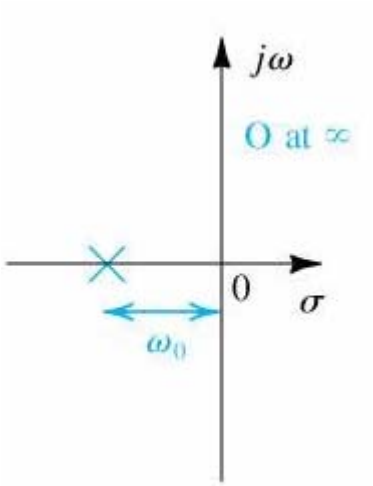
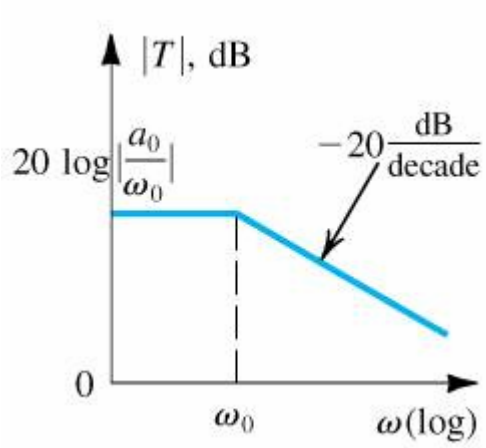
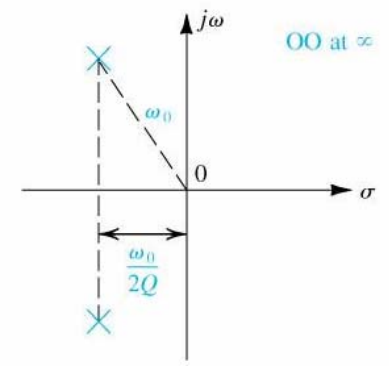
# Lect. 17: Higher-Order Filters (S&S 12.1-3)

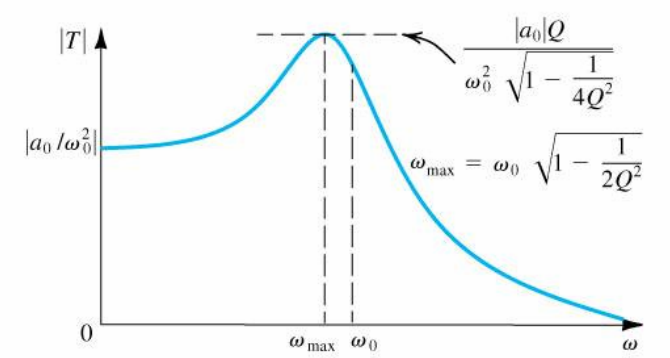
First-Order LP Filter




Second-Order LP Filter

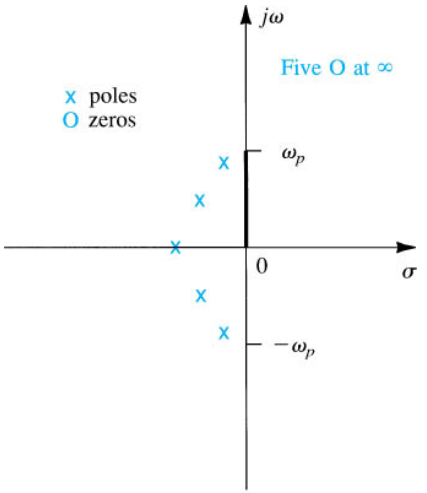


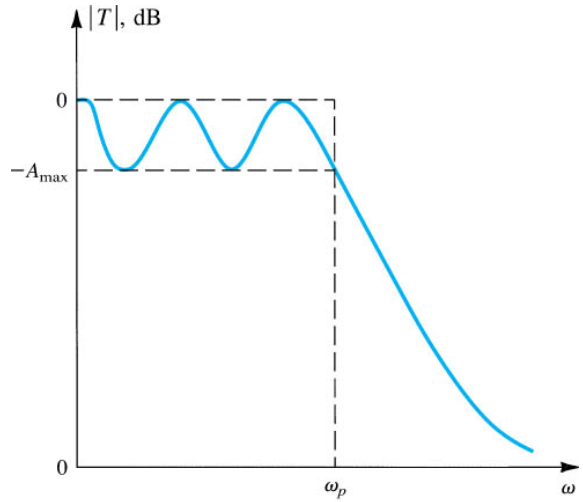
# Lect. 17: Higher-Order Filters

Examples of
Fifth-Order LP Filter

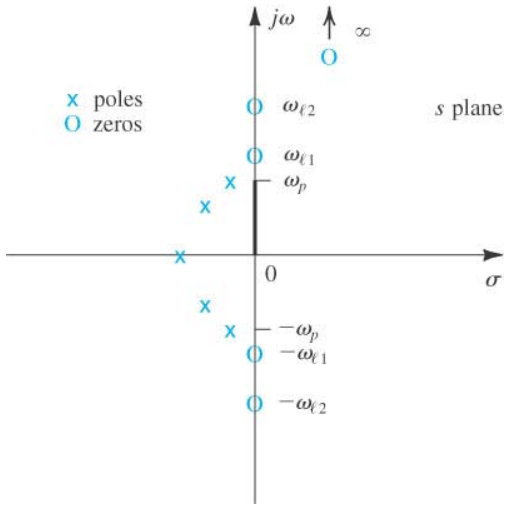
(many other possibilities)

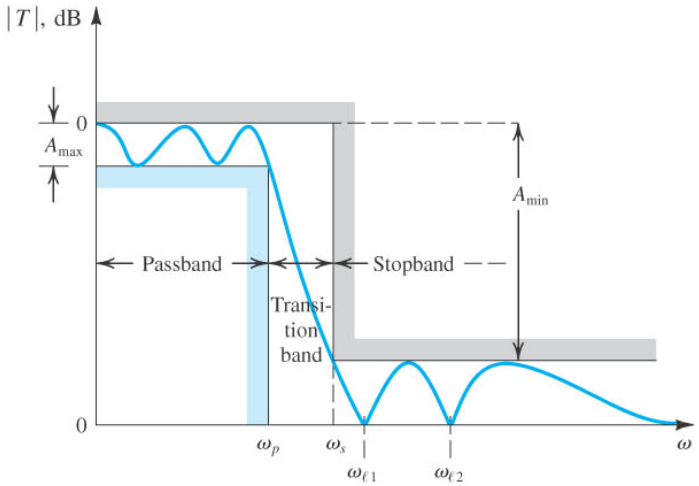



(b)



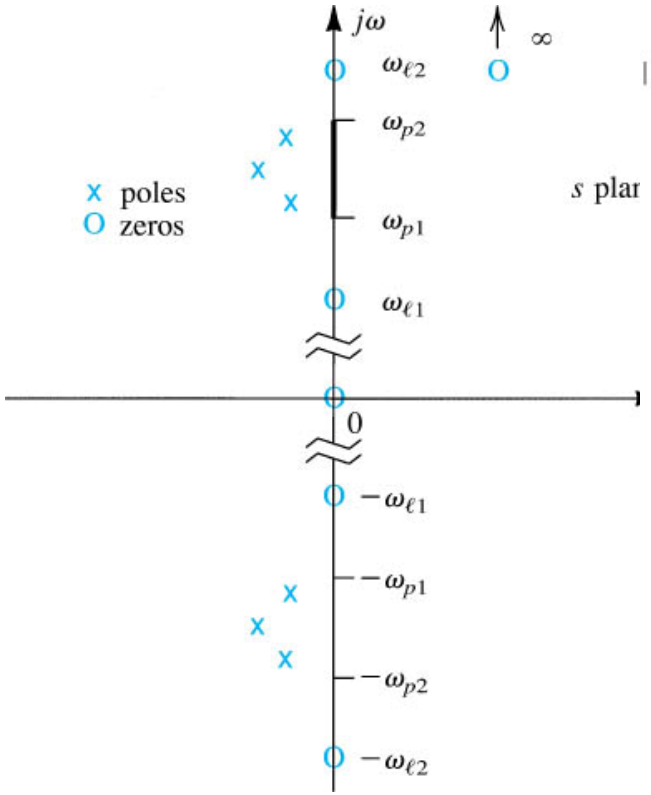

(a)

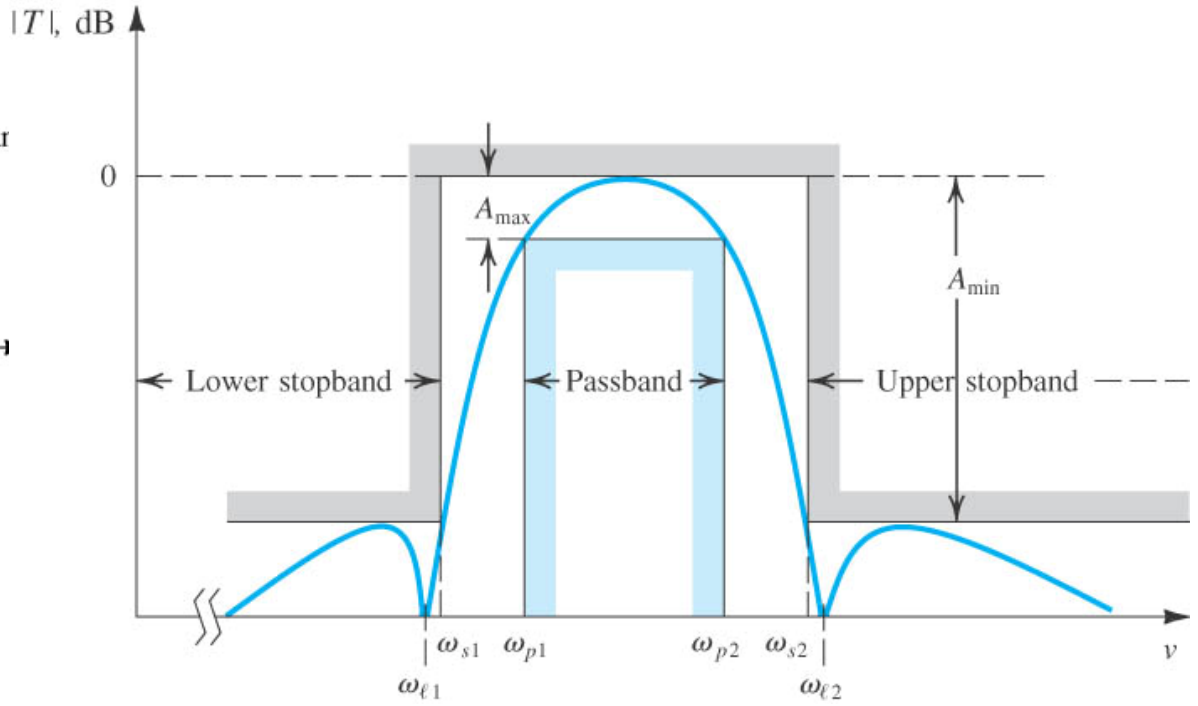


# Lect. 17: Higher-Order Filters

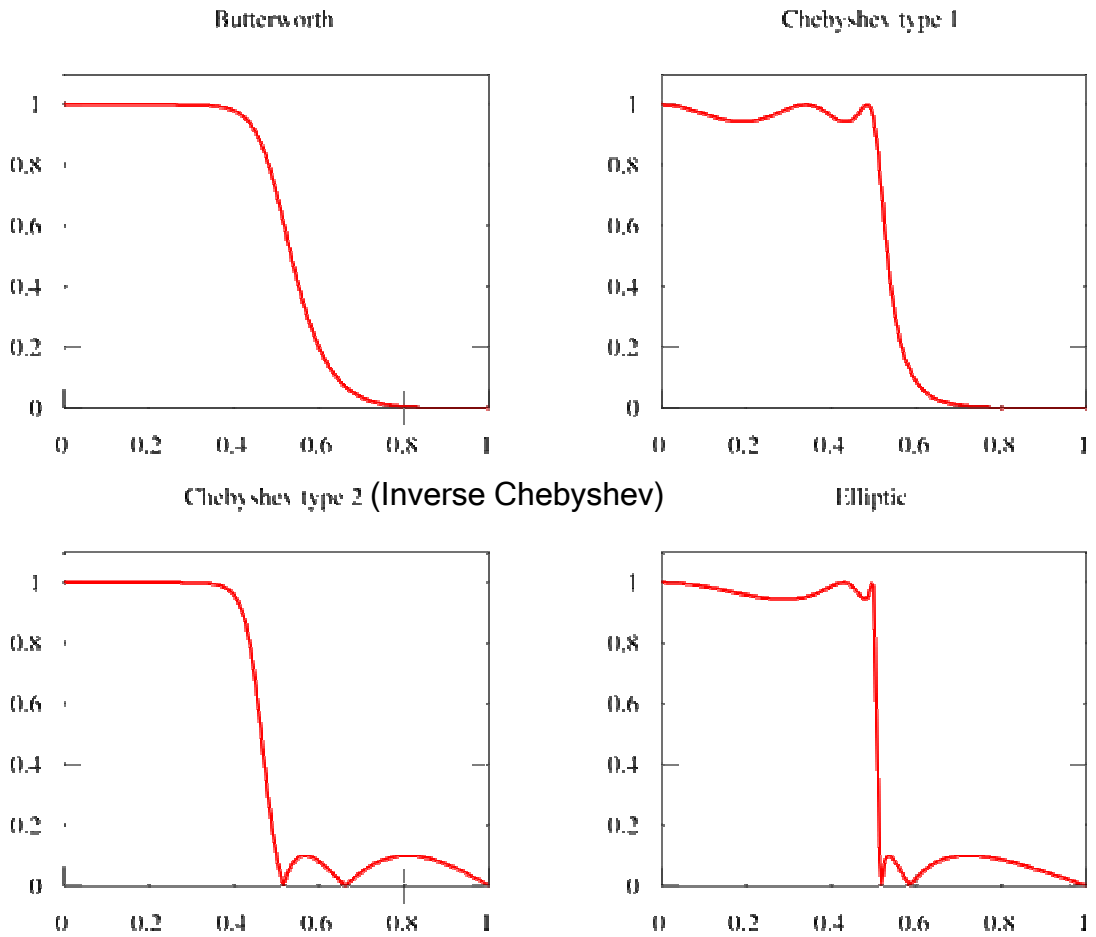
Example of Sixth-Order BP Filter
(many other possibilities)



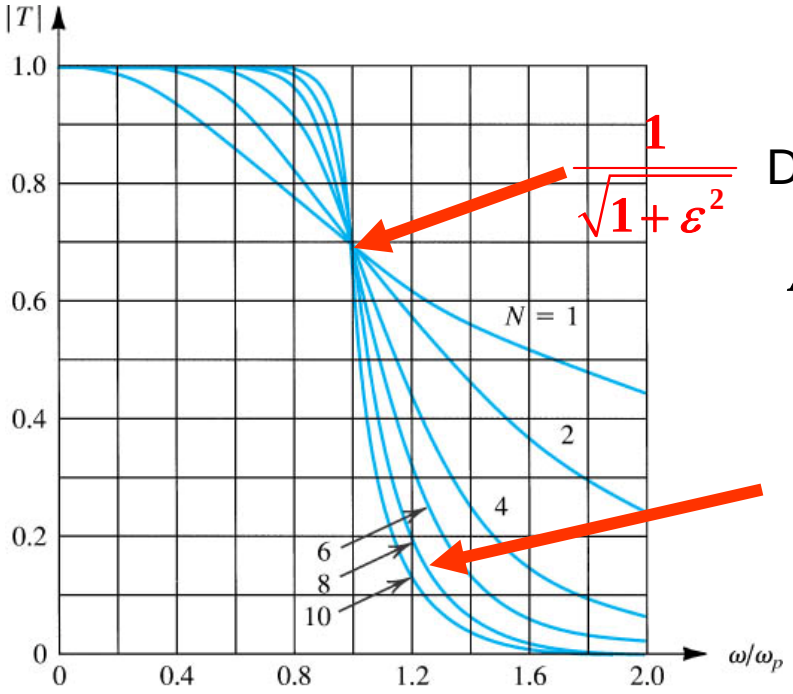
# Lect. 17: Higher-Order Filters

Different types of LP filters



# Lect. 17: Higher-Order Filters

Butterworth LP Filter $$|T(j\omega)| = \frac{1}{\sqrt{1+\varepsilon^2\left(\frac{\omega}{\omega_p}\right)^{2N}}}$$



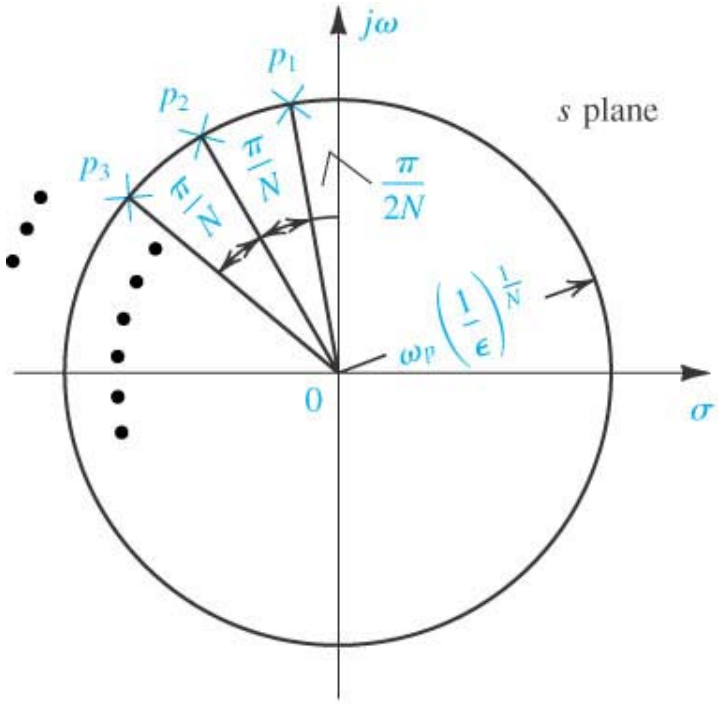

Determine ε so that $A_{max}$ is satisfied

$$A_{max} = 20\log\sqrt{1+\varepsilon^2}$$

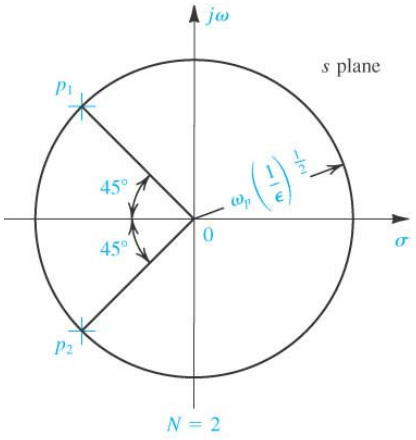
Determine N for the required stop-band attenuation

# Lect. 17: Higher-Order Filters

Pole-Zero diagrams for Butterworth Filter

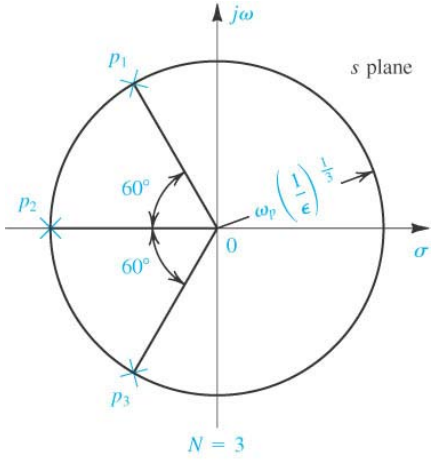



(a)




N = 2

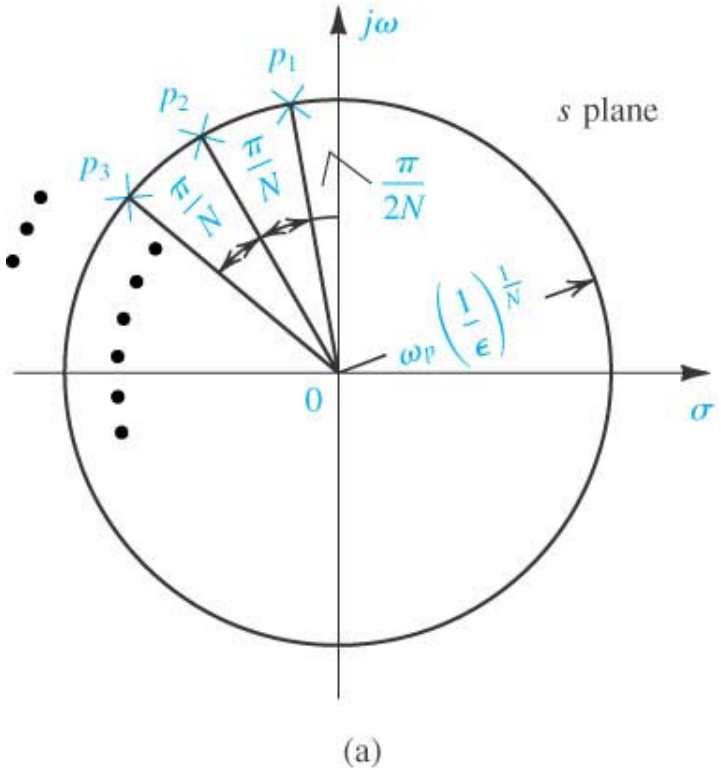
(b)




N = 3

(c)

Butterworth Filter




(a)

$$T(s) = K \frac{\omega_0^N}{(s-p_1)(s-p_2)\cdots(s-p_N)}$$

$$\omega_0 = \omega_p \left(\frac{1}{\varepsilon}\right)^{\frac{1}{N}}$$

# Lect. 17: Higher-Order Filters

How to design higher-order filters with electronic circuits

1. Select the filter type with desired filter specifications. ➔ System specifications

2. Obtain the required transfer function. ➔ Previous lecture materials for Butterworth
   Or use the software package (MATLAB)

3. Derive the corresponding block diagram

4. Design the circuit for the given block diagram

➔ Proejct #3