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Transient and Steady State Response Formulas

Calculators! Examples! Conversions!

List of 19 Transient and Steady State Response Formulas

Transient and Steady State Response

Second Order System

1) Delay Time

Open Calculator

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

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

2) First Peak Overshoot

Open Calculator

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

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

3) First Peak Undershoot

Open Calculator

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

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

4) Number of Oscillations

Open Calculator

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

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

5) Peak Time

Open Calculator

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

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

6) Peak Time given Damping Ratio

Open Calculator

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

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

7) Rise Time given Damped Natural Frequency

Open Calculator

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

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

8) 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 $$0.137073\text{s} = \frac{\pi - \left(0.27\text{rad} \cdot \frac{\pi}{180}\right)}{23\text{Hz} \cdot \sqrt{1 - (0.1)^2}}$$

9) Rise Time given Delay Time

Open Calculator

fx $$t_r = 1.5 \cdot t_d$$

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

10) Setting Time when Tolerance is 2 Percent

Open Calculator

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

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

11) Setting Time when Tolerance is 5 Percent

Open Calculator

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

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

12) Time of Peak Overshoot in Second Order System

Open Calculator

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

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

13) Time Period of Oscillations

Open Calculator

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

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

14) Time Response in Overdamped Case

Open Calculator

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

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

15) Time Response in Undamped Case

Open Calculator

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

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

16) Time Response of Critically Damped System

Open Calculator

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

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

Steady State Error

17) Steady State Error for Type 1 System

Open Calculator

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

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

18) Steady State Error for Type 2 System

Open Calculator

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

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

19) Steady State Error for Type Zero System

Open Calculator

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

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

Variables Used

- **A** Coefficient Value
- **C_t** Time Response for Second Order System
- **e_{ss}** Steady State Error
- **k** Kth Value
- **K_a** Acceleration Error Constant
- **K_p** Position of Error Constant
- **K_v** Velocity Error Constant
- **M_o** Peak Overshoot
- **M_u** Peak Undershoot
- **n** Number of Oscillations *(Hertz)*
- **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)*
- **ω_d** Damped Natural Frequency *(Hertz)*
- **ω_n** Natural Frequency of Oscillation *(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: **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: **Time** in Second (s)
  Time Unit Conversion
- Measurement: **Angle** in Radian (rad)
  Angle Unit Conversion
- Measurement: **Frequency** in Hertz (Hz)
  Frequency 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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