NETWORK THEORY

LECTURE 1

SECTION-D:TYPES OF FILTERS AND THEIR CHARACTERISTICS

Active Filters

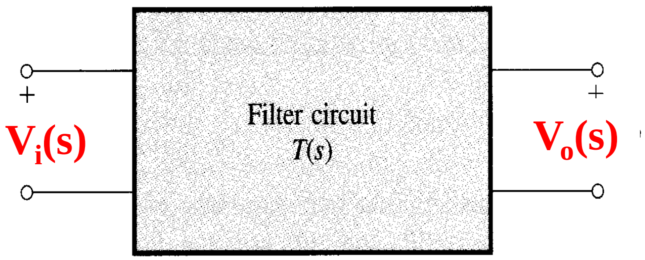


Fig. 11.1 The filters studied in this chapter are linear circuits represented by the general two-port network shown. The filter transfer function $T(s) \equiv V_o(s)/V_i(s)$.

Transfer Function

$$T(s) = \frac{V_o(s)}{V_i(s)}$$

Magnitude can be expressed as:

Gain function $G(\omega)$ for $|A(\omega)| > 1$

$$G(\omega) = 20\log|T(\omega)| \text{ in dB}$$

or

Attenuation function $A(\omega)$ for $|A(\omega)| < 1$

$$A(\omega) = -20\log|T(\omega)| \text{ in dB}$$

- **Based on use of amplifiers to achieve filter function**
- **Frequently use op amps so filter may have some gain as well.**
- **Alternative to LRC-based filters**
- **Benefits**
  - **Provide improved characteristics**
  - **Smaller size and weight**
  - **Monolithic integration in IC**
  - **Implement without inductors**
  - **Lower cost**
  - **More reliable**
  - **Less power dissipation**
- **Price**
  - **Added complexity**
  - **More design effort**

Filter Types

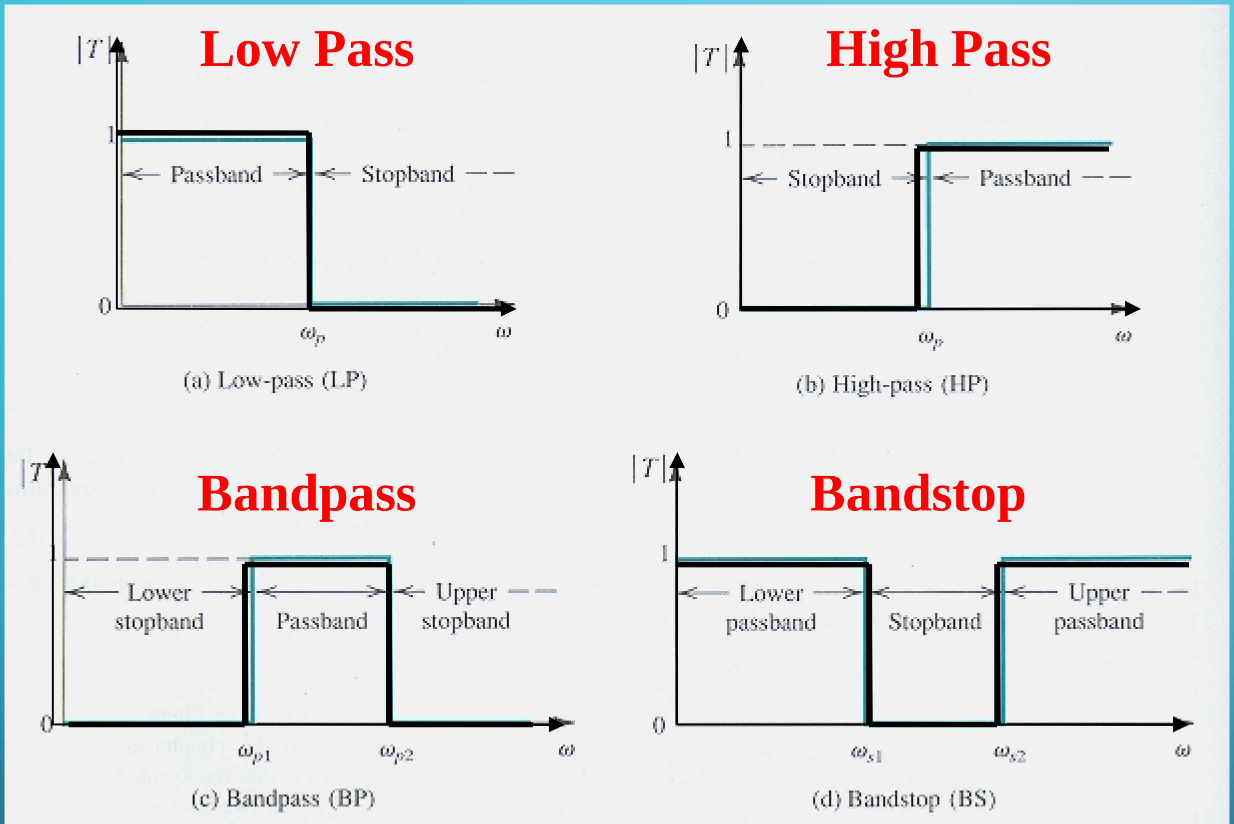


Fig. 11.2 Ideal transmission characteristics of the four major filter types: **(a)** low-pass (LP), **(b)** high-pass (HP), **(c)** bandpass (BP), and **(d)** bandstop (BS).

* **Four major filter types:**
  - **Low pass** (blocks high frequencies)
  - **High pass** (blocks low frequencies)
  - **Bandpass** (blocks high and low frequencies except in narrow band)
  - **Bandstop** (blocks frequencies in a narrow band)

Filter Specifications

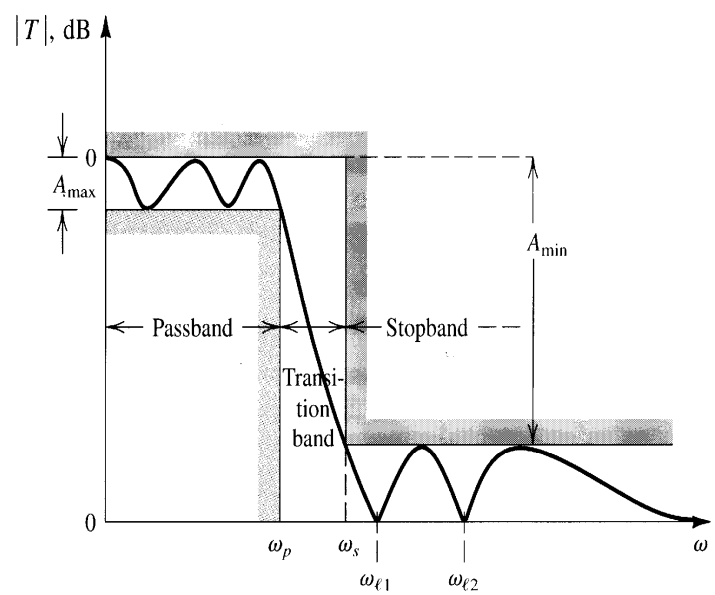


Fig. 11.3 Specification of the transmission characteristics of a low-pass filter. The magnitude response of a filter that just meets specifications is also shown.

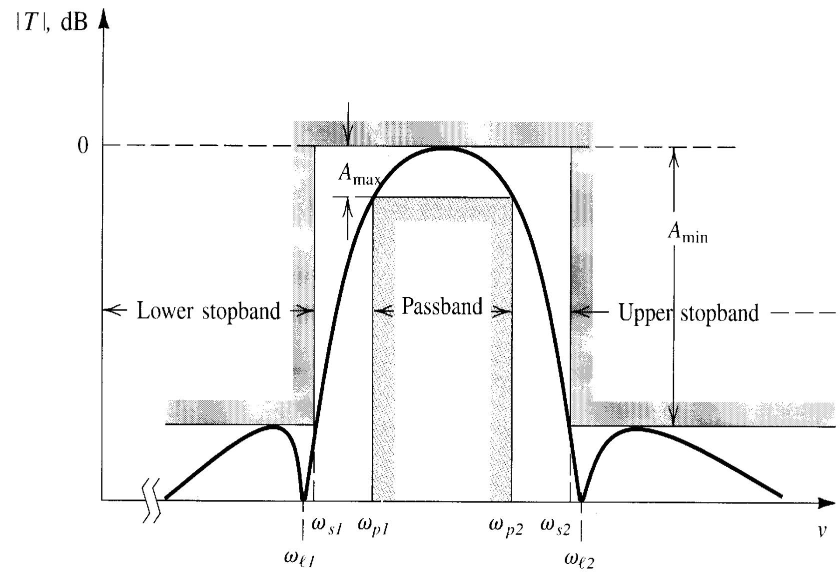


Fig. 11.4 Transmission specifications for a bandpass filter. The magnitude response of a filter that just meets specifications is also shown. Note that this particular filter has a monotonically decreasing transmission in the passband on both sides of the peak frequency.

* **Specifications - four parameters needed**

- **Example – low pass filter: A_{min}, A_{max}, Passband, Stopband**
- **Parameters specify the basic characteristics of filter, e.g. low pass filtering**
- **Specify limitations to its ability to filter, e.g. nonuniform transmission in passband, incomplete blocking of frequencies in stopband**

Filter Transfer Function

* ***Any filter transfer function T(s) can be written as a ratio of two polynomials in "s"***

$$T(s) = \frac{a_M s^M + a_{M-1} s^{M-1} + ... + a_o}{s^N + b_{N-1} s^{N-1} + ... + b_o}$$

* Where $M < N$ and N is called the "order" of the filter function
  - Higher N means better filter performance
  - Higher N also means more complex circuit implementation
* Filter transfer function T(s) can be rewritten as

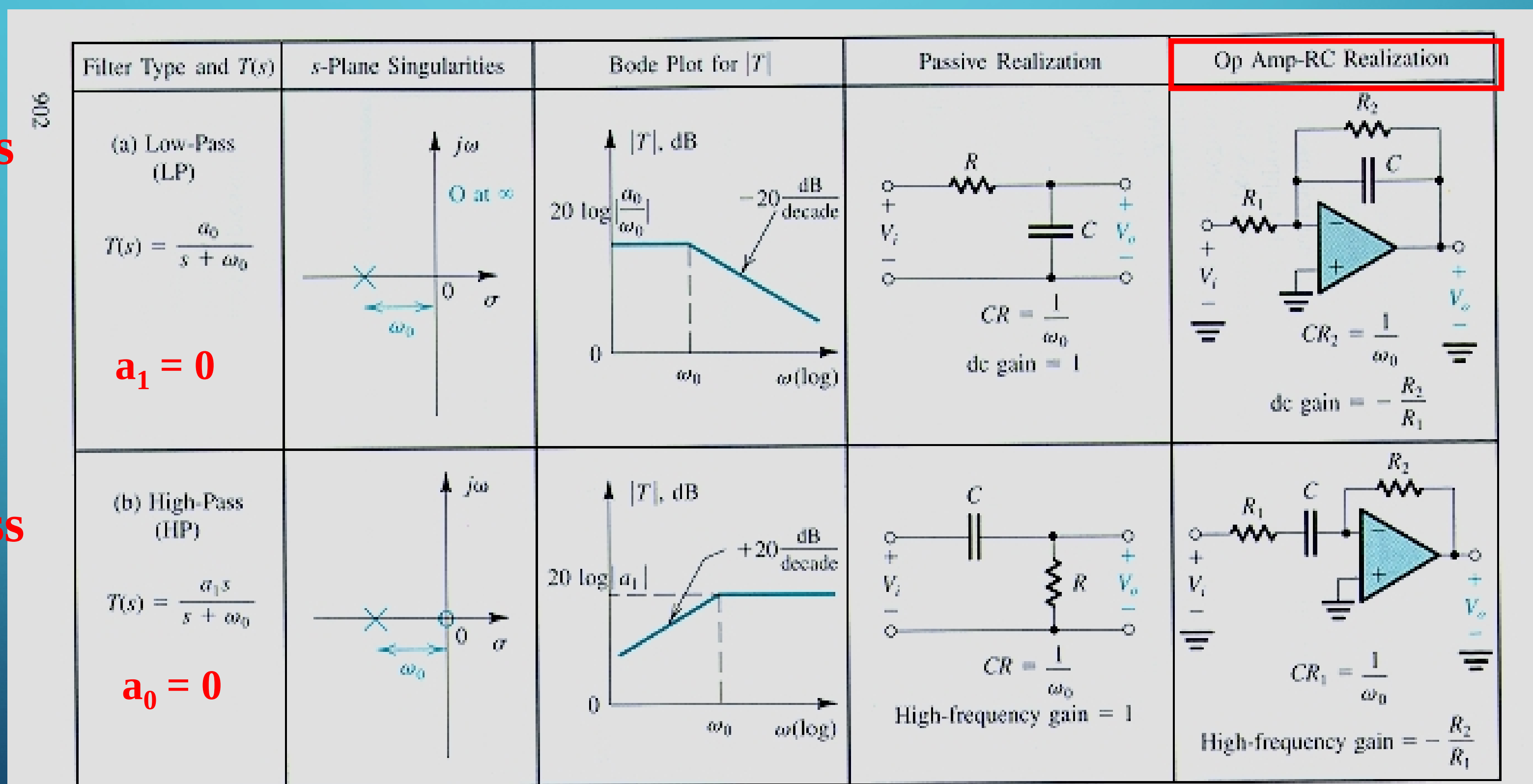
$$T(s) = \frac{a_M (s - z_1)(s - z_2)....(s - z_M)}{(s - p_1)(s - p_2)....(s - p_N)}$$

  - where z's are "zeros" and p's are "poles" of T(s)
  - where poles and zeroes can be real or complex
* ***Form of transfer function is similar to low frequency function $F_L(s)$ seen previously for amplifiers where $A(s) = A_M F_L(s) F_H(s)$***

First Order Filter Functions

*** First order filter functions are of the general form**

$$T(s) = \frac{a_1 s + a_o}{s + \omega_0} = \frac{a_1\left(s + \dfrac{a_o}{a_1}\right)}{s + \omega_0}$$



Filter Type and $T(s)$	s-Plane Singularities	Bode Plot for $\|T\|$	Passive Realization	Op Amp-RC Realization
(a) Low-Pass (LP) $T(s) = \frac{a_0}{s + \omega_0}$	$j\omega$; O at ∞; ω_0; 0; σ	$\|T\|$, dB; $20 \log \left\|\frac{a_0}{\omega_0}\right\|$; −20 dB/decade; 0; ω_0; ω(log)	R; C; V_i; V_o; $CR = \frac{1}{\omega_0}$; dc gain = 1	R_2; C; R_1; V_i; V_o; $CR_2 = \frac{1}{\omega_0}$; dc gain $= -\frac{R_2}{R_1}$
(b) High-Pass (HP) $T(s) = \frac{a_1 s}{s + \omega_0}$	$j\omega$; ω_0; 0; σ	$\|T\|$, dB; $20 \log \|a_1\|$; +20 dB/decade; 0; ω_0; ω(log)	C; R; V_i; V_o; $CR = \frac{1}{\omega_0}$; High-frequency gain = 1	R_1; C; R_2; V_i; V_o; $CR_1 = \frac{1}{\omega_0}$; High-frequency gain $= -\frac{R_2}{R_1}$

Low Pass — $a_1 = 0$

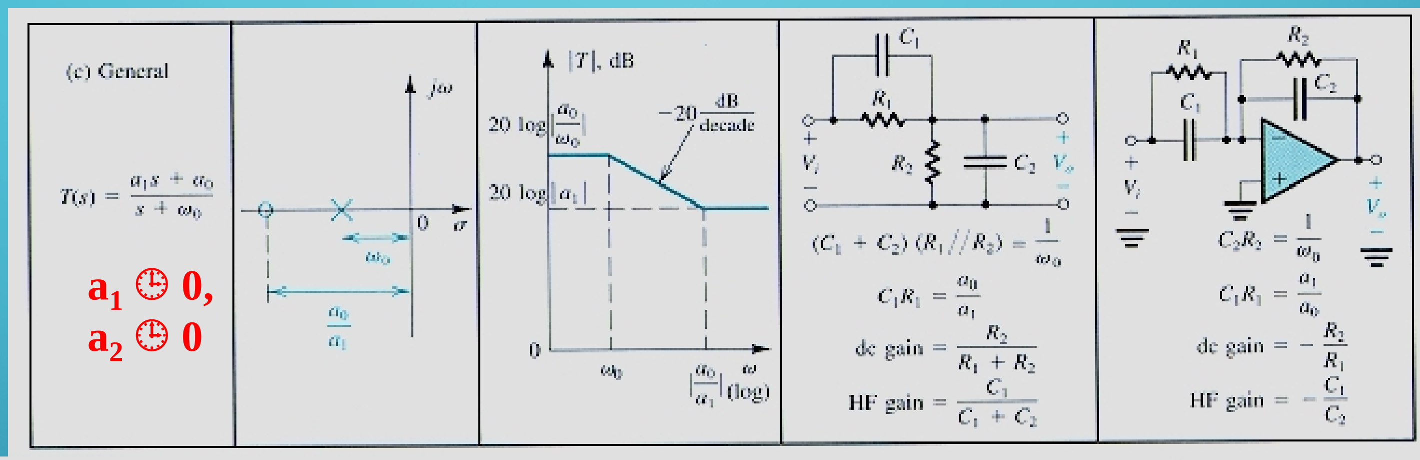
High Pass — $a_0 = 0$

First Order Filter Functions

*** First order filter functions are of the form**

$$T(s) = \frac{a_1 s + a_o}{s + \omega_0} = \frac{a_1\left(s + \frac{a_o}{a_1}\right)}{s + \omega_0}$$

General



$a_1 \neq 0$,
$a_2 \neq 0$

All Pass

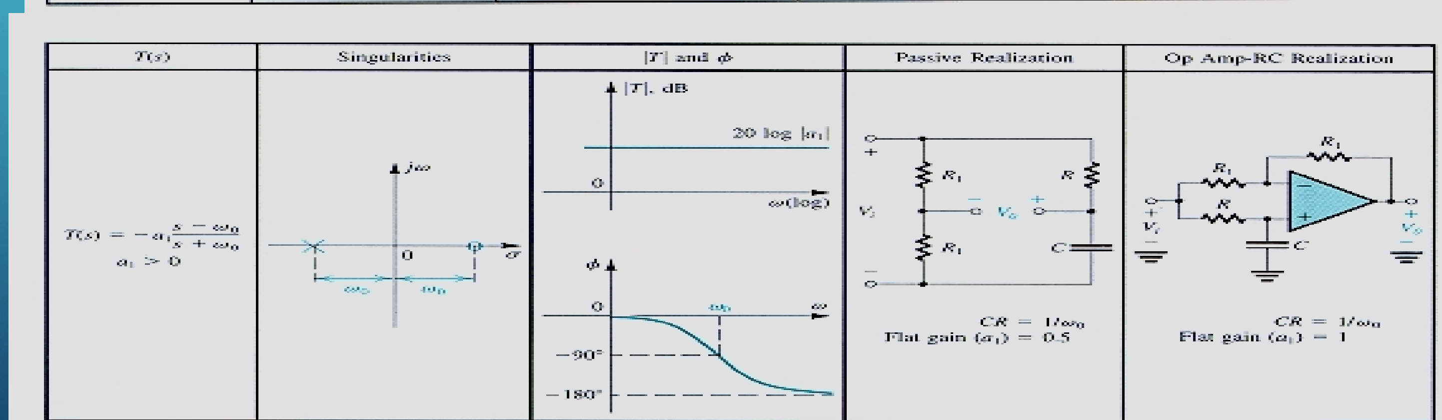


Fig. 11.14 First-order all-pass filter.