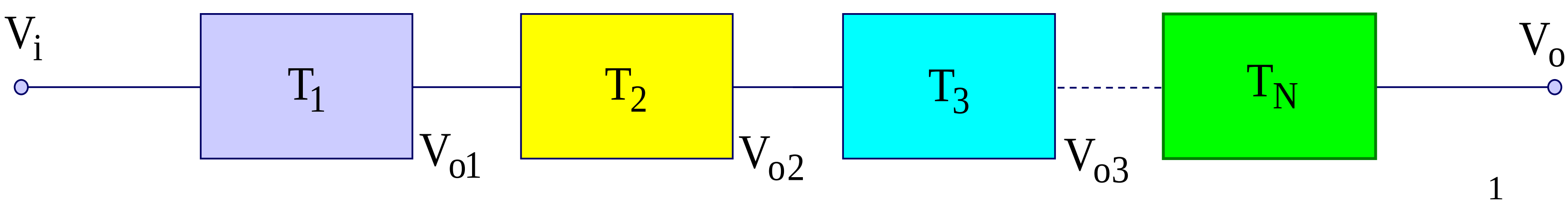
High-Order Filters

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

- Cascade approach

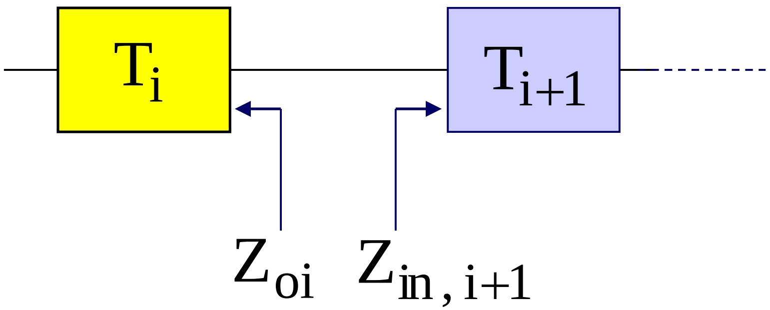
$$T(s) = \prod_{i=1}^{N} T_i(s)$$

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



- 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 $Z_{oi} \ll Z_{in\,(i+1)}$



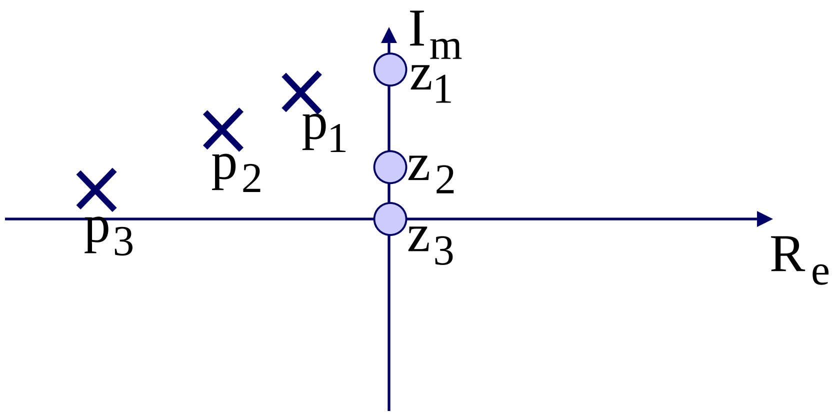
Condition $Z_{oi} \ll Z_{in,\,i+1}$

- **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 $\qquad Q_1 < Q_2 < Q_3$

HP with Q_3