

$$|F|^2 = \frac{1}{1 + \varepsilon^2 H} = F(s)F(-s) \quad , \quad \alpha(\omega) = -10 \log |F|^2 = 10 \log(1 + \varepsilon^2 H) \quad , \quad \beta(\omega) = -\angle F(j\omega) \quad , \quad T(\omega) = \beta'(\omega)$$

$$\int_0^\infty T(\omega) d\omega = \frac{\pi}{2} (N + M_R - M_L)$$

$$H = \omega^{2N} \quad , \quad p_k = R \left\{ -\sin[(2k-1)\frac{\pi}{2N}] + j \cos[(2k-1)\frac{\pi}{2N}] \right\} \quad , \quad k = 1, \dots, N \quad , \quad R = \frac{1}{\sqrt[N]{\varepsilon}} \quad : \text{باترورث}$$

$$H = T_N^2(\omega) \quad , \quad T_N(\omega) = \cos(N \cos^{-1} \omega) = \text{ch}(N \text{ch}^{-1} \omega) \quad : \text{چپی شف}$$

$$p_k = -a \sin[(2k-1)\frac{\pi}{2N}] + j b \cos[(2k-1)\frac{\pi}{2N}] \quad , \quad k = 1, \dots, N \quad , \quad a = \text{sh}(\frac{1}{N} \text{sh}^{-1}(\frac{1}{\varepsilon})) \quad , \quad b = \text{ch}(\frac{1}{N} \text{sh}^{-1}(\frac{1}{\varepsilon}))$$

$$T_{N+1} = 2\omega T_N - T_{N-1} \quad , \quad T_{2N} = 2T_N^2 - 1$$

$$H = L_N^2(\omega) \quad , \quad L_N(\omega) = T_N(\Omega) \quad , \quad \Omega^2 = \cos^2(\frac{\pi}{2N})\omega^2 + \sin^2(\frac{\pi}{2N}) \quad \text{روابط چپی شف بدون افت dc درجه زوج}$$

$$H = \frac{T_N^2(\omega_a)}{T_N^2(\frac{\omega}{\omega_a})} \quad , \quad z_k = \frac{j\omega_a}{\cos(2k-1)\frac{\pi}{2N}} \quad \text{صفرهای انتقال فیلتر چپی شف معکوس} \quad : \text{چپی شف معکوس}$$

$$p_k = \frac{\omega_a}{P_k} \quad , \quad P_k = -a \sin[(2k-1)\frac{\pi}{2N}] + j b \cos[(2k-1)\frac{\pi}{2N}] \quad , \quad k = 1, \dots, N$$

$$a = \text{sh}(\frac{1}{N} \text{sh}^{-1}(\frac{1}{\varepsilon})) \quad , \quad b = \text{ch}(\frac{1}{N} \text{sh}^{-1}(\frac{1}{\varepsilon})) \quad , \quad E = \frac{1}{\varepsilon T_N(\omega_a)}$$

N	2	3	4	5	6	7	8	9	10	بسل :
$T_0 \omega_{3dB}$	1.359	1.753	2.111	2.424	2.694	2.947	3.174	3.389	$\sqrt{(2N-1)\ln(2)}$	

$$\frac{M}{N} = \frac{1}{T_0 s} + \frac{1}{\frac{3}{T_0 s} + \frac{1}{\frac{5}{T_0 s} + \dots}} \quad |F|^2 = \frac{1}{\sum_{i=0}^N \frac{2^i}{i!} (\frac{\omega}{\omega_0})^{2i}} \quad : \text{گوسی}$$

$$F(s) = \frac{\sigma - s}{\sigma + s} \quad , \quad \beta = 2 \text{tg}^{-1}(\frac{\omega}{\sigma}) \quad , \quad T(\omega) = \frac{2}{1 + (\frac{\omega}{\sigma})^2} \quad : \text{تمام گذر}$$

$$F(s) = \frac{s^2 - \frac{\omega_0}{Q}s + \omega_0^2}{s^2 + \frac{\omega_0}{Q}s + \omega_0^2} \quad , \quad \beta = 2 \text{tg}^{-1}(\frac{\omega \omega_0}{Q(\omega_0^2 - \omega^2)}) \quad , \quad T(\omega) = \frac{2Q}{\omega_0} \frac{1 + (\frac{\omega_0}{\omega})^2}{1 + Q^2 (\frac{\omega_0}{\omega} - \frac{\omega}{\omega_0})^2}$$

$$F(s) = \frac{M(s) - N(s)}{M(s) + N(s)} \quad , \quad \frac{N}{j} = M \text{tg}(\frac{\phi}{2}) \quad \text{روابط روش مستقیم تقریب مشخصه فاز دلخواه } (\phi)$$

فاکتور باترورث در تقریب مشخصه دامنه دلخواه :

$$[1 + (\frac{\omega}{\omega_i})^{2N}] \quad , \quad [1 + (\frac{s}{j\omega_i})^{2N}] = 0 \rightarrow p_k = \omega_i \left\{ -\sin[(2k-1)\frac{\pi}{2N}] + j \cos[(2k-1)\frac{\pi}{2N}] \right\}$$