Important MOS IC Fabrication Formulas PDF

Formulas
Examples
with Units

List of 15
Important MOS IC Fabrication Formulas

1) Acceptor Dopant Concentration Formula

Evaluate Formula

Formula

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

Example with Units

$$1E{+}32\,\text{electrons/m}^3 = \frac{1}{2 \cdot 3.1416 \cdot 3.2\,\mu\text{m} \cdot 5.5\,\mu\text{m} \cdot 1.6E\text{-}19\,\text{c} \cdot 400\,\text{m}^2/\text{V*s} \cdot 1.4\,\mu\text{F}}$$

2) Body Effect in MOSFET Formula

Evaluate Formula

Formula

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

Example with Units

$$3.9626\,\text{V} = 3.4\,\text{V} + 0.56 \cdot \left(\sqrt{2 \cdot 0.25\,\text{V} + 2.43\,\text{V}} - \sqrt{2 \cdot 0.25\,\text{V}}\right)$$

3) Channel Resistance Formula

Evaluate Formula

Formula

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

Example with Units

$$3.4632\,\Omega = \frac{3.2\,\mu\text{m}}{5.5\,\mu\text{m}} \cdot \frac{1}{30\,\text{m}^2/\text{V*s} \cdot 0.0056\,\text{electrons/m}^3}$$

4) Critical Dimension Formula

Evaluate Formula

Formula

$$CD = k_1 \cdot \frac{\lambda_l}{NA}$$

Example with Units

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

5) Depth of Focus Formula

Evaluate Formula

Formula

$$DOF = k_2 \cdot \frac{\lambda_l}{NA^2}$$

Example with Units

$$1.3013\,\mu\text{m} = 3 \cdot \frac{223\,\text{nm}}{0.717^2}$$

6) Die Per Wafer Formula

Evaluate Formula

Formula

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

Example with Units

$$803.2481 = \frac{3.1416 \cdot 150\,\text{mm}^2}{4 \cdot 22\,\text{mm}^2}$$

7) Donor Dopant Concentration Formula

Evaluate Formula

Formula

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

Example with Units

$$1.7E{+}23\,\text{electrons/m}^3 = \frac{2.015\,\text{A} \cdot 3.2\,\mu\text{m}}{1.6E\text{-}19\,\text{C} \cdot 5.5\,\mu\text{m} \cdot 30\,\text{m}^2/\text{V*s} \cdot 1.4\,\mu\text{F}}$$

8) Drain Current of MOSFET at Saturation Region Formula

Evaluate Formula

Formula

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

Example with Units

$$0.0137\,\text{A} = \frac{0.0025\,\text{S}}{2} \cdot \left(2.45\,\text{V} - 3.4\,\text{V}\right)^2 \cdot \left(1 + 9 \cdot 1.24\,\text{V}\right)$$

9) Drift Current Density due to Free Electrons Formula

Evaluate Formula

Formula

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

Example with Units

$$53.8331\,\mu\text{A} = 1.6E\text{-}19\,\text{C} \cdot 1E{+}6\,\text{electrons/cm}^3 \cdot 30\,\text{m}^2/\text{V*s} \cdot 11.2\,\text{V/m}$$

10) Drift Current Density due to Holes Formula

Evaluate Formula

Formula

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

Example with Units

$$0.0718\,\text{A/mm}^2 = 1.6E\text{-}19\,\text{C} \cdot 1E{+}20\,\text{electrons/m}^3 \cdot 400\,\text{m}^2/\text{V*s} \cdot 11.2\,\text{V/m}$$

11) Equivalent Oxide Thickness Formula

Evaluate Formula

Formula

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

Example with Units

$$14.6681\,\text{nm} = 8.5\,\text{nm} \cdot \left(\frac{3.9}{2.26} \right)$$

12) Maximum Dopant Concentration Formula

Evaluate Formula

Formula

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

Example with Units

$$4.9\text{E-}9\,\text{electrons/cm}^3 = 0.005 \cdot \exp\left(- \frac{1\text{E-}23\,\text{J}}{1.4\text{E-}23\,\text{J/K} \cdot 24.5\,\text{K}} \right)$$

13) MOSFET Unity-Gain Frequency Formula

Evaluate Formula

Formula

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

Example with Units

$$37.415\,\text{kHz} = \frac{2.2\,\text{S}}{56\,\mu\text{F} + 2.8\,\mu\text{F}}$$

14) Propagation Time Formula

Evaluate Formula

Formula

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

Example with Units

$$0.7782\,\text{s} = 0.7 \cdot 13 \cdot \left(\frac{13 + 1}{2} \right) \cdot 542\,\Omega \cdot 22.54\,\mu\text{F}$$

15) Switching Point Voltage Formula

Evaluate Formula

Formula

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

Example with Units

$$19.1594\,\text{V} = \frac{6.3\,\text{V} + 3.14\,\text{V} + 25\,\text{V} \cdot \sqrt{\frac{18}{6.5}}}{1 + \sqrt{\frac{18}{6.5}}}$$

Variables used in list of MOS IC Fabrication Formulas above

- 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
- $k_{high\text{-}k}$ 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)*

Constants, Functions, Measurements used in list of MOS IC Fabrication Formulas above

- constant(s): **pi**, 3.14159265358979323846264338327950288 *Archimedes' constant*
- constant(s): **[BoltZ]**, 1.38064852E-23 *Boltzmann constant*
- constant(s): **[Charge-e]**, 1.60217662E-19 *Charge of electron*
- Functions: **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.*
- Functions: **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 (mm²) *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)

- **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)*
- $t_{high\text{-}k}$ 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)*

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

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