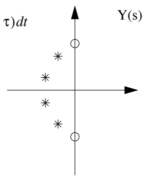
LECTURE 6

Filter

• Continuous-Time Filters

$$y(t) = \int_{-\infty}^{\infty} h(\tau)x(t-\tau)d\tau$$

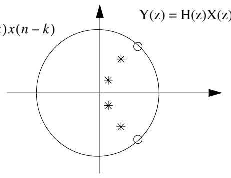
Y(s) = H(s)X(s)



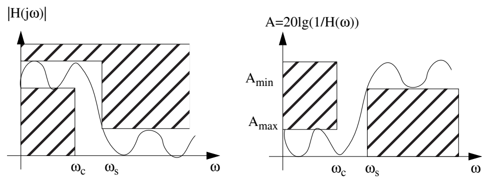
• Discrete-Time Filters

$$y(n) = \sum_{k=-\infty}^{\infty} h(k)x(n-k)$$

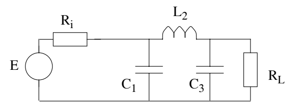
Y(z) = H(z)X(z)



Filter Specification

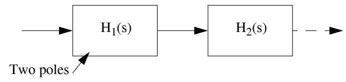


Doubly Terminated LC Ladders



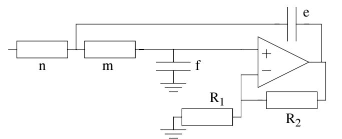
+ Insensitive to parameter variations
- Inductors can not be fabricated on chip

Biquad Sections



+ Simple regular cascaded building blocks
+ Each pole pair can individually be moved
- Sensitive to parameter variations

• Example

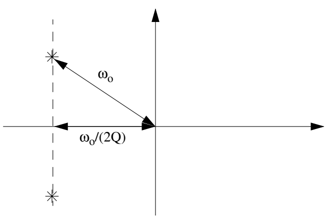


$$H(s) = \frac{A}{mnef} \cdot \frac{1}{s^2 + \left(\frac{1}{me} + \frac{1}{ne} + \frac{1-A}{mf}\right) \cdot s + \frac{1}{mnef}}$$

where $A = 1 + \frac{R_2}{R_1}$

• Q-factor

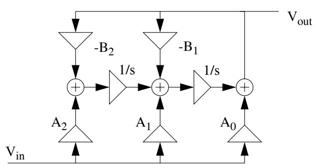
$$H(s) = \frac{K}{s^2 + \frac{\omega_0}{Q} \cdot s + \omega_0^2}$$



Signal Flow Graph

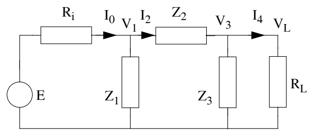
$$H(s) = \frac{A_0 \cdot s^2 + A_1 \cdot s + A_2}{s^2 + B_1 \cdot s + B_2} \Rightarrow$$

$$V_{out} = A_0 \cdot V_{in} + \frac{1}{s} \cdot \left(V_{in} \cdot A_1 - V_{out} \cdot B_1 + \frac{V_{in} \cdot A_2 - V_{out} \cdot B_2}{s}\right)$$



Leapfrog Filters

Simulates Ladder Filters => Insensitive to parameter variations.



$$I_0 = \frac{1}{R_i}(E - V_1),\ V_1 = Z_1(I_0 - I_2),\ I_2 = Y_2(V_1 - V_3)$$

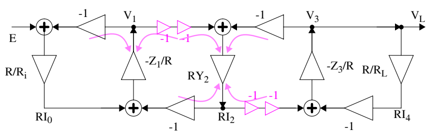
$$V_3 = Z_3(I_2 - I_4),\ I_4 = V_3/R_L$$

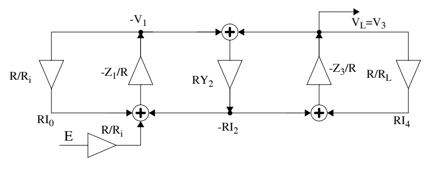
Introduce resistance R to get voltage as variables

$$RI_0 = \frac{R}{R_i}(E - V_1),\ V_1 = \frac{Z_1}{R}(RI_0 - RI_2),\ RI_2 = RY_2(V_1 - V_3)$$

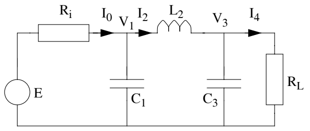
$$V_3 = \frac{Z_3}{R}(RI_2 - RI_4),\ RI_4 = RV_3/R_L$$

• Signal Flow Graph





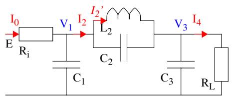
• Filters with no Finite Zeros



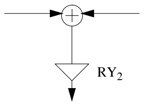
$$Z_1 = \frac{1}{SC_1}, Y_2 = \frac{1}{SL_2}, Z_3 = \frac{1}{SC_3}$$

Only integrators are needed.

• Elliptic Filters

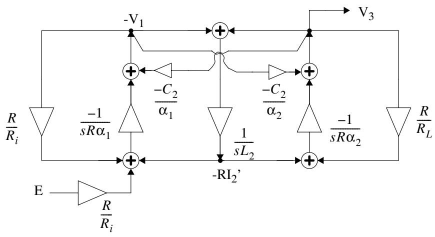


Problem:



$Y_2 = 1/sL_2 + \mathbf{sC_2}$

For the implementation we prefer to have only integrators. => Use I_2' as a variable.



$\alpha_1 = C_1 + C_2$; $\alpha_2 = C_2 + C_3$

Analoga Tidsdiskreta Integrerade Kretsar, TSTE80

Scaling

- The Signals are usually limited by the supply voltages: Signal swing < $V_{dd} - V_{ss}$
- Small signal swing => Low SNR

Change the signal swing in important nodes to have

$$max(|H_i(j\omega)|) = max\left(\frac{|X_i(j\omega)|}{V_{in}(j\omega)}\right) = 1$$

Principle: Multiply all input signals to a sub-net by k_i and divide all output signal with the same factor.

The principle above is based on that if we do not change the loop gains in the signal flow graph the poles of the transfer function are fixed.

• Example