DC-controlled low-pass filter has variable breakpoint

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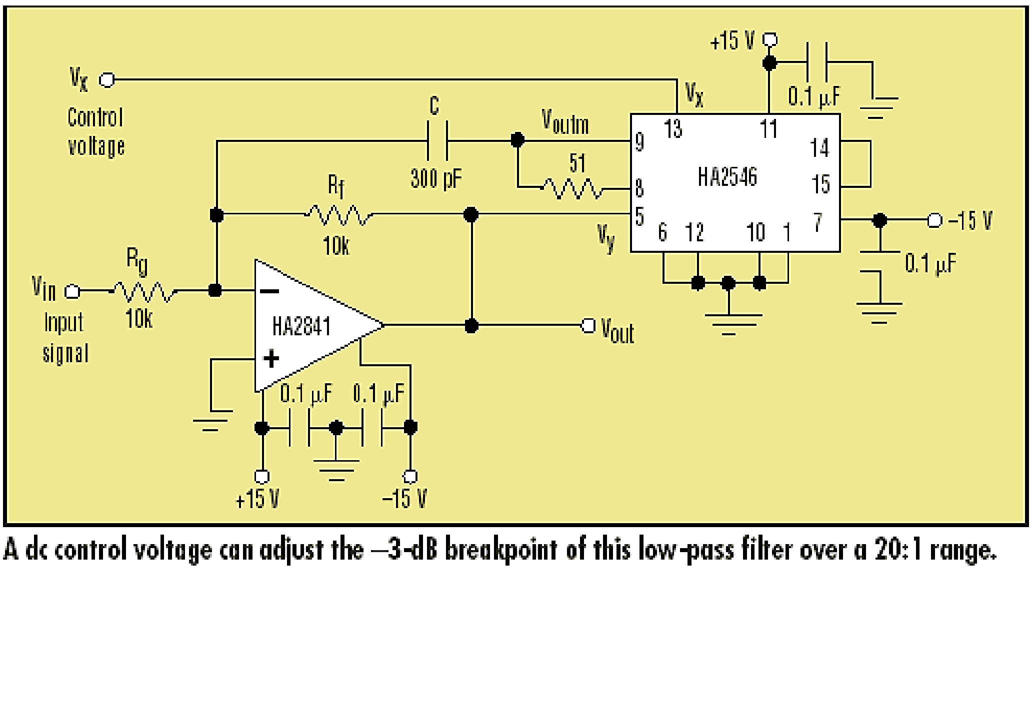
When maximum performance is demanded from communications systems, test equipment, or any other frequency-sensitive systems, it's imperative to get the point where the filter response is –3 dB (the breakpoint of the low-pass filter) placed exactly right. Placing the breakpoint correctly ensures minimum distortion in the passband while yielding maximum attenuation of unwanted frequencies in the stopband. This is very hard to accomplish in multiple frequency systems because when a break frequency is placed correctly for one task it is, usually by definition, wrong for another task.

The described low-pass filter has a breakpoint that's continuously variable over a range of 20 to 1 by varying the dc control voltage. The gain stays constant regardless of the breakpoint setting. If digital control is advantageous, a DAC can easily be interfaced into the control voltage port because the control voltage ranges from 0 to 1.5 V.

The HA2841 op amp is the main amplification element in the circuit, and it was chosen because it has excellent dc characteristics coupled with high frequency response (see the figure). The input signal is amplified by the op amp, but only the dc portion of the output signal is fed directly back to the op-amp summing junction. This fixes the dc gain at –Rf/Rg. The ac portion of the output signal is passed through the HA2546 high-frequency multiplier before it's fed back to the summing junction.



A dc control voltage can adjust the –3-dB breakpoint of this low-pass filter over a 20:1 range.

The HA2546 was chosen for this application because it's extremely small time delay doesn't introduce distortion. The feedback capacitor (C) blocks any dc multiplier errors. As Vx changes, the multiplier gain changes, so the apparent value of C changes. Consequently, the breakpoint frequency is forced to change. In the equation for the multiplier, Voutm is the multiplier output voltage:

$$V_{outm} = \left(\frac{V_x V_y}{2}\right) = \left(\frac{V_x V_{out}}{2}\right)$$

The equation for the complete circuit response is:

$$\frac{-V_{out}}{V_{in}} = \left(\frac{R_f}{R_g}\right)\left(\frac{1}{\left(1+\left(\frac{V_x R_f C}{2}\right)\right)}\right)$$

$$\omega = 2\pi F = \frac{1}{V_x R_f C}$$

The control voltage (Vx), in conjunction with Rf and C, determine the breakpoint frequency, ω. Rf and C are used to center the frequency range, and Vx varies the frequency within this range. Both Rf and Rg set the gain, so there's plenty of flexibility in the component selection. The component values shown yield a frequency range from 1.7 MHz when Vx = 0.1 V to 80 kHz when Vx = 1.25 V. The control input is similar to an op-amp input, thus it needn't be driven by a low-impedance source. This input may be driven from a DAC to obtain digital control of the breakpoint, but the DAC output voltage must be level-shifted to 0 to 1.5 V.