oprava

$$i(t) = C\frac{dy(t)}{dt}$$

$$\frac{x(t)-y(t)}{R} = C\frac{dy(t)}{dt}$$

———————————— spojeni - oprava

$$h[n] = h_1[n] + h_2[n]$$

———————————— Cas vs frekvemce - v case

$$y[n] = b_0x[n] + b_1x[n-1] + \ldots + b_Qx[n-Q] \quad -a_1y[n-1] - \ldots - a_Py[n-P]$$

$$y[n] = \sum_{k=0}^{Q} b_k x[n-k] - \sum_{k=1}^{P} a_k y[n-k]$$

spojite

$$a_0y(t) + a_1\frac{dy(t)}{dt} + a_2\frac{d^2y(t)}{dt^2} + \ldots + a_P\frac{d^Py(t)}{dt^P} = b_0x(t) + b_1\frac{dx(t)}{dt} + b_2\frac{d^2x(t)}{dt^2} + \ldots + b_Q\frac{d^Qx(t)}{dt^Q}$$

$$\sum_{k=0}^{P} a_k\frac{d^ky(t)}{dt^k} = \sum_{k=0}^{Q} b_k\frac{d^kx(t)}{dt^k}$$

————- dirac and convolution ————

$$x(t) \star \delta(t) = x(t)$$

$$x(t) \star \delta(t-\tau) = x(t-\tau)$$

$$x(t) \star [\delta(t) + \delta(t-\tau) + \delta(t-2\tau)] = x(t) + x(t-\tau) + x(t-2\tau)$$

—— causality

$$h[n] = 0 \quad \text{for} \quad n < 0$$

$$h(t) = 0 \quad \text{for} \quad t < 0$$

================= freq =============

$$\omega = 2\pi f$$

$$X(j\omega) = \text{FT}\{x(t)\} = \int_{-\infty}^{+\infty} x(t)e^{-j\omega t}dt$$

$$Y(j\omega) = \text{FT}\{y(t)\} = \int_{-\infty}^{+\infty} y(t)e^{-j\omega t}dt$$

$$y(y) = x(t) \star h(t) = \int_{-\infty}^{+\infty} x(\tau)h(t-\tau)d\tau$$

$$Y(j\omega) = X(j\omega)H(j\omega)$$

$$H(j\omega) = \text{FT}\{h(t)\} = \int_{-\infty}^{+\infty} h(t)e^{-j\omega t}dt$$

============ laplace =======================

$$X(s) = \int_{-\infty}^{+\infty} x(t)e^{-st}dt$$

$$x(t) \xrightarrow{\mathcal{L}} X(s)$$

$$ax(t) \xrightarrow{\mathcal{L}} aX(s)$$

$$a_1x_1(t) + a_2x_2(t) \xrightarrow{\mathcal{L}} a_1X_1(s) + a_2X_2(s)$$

$$\frac{dx^k(t)}{dt^k} \xrightarrow{\mathcal{L}} X(s)s^k$$

$$\frac{dx(t)}{dt} \xrightarrow{\mathcal{L}} X(s)s$$

Vztah s FT

$$X(j\omega) = \int_{-\infty}^{+\infty} x(t)e^{-j\omega t}dt \qquad X(s) = \int_{-\infty}^{+\infty} x(t)e^{-st}dt$$

$$s \longrightarrow j\omega$$

$$X(j\omega) = X(s)|_{s=j\omega}.$$

———— processing diff eq by laplace —————-

$$a_0y(t) + a_1\frac{dy(t)}{dt} + a_2\frac{d^2y(t)}{dt^2} + \ldots + a_P\frac{d^Py(t)}{dt^P} = b_0x(t) + b_1\frac{dx(t)}{dt} + b_2\frac{d^2x(t)}{dt^2} + \ldots + b_Q\frac{d^Qx(t)}{dt^Q}$$

$$a_0Y(s) + a_1Y(s)s + a_2Y(s)s^2 + \ldots + a_PY(s)s^P = b_0X(s) + b_1X(s)s + b_2X(s)s^2 + \ldots + b_QX(s)s^Q$$

$$\frac{Y(s)}{X(s)}$$

$$H(s) = \frac{Y(s)}{X(s)}$$

$$a_0Y(s) + a_1Y(s)s + a_2Y(s)s^2 + \ldots + a_PY(s)s^P = b_0X(s) + b_1X(s)s + b_2X(s)s^2 + \ldots + b_QX(s)s^Q$$

$$Y(s)(a_0 + a_1s + a_2s^2 + \ldots + a_Ps^P) = X(s)(b_0 + b_1s + b_2s^2 + \ldots + b_Qs^Q)$$

$$\frac{Y(s)}{X(s)} = \frac{b_0 + b_1s + b_2s^2 + \ldots + b_Qs^Q}{a_0 + a_1s + a_2s^2 + \ldots + a_Ps^P}$$

$$H(s) = \frac{b_0 + b_1s + b_2s^2 + \ldots + b_Qs^Q}{a_0 + a_1s + a_2s^2 + \ldots + a_Ps^P} = \frac{\sum_{k=0}^{Q} b_ks^k}{\sum_{k=0}^{P} a_ks^k}$$

$$B(s) = \sum_{k=0}^{Q} b_ks^k$$

$$A(s) = \sum_{k=0}^{P} a_ks^k$$

— to freq response

$$H(j\omega) = H(s)|_{s=j\omega} = \frac{\sum_{k=0}^{Q} b_k\ (j\omega)^k}{\sum_{k=0}^{P} a_k\ (j\omega)^k}$$

$$H_{dB}(j\omega) = 20\log_{10}|H(j\omega)| = 10\log_{10}|H(j\omega)|^2$$

————— factorization

$$H(s) = \frac{b_0 + b_1s + b_2s^2 + \ldots + b_Qs^Q}{a_0 + a_1s + a_2s^2 + \ldots + a_Ps^P}$$

$$H(s) = \frac{b_Q(s-n_1)(s-n_2)\ldots(s-n_Q)}{a_P(s-p_1)(s-p_2)\ldots(s-p_Q)} = \frac{b_Q\prod_{k=0}^{Q}(s-n_k)}{a_P\prod_{k=0}^{P}(s-p_k)}$$

$$H(j\omega) = \frac{b_Q(j\omega-n_1)(j\omega-n_2)\ldots(j\omega-n_Q)}{a_P(j\omega-p_1)(j\omega-p_2)\ldots(j\omega-p_P)}$$

modul

$$|H(j\omega)| = \frac{b_Q|j\omega-n_1|\ |j\omega-n_2|\ldots|j\omega-n_Q|}{a_P|j\omega-p_1|\ |j\omega-p_2|\ldots|j\omega-p_P|} = \frac{b_Q \text{ product of lengths of blue vectors}}{a_P \text{ product of lengths of red vectors}}$$

argument

$$\arg H(j\omega) = \arg(j\omega - n_1) + \arg(j\omega - n_2) + \ldots + \arg(j\omega - n_Q) - \arg(j\omega - p_1) - \arg(j\omega - p_2) - \ldots - \arg(j\omega - p_P)$$

$$= \text{sum of angles of blue vectors} - \text{sum of angles of red vectors}$$