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Control System Design Formulas

Calculators! Examples! Conversions!

List of 31 Control System Design Formulas

Control System Design

1) Angle of Asymptotes

Open Calculator

fx $$\phi_k = \frac{(2 \cdot (\text{modulus}(N - M) - 1) + 1) \cdot \pi}{\text{modulus}(N - M)}$$

ex $$5.834386\text{rad} = \frac{(2 \cdot (\text{modulus}(13 - 6) - 1) + 1) \cdot \pi}{\text{modulus}(13 - 6)}$$

2) Bandwidth Frequency given Damping Ratio

Open Calculator

fx $$f_b = \omega_n \cdot \left(\sqrt{1 - \left(2 \cdot \zeta^2\right)} + \sqrt{\zeta^4 - \left(4 \cdot \zeta^2\right) + 2} \right)$$

ex $$54.96966\text{Hz} = 23\text{Hz} \cdot \left(\sqrt{1 - \left(2 \cdot (0.1)^2\right)} + \sqrt{(0.1)^4 - \left(4 \cdot (0.1)^2\right) + 2} \right)$$

3) Damped Natural Frequency

Open Calculator

fx $$\omega_d = \omega_n \cdot \sqrt{1 - \zeta^2}$$

ex $$22.88471\text{Hz} = 23\text{Hz} \cdot \sqrt{1 - (0.1)^2}$$

4) Damping Ratio given Critical Damping

Open Calculator

fx $$\zeta = \frac{C}{C_c}$$

ex $$0.100334 = \frac{0.6}{5.98}$$

5) Damping Ratio given Percentage Overshoot

Open Calculator

fx $$\zeta = -\frac{\ln\left(\frac{\%_o}{100}\right)}{\sqrt{\pi^2 + \ln\left(\frac{\%_o}{100}\right)^2}}$$

ex $$0.100106 = -\frac{\ln\left(\frac{72.9}{100}\right)}{\sqrt{\pi^2 + \ln\left(\frac{72.9}{100}\right)^2}}$$

6) Damping Ratio or Damping Factor

Open Calculator

fx $$\zeta = \frac{c}{2 \cdot \sqrt{m \cdot K_{spring}}}$$

ex $$0.188147 = \frac{16}{2 \cdot \sqrt{35.45\text{kg} \cdot 51\text{N/m}}}$$

7) Delay Time

Open Calculator

$$t_d = \frac{1 + (0.7 \cdot \zeta)}{\omega_n}$$

$$0.046522\text{s} = \frac{1 + (0.7 \cdot 0.1)}{23\text{Hz}}$$

8) First Peak Overshoot

Open Calculator

$$M_o = e^{-\frac{\pi \cdot \zeta}{\sqrt{1-\zeta^2}}}$$

$$0.729248 = e^{-\frac{\pi \cdot 0.1}{\sqrt{1-(0.1)^2}}}$$

9) First Peak Undershoot

Open Calculator

$$M_u = e^{-\frac{2 \cdot \zeta \cdot \pi}{\sqrt{1-\zeta^2}}}$$

$$0.531802 = e^{-\frac{2 \cdot 0.1 \cdot \pi}{\sqrt{1-(0.1)^2}}}$$

10) Gain-Bandwidth Product

Open Calculator

$$G.B = \text{modulus}(A_M) \cdot BW$$

$$56.16\text{Hz} = \text{modulus}(0.78) \cdot 72\text{b/s}$$

11) Number of Asymptotes

Open Calculator

fx $$N_a = N - M$$

ex $$7 = 13 - 6$$

12) Number of Oscillations

Open Calculator

fx $$n = \frac{t_s \cdot \omega_d}{2 \cdot \pi}$$

ex $$6.365281\text{Hz} = \frac{1.748\text{s} \cdot 22.88\text{Hz}}{2 \cdot \pi}$$

13) Peak Time

Open Calculator

fx $$t_p = \frac{\pi}{\omega_d}$$

ex $$0.137307\text{s} = \frac{\pi}{22.88\text{Hz}}$$

14) Peak Time given Damping Ratio

Open Calculator

fx $$t_p = \frac{\pi}{\omega_n \cdot \sqrt{1 - \zeta^2}}$$

ex $$0.137279\text{s} = \frac{\pi}{23\text{Hz} \cdot \sqrt{1 - (0.1)^2}}$$

15) Percentage Overshoot

Open Calculator

fx $$\%_o = 100 \cdot \left(e^{\frac{-\zeta \cdot \pi}{\sqrt{1 - \left(\zeta^2\right)}}} \right)$$

ex $$72.92476 = 100 \cdot \left(e^{\frac{-0.1 \cdot \pi}{\sqrt{1 - \left((0.1)^2\right)}}} \right)$$

16) Q-Factor

Open Calculator

fx $$Q = \frac{1}{2 \cdot \zeta}$$

ex $$5 = \frac{1}{2 \cdot 0.1}$$

17) Resonant Frequency

Open Calculator

fx $$\omega_r = \omega_n \cdot \sqrt{1 - 2 \cdot \zeta^2}$$

ex $$22.76884\text{Hz} = 23\text{Hz} \cdot \sqrt{1 - 2 \cdot (0.1)^2}$$

18) Resonant Peak

Open Calculator

fx $$M_r = \frac{1}{2 \cdot \zeta \cdot \sqrt{1 - \zeta^2}}$$

ex $$5.025189 = \frac{1}{2 \cdot 0.1 \cdot \sqrt{1 - (0.1)^2}}$$

19) Rise Time given Damped Natural Frequency

Open Calculator

fx $$t_r = \frac{\pi - \Phi}{\omega_d}$$

ex $$0.125507\text{s} = \frac{\pi - 0.27\text{rad}}{22.88\text{Hz}}$$

20) Rise Time given Damping Ratio

Open Calculator

fx $$t_r = \frac{\pi - \left(\Phi \cdot \frac{\pi}{180}\right)}{\omega_n \cdot \sqrt{1 - \zeta^2}}$$

ex $$0.137073\text{s} = \frac{\pi - \left(0.27\text{rad} \cdot \frac{\pi}{180}\right)}{23\text{Hz} \cdot \sqrt{1 - (0.1)^2}}$$

21) Rise Time given Delay Time

Open Calculator

fx $$t_r = 1.5 \cdot t_d$$

ex $$0.06\text{s} = 1.5 \cdot 0.04\text{s}$$

22) Setting Time when Tolerance is 2 Percent

Open Calculator

fx $$t_s = \frac{4}{\zeta \cdot \omega_d}$$

ex $$1.748252\text{s} = \frac{4}{0.1 \cdot 22.88\text{Hz}}$$

23) Setting Time when Tolerance is 5 Percent

Open Calculator

fx $$t_s = \frac{3}{\zeta \cdot \omega_d}$$

ex $$1.311189\text{s} = \frac{3}{0.1 \cdot 22.88\text{Hz}}$$

24) Steady State Error for Type 1 System

Open Calculator

fx $$e_{ss} = \frac{A}{K_v}$$

ex $$0.064516 = \frac{2}{31}$$

25) Steady State Error for Type 2 System

Open Calculator

fx $$e_{ss} = \frac{A}{K_a}$$

ex $$0.060606 = \frac{2}{33}$$

26) Steady State Error for Type Zero System

Open Calculator

$$fx\quad e_{ss} = \frac{A}{1 + K_p}$$

$$ex\quad 0.060606 = \frac{2}{1 + 32}$$

27) Time of Peak Overshoot in Second Order System

Open Calculator

$$fx\quad T_{po} = \frac{(2 \cdot k - 1) \cdot \pi}{\omega_d}$$

$$ex\quad 1.235766\text{s} = \frac{(2 \cdot 5 - 1) \cdot \pi}{22.88\text{Hz}}$$

28) Time Period of Oscillations

Open Calculator

$$fx\quad T = \frac{2 \cdot \pi}{\omega_d}$$

$$ex\quad 0.274615\text{s} = \frac{2 \cdot \pi}{22.88\text{Hz}}$$

29) Time Response in Overdamped Case

fx Open Calculator

$$C_t = 1 - \left(\frac{e^{-\left(\zeta_{over} - \left(\sqrt{\left(\zeta_{over}^2\right) - 1}\right)\right) \cdot (\omega_n \cdot T)}}{2 \cdot \sqrt{\left(\zeta_{over}^2\right) - 1 \cdot \left(\zeta_{over} - \sqrt{\left(\zeta_{over}^2\right) - 1}\right)}} \right)$$

ex $$0.807466 = 1 - \left(\frac{e^{-\left(1.12 - \left(\sqrt{\left((1.12)^2\right) - 1}\right)\right) \cdot (23\text{Hz} \cdot 0.15\text{s})}}{2 \cdot \sqrt{\left((1.12)^2\right) - 1 \cdot \left(1.12 - \sqrt{\left((1.12)^2\right) - 1}\right)}} \right)$$

30) Time Response in Undamped Case

fx $$C_t = 1 - \cos(\omega_n \cdot T)$$

Open Calculator

ex $$1.952818 = 1 - \cos(23\text{Hz} \cdot 0.15\text{s})$$

31) Time Response of Critically Damped System

fx $$C_t = 1 - e^{-\omega_n \cdot T} - \left(e^{-\omega_n \cdot T} \cdot \omega_n \cdot T\right)$$

Open Calculator

ex $$0.858732 = 1 - e^{-23\text{Hz} \cdot 0.15\text{s}} - \left(e^{-23\text{Hz} \cdot 0.15\text{s}} \cdot 23\text{Hz} \cdot 0.15\text{s}\right)$$

Variables Used

- $\%_o$ Percentage Overshoot
- **A** Coefficient Value
- A_M Amplifier Gain in Mid Band
- **BW** Amplifier Bandwidth *(Bit Per Second)*
- **c** Damping Coefficient
- **C** Actual Damping
- C_c Critical Damping
- C_t Time Response for Second Order System
- e_{ss} Steady State Error
- f_b Bandwidth Frequency *(Hertz)*
- **G.B** Gain-Bandwidth Product *(Hertz)*
- **k** Kth Value
- K_a Acceleration Error Constant
- K_p Position of Error Constant
- K_{spring} Spring Constant *(Newton per Meter)*
- K_v Velocity Error Constant
- **m** Mass *(Kilogram)*
- **M** Number of Zeroes
- M_o Peak Overshoot
- M_r Resonant Peak
- M_u Peak Undershoot
- **n** Number of Oscillations *(Hertz)*

- **N** Number of Poles
- **N_a** Number of Asymptotes
- **Q** Q Factor
- **T** Time Period for Oscillations *(Second)*
- **t_d** Delay Time *(Second)*
- **t_p** Peak Time *(Second)*
- **T_{po}** Time of Peak Overshoot *(Second)*
- **t_r** Rise Time *(Second)*
- **t_s** Setting Time *(Second)*
- **ζ** Damping Ratio
- **ζ_{over}** Overdamping Ratio
- **Φ** Phase Shift *(Radian)*
- **ϕ_k** Angle of Asymptotes *(Radian)*
- **ω_d** Damped Natural Frequency *(Hertz)*
- **ω_n** Natural Frequency of Oscillation *(Hertz)*
- **ω_r** Resonant Frequency *(Hertz)*

Constants, Functions, Measurements used

- Constant: **pi**, 3.14159265358979323846264338327950288
  Archimedes' constant
- Constant: **e**, 2.71828182845904523536028747135266249
  Napier's constant
- Function: **cos**, cos(Angle)
  Cosine of an angle is the ratio of the side adjacent to the angle to the hypotenuse of the triangle.
- Function: **ln**, ln(Number)
  The natural logarithm, also known as the logarithm to the base e, is the inverse function of the natural exponential function.
- Function: **modulus**, modulus
  Modulus of a number is the remainder when that number is divided by another number.
- 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: **Weight** in Kilogram (kg)
  Weight Unit Conversion
- Measurement: **Time** in Second (s)
  Time Unit Conversion
- Measurement: **Angle** in Radian (rad)
  Angle Unit Conversion
- Measurement: **Frequency** in Hertz (Hz)
  Frequency Unit Conversion
- Measurement: **Bandwidth** in Bit Per Second (b/s)
  Bandwidth Unit Conversion

- Measurement: **Stiffness Constant** in Newton per Meter (N/m)
  Stiffness Constant Unit Conversion

Check other formula lists

- Control System Design Formulas
- Electrical Control System Modelling Formulas
- Transient and Steady State Response Formulas

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