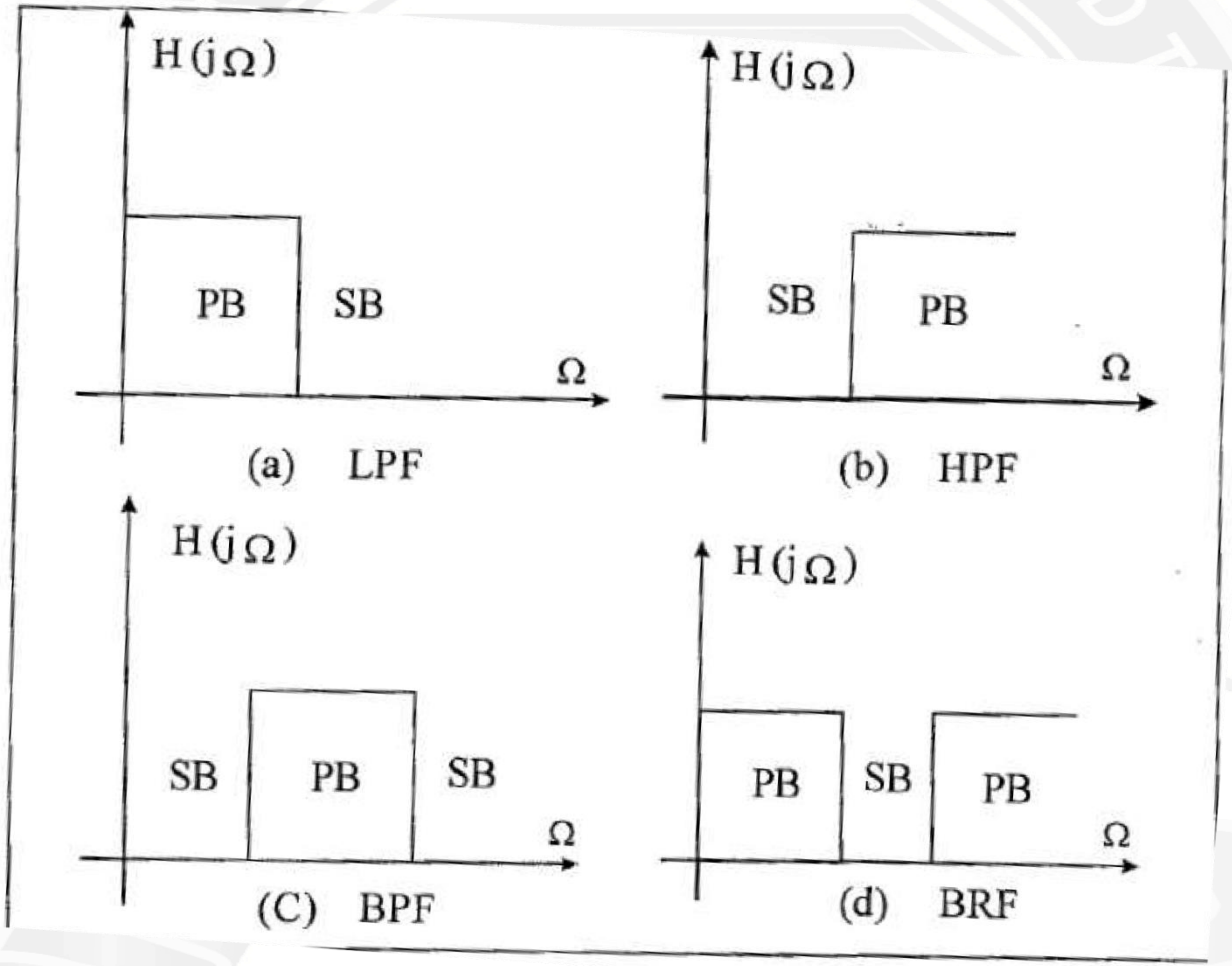
Characteristics of practical frequency selective filters



Digital Vs. Analog filter

	Analog filter	Digital filter
i)	Analog filter processes analog input and generates analog output.	A digital filter processes and generate digital data.
ii)	They are constructed from active (or) passive electronic components.	They consists of elements like adders, multiplier and delay unit.
iii)	Analog filter is described by a differential equation.	Digital filter is represented by a difference equation.
iv)	The frequency response of an analog fitter can be modified by changing the components.	The frequency response can be changed by changing the fitter coefficients.

Advantages of digital filters

i) Unlike analog filter, the digital filter performance is not influenced by component ageing, temperature and power supply variation.

ii) A digital filter is highly immune to noise and possesses considerable parameters stability.

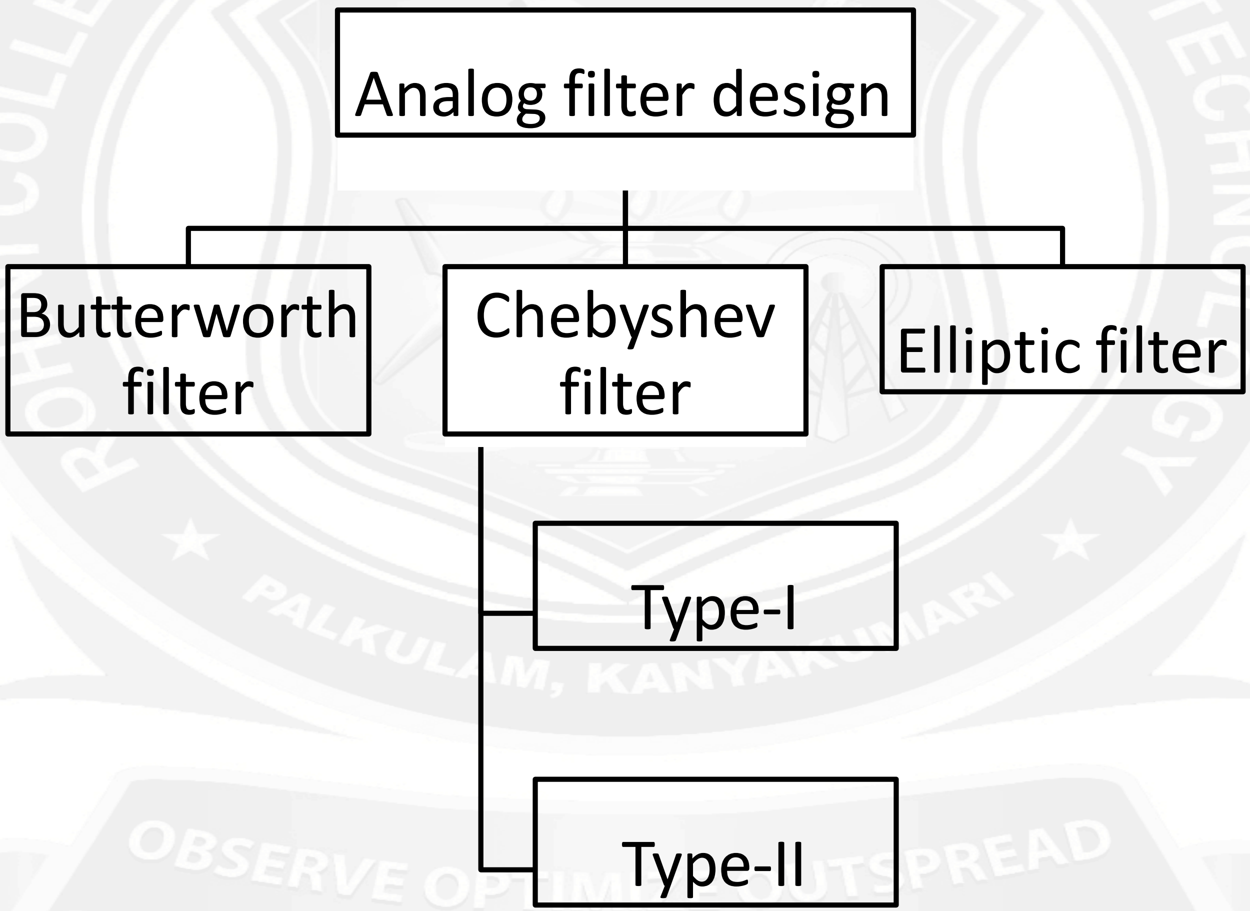
iii) Digital filter afford a wide variety of shapes for the amplitude and phase response. There are no problem of input (or) output impedance matching with digital filter.

iv) Digital filter can be osperated over a wide range of frequencies.

v) The coefficients of digital filter can be programmed and altered any time to obtain the desired characteristics.

vi) Multiple filtering is possible only in digital filter.

IIR Filter design



Analog Butterworth filter design

- Step-1: from the given specification, find the order of filter 'N'

$$N \geq \frac{\log\left[\sqrt{\dfrac{10^{0.1\alpha_s}-1}{10^{0.1\alpha_p}-1}}\right]}{\log\left(\dfrac{\Omega_s}{\Omega_p}\right)} \geq \frac{\log(\lambda/\varepsilon)}{\log\left(\dfrac{\Omega_s}{\Omega_p}\right)}$$

Where $\varepsilon_1 = \sqrt{10^{0.1\alpha_p}-1}$

$$\lambda = \sqrt{10^{0.1\alpha_s}-1}$$

Analog Butterworth filter design

- Step-2: Round off the above found ‘N’ to its next highest integer
- Step-3: Find the normalized transfer function H(s) for Ωc=1 rad/s, for the value of N

$$H(s) = \frac{N_r \text{ polynomial}}{D_r \text{ polynomial}}$$

- For Butterworth filter Nr polynomial is always 1

- Step-4: calculate the value of cut-off frequency Ω_c using,

$$\Omega_C = \frac{\Omega_P}{\left(10^{0.1\alpha_p} - 1\right)^{1/2N}} = \frac{\Omega_P}{\varepsilon^{1/N}}$$

Step 5:

Find the transfer function

$H_a(s)$ for the above values of Ω_c by substituting $s \rightarrow s/\Omega_c$ in H (s)

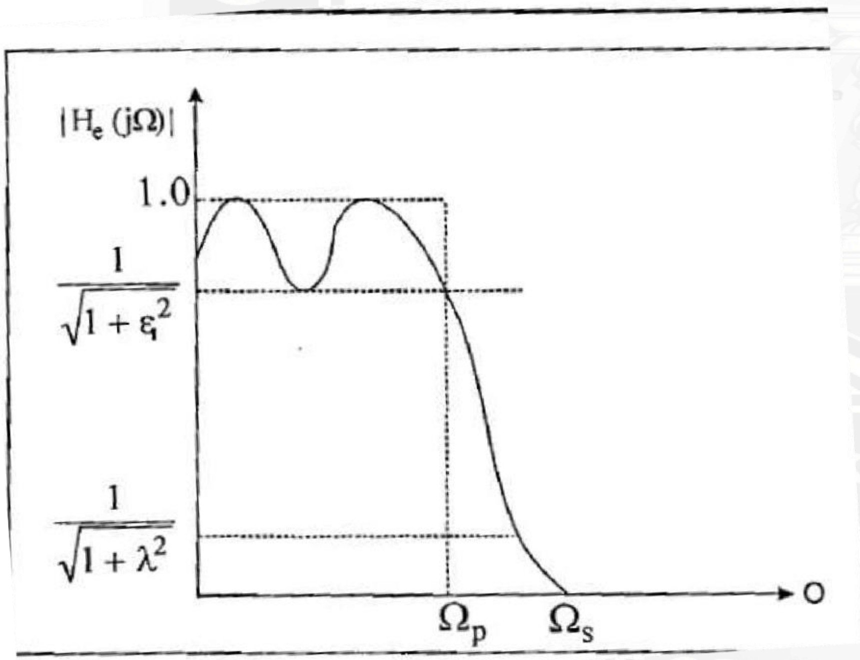
For HPF Ha(s) $= H(s) \mid s \rightarrow \Omega c/s$

For LPF Ha(s) $= H(s) \mid s \rightarrow s/\Omega c$

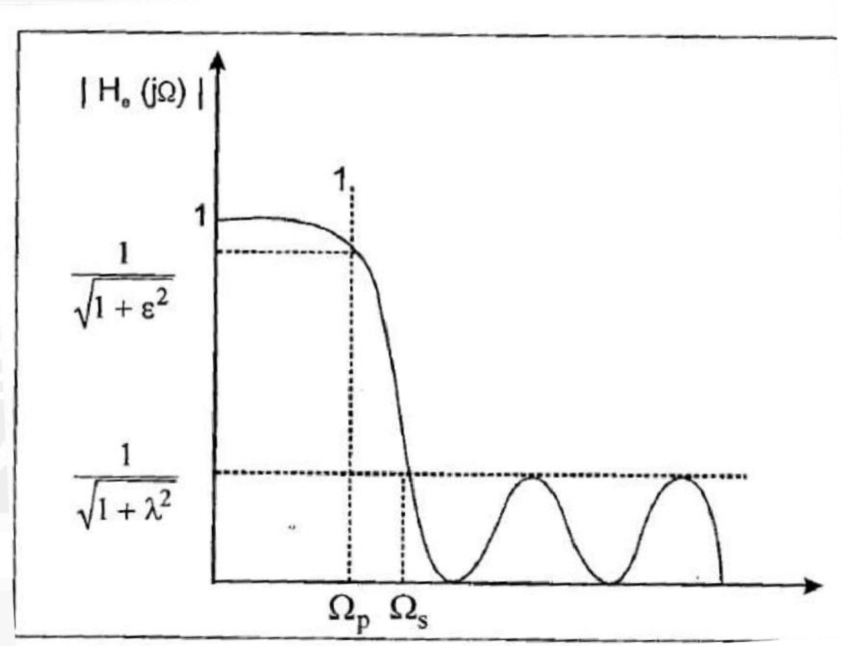
Step-6: To find Ha(s)

Analog Chebyshev filter

Type-I Chebyshev filter



Type-II Chebyshev filter



Steps to design of analog Chebyshev filter

- Step-1: Find N

$$N \geq \frac{\cosh^{-1} \lambda / \xi}{\cosh^{-1} \frac{\Omega_s}{\Omega_p}} \geq \frac{\cosh^{-1} \sqrt{\frac{10^{0.1\alpha_s} - 1}{10^{0.1\alpha_p} - 1}}}{\cosh^{-1} \frac{\Omega_s}{\Omega_p}}$$

- Step-2: Round off the above found ‘N’ to its next highest integer

Steps to design of analog Chebyshev filter

- step-3: Using following formula find the values of a & b which are minor and major axis of ellipse respectively

$$a = \Omega_p \frac{[\mu^{1/N} - \mu^{-1/N}]}{2} \quad b = \Omega_p \frac{[\mu^{1/N} + \mu^{-1/N}]}{2}$$

Where $\mu = \xi^{-1} + \sqrt{\xi^{-2} + 1}$

$$\varepsilon = \sqrt{10^{0-1\alpha_p} - 1}$$

Steps to design of analog Chebyshev filter

- Step-4:

Calculate the poles of chebyshev filter which lie on the ellipse by using the formula

$$S_k = a\cos\varphi_k + jb\sin\varphi_k \quad k = 1, 2 \ldots N$$

$$\text{Where } \varphi_k = \pi/2 + \left(\frac{2k-1}{2N}\right)\pi, \; k = 1, 2 \ldots N$$

- Step-5: Find the Denominator polynomial of the transfer function using the above poles.

Steps to design of analog Chebyshev filter

- Step-6:

The Numerator of the transfer function depends on the value of N.

For N = odd, substitute s = 0 in Denominator polynomial & find the value. This value is equal to the Numerator of transfer function.

For N = even, substitute s = 0 in Denominator polynomial & divide the result by $\sqrt{1+\varepsilon^2}$, This value is equal to the numerator.