"Smart" Squelch for SSB

Editor's Note: W9MKV and W9YAN's "Smart Squelch" overwhelmed the competition to win the first *73 Magazine* Home-Brew Contest. The authors received a $250 prize in addition to the normal article payment. You can build this trend-setting project; W9MKV offers a PC board for $7.00 and a complete parts kit is available from Radiokit, Box 411, Greenville NH 03048, for $49.95. Congratulations to W9MKV and W9YAN for a job well done.

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This circuit detects the human voice but ignores noise, steady tones, and the Russian woodpecker HF radar pulses. It requires no receiver modification and works even when voice signals are below the noise level.

A squelch turns off receiver audio to eliminate annoying background noise when there is no signal. Squelch circuits in AM and FM receivers are carrier-operated. On single sideband, which has no carrier, squelching is more difficult. Most SSB rigs with squelch, e.g., the popular 2-meter multimode transceivers, use agc (S-meter) voltage to open squelch in SSB mode. Agc-operated squelch is adequate for strong signals on relatively quiet channels. Agc and VOX-type squelches open for any noise or heterodyne that exceeds a preset level. Weak signals often are missed because the threshold must be set above the noise level.

White noise sometimes can make you imagine tiny voices in the noise, but it won't fool the Smart Squelch. Detecting unreadably-weak signals is worthwhile if a change of antenna direction or receiver control settings will make them usable.

The audio-operated squelch circuit described here is similar in principle to Motorola's "Constant Sinad" squelch, a discrete-component circuit with 22 transistors.

Discriminating the Human Voice

People normally speak about three syllables per second. The squelch works by detecting voice-band energy (500-3000 Hz) which is varying in frequency at a *rate* of 0.5 to 3.25 Hz.

The circuit is a type of FM detector. It is insensitive to amplitude variations throughout the range where the input stage is not driven to saturation but background noise is strong enough to saturate the limiter. The squelch works properly with most speaker-level signals. You can connect it directly to the receiver's detector output, adjusting gain of input buffer amplifer U1A as necessary.

Performance

A receiver tuned to WWV provides a good demonstration of the circuit's capabilities. Squelch opens for voice announcements and ignores the rest of the transmissions.

The squelch can turn on well within the first spoken syllable. Speed of response depends mostly upon the rise-time of active low-pass filter U3A. The receiver is muted one second after the last voice detection. The beginning of a steady tone

Photo A. Squelch unit is attached to the right side of the HF SSB transceiver. Rectangular LEDs above the control knob indicate circuit status. (Photo by KA9FJS)

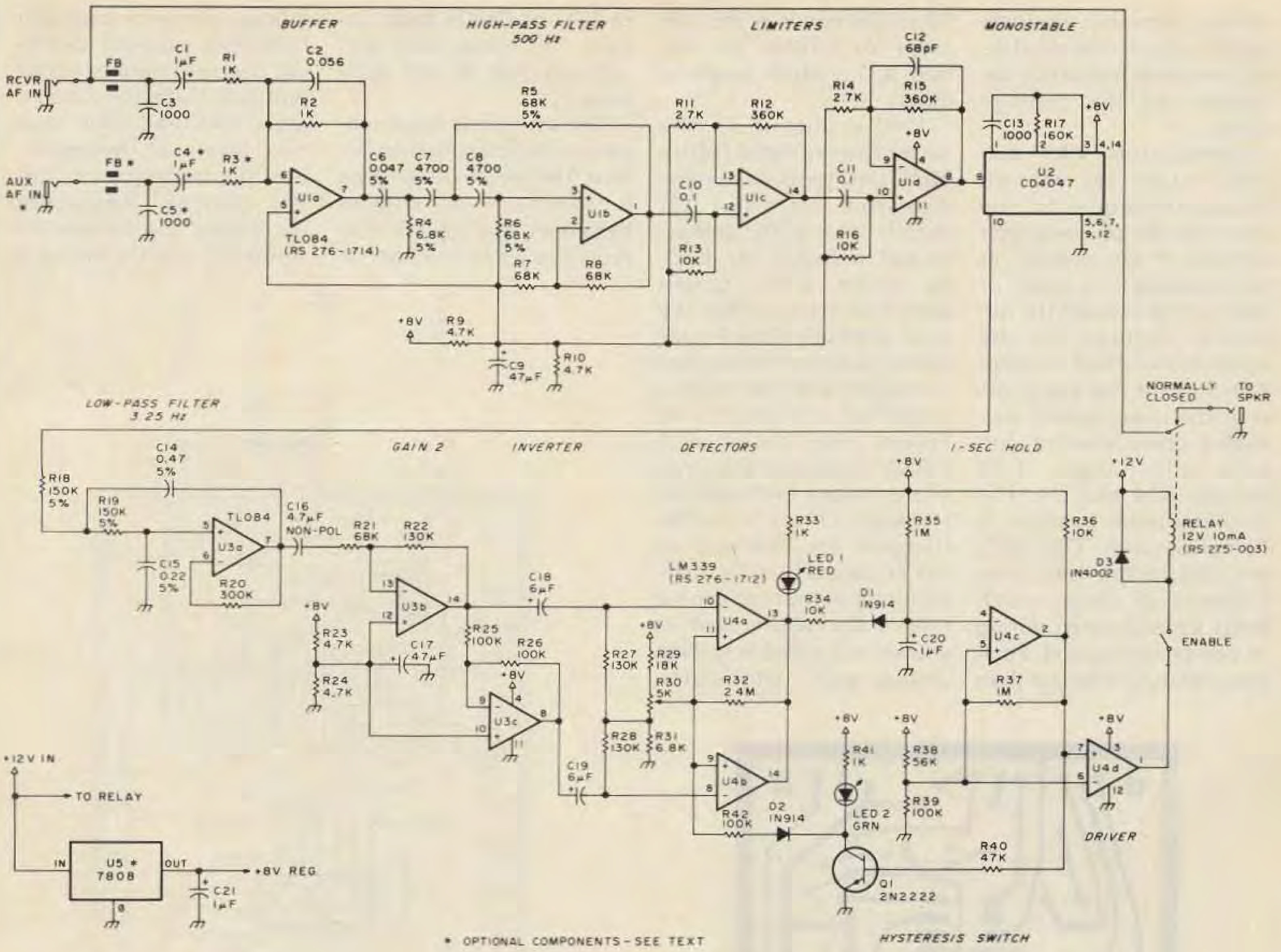

Fig. 1. Schematic diagram.

opens the squelch only momentarily. It opens intermittently on music. Response to CW depends on code speed and tone.

A single squelch circuit can control multiple receivers, unsquelching them all when any receiver detects a voice signal. (We like to monitor HF aircraft and marine frequencies plus 144.2 MHz—the 2-meter SSB calling frequency.)

The squelch is useful when rf radiation from computer systems overwhelms the normal squelch in a VHF FM receiver. It's also good for monitoring VHF/UHF mobile-telephone channels in systems where a constant idle tone is transmitted while no call is in progress. The circuit has other applications as a "smart" VOX (voice-operated switch) for transmitters, recorders, intercoms, security systems, remote-base systems, and repeater equipment.

Circuit Description

U1A is a unity-gain summing amplifier, input buffer, and low-pass filter with 3-kHz cutoff. U1A drives U1B, a third-order high-pass active filter with 3-dB cutoff at 500 Hz. We chose high-performance FET-input operational amplifiers so that active filters could use high resistances and small capacitors. The TL084 quad op-amp chip is equivalent to the National LF357.

U1C and U1D are limiter amplifiers with a combined gain of 85 dB. U1D's output is voice-band audio turned into constant-amplitude square waves. The square waves trigger CMOS monostable multivibrator U2. Output of U2 is a train of .33-millisecond pulses, one for each audio cycle. The *average* voltage of U2's output is proportional to the input *frequency*. U2 and the following low-pass filter form a frequency-to-voltage converter, i.e., FM detector, somewhat similar to an automobile tachometer circuit.

Active low-pass filter U3A cuts off at 3.25 Hz, the best compromise between noise-falsing and the rate at which people speak syllables.[2] Note that U3A has no bias network even though the amplifier uses a single-polarity power supply. U2's averaged pulses keep the output of U3A at 5 to 6 volts with normal noise input from the receiver. R17, which sets U2's period, can be varied to keep U3A's quiescent output voltage near the center of its range.

On very quiet channels there may not be enough pulses from U2 to keep U3A properly biased. False detects may occur as U3A's output goes in and out of its linear range. You can inject extra noise or low-level tone into the squelch circuit's auxiliary input to achieve the desired results for your particular application.

U3A's output is ac-coupled to U3B, which amplifies with a gain of 2, and thence to U3C, a unity-gain inverter. U3B and U3C together form a phase splitter with a gain of 2. The phase splitter provides positive-going outputs for positive *and* negative frequency deviations of the receiver audio.

Comparators U4A and U4B detect the rate-of-change-of-frequency signals from the phase-splitter outputs. If the voltage at the inverting (−) input of U4A *or* U4B exceeds the reference voltage set by squelch-threshold control R30, then the low-going level at the comparators' paralleled open-collector outputs discharges C20 through R34 and D1. The discharge time constant is 10 milliseconds. C20, R35, and comparator U4C form a time-delay circuit which holds squelch open during its one-second period. Each detector output longer than 10 milliseconds resets the timer for another one second. R35 controls length of delay.

U4C's output is the squelch-open signal (active high). U4C turns on hysteresis-switch transistor Q1 (which lights LED2) and activates output-driver U4D. As shown, U4D's output goes high to unsquelch. We used normally-closed relay contacts so that the speaker is enabled when the relay is turned off or if power is removed from the squelch circuit. To reverse the sense of the output, exchange the (+) and (−) inputs of U4D. (Jumpers are provided on the PC board.) U4D's open-collector output can drive a relay in the speaker lead, as shown, or a gated amplifier, analog gate, optoisolator, or TTL or CMOS logic circuit. The comparator output can sink 50 mA maximum.

The squelch is more sensitive *after* opening than before. The sensitivity change is called *hysteresis*. With no hysteresis, the squelch may drop out while someone is talking. If there is too much hysteresis, squelch threshold becomes hard to adjust properly. Detector comparators U4A and U4B have two levels of hysteresis. Positive-feedback resistor R32 prevents comparator oscillation and lowers the threshold slightly during a

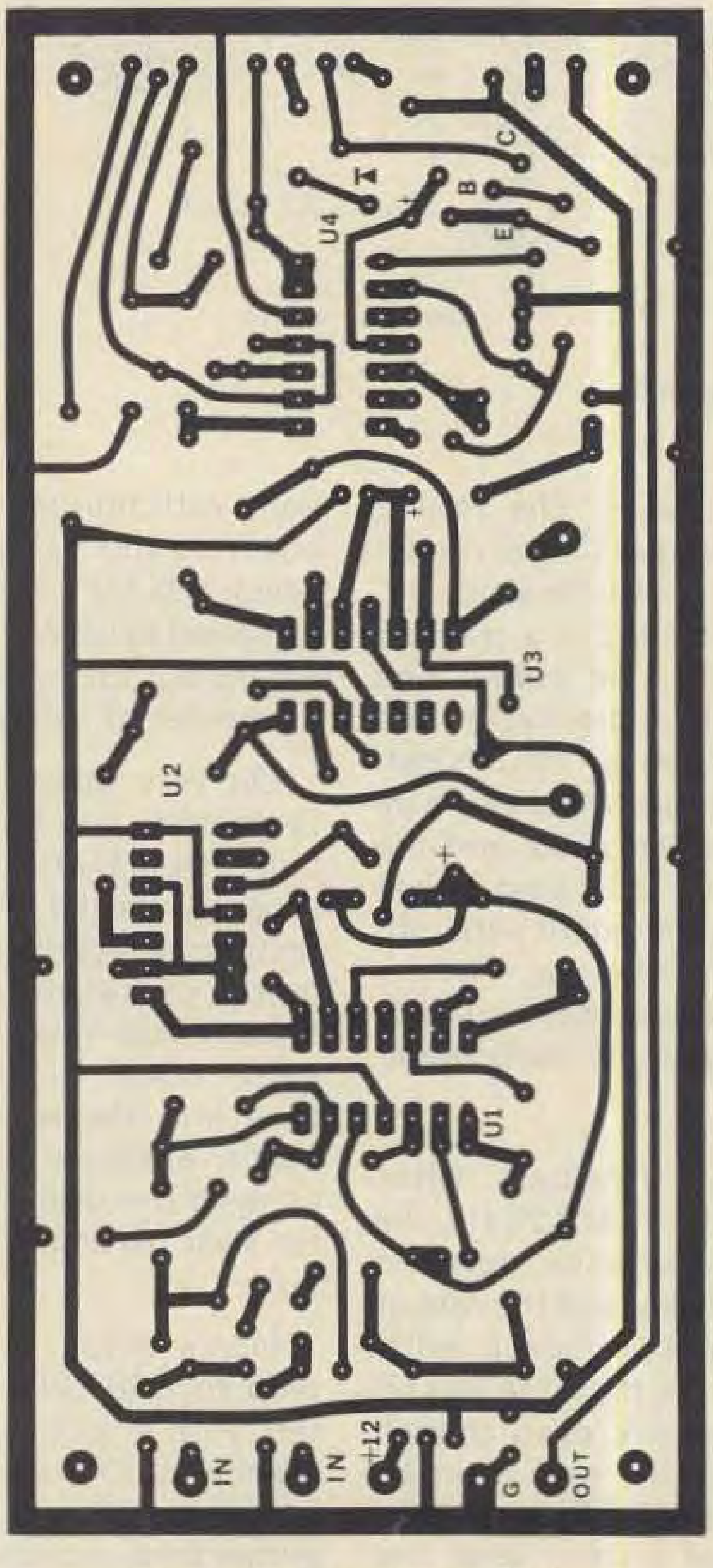

Fig. 2. PC board (foil side).

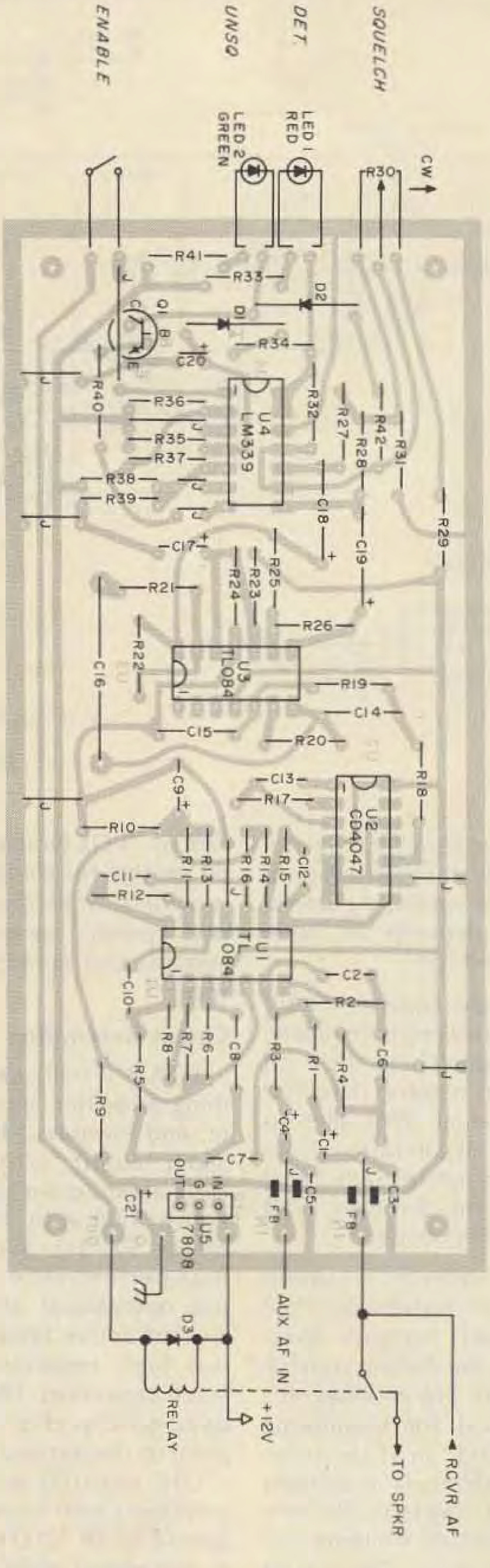

Fig. 3. Component layout.

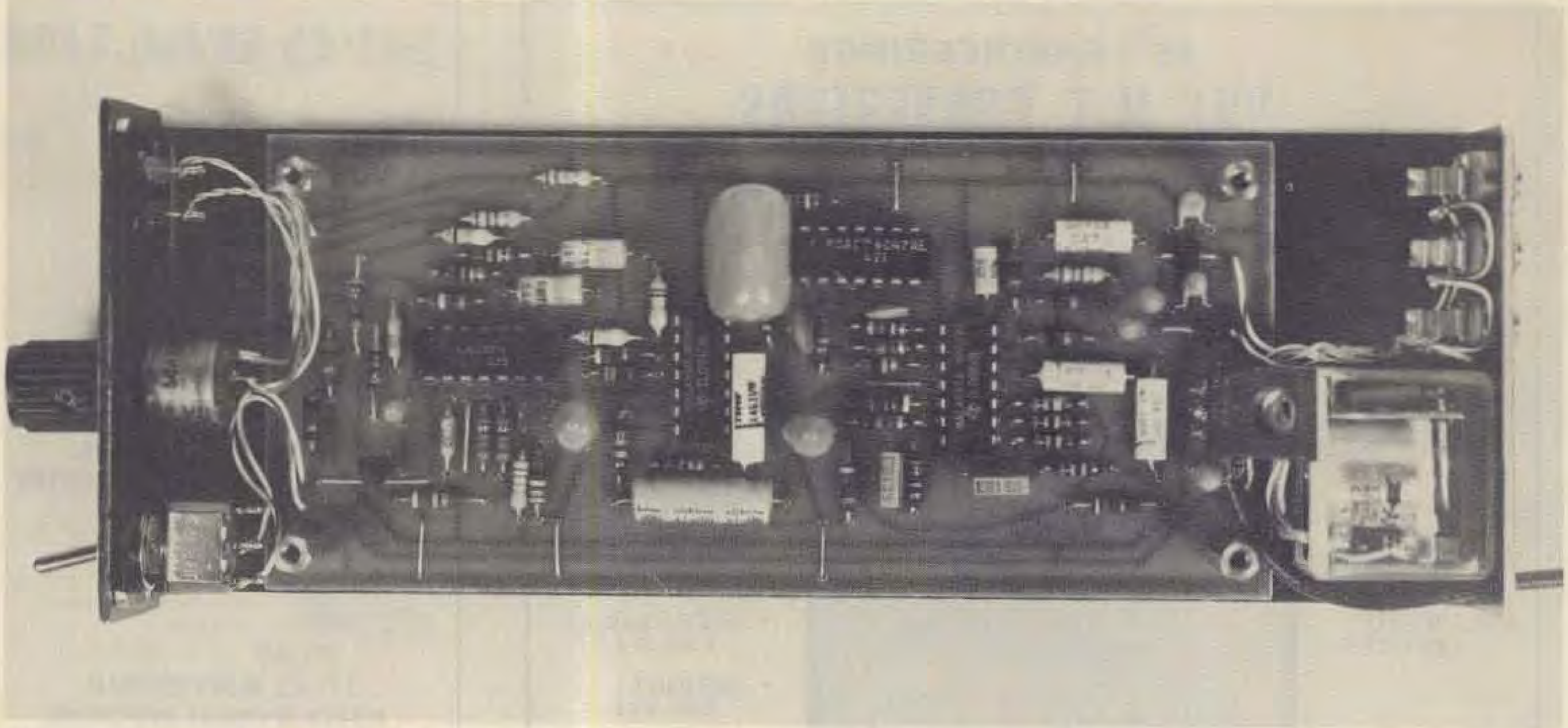

Photo B. Circuit board and chassis detail. The only external connections required are receiver audio, speaker, and 12 volts dc. (Photo by KA9FJS)

detect. Q1 conducts while squelch is open, further reducing the threshold voltage via R42 and D2. R42 determines the amount of hysteresis. The 100k value shown for R42 provides smooth squelch operation.

The circuit uses 25-30 mA plus relay current. The eight-volt-regulator IC, U5, should be used for mobile operation. Otherwise, the entire circuit can run from a well-regulated 12-volt supply. (Omit U5 and add a jumper between input and output pins of U5 on the PC board.)

Adjustment

LED1 lights whenever the detector is active. Listen to a voice signal and adjust the threshold control until LED1 blinks for every spoken syllable, then make fine adjustments as necessary for noise conditions. The *enable* switch allows you to adjust the squelch before activating the relay and allows you to unsquelch without disturbing the threshold setting. Scale markings around the control knob make it easier to reset an often-used level.

Construction

All-new parts cost about $40, using referenced items from Radio Shack and ECG. Resourceful hams can build

Parts List

Semiconductors			
U1, U3	TL084C quad BIFET op amp	2	$ 5.98
U2	CD4047 CMOS multivibrator (ECG 4047)	1	1.49
U4	LM339 quad comparator	1	1.50
U5	7808 8-volt regulator (optional—see text)	1	.99
Q1	2N2222 or equiv. silicon NPN transistor	1	.15
D1, D2	1N914 or equiv. silicon diode	2	.20
D3	1N4002 or equiv. silicon diode	1	.10
LED1	Red LED (rectangular)	1	.49
LED2	Green LED (rectangular)	1	.49
Capacitors (All 20 V or more)			
C12	68 pF	1	.12
C3, C5, C13	1000 pF	3	.45
C7, C8	4700 pF, 5%	2	.60
C6	0.047 uF, 5%	1	.30
C2	0.056 uF	1	.30
C10, C11	0.1 uF	2	.30
C15	0.22 uF, 5%	1	.40
C14	0.47 uF, 5%	1	.40
C1, C4, C20, C21	1 uF, electrolytic	4	1.60
C16	4.7 uF, non-polarized (RS 272-998)	1	.99
C18, C19	6 uF, electrolytic	2	2.36
C9, C17	47 uF, electrolytic	2	2.00

Resistors (All ¼ Watt; * = 5%)

R1, R2, R3, R33, R41	1k	5
R11, R14	2.7k	2
R9, R10, R23, R24	4.7k	4
R4*, R31	6.8k	2
R30	5k, linear pot	1
R13, R16, R34, R36	10k	4
R29	18k	1
R40	47k	1
R38	56k	1
R5*, R6*, R7, R8, R21	68k	5
R25, R26, R39, R42	100k	4
R22, R27, R28	130k	3
R18*, R19*	150k	2
R17	160k (see text)	1
R20	300k	1
R12, R15	360k	2
R35, R37	1M	2
R32	2.4M	1
		42 @ $.08 ea. = $3.28

Other

Ferrite beads	2	.10
Miniature earphone jacks	3	1.29
Relay, 12-volt SPDT (RS 275-003)	1	2.99
Switch, miniature toggle SPST	1	1.49
Control knob	1	.49
Hardware, PC board, chassis		10.00
Parts Total		$40.85

the circuit for substantially less.

We built several prototypes on universal printed-circuit cards. The only critical area is U1, where high limiter-amplifier gain can cause feedback oscillation in some layouts. Keep component leads as short as possible. Use 5% tolerance or better for frequency-determining components in active filters. The Radio Shack relay's frame must be insulated from ground. Mounting the relay on a rubber pad quiets its clicking and isolates it from vibration.

Conclusion

Although squelch effectiveness may diminish on very crowded amateur bands, a sensitive, discriminating squelch is very useful for net operations and scheduled contacts, especially with modern digitally-tuned receivers which can be preset to precise frequencies.

This circuit can be a starting point for many experiments. You could, for example, insert an analog delay device between audio input and output. If the delay were longer than the squelch response time, then squelch would open *before* the first spoken syllable reaches the loudspeaker.

Digital techniques could perform the function of the analog circuit described here, perhaps with improvements such as adaptive threshold and program-controlled time constants. We are experimenting with a microprocessor-based voice detector which may be the subject of a future 73 article. ■

References

[1]Don Lancaster, *Active Filter Cookbook*, Howard W. Sams & Co., Inc., 1975.

[2]Motorola *Micom* HF SSB Transceiver Service Manual, 1975.