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MOS IC Fabrication Formulas

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List of 15 MOS IC Fabrication Formulas

MOS IC Fabrication ↗

1) Acceptor Dopant Concentration ↗

fx

$$N_a = \frac{1}{2 \cdot \pi \cdot L_t \cdot W_t \cdot [\text{Charge-e}] \cdot \mu_p \cdot C_{\text{dep}}}$$

[Open Calculator ↗](#)

ex

$$1E^{32} \text{electrons/m}^3 = \frac{1}{2 \cdot \pi \cdot 3.2\mu\text{m} \cdot 5.5\mu\text{m} \cdot [\text{Charge-e}] \cdot 400\text{m}^2/\text{V*s} \cdot 1.4\mu\text{F}}$$

2) Body Effect in MOSFET ↗

fx

$$V_t = V_{\text{th}} + \gamma \cdot \left(\sqrt{2 \cdot \Phi_f + V_{\text{bs}}} - \sqrt{2 \cdot \Phi_f} \right)$$

[Open Calculator ↗](#)

ex

$$3.962586\text{V} = 3.4\text{V} + 0.56 \cdot \left(\sqrt{2 \cdot 0.25\text{V} + 2.43\text{V}} - \sqrt{2 \cdot 0.25\text{V}} \right)$$

3) Channel Resistance ↗

fx

$$R_{\text{ch}} = \frac{L_t}{W_t} \cdot \frac{1}{\mu_n \cdot Q_{\text{on}}}$$

[Open Calculator ↗](#)

ex

$$3.463203\Omega = \frac{3.2\mu\text{m}}{5.5\mu\text{m}} \cdot \frac{1}{30\text{m}^2/\text{V*s} \cdot 0.0056\text{electrons/m}^3}$$



4) Critical Dimension ↗

$$fx \quad CD = k_1 \cdot \frac{\lambda_1}{NA}$$

Open Calculator ↗

$$ex \quad 485.1883\text{nm} = 1.56 \cdot \frac{223\text{nm}}{0.717}$$

5) Depth of Focus ↗

$$fx \quad DOF = k_2 \cdot \frac{\lambda_1}{NA^2}$$

Open Calculator ↗

$$ex \quad 1.301331\mu\text{m} = 3 \cdot \frac{223\text{nm}}{(0.717)^2}$$

6) Die Per Wafer ↗

$$fx \quad DPW = \frac{\pi \cdot d_w^2}{4 \cdot S_d}$$

Open Calculator ↗

$$ex \quad 803.2481 = \frac{\pi \cdot (150\text{mm})^2}{4 \cdot 22\text{mm}^2}$$

7) Donor Dopant Concentration ↗

$$fx \quad N_d = \frac{I_{sat} \cdot L_t}{[\text{Charge-e}] \cdot W_t \cdot \mu_n \cdot C_{dep}}$$

Open Calculator ↗

$$ex \quad 1.7E^{23}\text{electrons/m}^3 = \frac{2A \cdot 3.2\mu\text{m}}{[\text{Charge-e}] \cdot 5.5\mu\text{m} \cdot 30\text{m}^2/\text{V*s} \cdot 1.4\mu\text{F}}$$



8) Drain Current of MOSFET at Saturation Region ↗

fx $I_d = \frac{\beta}{2} \cdot (V_{gs} - V_{th})^2 \cdot (1 + \lambda_i \cdot V_{ds})$

[Open Calculator ↗](#)

ex $0.013718A = \frac{0.0025S}{2} \cdot (2.45V - 3.4V)^2 \cdot (1 + 9 \cdot 1.24V)$

9) Drift Current Density due to Free Electrons ↗

fx $J_n = [\text{Charge-e}] \cdot n \cdot \mu_n \cdot E_i$

[Open Calculator ↗](#)

ex $53.83313\mu A = [\text{Charge-e}] \cdot 1E^6 \text{electrons/cm}^3 \cdot 30m^2/V*s \cdot 11.2V/m$

10) Drift Current Density due to Holes ↗

fx $J_p = [\text{Charge-e}] \cdot p \cdot \mu_p \cdot E_i$

[Open Calculator ↗](#)

ex

$0.071778A/mm^2 = [\text{Charge-e}] \cdot 1E^{20} \text{electrons/m}^3 \cdot 400m^2/V*s \cdot 11.2V/m$

11) Equivalent Oxide Thickness ↗

fx $EOT = t_{high-k} \cdot \left(\frac{3.9}{k_{high-k}} \right)$

[Open Calculator ↗](#)

ex $14.66814nm = 8.5nm \cdot \left(\frac{3.9}{2.26} \right)$



12) Maximum Dopant Concentration ↗

fx $C_s = C_o \cdot \exp\left(-\frac{E_s}{[BoltZ] \cdot T_a}\right)$

Open Calculator ↗

ex $4.9E^{-9}\text{electrons/cm}^3 = 0.005 \cdot \exp\left(-\frac{1E^{-23}J}{[BoltZ] \cdot 24.5K}\right)$

13) MOSFET Unity-Gain Frequency ↗

fx $f_t = \frac{g_m}{C_{gs} + C_{gd}}$

Open Calculator ↗

ex $37.41497\text{kHz} = \frac{2.2S}{56\mu F + 2.8\mu F}$

14) Propagation Time ↗

fx $T_p = 0.7 \cdot N \cdot \left(\frac{N + 1}{2}\right) \cdot R_m \cdot C_l$

Open Calculator ↗

ex $0.778203s = 0.7 \cdot 13 \cdot \left(\frac{13 + 1}{2}\right) \cdot 542\Omega \cdot 22.54\mu F$



15) Switching Point Voltage ↗**Open Calculator ↗**

$$V_s = \frac{V_{dd} + V_{tp} + V_{tn} \cdot \sqrt{\frac{\beta_n}{\beta_p}}}{1 + \sqrt{\frac{\beta_n}{\beta_p}}}$$



$$19.15938V = \frac{6.3V + 3.14V + 25V \cdot \sqrt{\frac{18}{6.5}}}{1 + \sqrt{\frac{18}{6.5}}}$$



Variables Used

- C_{dep} Depletion Layer Capacitance (*Microfarad*)
- C_{gd} Gate Drain Capacitance (*Microfarad*)
- C_{gs} Gate Source Capacitance (*Microfarad*)
- C_l Load Capacitance (*Microfarad*)
- C_o Reference Concentration
- C_s Maximum Dopant Concentration (*Electrons per Cubic Centimeter*)
- CD Critical Dimension (*Nanometer*)
- d_w Wafer Diameter (*Millimeter*)
- DOF Depth of Focus (*Micrometer*)
- DPW Die Per Wafer
- E_i Electric Field Intensity (*Volt per Meter*)
- E_s Activation Energy for Solid Solubility (*Joule*)
- EOT Equivalent Oxide Thickness (*Nanometer*)
- f_t Unity Gain Frequency in MOSFET (*Kilohertz*)
- g_m Transconductance in MOSFET (*Siemens*)
- I_d Drain Current (*Ampere*)
- I_{sat} Saturation Current (*Ampere*)
- J_n Drift Current Density due to Electrons (*Microampere*)
- J_p Drift Current Density due to Holes (*Ampere per Square Millimeter*)
- k_1 Process Dependent Constant
- k_2 Proportionality Factor
- k_{high-k} Dielectric Constant of Material



- L_t Transistor's Length (*Micrometer*)
- n Electron Concentration (*Electrons per Cubic Centimeter*)
- N Number of Pass Transistors
- N_a Acceptor Dopant Concentration (*Electrons per Cubic Meter*)
- N_d Donor Dopant Concentration (*Electrons per Cubic Meter*)
- NA Numerical Aperture
- p Hole Concentration (*Electrons per Cubic Meter*)
- Q_{on} Carrier Density (*Electrons per Cubic Meter*)
- R_{ch} Channel Resistance (*Ohm*)
- R_m Resistance in MOSFET (*Ohm*)
- S_d Size of Each Die (*Square Millimeter*)
- T_a Absolute Temperature (*Kelvin*)
- t_{high-k} Thickness of Material (*Nanometer*)
- T_p Propagation Time (*Second*)
- V_{bs} Voltage Applied to Body (*Volt*)
- V_{dd} Supply Voltage (*Volt*)
- V_{ds} Drain Source Voltage (*Volt*)
- V_{gs} Gate Source Voltage (*Volt*)
- V_s Switching Point Voltage (*Volt*)
- V_t Threshold Voltage with Substrate (*Volt*)
- V_{th} Threshold Voltage with Zero Body Bias (*Volt*)
- V_{tn} NMOS Threshold Voltage (*Volt*)
- V_{tp} PMOS Threshold Voltage (*Volt*)
- W_t Transistor's Width (*Micrometer*)
- β Transconductance Parameter (*Siemens*)



- β_n NMOS Transistor Gain
- β_p PMOS Transistor Gain
- γ Body Effect Parameter
- λ_i Channel Length Modulation Factor
- λ_l Wavelength in Photolithography (*Nanometer*)
- μ_n Electron Mobility (*Square Meter per Volt per Second*)
- μ_p Hole Mobility (*Square Meter per Volt per Second*)
- Φ_f Bulk Fermi Potential (*Volt*)



Constants, Functions, Measurements used

- **Constant:** pi, 3.14159265358979323846264338327950288
Archimedes' constant
- **Constant:** [BoltZ], 1.38064852E-23
Boltzmann constant
- **Constant:** [Charge-e], 1.60217662E-19
Charge of electron
- **Function:** exp, exp(Number)
n an exponential function, the value of the function changes by a constant factor for every unit change in the independent variable.
- **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:** Length in Micrometer (μm), Nanometer (nm), Millimeter (mm)
Length Unit Conversion 
- **Measurement:** Time in Second (s)
Time Unit Conversion 
- **Measurement:** Electric Current in Ampere (A), Microampere (μA)
Electric Current Unit Conversion 
- **Measurement:** Temperature in Kelvin (K)
Temperature Unit Conversion 
- **Measurement:** Area in Square Millimeter (mm^2)
Area Unit Conversion 
- **Measurement:** Energy in Joule (J)
Energy Unit Conversion 
- **Measurement:** Frequency in Kilohertz (kHz)
Frequency Unit Conversion 
- **Measurement:** Capacitance in Microfarad (μF)
Capacitance Unit Conversion 



- **Measurement:** **Electric Resistance** in Ohm (Ω)
Electric Resistance Unit Conversion ↗
- **Measurement:** **Electric Conductance** in Siemens (S)
Electric Conductance Unit Conversion ↗
- **Measurement:** **Wavelength** in Nanometer (nm), Micrometer (μm)
Wavelength Unit Conversion ↗
- **Measurement:** **Surface Current Density** in Ampere per Square Millimeter (A/mm²)
Surface Current Density Unit Conversion ↗
- **Measurement:** **Electric Field Strength** in Volt per Meter (V/m)
Electric Field Strength Unit Conversion ↗
- **Measurement:** **Electric Potential** in Volt (V)
Electric Potential Unit Conversion ↗
- **Measurement:** **Mobility** in Square Meter per Volt per Second (m²/V*s)
Mobility Unit Conversion ↗
- **Measurement:** **Electron Density** in Electrons per Cubic Meter (electrons/m³), Electrons per Cubic Centimeter (electrons/cm³)
Electron Density Unit Conversion ↗



Check other formula lists

- MOS IC Fabrication Formulas 

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