

# Active R Ladders: High-Frequency High-Order Low-Sensitivity Active R Filters Without External Capacitors

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**I. Overview.** Active R Ladders use the poles of operational amplifiers to provide state variables without the use of capacitors or inductors. Six Active R circuits are constructed from their passive equivalents, and the resulting "fundamental structures" can be combined according to basic rules to realize all elements of reactance ladders. These filters offer higher frequencies than achievable with RC designs, and are more suitable for inclusion on integrated circuits since they do not possess external capacitors. Several disadvantages exist, including dynamic range problems and temperature sensitivity, but these can be worked out with appropriate modifications to the circuit.

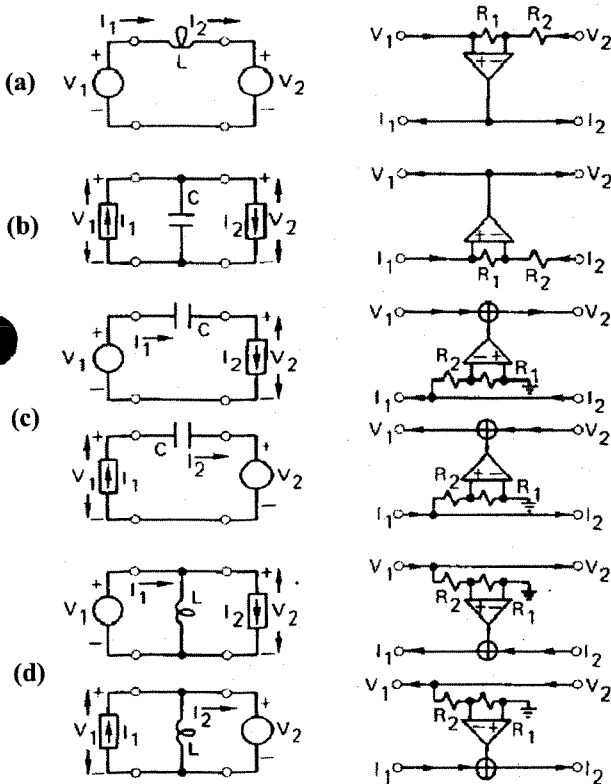


Fig 1. Basic Building Blocks. (a) Series Inductor. (b) Shunt capacitor. (c) Series capacitors. (d) Shunt inductors.

**II. Supporting Equations.**

$$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = \begin{pmatrix} 1 & Ls \\ 0 & 1 \end{pmatrix} \begin{pmatrix} V_2 \\ I_2 \end{pmatrix}$$

Equ 1. Passive series inductor ABCD Matrix

$$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = \begin{pmatrix} 1 & \frac{(R_1 + R_2)s}{R_1 GB} \\ 0 & 1 \end{pmatrix} \begin{pmatrix} V_2 \\ I_2 \end{pmatrix}$$

Equ 2. Active R series inductor ABCD Matrix

$$\frac{R_2}{R_1} = L \cdot GB - 1$$

Equ 3. Simulation of a series inductor

**III. Combination Rules.**

- 1) Active R circuits of Fig. 1 must be combined in such a way that voltage and current directions are properly matched from circuit to circuit.
- 2) Combinations must simulate KCL and KVL.

**IV. An Example.**

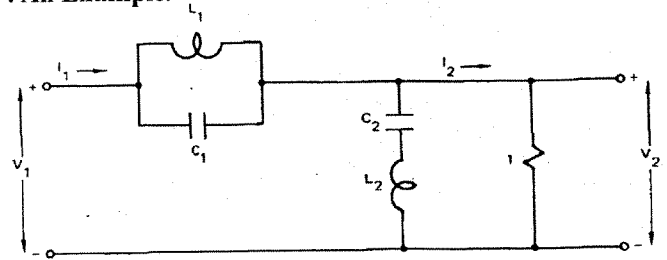


Fig 2. Passive Band Reject Filter

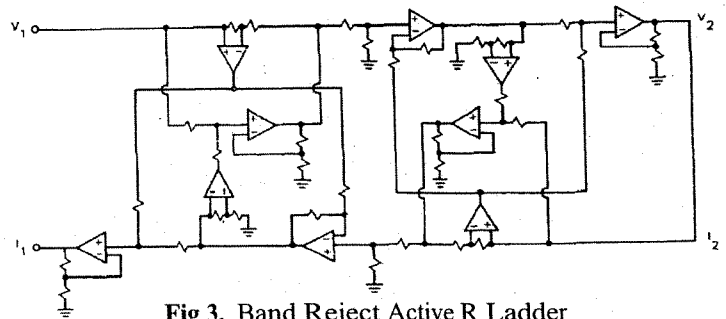


Fig 3. Band Reject Active R Ladder

**V. Results.**

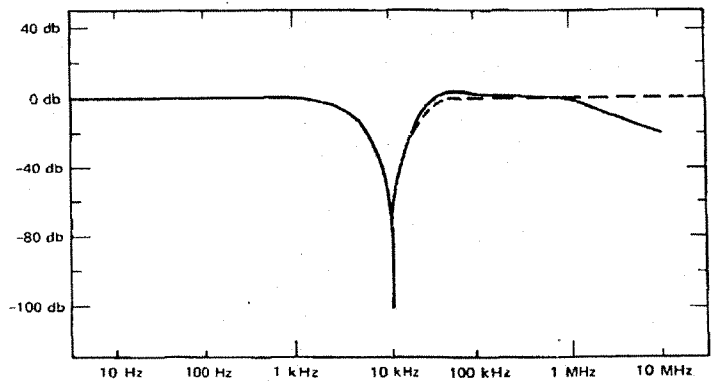


Fig 4. SPICE Simulation. (a) Dashed line - Passive Band Reject Filter. (b) Solid line - Active R Circuit

**VI. Conclusions.**

*Advantages*

- Offer high order circuits with low sensitivity.
- Ability to design circuits that operate at higher frequencies.
- No capacitors or inductors.

*Disadvantages*

- Sensitivity to temperature
- Dynamic range problems
- Require a large number of components