HI-PER Audio Filter

This project provides HIgh-PERformance CW filtering.

by David Cripe KC3ZQ

I've been watching with interest the proliferation of new audio filters utilizing Digital Signal Processing which have appeared lately on the ham radio market. Even though I'm all in favor of progress, I would really prefer to see products that the average ham could build for himself if he had the parts, or troubleshoot and fix if he had to. DSP can, without a doubt, provide some incredible improvements in performance of audio filters. However, not too many home-brewers have DSP chips laying about in their junk boxes, whereas a lot of us might have an LM324 or two. I contend there is still a lot of life left in the simple, lowly op amp!

I set out to design an active CW filter that would knock the socks off of any previously-published active filter design: one that could give a DSP design a run for its money; one that Joe Ham could build in a weekend and would cost less than a new set of finals for an FT-101.

Why mess with another active CW filter project? Well, the subject of CW filters is one in which the final page has yet to be written. Better CW filtering is one thing most hams wish for. For example, one of the more popular ham projects to come along in recent years has been the direct-conversion QRP rig. These rigs have the advantage of being simple, inexpensive, and easy to build. However, the direct conversion receiver cannot distinguish between upper and lower sidebands, so QRM can be a problem. The addition of good, sharp CW bandpass filtering to the direct-conversion receiver goes a long way to improving the usability of the rig, making it more practical for use in high-QRM situations.

Many commercial rigs suffer from poor CW filter designs which are either too broad, or suffer from excessive ringing. A good audio CW filter would be useful in these cases, as well. Many of the early SSB rigs had only a single-sideband IF filter, and no CW filtering. Finding a crystal CW filter for these antiques is by now nearly impossible. One example would be my old Heathkit HW-100, whose lack of a CW filter further motivated me to design my own!

Most active CW filter designs published so far have been really simple, utilizing one or two op-amp sections. If the bandwidth of these filters is made as narrow as that of a good CW crystal filter, they suffer from ringing, which tends to smear the transitions between the CW pulses and the spaces separating them, affecting the intelligibility of the CW characters. In order to achieve the maximum performance from the receiver, we must design a filter which has both a narrow bandwidth and minimal ringing.

In setting out to design the best active CW filter, I had to first discover the characteristics that made a good bandpass filter. While researching the subject of bandpass filters for CW reception, I discovered that there was far more to filter design than just throwing R's, C's and op amps at the problem. Apparently, the ringing one experiences in a poorly-designed CW filter comes from the phase response the filter possesses, rather than its amplitude response. Within the passband of the filter, the filter's phase shift versus frequency must possess a constant slope for the filter not to ring. The all-important slope of phase shift versus frequency is referred to as "group delay." A filter designer concerned only with designing a CW filter with a narrow amplitude response is likely to miss the requirement of constant group delay, ending up with a filter design that rings like a church bell. However, I found that a family of bandpass filters possessing the required flat group delay had been discovered by Blinchikoff [1]. These filters are optimized to possess minimal overshoot and ringing, and are ideal for this application.

Even with flat group delay, a minimum filter bandwidth is required for intelligibility of the code characters. Even though the information contained in 20-word-per-minute CW is concentrated mainly in a 25 Hertz bandwidth, without the addition of frequencies contained further away from the carrier, the CW signal sounds mushy and the characters are hard to distinguish. But, as one widens the CW filter to improve signal intelligibility, we increase its susceptibility to interference from close-by QRM. For this design, I chose a 200 Hz bandwidth as a compromise.

Figure 1 shows the filter topology and values of a passive version of this filter, 200 Hz wide, centered at 700 Hz. I have modified Blinchikoff's original design, adding a notch to the response at about 1600 Hz to sharpen the high-side QRM rejection of the filter, while leaving the filter's group delay essentially untouched.

Figure 2 shows the schematic of an active implementation of this filter. It uses its op amps in a configuration known as a "Generalized Immittance Converter" [2], (GIC), which allows the creation of active networks which simulate inductors, capacitors, etc. Unlike other active filter topologies, such as the Sallen-Key, with the GIC it is easy to make the conversion between a passive and active filter design. The schematic may seem complicated, but with careful layout and construction the circuit may be fabricated onto a few square inches of PC board which can be mounted inside most rigs, or outboarded in a separate box. The design here uses 12 op amps, which are contained in three 14-pin ICs. Despite the number of ICs, it won't blow the power budget of most QRPers, as the filter circuit consumes only about 10 milliamps. Although designed to run from 12 volts, the filter circuit will also work well from a 9 volt battery. The circuit does not require a split supply; the circuit containing op amps U1d and U3b provides a bias voltage in the middle of the supply voltage.

The filter circuit uses 1% tolerance resistors, as well as 0.022 µF capacitors, which must be fairly closely matched; 5% or better tolerance is preferred. These parts are available through sources such as Digi-Key or Mouser. The circuit can be assembled on a Radio Shack solder-pad perf board #276-168A or, better yet, on the custom PC board shown in Figure 3.

I have included a filter bypass relay K1, which can be used to switch out the CW filter when the operator wishes to return to SSB opera-

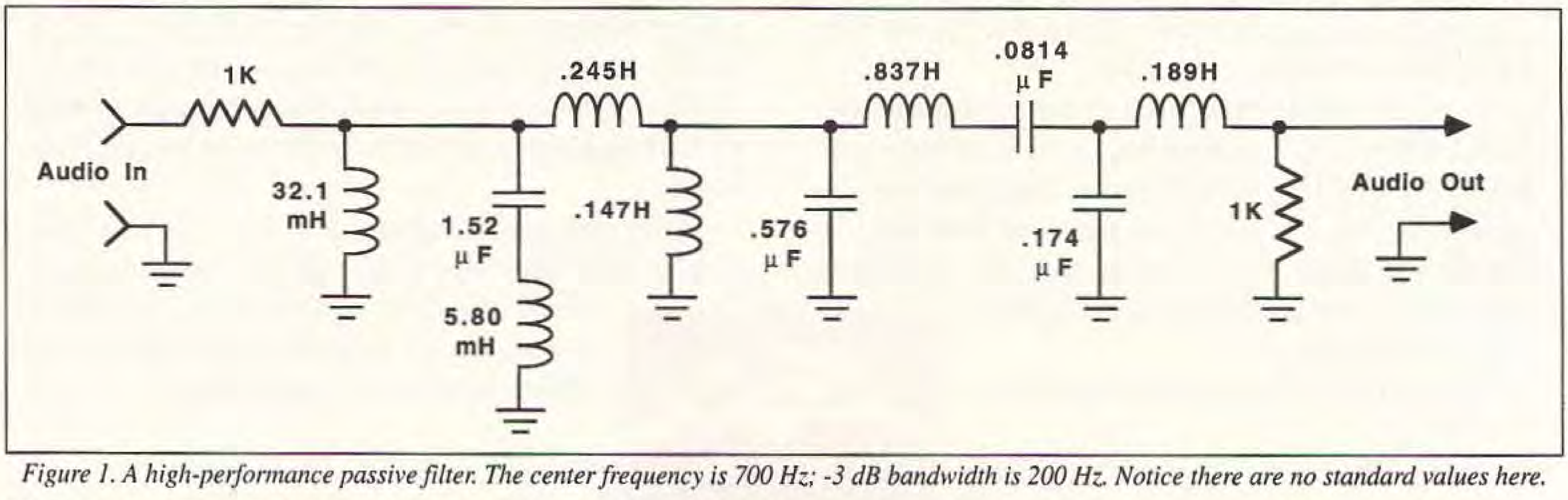

Figure 1. A high-performance passive filter. The center frequency is 700 Hz; -3 dB bandwidth is 200 Hz. Notice there are no standard values here.

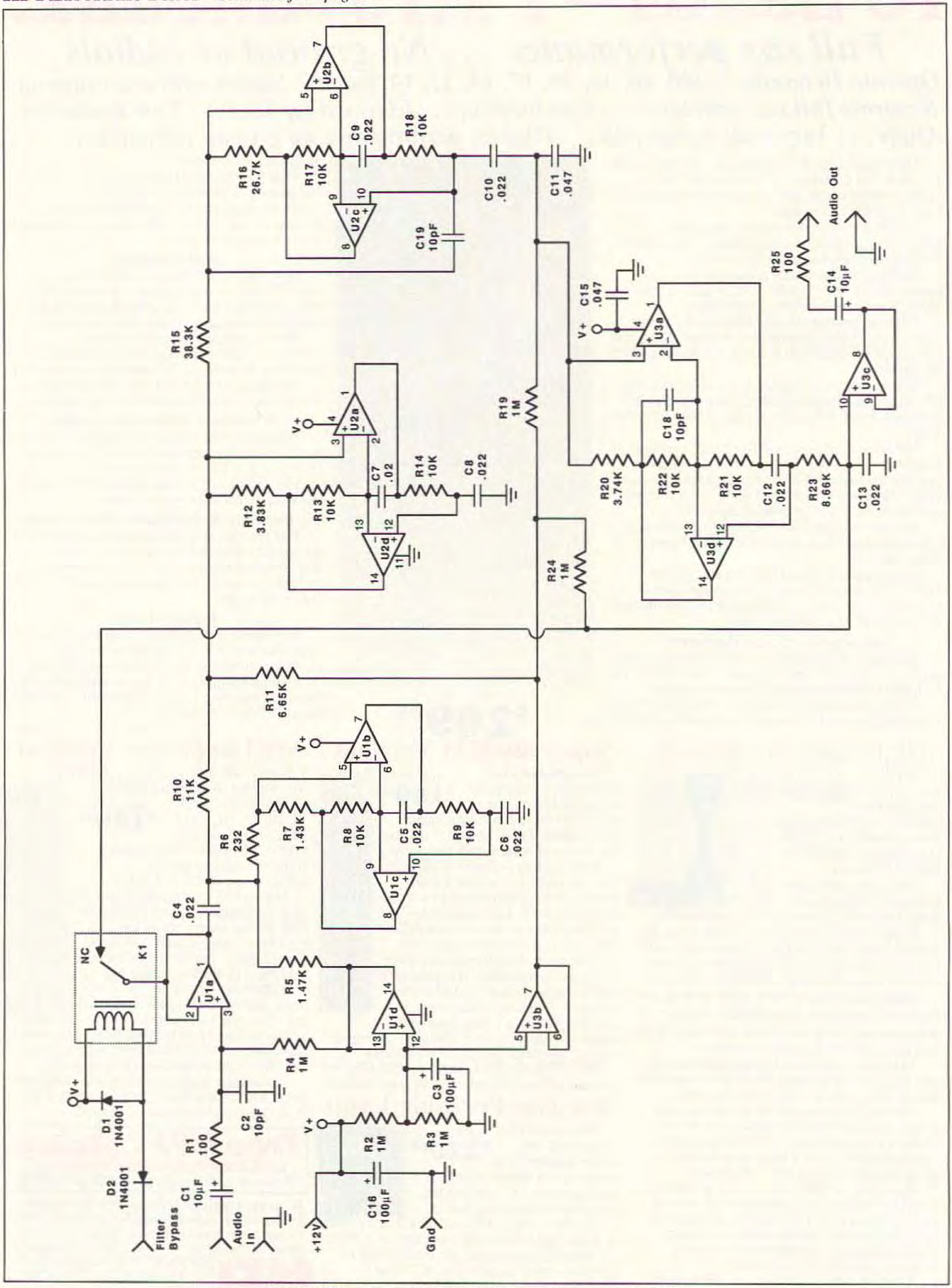

Figure 2. The active version of the high-performance audio filter.

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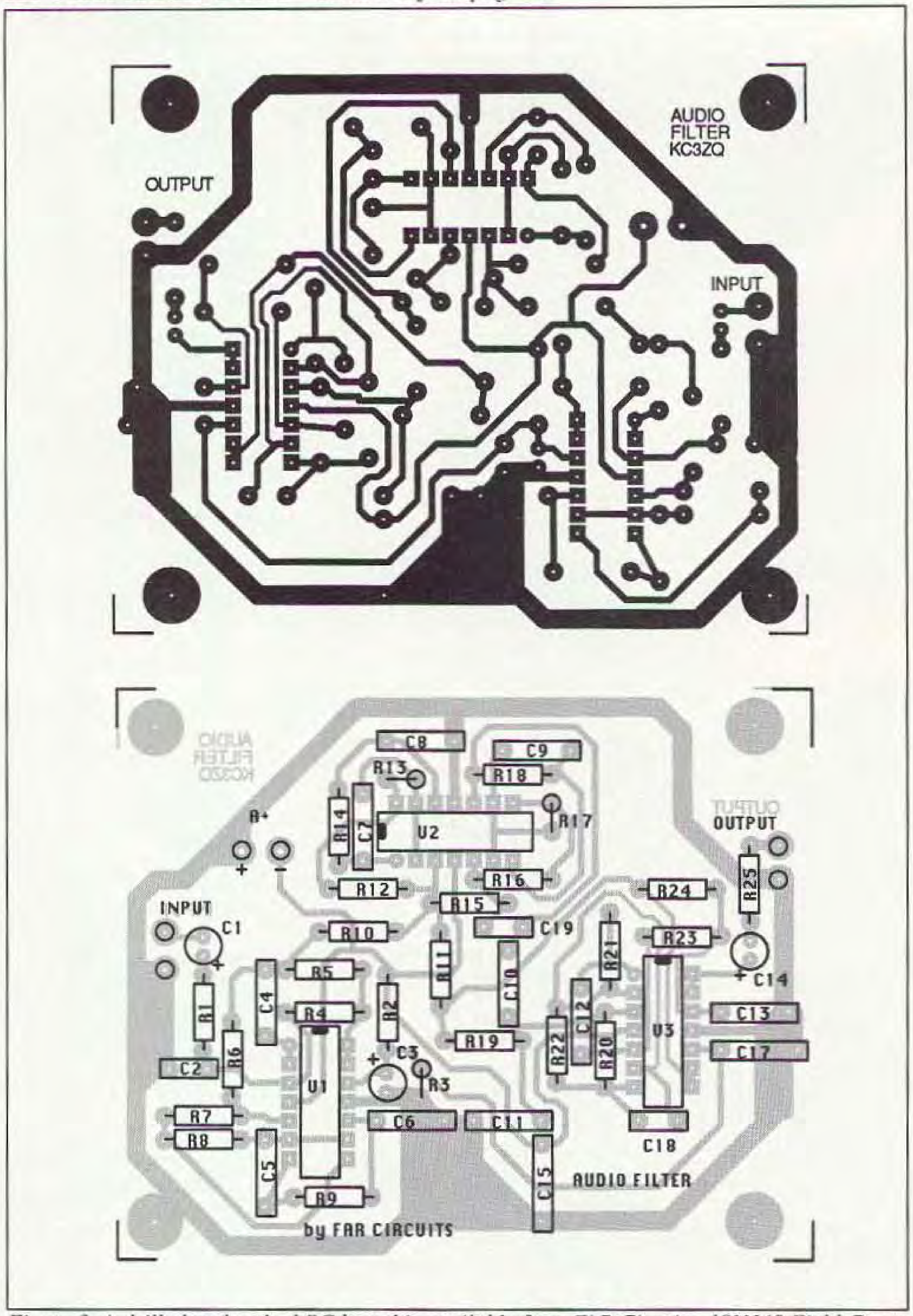

Figure 3. A drilled and etched PC board is available from FAR Circuits, 18N640 Field Court, Dundee IL 60118 for $4.50 plus $1.50 S&H per order.

tion. To activate the CW filter, a switch or relay contact within the rig must pull one terminal of the bypass relay to ground, opening the relay contacts. Those wishing to omit this feature, and operate the filter continuously may simply delete K1 and the diodes associated with it, D1 and D2.

Electrically, the filter should be mounted between the first and second audio stages in your rig. Use shielded wire to connect to the filter to help reduce RFI effects.

In operation, the performance of the filter is, in short, breathtaking. This is not your garden variety active filter here! In a noisy, interference-filled band, when the filter is switched in, everything but the desired signal falls away. After I installed this filter in my HW-100, I would have been hard pressed to distinguish between its performance and that of any of the best crystal CW filters in any other rig I have used. The lack of ringing in this filter made it better than quite a few other filters, crystal or otherwise, that I have used. This filter should give the same kind of performance to your direct-conversion rig, too.

I hope you enjoy this project, and find as much pleasure in its use as I did in its design. See you on the bands.

References:

1. Blinchikoff, H. and Zverev, A., *Filtering in the Time and Frequency Domains*, 1976, John Wiley and Sons, pp. 199-204.

2. Downs, Rick, "Vintage Filter Scheme Yields Low Distortion in New Audio Designs," *EDN*, November 7, 1991, pp. 267-272.

Parts List

R1,25	100 ohm
R2-4,19,24	1 meg
R5	1.47k, 1%
R6	232 ohm, 1%
R7	1.43k, 1%
R8,9,13,14, 17,18,21,22	10.0k, 1%
R10	11.0k, 1%
R11	6.65k, 1%
R12	3.83k, 1%
R15	38.3k, 1%
R16	26.7k, 1%
R20	3.74k, 1%
R23	8.66k, 1%
C1,3,14,16	100 µF electrolytic
C2,19,18	10 pF
C4-10,12,13	0.022 µF 5%
C11,15,17	0.047 µF 5%
U1-3	LM324 or equivalent quad op amp
D1,2	1N4001 or equivalent
K1	12 volt SPDT relay, RS# 275-241