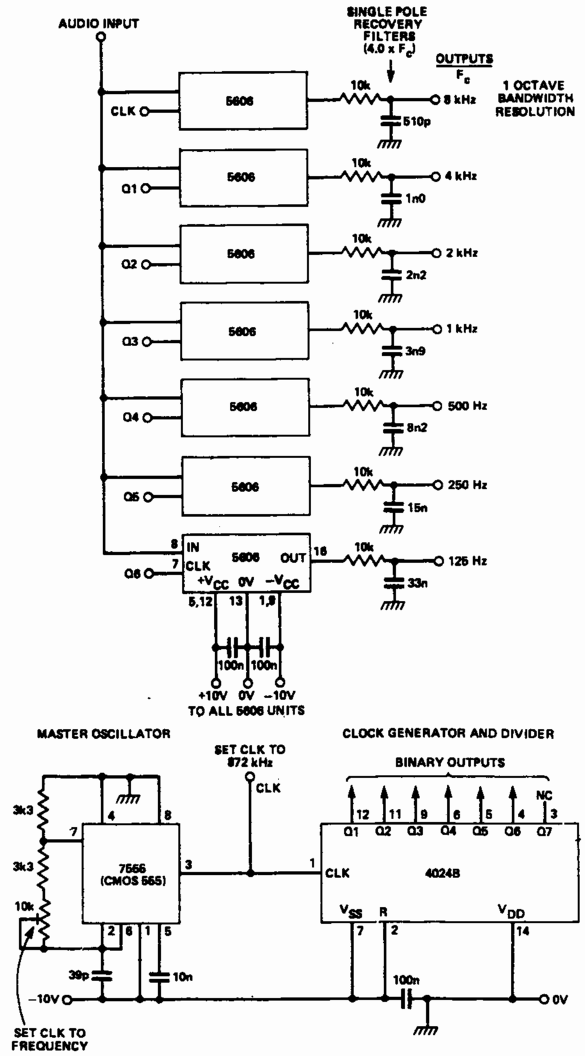
Designer's Notebook
Switch Capacitor Filters Part 2

Last month, we looked at some of the new switched capacitor ICs. This month, Tim Orr gets down to some circuits using them.

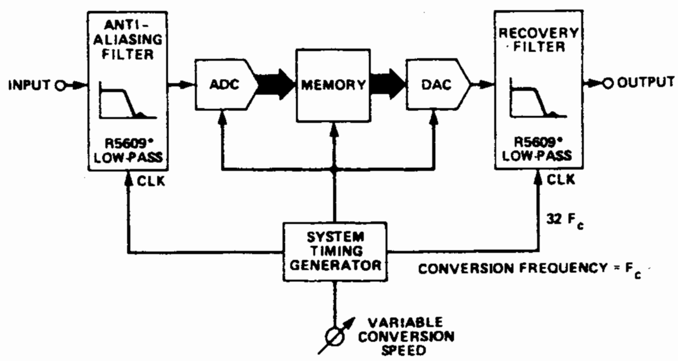
Seven-Octave Audio Analyser

The R5606 is a single octave filter. Each R5606 is clocked with a square wave generated by a seven-stage binary divider, so that successive filter break-points are spaced at exactly one octave intervals. The resulting circuit is very simple and may be used as a real-time audio analyser or as an audio equalizer with a steep filter roll-off. Half-octave or even ⅓ octave resolution could be obtained by using the R5605 or the R5604 respectively. The output signal is filtered by a simple single-pole low-pass filter to remove the effects of the sampling and the residual clock breakthrough. A simple anti-aliasing filter can also be used at the input to each filter, but this may not be considered necessary. A dynamic range of about 76 dB per channel should be obtained.



Audio Converter With Tracking Filter

The R5609 is a steep low-pass filter which can be used as an anti-aliasing filter and recovery filter in an audio converter, such as digital delay line. If the clock for the filter is derived from the system clock and the A-to-D converter, then the low-pass filter frequency will track any changes in the conversion speed.



* The R5609 has a rolloff slope of 100 dB/octave.

System bandwidth $= \frac{32 \times F_c}{100} = 0.32\ F_c$

Maximum theoretical bandwidth, as predicted by the sampling theorum = 0.5 F_c

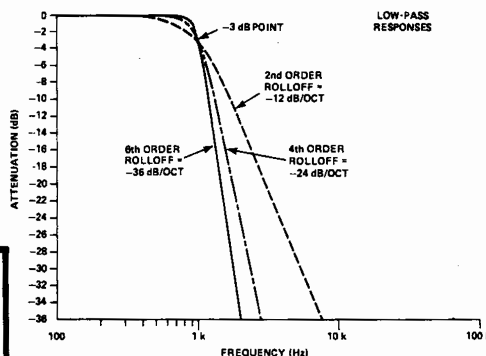
Low-Pass Response Using the MF10

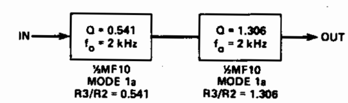
The frequency responses of second, fourth and sixth order maximally-flat low-pass filters are shown in the graph. These can be realized by cascading second order low-pass filter sections together. The table shows the break frequencies and Q factors for both maximally flat (Butterworth) and 3 dB ripple (Chebychev) responses. The maximally flat responses are easy to realize because all stages use the same clock frequency. The 3 dB ripple response requires awkward clock frequencies. A simple design example will illustrate how to use the filter.

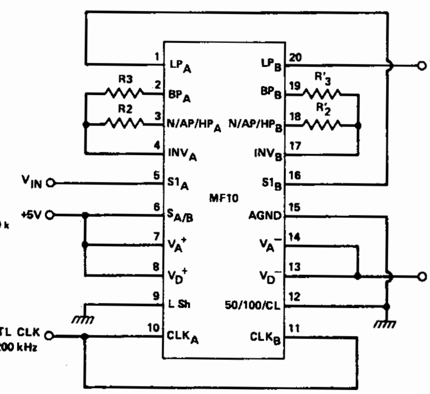
The figure shows a design for a fourth-order 2 kHz maximally-flat low-pass filter with an oferall gain of 1 in the pass band. From the table, the first stage should have a Q of 0.54 and a frequency of 2 kHz, the second stage, a Q of 1.306 and a frequency of 2kH. Mode 1a is the most simple realization of the second order low-pass filter. For the first section let R3 = 10k. Then R2 = 18.48k (15k + 3k6 would do). For the second stage let R2 = 10k, then R3 = 13.06k (9k1 + 3k9 is near enough). Both clock pins can be tied together and driven with a single 200 kHz clock (pin 12 grounded gives a clock-to-filter frequency ratio of 100 to 1).

LOW-PASS FILTER RESPONSE	1st STAGE		2nd STAGE		3rd STAGE	
	f_o	Q	f_o	Q	f_o	Q
2nd ORDER BUTTERWORTH (FLAT RESPONSE)	1.0 F	0.707				
2nd ORDER CHEBYCHEV (3dB RIPPLE)	0.84 F	1.304				
4th ORDER BUTTERWORTH	1.0 F	0.54	1.0 F	1.306		
4th ORDER CHEBYCHEV	0.443 F	1.076	0.95 F	5.58		
6th ORDER BUTTERWORTH	1.0 F	0.518	1.0 F	0.707	1.0 F	1.931
6th ORDER CHEBYCHEV	0.298 F	1.044	0.722 F	3.46	0.975 F	12.78

* For the equivalent highpass response, use the same Q factor but use the reciprocal of the frequency multiplier.

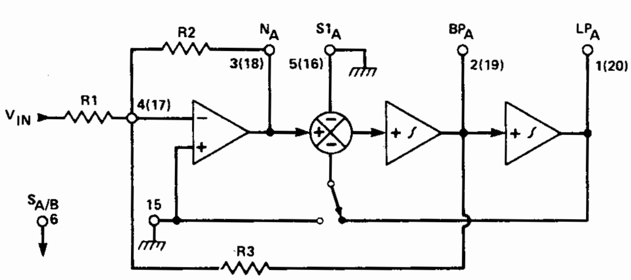




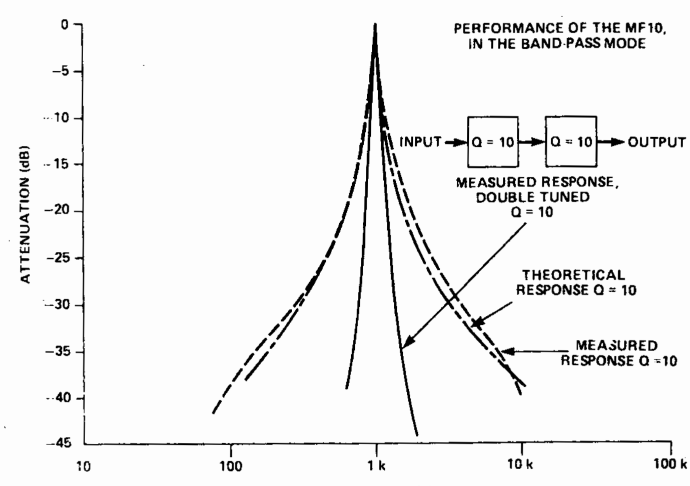


Band-Pass Response Using The MF10

A simple band-pass filter can be constructed using the circuit shown as mode 1 in the first article on switched capacitor ICs, and shown again to jog your memory! For a Q of 10, R3 = 100k, and R2 = 10k. To give the filter unity gain at resonance, R1 = R3 = 100k. The external clock frequency determines the resonant frequency. By cascading two filters with a Q of 10, a very sharp resonance curve is produced as you can see in the graph below. If the Q factor of each filter is increased further, then an even sharper response can be obtained, although this may result in a double peak if the relative resonant frequencies of the two filters deviate.



MODE 1



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