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# CMOS Power Metrics Formulas

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# List of 17 CMOS Power Metrics Formulas

## CMOS Power Metrics

### 1) Activity Factor

$$fx \quad \alpha = \frac{P_s}{C \cdot V_{bc}^2 \cdot f}$$

[Open Calculator !\[\]\(a870788d6ed9b8fd294b7654a8c8526b\_img.jpg\)](#)

$$ex \quad 1.625491 = \frac{0.13mW}{4.9\mu F \cdot (2.02V)^2 \cdot 4Hz}$$

### 2) Capacitive Load Power Consumption

$$fx \quad P_L = C_L \cdot V_{cc}^2 \cdot f_o \cdot S_{wo}$$

[Open Calculator !\[\]\(c50c8b7b2cc2cf9ff925edec0ee94c0d\_img.jpg\)](#)

$$ex \quad 2.944254mW = 5.01\mu F \cdot (1.55V)^2 \cdot 61Hz \cdot 4.01$$

### 3) Contention Current in Ratioed Circuits

$$fx \quad i_{con} = \left( \frac{P_{st}}{V_{bc}} \right) - (i_{st} + i_g + i_j)$$

[Open Calculator !\[\]\(f60b7a900783ac3fd531bfd9c111be6d\_img.jpg\)](#)

$$ex \quad 25.75149mA = \left( \frac{67.37mW}{2.02V} \right) - (1.6mA + 4.5mA + 1.5mA)$$



#### 4) Dynamic Power in CMOS

$$fx \quad P_{\text{dyn}} = P_{\text{sc}} + P_{\text{s}}$$

[Open Calculator !\[\]\(cbe80b694ebd74fcfe136a095b608235\_img.jpg\)](#)

$$ex \quad 46.13\text{mW} = 46\text{mW} + 0.13\text{mW}$$

#### 5) Gate Leakage through Gate Dielectric

$$fx \quad i_g = \left( \frac{P_{\text{st}}}{V_{\text{bc}}} \right) - (i_{\text{st}} + i_{\text{con}} + i_j)$$

[Open Calculator !\[\]\(3e2231b1ad3ca8da8658228c00dd08e0\_img.jpg\)](#)

$$ex \quad 4.501485\text{mA} = \left( \frac{67.37\text{mW}}{2.02\text{V}} \right) - (1.6\text{mA} + 25.75\text{mA} + 1.5\text{mA})$$

#### 6) Gates on Critical Path

$$fx \quad N_g = D \cdot \frac{i_{\text{off}} \cdot (10^V - \{bc\})}{C_g \cdot [\text{BoltZ}] \cdot V_{\text{bc}}}$$

[Open Calculator !\[\]\(0d5ec72f61334709c3fc9450209b754f\_img.jpg\)](#)

$$ex \quad 0.000957 = 1.3E^{-25} \cdot \frac{0.01\text{mA} \cdot (10^{2.02\text{V}})}{5.1\text{mF} \cdot [\text{BoltZ}] \cdot 2.02\text{V}}$$

#### 7) Leakage Energy in CMOS

$$fx \quad E_{\text{leak}} = E_t - E_s$$

[Open Calculator !\[\]\(b64b40baaee5acddc1eab8538ba84754\_img.jpg\)](#)

$$ex \quad 7\text{pJ} = 42\text{pJ} - 35\text{pJ}$$



## 8) Output Switching at Load Power Consumption

$$fx \quad S_{wo} = \frac{P_L}{C_L \cdot V_{cc}^2 \cdot f_o}$$

[Open Calculator !\[\]\(e78f798d4ea5c530c9db49e7d26e6b95\_img.jpg\)](#)

$$ex \quad 4.004206 = \frac{2.94mW}{5.01\mu F \cdot (1.55V)^2 \cdot 61Hz}$$

## 9) Power Supply Rejection Ratio

$$fx \quad P_{sr} = 20 \cdot \log_{10} \left( \frac{V_{in}}{V_{out}} \right)$$

[Open Calculator !\[\]\(05be7c7a8995decd503647c99211f7c2\_img.jpg\)](#)

$$ex \quad 2.963504dB = 20 \cdot \log_{10} \left( \frac{7.23V}{5.14V} \right)$$

## 10) Short-Circuit Power in CMOS

$$fx \quad P_{sc} = P_{dyn} - P_s$$

[Open Calculator !\[\]\(fe3aebe81acea8d45108cd2768939da7\_img.jpg\)](#)

$$ex \quad 46mW = 46.13mW - 0.13mW$$

## 11) Static Power in CMOS

$$fx \quad P_{st} = P_t - P_{dyn}$$

[Open Calculator !\[\]\(899d8b7697d64725bf017d3296cfcf1b\_img.jpg\)](#)

$$ex \quad 67.37mW = 113.5mW - 46.13mW$$



## 12) Subthreshold Leakage through OFF Transistors

[Open Calculator !\[\]\(bd1a142de767a21e5362c595f844a4ff\_img.jpg\)](#)

$$fx \quad i_{st} = \left( \frac{P_{st}}{V_{bc}} \right) - (i_g + i_{con} + i_j)$$

$$ex \quad 1.601485mA = \left( \frac{67.37mW}{2.02V} \right) - (4.5mA + 25.75mA + 1.5mA)$$

## 13) Switching Energy in CMOS

[Open Calculator !\[\]\(830769b31eeeaca920791081939ff8ba\_img.jpg\)](#)

$$fx \quad E_s = E_t - E_{leak}$$

$$ex \quad 35pJ = 42pJ - 7pJ$$

## 14) Switching Power

[Open Calculator !\[\]\(47734e4656765d20df4fdbd5b7aff048\_img.jpg\)](#)

$$fx \quad P_s = \alpha \cdot (C \cdot V_{bc}^2 \cdot f)$$

$$ex \quad 0.13196mW = 1.65 \cdot (4.9\mu F \cdot (2.02V)^2 \cdot 4Hz)$$

## 15) Switching Power in CMOS

[Open Calculator !\[\]\(41aea2746216b27a6939d696d8e035da\_img.jpg\)](#)

$$fx \quad P_s = (V_{dd}^2) \cdot f \cdot C$$

$$ex \quad 0.130465mW = ((2.58V)^2) \cdot 4Hz \cdot 4.9\mu F$$

## 16) Total Energy in CMOS

[Open Calculator !\[\]\(179f167ede0522ebb4ea025b3ad78ca7\_img.jpg\)](#)

$$fx \quad E_t = E_s + E_{leak}$$

$$ex \quad 42pJ = 35pJ + 7pJ$$



## 17) Total Power in CMOS

$$fx \quad P_t = P_{st} + P_{dyn}$$

[Open Calculator !\[\]\(d3fb9f94af8b26d1c844efa9a98805b0\_img.jpg\)](#)

$$ex \quad 113.5mW = 67.37mW + 46.13mW$$



## Variables Used

- **C** Capacitance (*Microfarad*)
- **C<sub>g</sub>** Capacitance of Gate to Channel (*Millifarad*)
- **C<sub>L</sub>** External Load Capacitance (*Microfarad*)
- **D** Duty Cycle
- **E<sub>leak</sub>** Leakage Energy in CMOS (*Picojoule*)
- **E<sub>s</sub>** Switching Energy in CMOS (*Picojoule*)
- **E<sub>t</sub>** Total Energy in CMOS (*Picojoule*)
- **f** Frequency (*Hertz*)
- **f<sub>o</sub>** Output Signal Frequency (*Hertz*)
- **i<sub>con</sub>** Contention Current (*Milliampere*)
- **i<sub>g</sub>** Gate Current (*Milliampere*)
- **i<sub>j</sub>** Junction Current (*Milliampere*)
- **i<sub>off</sub>** Off Current (*Milliampere*)
- **i<sub>st</sub>** Subthreshold Current (*Milliampere*)
- **N<sub>g</sub>** Gates on Critical Path
- **P<sub>dyn</sub>** Dynamic Power (*Milliwatt*)
- **P<sub>L</sub>** Capacitive Load Power Consumption (*Milliwatt*)
- **P<sub>s</sub>** Switching Power (*Milliwatt*)
- **P<sub>sc</sub>** Short-Circuit Power (*Milliwatt*)
- **P<sub>sr</sub>** Power Supply Rejection Ratio (*Decibel*)
- **P<sub>st</sub>** CMOS Static Power (*Milliwatt*)










- $P_t$  Total Power (Milliwatt)
- $S_{wo}$  Output Switching
- $V_{bc}$  Base Collector Voltage (Volt)
- $V_{cc}$  Supply Voltage (Volt)
- $V_{dd}$  Positive Voltage (Volt)
- $V_{in}$  Input Voltage Ripple (Volt)
- $V_{out}$  Output Voltage Ripple (Volt)
- $\alpha$  Activity Factor





## Constants, Functions, Measurements used

- **Constant:** [**BoltZ**], 1.38064852E-23 Joule/Kelvin  
*Boltzmann constant*
- **Function:** **log10**, log10(Number)  
*Common logarithm function (base 10)*
- **Measurement:** **Electric Current** in Milliampere (mA)  
*Electric Current Unit Conversion* 
- **Measurement:** **Energy** in Picojoule (pJ)  
*Energy Unit Conversion* 
- **Measurement:** **Power** in Milliwatt (mW)  
*Power Unit Conversion* 
- **Measurement:** **Noise** in Decibel (dB)  
*Noise Unit Conversion* 
- **Measurement:** **Frequency** in Hertz (Hz)  
*Frequency Unit Conversion* 
- **Measurement:** **Capacitance** in Microfarad ( $\mu\text{F}$ ), Millifarad (mF)  
*Capacitance Unit Conversion* 
- **Measurement:** **Electric Potential** in Volt (V)  
*Electric Potential Unit Conversion* 



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