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Digital Potentiometers Enable Programmable Biquadratic Filter

The use of three digital potentiometers and three op amps allow easy software configuration of a versatile programmable filter.

Of the many types of analog filters available to electronics engineers, few allow easy adjustments of the filter parameters. The biquadratic (biquad) filter is an exception, however. You can change this filter's corner frequency (ω_0), quality factor (Q), and gain (H) by adjusting the values of three resistors. To illustrate this adjustment, the lowpass biquad circuit of **Figure 1** includes three digital potentiometers configured as variable resistors in the feedback loops. Altering the settings of these digital pots changes the filter characteristics.

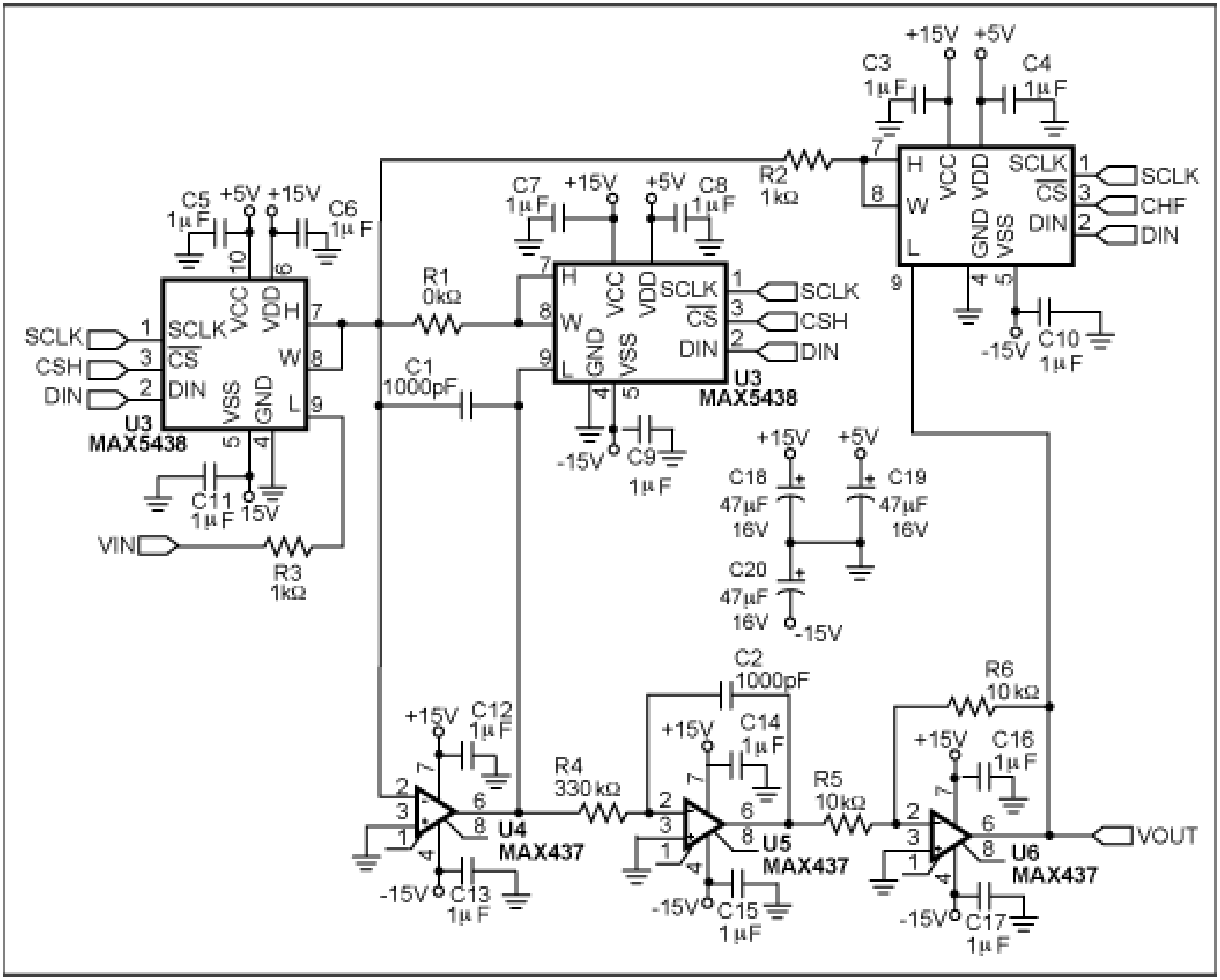

Figure 1. Digital potentiometers adjust the corner frequency, Q, and gain for this biquad analog filter.

The circuit produces corner frequencies between 5.5kHz and 55kHz, Q values between 0.055 and 5.5 (depending on the selected ω_o), and H between 1 and 100 (also dependent on the selected ω_o). To tune the biquad filter, you set wo (in rad/s) by adjusting the digital pot U2 through the SPI interface. In the same fashion, set Q by adjusting U1 and gain by adjusting U3.

Note that adjusting Q does not affect the wo setting, nor does an H adjustment affect the settings of Q or ω_o. Equations 1, 2, and 3 demonstrate this orthogonal tuning for the biquad filter:

$$\omega_o^2 = \frac{1}{(R_2 + R_{U2})R_4C_1C_2} \quad \text{(Eq 1)}$$

$$Q = \sqrt{\frac{(R_1 + R_{U1})^2 C_1}{(R_2 + R_{U2})R_4C_2}} \quad \text{(Eq 2)}$$

$$H = \frac{R_2 + R_{U2}}{R_3 + R_{U3}} \quad \text{(Eq 3)}$$

The Figure 1 circuit is substantially more complex than the switched-capacitor approach usually integrated into an IC. However, the switching noise and low bandwidth of a switched-capacitor filter are unacceptable in many applications (**Figure 2**). A biquad filter offers better frequency and noise performance in exchange for more PC-board space. And, because monolithic switched-capacitor filters are usually expensive, the biquad circuit of Figure 1 may not represent an increase in cost.

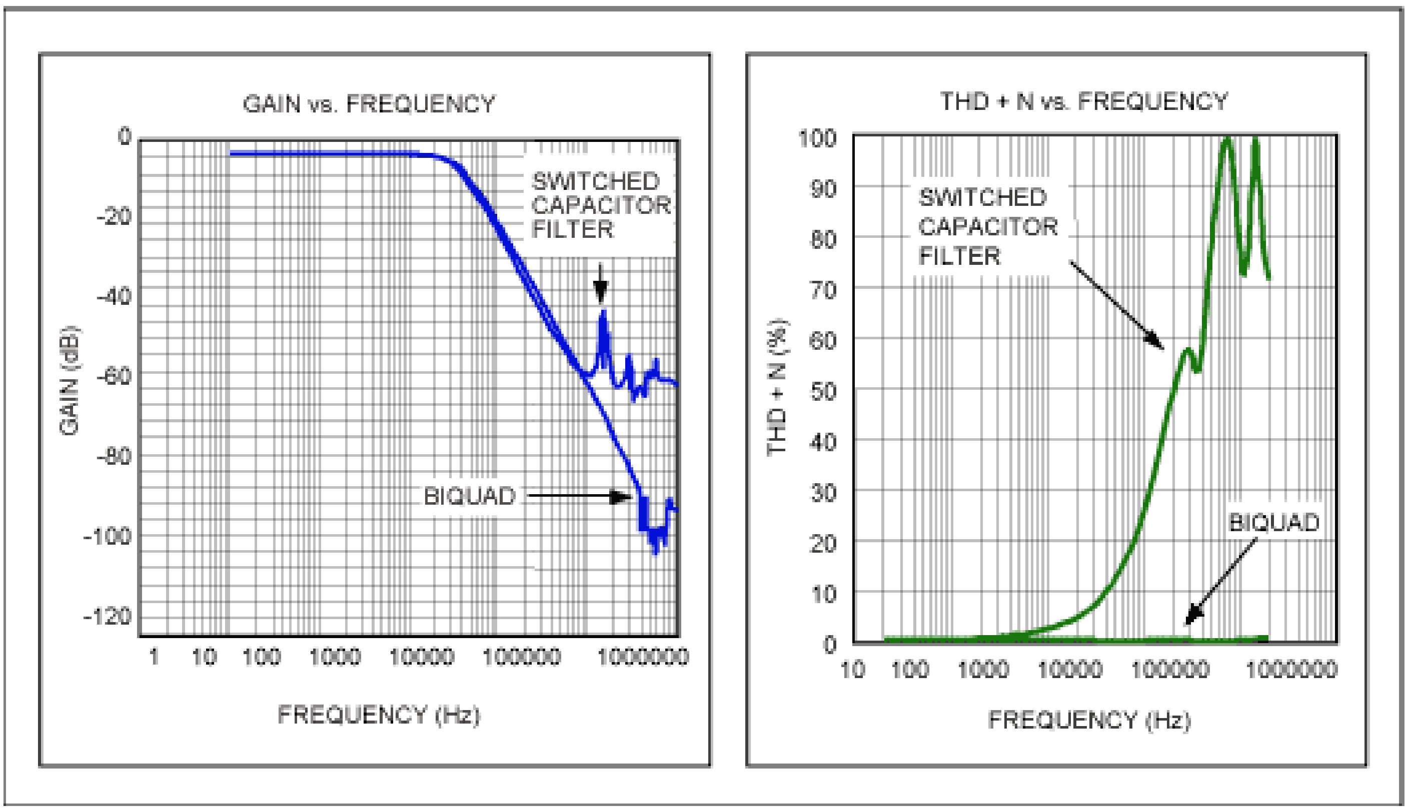

Figure 2. Noise and low bandwidth plague switched-capacitor filters, but biquad filters can operate at higher frequencies, as they are not limited by capacitor switching speed. The biquad filter of Figure 1 maintains less than 1% THD+N over the 20Hz to 200kHz range.

Many filter applications require higher supply voltages or bipolar operation or both, so the single 5V supply associated with most switched-capacitor filters may be inadequate for some applications. To accommodate, you can implement ±15V voltage rails using digital pots and highvoltage op amps (such as the MAX5438 and MAX437).

The biquad filter is not limited to the lowpass response only. Highpass, bandpass, bandstop, and allpass responses can be produced by adding a fourth op amp to selected terminals of the original lowpass design (**Figure 3**).

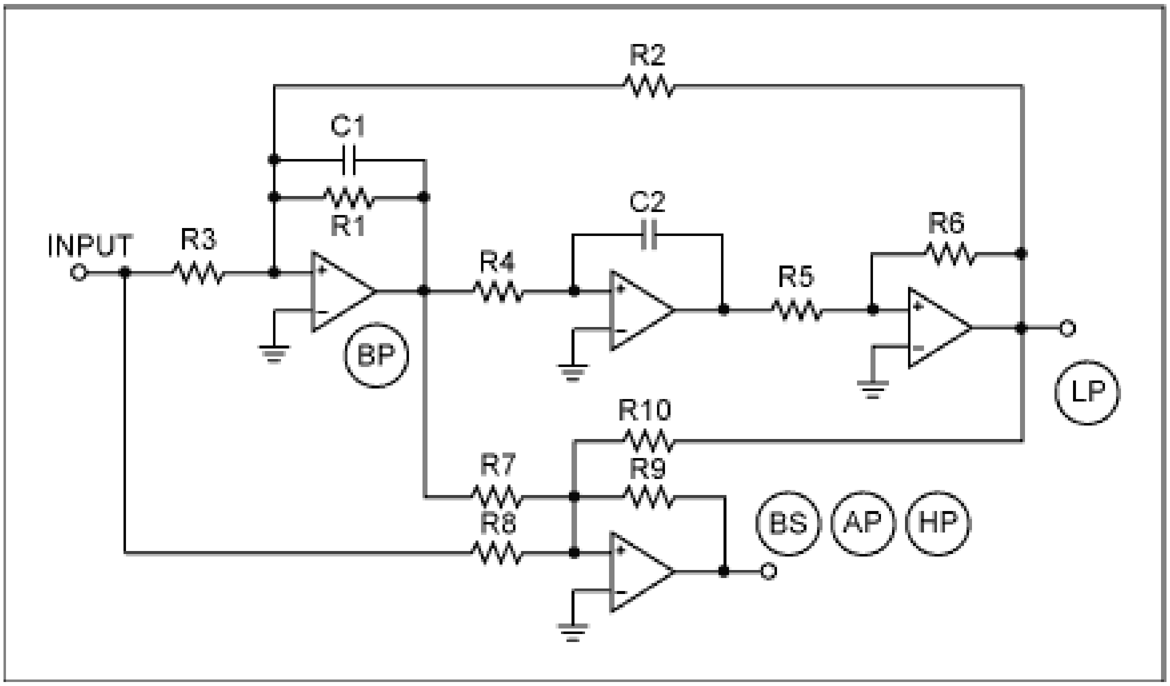

Figure 3. The standard biquad filter circuit produces lowpass (LP) and bandpass (BP) responses, and the addition of a fourth op amp produces a highpass (HP) response. Removing R10 (and adjusting various component values) produces a notch or band-stop (BS) response, or an allpass response.

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More Information