Georiga Institute of Technology

School of Electrical & Computer Engineering

EE4086 **Operational Amplifier Design** **Class Handout**

A General Bi–Quad Circuit

The circuit diagram gives a general four op–amp biquad circuit that can be used to realize any transfer function of the form

$$\frac{V_o}{V_i} = -K\,\frac{(s/\omega_N)^2 + (1/Q_N)(s/\omega_N) + 1}{(s/\omega_D)^2 + (1/Q_D)(s/\omega_D) + 1}$$

Let the constants a, b, c, d, and m be given by the equations:

$$a = \omega_D/Q_D \qquad b = \omega_D^2 \qquad c = K\omega_D^2/Q_N\omega_N \qquad d = K\omega_D^2 \qquad m = K\omega_D^2/\omega_N^2$$

The positions of the two switches in the circuit are determined by the following conditions:

Case A1:	Position A if $ma > c$ and $mb \geq d$
Case A2:	Position A if $ma = c$ and $mb > d$
Case B1:	Position B if $ma > c$ and $mb < d$
Case B2:	Position B if $ma = c$ and $mb < d$
Case C:	Position C if $ma < c$ and $mb \geq d$
Case D:	Position D if $ma < c$ and $mb < d$

In the circuit design equations that follow, C_1, C_2, R_{10}, k_1, and k_2 are arbitrary.

$$R_1 = \frac{1}{aC_1} \qquad R_2 = \frac{|k_1|}{\sqrt{b}C_2} \qquad R_3 = \frac{1}{|k_1|\sqrt{b}C_1} \qquad R_4 = \frac{1}{|k_2(ma - c)|C_1}$$

$$R_5 = R_3 \qquad R_6 = R_3 \qquad R_7 = |k_2|R_{10} \qquad R_8 = \frac{|k_2(ma - c)|}{|k_1(mb - d)|}\sqrt{b}R_{10}$$

$$R_9 = R_{10}/m \quad \text{for cases A1, A2, B1, B2, and C}$$

$$= (b/d)R_{10} \quad \text{for case D}$$

For cases A2 and B2

$$R_4 = \frac{\sqrt{b}}{|k_2(mb - d)|C_1} \qquad R_8 = \left| \frac{k_2}{k_1} \right| R_{10} \qquad R_7 = \text{open circuit}$$

The reference for this circuit design is: J. Tow, "Design Formulas for Active RC Filters Using Operational Amplifier Biquad," *Electronics Letters,* No. 15, pp. 339–341, July 1969.