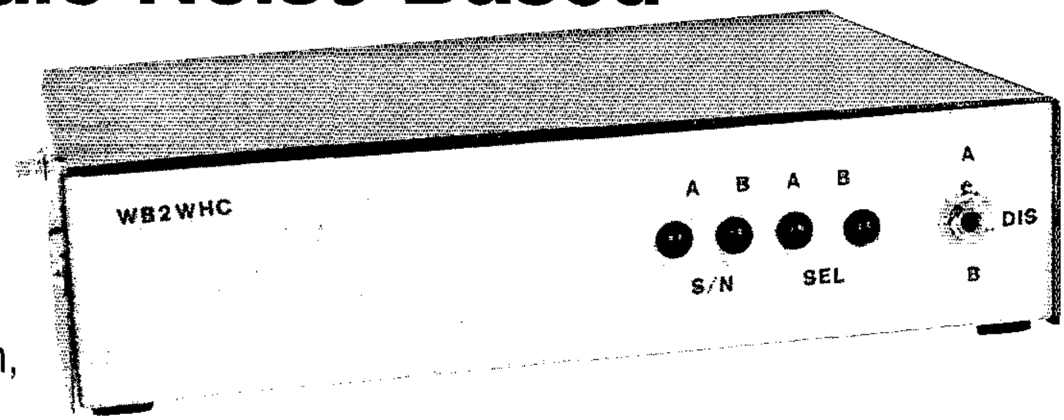
An Audio-Noise-Based Voting Circuit



Not a politician, this candidate delivers what it promises—the best signal available.

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As hand-held transceivers (H-Ts) become smaller, and low-power, battery-conserving operation becomes more popular, the disparity between the transmitting range of a typical 100-watt repeater compared to the repeater-accessing range of a typical 1-watt or less H-T becomes more and more apparent. How often have you found it difficult (or impossible) to access a repeater with a low-power H-T even though you can hear the repeater at full quieting? This can happen even if the repeater is equipped with a high-sensitivity, state-of-the-art receiver.

Here's where *diversity reception* and *voting circuits* can play an important and helpful part. Diversity reception improves a repeater's receiving capability by making use of a *second receiver* tuned to the repeater's input frequency. This receiver is sometimes located at the main repeater site and connected to a separate antenna. More often, however, the second receiver is at another site in an area not well covered by the main-site receiver. So positioned, this second receiver is sometimes called a *satellite* receiver. The signal received by the satellite receiver is relayed to the main repeater site via a radio (or wire) link. In either case, the satellite receiver provides enhanced receiving capability for the repeater.

At the main repeater site, a voting circuit selects the better of the two received signals and sends the chosen signal to the repeater's transmitter. If only one of the two receivers is able to hear the signal, the job of selecting the better signal is easy! Often, however, *both* receivers can hear the signal. Then, only the receiver with the better signal must be selected. Why? Because simply adding the two audio signals from both receivers results in a signal that is nearly as noisy as the noisier of the two signals. We want only the *quieter* signal.

That's the function of a voting circuit: It votes for the receiver with the better signal. Some voting circuits work by comparing the S-meter or AGC-voltage level of the two receivers and selecting the audio from the receiver with the greater amplitude. Although this method can work well, it has two problems. Because the satellite receiver often is remotely located, a telemetry system is required to relay the satellite-receiver's S-meter reading (as well as its audio output) to the main site so that the satellite and main receiver S-meter readings can be compared. Also, selecting the receiver with the higher S-meter reading doesn't always yield the quieter audio. For example, a receiver that's in a high-noise area, or is affected by desense, may have a higher S-meter reading, yet it delivers noisier audio than the other receiver, which may be in a quiet area.

The voting circuit described here[1,2] compares the noise levels within the two audio signals and selects the signal with the lower audio-noise level and better quieting. Because this method uses only the audio signals, no telemetry information from the satellite, or local receiver, is needed. Only the carrier-operated relay (COR) and audio signals from the two receivers are used.

Theory of Operation

Refer to Fig 1. The incoming audio signals from the two receivers are amplified by U1A and U1B and adjusted to equal output levels by **GAIN** potentiometers R1 and R2. It's important that the two output levels be matched so that the voter can make a fair comparison. The audio signals are fed to U4A, which acts as an SPDT switch and selects one signal to be fed to the repeater transmitter via level-setting control R3, **TX DEVIATION**. The audio signals are also fed through high-pass filters consisting of R15, R18, C8 and C9, which attenuate the lower-frequency audio components. The higher-frequency components are fed to the half-wave noise rectifiers U2A and U2B.

At U2A and U2B, the audio signals are half-wave rectified by the zero-biased op-amp noise rectifiers. These op amps rectify by amplifying only the positive-going portion of the audio. The rectified outputs pass through U4B and U4C acting as SPDT switches. These switches substitute a fixed 6-V dc level for the noise-rectifier output when the associated receiver COR is closed. This causes the voter to consider a receiver that is not receiving a signal (and has a closed squelch) as having a very noisy audio output, rather than no audio output. This is done so that if one receiver has a closed squelch with no audio output, and the other receiver has an open squelch, the voter will select the receiver with the opened squelch regardless of how noisy that signal may be.

Dc voltages output from the noise-substitution gates and noise rectifiers are filtered by RC circuits R21/C10 and R29/C11, which average the dc voltage before comparison. Such averaging causes the voter to ignore short transient effects when comparing receiver signals.

At these RC circuits, and TP3 and TP4, the filtered dc voltages represent the average quieting level of the two receiver signals. A lower voltage represents more quieting. After being reduced by about 20%, each of these two voltages is compared to the voltage from the other channel. The channel with a voltage 20% or more lower than the opposite channel is selected as the better channel. Resistive dividers R23/R24 and R30/R31 perform the necessary 20% quieting-voltage reduction for the comparison.

When both receivers are fully quieted, both channels have nearly the same detected voltage because they have the same audio, and neither channel is chosen as being better. The set/reset memory latch flip-flop (U5A and U5B) remembers which channel was the last one selected as the better one and maintains that selection. This causes the voter to stay with the currently selected

[1]Notes appear on page 26.

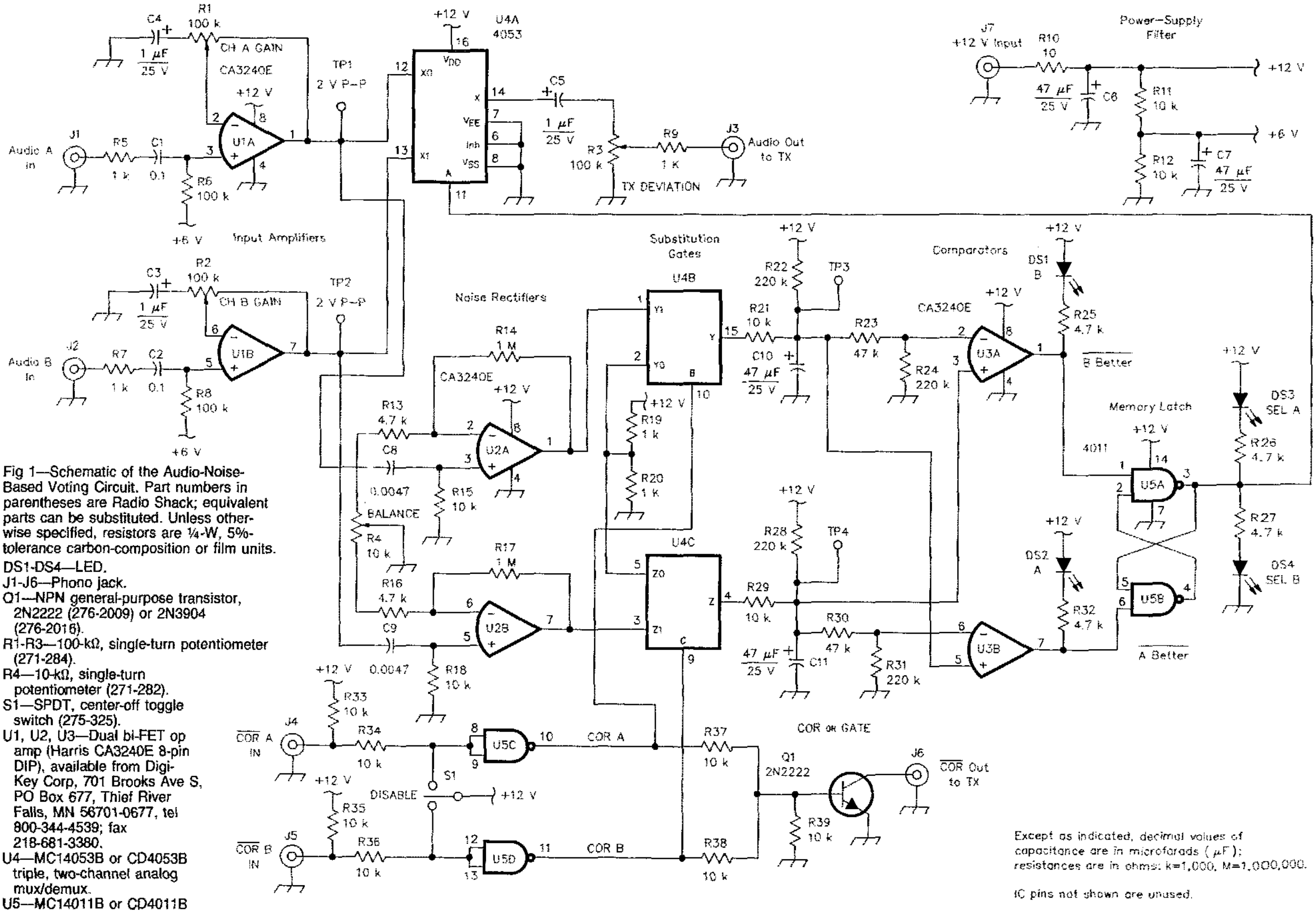

Fig 1—Schematic of the Audio-Noise-Based Voting Circuit. Part numbers in parentheses are Radio Shack; equivalent parts can be substituted. Unless otherwise specified, resistors are ¼-W, 5%-tolerance carbon-composition or film units.

DS1-DS4—LED.
J1-J6—Phono jack.
Q1—NPN general-purpose transistor, 2N2222 (276-2009) or 2N3904 (276-2016).
R1-R3—100-kΩ, single-turn potentiometer (271-284).
R4—10-kΩ, single-turn potentiometer (271-282).
S1—SPDT, center-off toggle switch (275-325).
U1, U2, U3—Dual bi-FET op amp (Harris CA3240E 8-pin DIP), available from Digi-Key Corp, 701 Brooks Ave S, PO Box 677, Thief River Falls, MN 56701-0677, tel 800-344-4539; fax 218-681-3380.
U4—MC14053B or CD4053B triple, two-channel analog mux/demux.
U5—MC14011B or CD4011B quad, two-input **NAND** gate.

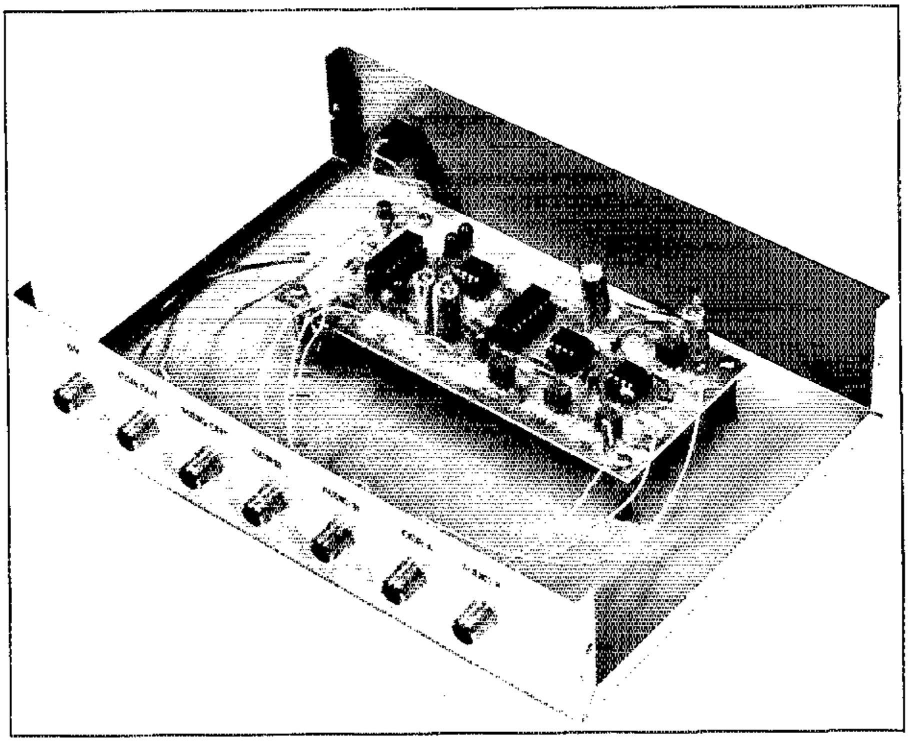

Fig 2—An inside view of the author's FAR Circuits PC-board prototype. No crowding here! The voter is built in a 3-1/16 × 8-1/4 × 6-1/8-inch Radio Shack enclosure (#270-274); a Radio Shack #270-253 cabinet will accommodate the board, too. The 5-5/16 × 2-3/8-inch PC board is supported by 5/8-inch standoffs. Axial-lead electrolytics standing on end (as shown here) can be used in lieu of radial-lead capacitors. The input and output phono jacks are mounted on the rear panel. The LEDs can be mounted directly on the PC board as shown here, or dress up the unit by placing them on the front panel as shown in the title photo.

receiver when it cannot determine which one is better. (In this, the electronic voter is not unlike voters in a political election: It favors the incumbent!) The output of the memory latch flip-flop controls the SPDT audio-selector switch, U4A.

The COR signals from both receivers are logically **OR**ed by R37, R38 and Q1 so that either receiver COR can activate the repeater transmitter. The voter is designed for active-low COR logic. A 0-volt logic signal means that a signal is being received, and a +12-volt, or a +5-volt signal, means one is not being received. S1 allows either receiver to be disabled by overriding its COR signal. In the center (**OFF**) position, neither receiver is disabled and the voter selects the receiver it wants. The voter COR output is designed to provide a logic low when a receiver detects a signal.

Construction

The prototype was wired point-to-point, but the FAR Circuits PC board makes construction easier. Use IC sockets, observe polarity when installing polarized capacitors, properly orient the ICs when inserting them into their sockets and don't use a blowtorch to solder the components to the PC board: a 25- to 40-W soldering iron is sufficient.

Most of the circuitry operates at audio frequencies, therefore, lead lengths are not critical. The input and output circuits include RF-isolation resistors so that the voter operates properly in a high-RF environment. Use a metal enclosure and shielded cables and connectors to assist in RFI rejection.

The CA3240 dual bi-FET op amps (U1, U2 and U3) are specially designed to operate correctly with 0 volts on the input pins and have very high-impedance inputs. Note: *741 and 1458 op amps may not operate correctly and should not be used!* CA3240E op amps are available from Digi-Key (see the Fig 1 caption for Digi-Key's address).

Adjustment

Because the voter uses the receiver audio signals for comparison, the system works best when the audio-signal levels and frequency response from the two receivers are matched as closely as possible. To align the voter, open the squelch of both receivers with no RF-input signal present so that both audio signals consist of full-level audio noise. With an oscilloscope attached to TP1 and TP2, adjust each **GAIN** control, R1 and R2, for a noise amplitude of 2 volts P-P at the outputs of U1A and U1B. If an oscilloscope is not available, adjust the controls for a 0.5-volt ac level at those test points; use a series-connected 0.1-μF capacitor to remove the dc component.

Adjust **BALANCE** control R4 so that TP3 and TP4 have equal dc voltages when measured with a high-impedance dc voltmeter or an oscilloscope. The voltages measured should both be +3. If the dc value is too low or too high, equally readjust R1 and R2 while maintaining equal ac-voltage levels at TP1 and TP2. Next, feed the same modulated signal into both receivers and adjust R3 (**TX DEVIATION**) so that the repeater transmitter has slightly more deviation than the received input signal. The repeater transmit audio should sound the same when S1 (**DISABLE**) is operated back and forth to manually select each receiver. Finally, place S1 in the center (**OFF**) position, and adjust the receiver squelches.

DS1 and DS2 indicate which receiver, if any, is being detected as having a better signal. With a high audio level present, when both receivers are near full quieting, or if neither receiver is detecting a signal, neither LED will illuminate because the voter cannot make a determination, and the preexisting selection is maintained by the memory latch. DS3 and DS4 indicate which of the two channels has been selected for transmission.

Acknowledgments and Summary

My thanks to Steve DeWell, KB7NKB, for constructing the voter prototype, Woody Boehm, WB9CQX, for his help testing and installing the remote receiving equipment and Ken Nichols, WA7HXZ, for providing us with a site for the satellite receiver. The prototype voter is currently in operation on WB2WHC/R (146.36/146.96) in Phoenix, Arizona. If you'd like additional information, contact me at 602-436-4727 during business hours.

Notes

[1]PC boards are available from FAR Circuits, 18N640 Field Ct, Dundee, IL 60118. Price: $5, plus $1.50 shipping and handling.

[2]A PC-board template package is available free from the ARRL. Address your request for the KOLBER AUDIO-NOISE-BASED VOTING CIRCUIT TEMPLATE to: Technical Department Secretary, ARRL, 225 Main St, Newington, CT 06111. Please be sure to enclose a business-size SASE.

Mark Kolber has been an Amateur Radio operator since 1966. He holds an Advanced class ticket and operates mostly 2- and 10-meter FM. In 1973, Mark earned a BSEE degree from The New Jersey Institute of Technology, Newark, New Jersey (formerly Newark College of Engineering). After moving to Arizona in 1984, he earned an MSEE degree from Arizona State University, Tempe, Arizona, in 1989. Mark is employed at the Business and Computer Aviation Systems Division of Honeywell as a Principal Engineer designing navigation and communications equipment for business and commercial aircraft.