# E4215: Analog Filter Synthesis and Design
# Transfer functions realizable in a biquad

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18 Feb. 2003

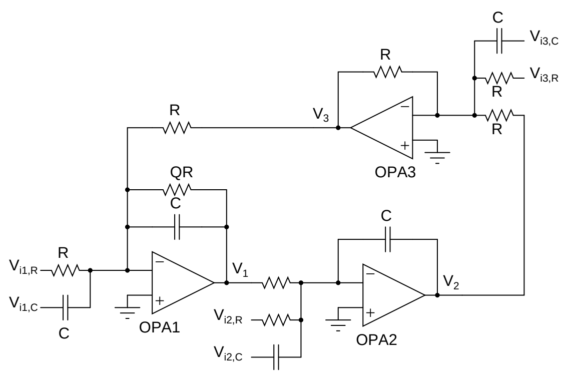


Figure 1: Tow-Thomas biquad with various possible inputs

Table 1: Transfer function between different inputs and outputs in Fig. 1. $D(s) = 1 + \dfrac{sCR}{Q} + (sCR)^2$

| | $V_1$ | $V_2$ | $V_3$ |
|---|---|---|---|
| $V_{i1,R}$ | $-\dfrac{sCR}{D(s)}$ | $\dfrac{1}{D(s)}$ | $-\dfrac{1}{D(s)}$ |
| $V_{i2,R}$ | $-\dfrac{1}{D(s)}$ | $-\dfrac{1/Q + sCR}{D(s)}$ | $\dfrac{1/Q + sCR}{D(s)}$ |
| $V_{i3,R}$ | $\dfrac{sCR}{D(s)}$ | $-\dfrac{1}{D(s)}$ | $-\dfrac{sCR/Q + (sCR)^2}{D(s)}$ |
| $V_{i1,C}$ | $-\dfrac{(sCR)^2}{D(s)}$ | $\dfrac{sCR}{D(s)}$ | $-\dfrac{sCR}{D(s)}$ |
| $V_{i2,C}$ | $-\dfrac{sCR}{D(s)}$ | $-\dfrac{sCR/Q + (sCR)^2}{D(s)}$ | $\dfrac{sCR/Q + (sCR)^2}{D(s)}$ |
| $V_{i3,C}$ | $\dfrac{(sCR)^2}{D(s)}$ | $-\dfrac{sCR}{D(s)}$ | $-\dfrac{(sCR)^2/Q + (sCR)^3}{D(s)}$ |

The last row in Table 1 using the capacitive input $V_{i3,C}$ is not practical because it introduces an extra pole in the feedback around opamp OPA3, degrading stability (as in an opamp differentiator).