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# Digital Communication Formulas

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# List of 25 Digital Communication Formulas

## Digital Communication

### Modulation Parameters

#### 1) Attenuation given Power of 2 Signals

$$fx \quad dB = 10 \cdot \left( \log_{10} \left( \frac{P_2}{P_1} \right) \right)$$

[Open Calculator !\[\]\(de95854c7ee024cfadc48187bbb781b2\_img.jpg\)](#)

$$ex \quad -10.888424dB = 10 \cdot \left( \log_{10} \left( \frac{14.67W}{180W} \right) \right)$$

#### 2) Attenuation given Voltage of 2 Signals

$$fx \quad dB = 20 \cdot \left( \log_{10} \left( \frac{V_2}{V_1} \right) \right)$$

[Open Calculator !\[\]\(6a9b39b98eb945faa14c645ec99e4eaa\_img.jpg\)](#)

$$ex \quad -10.881361dB = 20 \cdot \left( \log_{10} \left( \frac{20V}{70V} \right) \right)$$

#### 3) Bit Rate

$$fx \quad R = f_s \cdot \text{BitDepth}$$

[Open Calculator !\[\]\(f1c5da15572e3e09d343161be98f508d\_img.jpg\)](#)

$$ex \quad 360kb/s = 0.3kHz \cdot 1200$$



#### 4) Bit Rate of Raised Cosine Filter given Time Period

$$fx \quad R_s = \frac{1}{T}$$

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

$$ex \quad 142.8571 \text{ kb/s} = \frac{1}{7 \mu\text{s}}$$

#### 5) Bit Rate of Raised Cosine Filter using Rolloff Factor

$$fx \quad R_s = \frac{2 \cdot f_b}{1 + \alpha}$$

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

$$ex \quad 142.8533 \text{ kb/s} = \frac{2 \cdot 107.14 \text{ kb/s}}{1 + 0.5}$$

#### 6) Bit Rate using Bit Duration

$$fx \quad R = \frac{1}{T_b}$$

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

$$ex \quad 360.036 \text{ kb/s} = \frac{1}{2.7775 \mu\text{s}}$$

#### 7) Number of Quantization Levels

$$fx \quad N_{lvl} = 2^N - \{res\}$$

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

$$ex \quad 4 = 2^{0.002 \text{ kb}}$$



## 8) Number of Samples

$$fx \quad N_s = \frac{f_m}{f_s}$$

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

$$ex \quad 0.51 = \frac{0.153\text{kHz}}{0.3\text{kHz}}$$

## 9) Nyquist Sampling Frequency

$$fx \quad f_s = 2 \cdot F_m$$

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

$$ex \quad 0.3\text{kHz} = 2 \cdot 0.15\text{kHz}$$

## 10) Quantization Step Size

$$fx \quad \Delta = \frac{V_{\max} - V_{\min}}{N_{\text{lvl}}}$$

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

$$ex \quad 0.9\text{V} = \frac{5\text{V} - 1.4\text{V}}{4}$$

## 11) Signal to Noise Ratio

$$fx \quad \text{SNR} = (6.02 \cdot N_{\text{res}}) + 1.76$$

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

$$ex \quad 13.8\text{dB} = (6.02 \cdot 0.002\text{kb}) + 1.76$$



## Modulation Techniques

### 12) Bandwidth Efficiency in Digital Communication

$$\text{fx } S = \frac{R}{\text{BW}}$$

[Open Calculator !\[\]\(74d4806277d7e73349d8e8c0897931e9\_img.jpg\)](#)

$$\text{ex } 9 = \frac{360\text{kb/s}}{40\text{kHz}}$$

### 13) Bandwidth of ASK given Bit Rate

$$\text{fx } \text{BW}_{\text{ASK}} = (1 + \alpha) \cdot \left( \frac{R}{n_b} \right)$$

[Open Calculator !\[\]\(8bba887393ca45b761e5cb49e755e762\_img.jpg\)](#)

$$\text{ex } 33.75\text{kHz} = (1 + 0.5) \cdot \left( \frac{360\text{kb/s}}{16} \right)$$

### 14) Bandwidth of FSK

$$\text{fx } \text{BW}_{\text{FSK}} = R \cdot (1 + \alpha) + (2 \cdot \Delta f)$$

[Open Calculator !\[\]\(0fb13ad0bfa3d86868cdd3883e5665b3\_img.jpg\)](#)

$$\text{ex } 545.98\text{kHz} = 360\text{kb/s} \cdot (1 + 0.5) + (2 \cdot 2.99\text{kHz})$$

### 15) Bandwidth of Multilevel FSK

$$\text{fx } \text{BW}_{\text{MFSK}} = R \cdot (1 + \alpha) + (2 \cdot \Delta f \cdot (L - 1))$$

[Open Calculator !\[\]\(e50091943b385fe16d3277389202856f\_img.jpg\)](#)

$$\text{ex } 551.96\text{kHz} = 360\text{kb/s} \cdot (1 + 0.5) + (2 \cdot 2.99\text{kHz} \cdot (3 - 1))$$



16) Bandwidth of Multilevel PSK Open Calculator 

$$fx \quad BW_{MPSK} = R \cdot \left( \frac{1 + \alpha}{\log_2(L)} \right)$$

$$ex \quad 340.7021\text{kHz} = 360\text{kb/s} \cdot \left( \frac{1 + 0.5}{\log_2(3)} \right)$$

17) Bandwidth of Raised Cosine Filter Open Calculator 

$$fx \quad f_b = \frac{1 + \alpha}{2 \cdot T}$$

$$ex \quad 107.1429\text{kb/s} = \frac{1 + 0.5}{2 \cdot 7\mu\text{s}}$$

18) Baud Rate Open Calculator 

$$fx \quad r = \frac{R}{n_b}$$

$$ex \quad 22.5\text{kbaud} = \frac{360\text{kb/s}}{16}$$




19) Probability Error of BPSK for Raised Cosine Filter 

$$\text{fx } e_{\text{BPSK}} = \left(\frac{1}{2}\right) \cdot \text{erfc}\left(\sqrt{\frac{\epsilon_s}{N_0}}\right)$$

Open Calculator 

$$\text{ex } 0.499999 = \left(\frac{1}{2}\right) \cdot \text{erfc}\left(\sqrt{\frac{1.2\text{e-}11\text{J}}{10}}\right)$$

20) Probability Error of DPSK 

$$\text{fx } e_{\text{DPSK}} = \left(\frac{1}{2}\right) \cdot e^{-\left(\frac{\epsilon_b}{N_0}\right)}$$

Open Calculator 

$$\text{ex } 0.5 = \left(\frac{1}{2}\right) \cdot e^{-\left(\frac{55\text{e-}12\text{J}}{10}\right)}$$


21) Rolloff Factor 

$$\text{fx } \alpha = \left(\frac{\text{BW}_{\text{ASK}} \cdot n_b}{R}\right) - 1$$

Open Calculator 

$$\text{ex } 0.5 = \left(\frac{33.75\text{kHz} \cdot 16}{360\text{kb/s}}\right) - 1$$



22) Sampling Period 

$$fx \quad T_s = \frac{1}{f_s}$$

Open Calculator 

$$ex \quad 3333.333\mu s = \frac{1}{0.3kHz}$$

23) Sampling Theorem 

$$fx \quad f_s = 2 \cdot f_m$$

Open Calculator 


$$ex \quad 0.306kHz = 2 \cdot 0.153kHz$$

24) Signal Time Period 

$$fx \quad T = \frac{1 + \alpha}{2 \cdot f_b}$$

Open Calculator 

$$ex \quad 7.000187\mu s = \frac{1 + 0.5}{2 \cdot 107.14kb/s}$$

25) Symbol Time 

$$fx \quad T_{syb} = \frac{R}{N}$$

Open Calculator 

$$ex \quad 40000\mu s = \frac{360kb/s}{9000kb}$$





## Variables Used









- **BitDepth** Bit Depth
- **BW** Signal Bandwidth (Kilohertz)
- **BW<sub>ASK</sub>** Bandwidth of ASK (Kilohertz)
- **BW<sub>FSK</sub>** Bandwidth of FSK (Kilohertz)
- **BW<sub>MFSK</sub>** Bandwidth of Multilevel FSK (Kilohertz)
- **BW<sub>MPSK</sub>** Bandwidth of Multilevel PSK (Kilohertz)
- **dB** Attenuation (Decibel)
- **e<sub>BPSK</sub>** Probability Error of BPSK
- **e<sub>DPSK</sub>** Probability Error of DPSK
- **f<sub>b</sub>** Bandwidth of Raised Cosine Filter (Kilobit per Second)
- **f<sub>m</sub>** Maximum Frequency (Kilohertz)
- **F<sub>m</sub>** Message Signal Frequency (Kilohertz)
- **f<sub>s</sub>** Sampling Frequency (Kilohertz)
- **L** Number of Level
- **N** Bits Conveyed Per Symbol (Kilobit)
- **N<sub>0</sub>** Noise Density
- **n<sub>b</sub>** Number of Bits
- **N<sub>|V|</sub>** Number of Quantisation Levels
- **N<sub>res</sub>** Resolution of ADC (Kilobit)
- **N<sub>s</sub>** Number of Samples
- **P<sub>1</sub>** Power 1 (Watt)



- $P_2$  Power 2 (Watt)
- $r$  Baud Rate (Kilobit per Second)
- $R$  Bit Rate (Kilobit per Second)
- $R_s$  Bit Rate of Raised Cosine Filter (Kilobit per Second)
- $S$  Bandwidth Efficiency
- $SNR$  Signal to Noise Ratio (Decibel)
- $T$  Signal Time Period (Microsecond)
- $T_b$  Bit Duration (Microsecond)
- $T_s$  Sampling Period (Microsecond)
- $T_{syb}$  Symbol Time (Microsecond)
- $V_{max}$  Maximum Voltage (Volt)
- $V_{min}$  Minimum Voltage (Volt)
- $V1$  Voltage 1 (Volt)
- $V2$  Voltage 2 (Volt)
- $\alpha$  Rolloff Factor
- $\Delta$  Quantization Step Size (Volt)
- $\Delta f$  Difference in Frequency (Kilohertz)
- $\epsilon_b$  Energy per Bit (Joule)
- $\epsilon_s$  Energy per Symbol (Joule)



# Constants, Functions, Measurements used

- **Constant:** **e**, 2.71828182845904523536028747135266249  
*Napier's constant*
- **Function:** **erfc**, erfc(Number)  
*Gauss complementary error function (non-elementary special function)*
- **Function:** **log10**, log10(Number)  
*Common logarithm function (base 10)*
- **Function:** **log2**, log2(Number)  
*Binary logarithm function (base 2)*
- **Function:** **sqrt**, sqrt(Number)  
*Square root function*
- **Measurement:** **Time** in Microsecond ( $\mu\text{s}$ )  
*Time Unit Conversion* 
- **Measurement:** **Energy** in Joule (J)  
*Energy Unit Conversion* 
- **Measurement:** **Power** in Watt (W)  
*Power Unit Conversion* 
- **Measurement:** **Frequency** in Kilohertz (kHz)  
*Frequency Unit Conversion* 
- **Measurement:** **Data Storage** in Kilobit (kb)  
*Data Storage Unit Conversion* 
- **Measurement:** **Data Transfer** in Kilobit per Second (kbps)  
*Data Transfer Unit Conversion* 
- **Measurement:** **Electric Potential** in Volt (V)  
*Electric Potential Unit Conversion* 
- **Measurement:** **Sound** in Decibel (dB)  
*Sound Unit Conversion* 



- **Measurement: Bandwidth** in Kilobit per Second (kb/s)

*Bandwidth Unit Conversion* 



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