \psi_0 = V_t \cdot \ln \left(\frac{N_a \cdot N_d}{n_i^2} \right)$$

[Open Calculator !\[\]\(0d5ec72f61334709c3fc9450209b754f_img.jpg\)](#)

$$\text{ex } 18.81808\text{V} = 0.55\text{V} \cdot \ln \left(\frac{1100/\text{m}^3 \cdot 1.9\text{e}14/\text{m}^3}{(17)^2} \right)$$

7) Capacitance Offpath

$$\text{fx } C_{\text{offpath}} = C_t - C_{\text{onpath}}$$

[Open Calculator !\[\]\(b64b40baaee5acddc1eab8538ba84754_img.jpg\)](#)

$$\text{ex } 9\text{pF} = 12.2\text{pF} - 3.2\text{pF}$$



8) Capacitance Onpath

$$\text{fx } C_{\text{onpath}} = C_t - C_{\text{offpath}}$$

[Open Calculator !\[\]\(e78f798d4ea5c530c9db49e7d26e6b95_img.jpg\)](#)

$$\text{ex } 3.2\text{pF} = 12.2\text{pF} - 9\text{pF}$$

9) Change in Frequency Clock

$$\text{fx } \Delta f = K_{\text{vco}} \cdot V_{\text{ctrl}}$$

[Open Calculator !\[\]\(05be7c7a8995decd503647c99211f7c2_img.jpg\)](#)

$$\text{ex } 0.07\text{Hz} = 0.01 \cdot 7\text{V}$$

10) Ground to Aggression Capacitance

$$\text{fx } C_{\text{adj}} = \frac{(R_{\text{vi}} \cdot k \cdot C_{\text{gnd}}) - (R_{\text{agr}} \cdot C_{\text{ga}})}{R_{\text{agr}} - R_{\text{vi}} \cdot k}$$

[Open Calculator !\[\]\(fe3aebe81acea8d45108cd2768939da7_img.jpg\)](#)

$$\text{ex } 8.829426\text{pF} = \frac{(1.98 \cdot 0.62 \cdot 2.98\text{pF}) - (1.13 \cdot 4\text{pF})}{1.13 - 1.98 \cdot 0.62}$$

11) Lock Voltage

$$\text{fx } V_{\text{lock}} = V_{\text{ctrl}} - V_{\text{offl}}$$

[Open Calculator !\[\]\(899d8b7697d64725bf017d3296cfcf1b_img.jpg\)](#)

$$\text{ex } 2\text{V} = 7\text{V} - 5\text{V}$$

12) Off-Path Capacitance of CMOS

$$\text{fx } C_{\text{offpath}} = C_{\text{onpath}} \cdot (b - 1)$$

[Open Calculator !\[\]\(40770d9ed6ed4f1222ebf89a1396e8b2_img.jpg\)](#)

$$\text{ex } 8.992\text{pF} = 3.2\text{pF} \cdot (3.81 - 1)$$



13) Output Clock Phase

$$f_x \Phi_{\text{out}} = 2 \cdot \pi \cdot V_{\text{ctrl}} \cdot K_{\text{vco}}$$

[Open Calculator !\[\]\(e2376d476d06eb31946dc01a69a4403a_img.jpg\)](#)

$$ex \ 0.439823 = 2 \cdot \pi \cdot 7V \cdot 0.01$$

14) Static Current

$$f_x i_{\text{static}} = \frac{P_{\text{static}}}{V_{\text{bc}}}$$

[Open Calculator !\[\]\(0b5e7e25e8775f7e7e80906ada4f0021_img.jpg\)](#)

$$ex \ 2.940594mA = \frac{5.94mW}{2.02V}$$

15) Static Power Dissipation

$$f_x P_{\text{static}} = i_{\text{static}} \cdot V_{\text{bc}}$$

[Open Calculator !\[\]\(bd3b31712ad9bab5a241210fa6925cdd_img.jpg\)](#)

$$ex \ 5.9994mW = 2.97mA \cdot 2.02V$$

16) Thermal Voltage of CMOS

$$f_x V_t = \frac{\psi_o}{\ln\left(\frac{N_a \cdot N_d}{n_i^2}\right)}$$

[Open Calculator !\[\]\(7bc43b319a082987e20f7bf78f4bab80_img.jpg\)](#)

$$ex \ 0.549472V = \frac{18.8V}{\ln\left(\frac{1100/m^3 \cdot 1.9e14/m^3}{(17)^2}\right)}$$



17) Time Constant Ratio of Agression to Victim

$$\text{fx } k = \frac{\tau_{\text{agr}}}{\tau_{\text{vi}}}$$

[Open Calculator !\[\]\(d3fb9f94af8b26d1c844efa9a98805b0_img.jpg\)](#)

$$\text{ex } 0.616915 = \frac{1.24}{2.01}$$

18) Total Capacitance Seen by Stage

$$\text{fx } C_t = C_{\text{onpath}} + C_{\text{offpath}}$$

[Open Calculator !\[\]\(e1d6102fe77919492c04879c8450f1f5_img.jpg\)](#)

$$\text{ex } 12.2\text{pF} = 3.2\text{pF} + 9\text{pF}$$

19) VCO Control Voltage

$$\text{fx } V_{\text{ctrl}} = V_{\text{lock}} + V_{\text{offl}}$$

[Open Calculator !\[\]\(ab4e2b3fc7e7887b7a72f548aa6f5e60_img.jpg\)](#)

$$\text{ex } 7\text{V} = 2\text{V} + 5\text{V}$$

20) VCO Offset Voltage

$$\text{fx } V_{\text{offl}} = V_{\text{ctrl}} - V_{\text{lock}}$$

[Open Calculator !\[\]\(5abce1a84a655b073239ab33e1199487_img.jpg\)](#)

$$\text{ex } 5\text{V} = 7\text{V} - 2\text{V}$$



21) VCO Single Gain Factor

$$\text{fx } K_{\text{vco}} = \frac{\Delta f}{V_{\text{ctrl}}}$$

[Open Calculator !\[\]\(9dfdaff1d86ba3c1f8353b4d1b61b8c5_img.jpg\)](#)

$$\text{ex } 0.011429 = \frac{0.08\text{Hz}}{7\text{V}}$$

22) Victim Driver

$$\text{fx } R_{\text{vi}} = \frac{R_{\text{agr}} \cdot (C_{\text{ga}} + C_{\text{adj}})}{k \cdot (C_{\text{adj}} + C_{\text{gnd}})}$$

[Open Calculator !\[\]\(2b376d1a92330ab09dad2665d2f89bf5_img.jpg\)](#)

$$\text{ex } 1.991891 = \frac{1.13 \cdot (4\text{pF} + 8\text{pF})}{0.62 \cdot (8\text{pF} + 2.98\text{pF})}$$

23) Victim Time Constant

$$\text{fx } \tau_{\text{vi}} = \frac{\tau_{\text{agr}}}{k}$$

[Open Calculator !\[\]\(c444627dab9fee9a1550c053ffaaaae2_img.jpg\)](#)

$$\text{ex } 2 = \frac{1.24}{0.62}$$

24) Victim Voltage

$$\text{fx } V_{\text{tm}} = \frac{V_{\text{agr}} \cdot C_{\text{adj}}}{C_{\text{gnd}} + C_{\text{adj}}}$$

[Open Calculator !\[\]\(06a315363e7801bba8c7489a6694af19_img.jpg\)](#)

$$\text{ex } 12.75046\text{V} = \frac{17.5\text{V} \cdot 8\text{pF}}{2.98\text{pF} + 8\text{pF}}$$



Variables Used







- **b** Branching Effort
- **C_{adj}** Adjacent Capacitance (*Picofarad*)
- **C_{ga}** Ground A Capacitance (*Picofarad*)
- **C_{gnd}** Ground Capacitance (*Picofarad*)
- **C_{offpath}** Capacitance Offpath (*Picofarad*)
- **C_{onpath}** Capacitance Onpath (*Picofarad*)
- **C_t** Total Capacitance in Stage (*Picofarad*)
- **i_{static}** Static Current (*Milliampere*)
- **k** Time Constant Ratio
- **K_{vco}** VCO Gain
- **N_a** Acceptor Concentration (*1 per Cubic Meter*)
- **N_d** Donor Concentration (*1 per Cubic Meter*)
- **n_i** Intrinsic Electron Concentration
- **P_{static}** Static Power (*Milliwatt*)
- **R_{agr}** Agression Driver
- **R_{vi}** Victim Driver
- **V_{agr}** Agressor Voltage (*Volt*)
- **V_{bc}** Base Collector Voltage (*Volt*)
- **V_{ctrl}** VCO Control Voltage (*Volt*)
- **V_{lock}** Lock Voltage (*Volt*)
- **V_{offl}** VCO Offset Voltage (*Volt*)



- V_t Thermal Voltage (Volt)
- V_{tm} Victim Voltage (Volt)
- Δf Change in Frequency of Clock (Hertz)
- T_{agr} Agression Time Constant
- T_{vi} Victim Time Constant
- Φ_{out} Output Clock Phase
- ψ_o Built-in Potential (Volt)





Constants, Functions, Measurements used

- **Constant:** **pi**, 3.14159265358979323846264338327950288
Archimedes' constant
- **Function:** **ln**, ln(Number)
Natural logarithm function (base e)
- **Measurement:** **Electric Current** in Milliampere (mA)
Electric Current Unit Conversion 
- **Measurement:** **Power** in Milliwatt (mW)
Power Unit Conversion 
- **Measurement:** **Frequency** in Hertz (Hz)
Frequency Unit Conversion 
- **Measurement:** **Capacitance** in Picofarad (pF)
Capacitance Unit Conversion 
- **Measurement:** **Electric Potential** in Volt (V)
Electric Potential Unit Conversion 
- **Measurement:** **Carrier Concentration** in 1 per Cubic Meter ($1/m^3$)
Carrier Concentration Unit Conversion 



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