

Perturbation:

$$\ddot{y} + 2\beta \dot{y} + (\alpha^2 + \beta^2)^2 y = 0$$

$$y_t = H e^{-\beta t} \sin(\phi + \alpha t)$$

y_0, \dot{y}_0 initial values at $t = t_0$

$$y_t = P(t-t_0) y_0 + Q(t-t_0) \dot{y}_0$$

$$P_T = \frac{\sqrt{\alpha^2 + \beta^2}}{\alpha} e^{-\beta T} \sin(v + \alpha T)$$

$$Q_T = \frac{1}{\alpha} e^{-\beta T} \sin \alpha T$$

$$\sin v = \frac{\alpha}{\sqrt{\alpha^2 + \beta^2}}$$
$$\cos v = \frac{\beta}{\sqrt{\alpha^2 + \beta^2}}$$

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