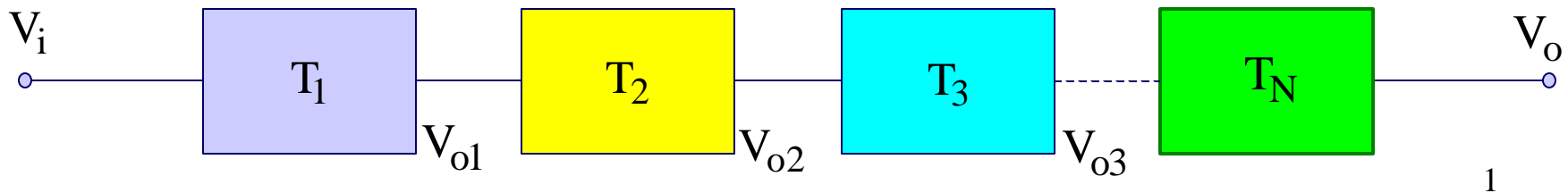


High-Order Filters

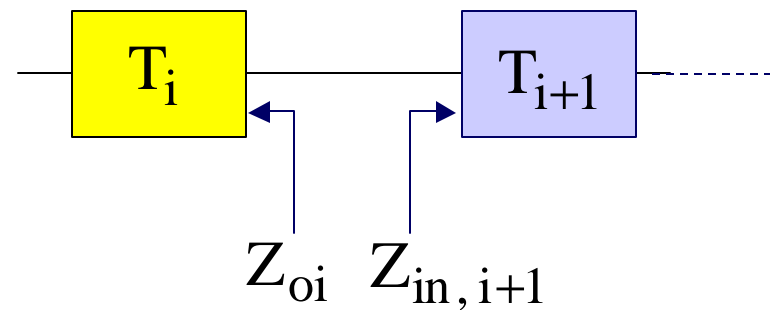
- There are two main approaches for implementing high-order filters:
 - **Cascade**
 - Multiple Feedback Architecture: **Leap Frog**, Follow the Leader, etc
- Cascade approach

$$T(s) = \prod_{i=1}^N T_i(s)$$

where $T_i(s) = K_i \frac{s^2 + C_i s + d_i}{s^2 + \left(\frac{\omega_o}{Q}\right)_i s + \omega_{oi}^2}$



- $T(s)$ can be realized by a cascade of circuits blocks, each of these blocks realizes the biquadratic function $T_i(s)$.
- Each biquad is independent of any biquad if $Z_{oi} \ll Z_{in(i+1)}$

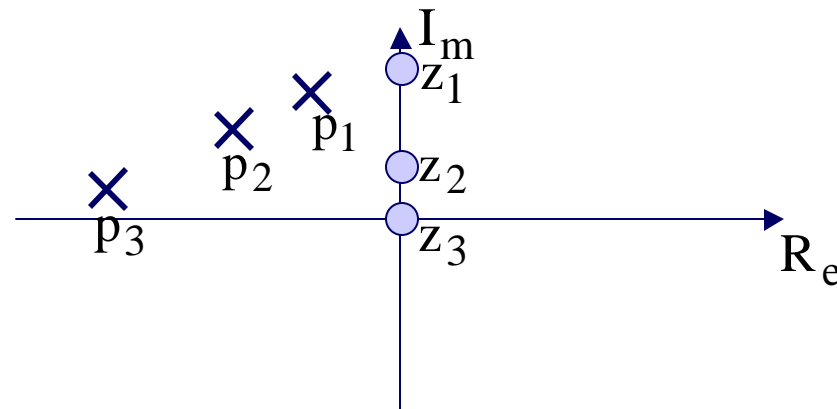


Condition $Z_{oi} \ll Z_{in,i+1}$

- **Degrees of freedom**

- Physical position of each biquad in the cascade
- Distribution of the overall gain in the different biquads
- Pole-Zero pairing

- Optimal goals for cascade filters
 - Maximization of dynamic range
 - Maximization of the signal-to-noise ration
- Additional desirable features
 - Simplification of the tuning procedure
 - Minimization of the pass band attenuation
- Pole-zero pairing
 - Pair each complex pole with its nearest complex zero. This will maximize the dynamic range of each biquad.
 - Starting with the pole of highest Q factor, i.e.,



- How about the cases for zeros at zero and infinity?

$$T(s) = \frac{ks^3}{(s^2 + b_1s + C_1)(s^2 + b_2s + C_2)(s^2 + b_3s + C_3)}$$

- Options

$$T(s) = \frac{k_1}{s^2 + b_1s + C_1} \frac{k_2s^2}{s^2 + b_2s + C_2} \frac{k_3s}{s^2 + b_3s + C_3}$$

$$T(s) = \frac{k_1s}{s^2 + b_1s + C_1} \frac{k_2s}{s^2 + b_1s + C_1} \frac{k_3s}{s^2 + b_1s + C_1}$$

- Advantages and disadvantages

- Cascade sequence

- Several options N!
- Cascade in increasing Q factors.

LP with Q_1

BP with Q_1

HP with Q_3

$$Q_1 < Q_2 < Q_3$$