

Group delay low pass

$$\tau(j\omega) = \sum_{i=1}^n \tau_i(j\omega)$$

$$\tau_i(j\omega) = -d(\arg(H_i(j\omega))) / d\omega$$

with standard (normalized lowpass):

$$H_i = 1 / (1 + j2\xi\Omega + \Omega^2)$$

$$\Omega = \omega / \omega_p \quad (\omega_p = \text{pole frequency})$$

$$\xi = 1/2Q_p \quad (Q_p = \text{pole quality factor})$$

$$\arg(H_i) = \arctan(\text{IMG} / \text{R}) = 2\xi\omega / (1 - \Omega^2)$$

$$\tau_i(j\omega) = -d(\arg(H_i(j\omega))) / d\omega = 2\xi \frac{1 + \Omega^2}{1 + 2\Omega^2(2\xi^2 - 1) + \Omega^4}.$$