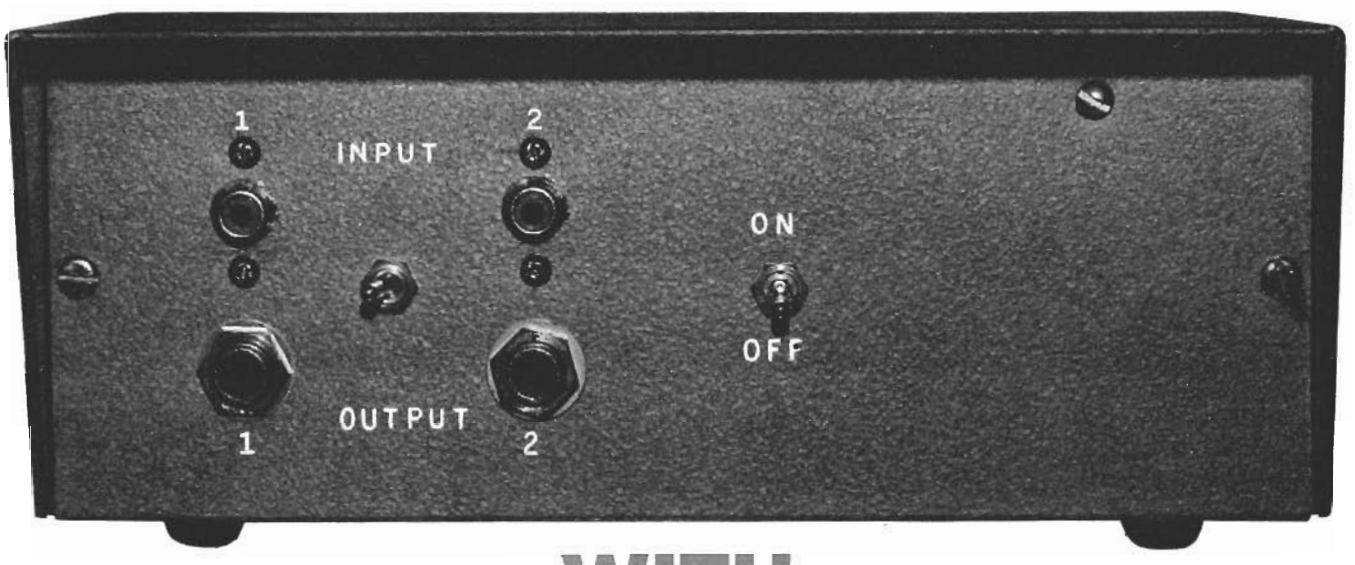
ENJOY PRIVATE MESSAGES



WITH A VOICE SCRAMBLER

Low-cost IC circuit makes message unintelligible without a similar unit

BY JOSEPH B. WICKLUND JR.

WOULD you like to be able to keep unauthorized people from listening to your private communications? Thanks to recent advances in integrated circuit technology, it is possible to build a low-cost voice scrambler that will make your message unintelligible to anyone who doesn't have a compatible unscrambler. Of course, voice scramblers have been around for many years, but most of them are too expensive or too difficult to use (or both). This circuit is easy to build, is reliable, and can be used as either the scrambler or unscrambler.

(Continued on page 42)

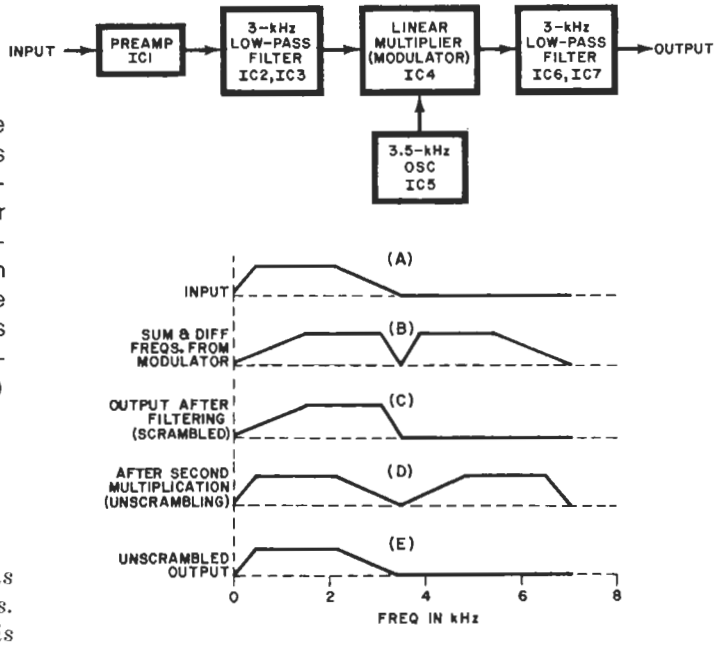
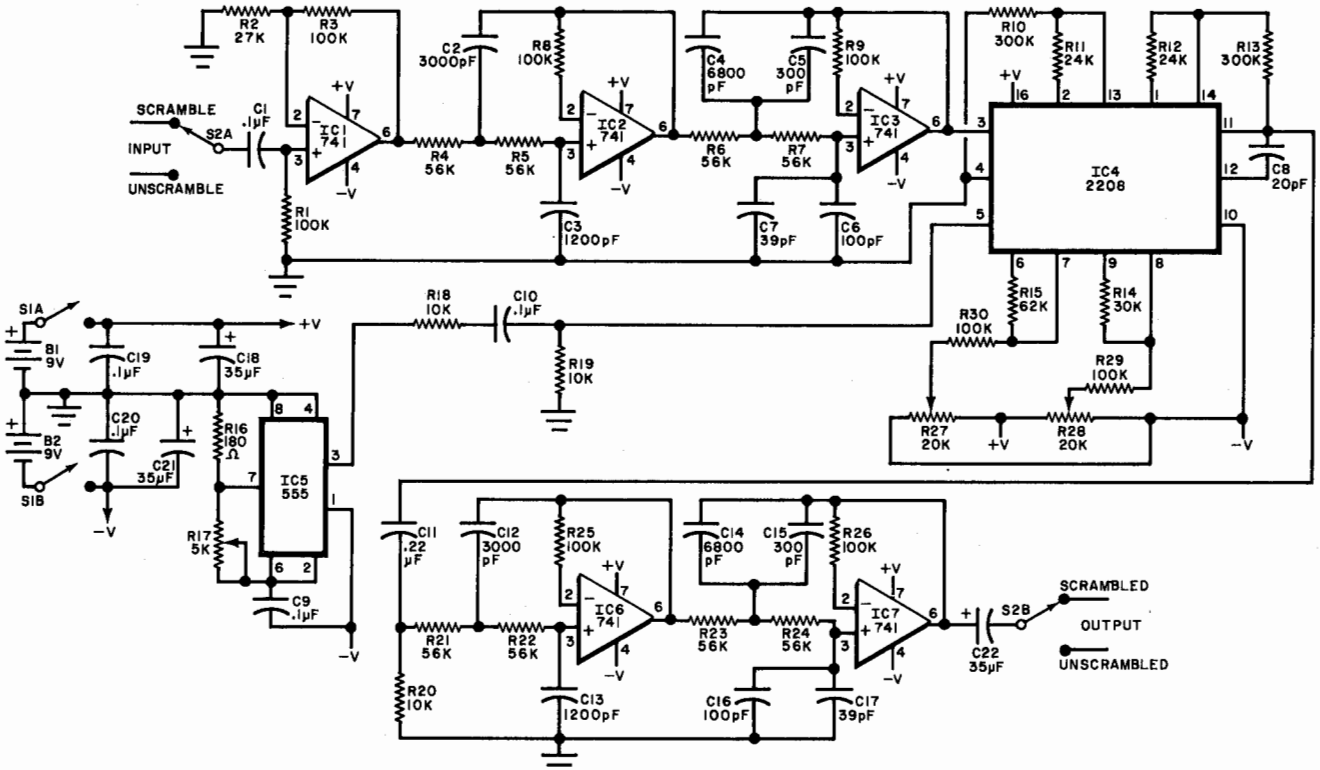


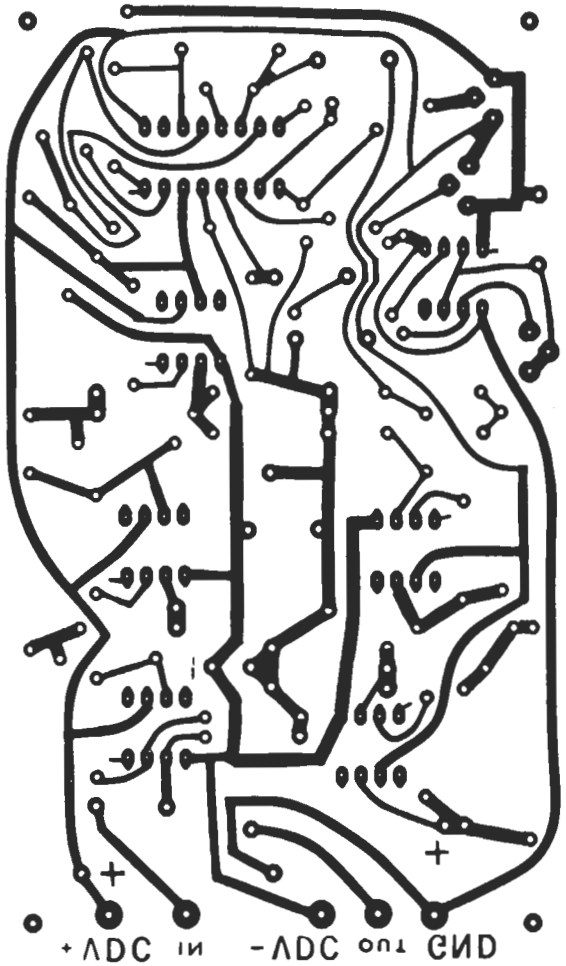
Fig. 1. Block diagram and waveforms show how the scrambler works. (A) is incoming signal; (B) is sum and difference; and (C) is output after filtering. Unscrambling is shown in (D) and (E).

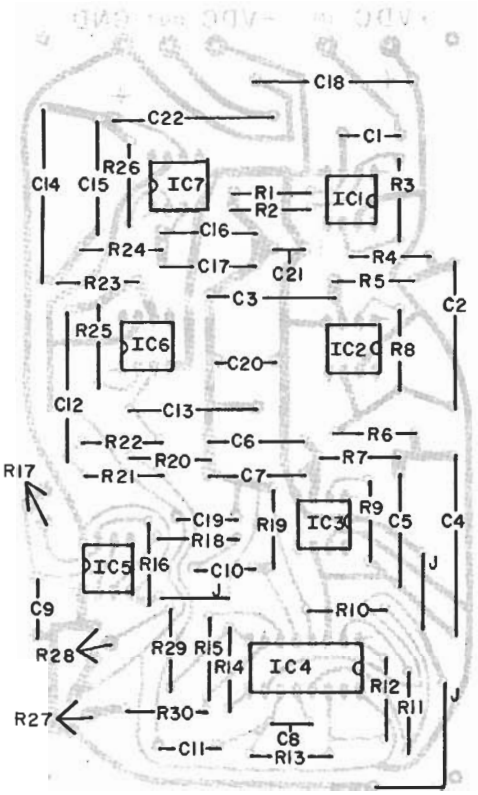


PARTS LIST

B1, B2—9-volt battery (see text)
C1, C9, C10, C19, C20—0.1 μF Mylar capacitor
C2, C12—3000-pF, 5% capacitor
C3, C13—1200-pF, 5% capacitor
C4, C14—6800-pF, 5% capacitor
C5, C15—300-pF, 5% capacitor
C6, C16—100-pF, 5% capacitor
C7, C17—39-pF, 5% capacitor
C8—20-pF, 5% capacitor
C11—0.22-μF, Mylar capacitor
C18, C21, C22—35-μF, 25-volt electrolytic capacitor
IC1, IC2, IC3, IC6, IC7—741 op amp
IC4—2208 multiplier (Exar)
IC5—555 timer
R1, R3, R8, R9, R25, R26, R29, R30—100,000 ohm, ¼-watt, 10% resistor
R2—27,000-ohm, ¼-watt, 10% resistor
R4-R7, R21-R24—56,000-ohm, ¼-watt, 5% resistor
R10, R13—300,000-ohm, ¼-watt, 5% resistor
R14—30,000-ohm, ¼-watt, 5% resistor
R15—62,000-ohm, ¼-watt, 5% resistor
R16—180-ohm, ¼-watt, 10% resistor
R17—5000-ohm trimmer potentiometer
R18-R20—10,000-ohm, ¼-watt, 10% resistor
R27, R28—20,000-ohm trimmer potentiometer
S1, S2—Dpdt switch
Misc.—Suitable chassis (Bud SC2132), battery holders and connectors, mounting hardware, suitable input/output jacks, etc.
Note—The following are available from Northwest Engineering Co., 801 Duchess Rd., Bothell, WA 98011: Pc board (N007-PCB) at $8; IC4 (N007-MULT) at $9.25; Kit of pc board and board mounted parts (N007-PK) at $34.50. All postage paid in U.S. via parcel post or UPS.

Fig. 2. Complete schematic of Scrambler.





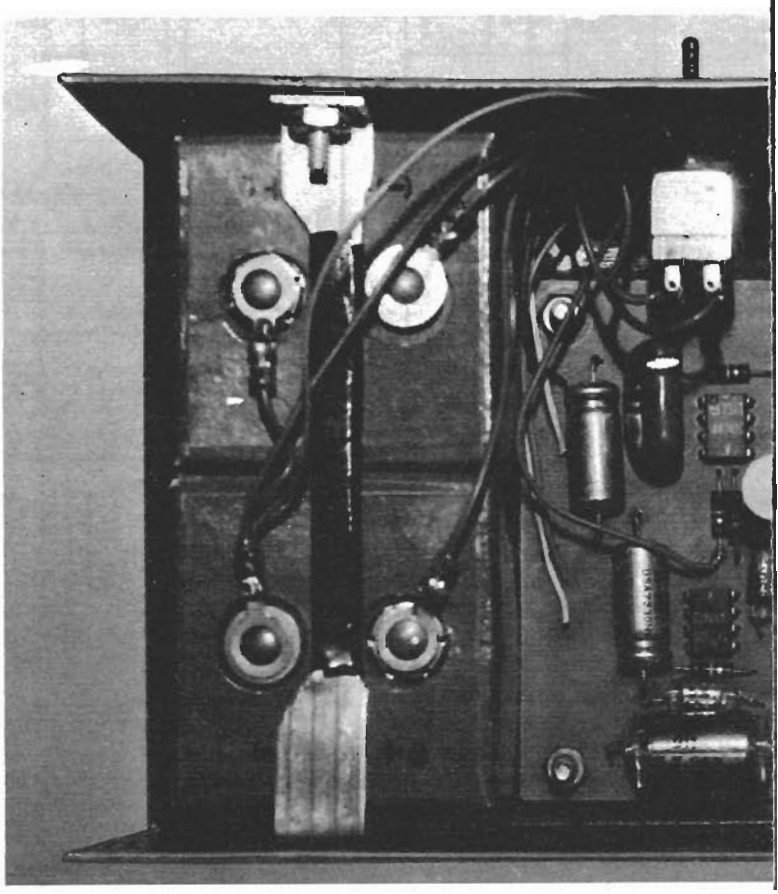


Fig. 3. Actual-size foil pattern for scrambler is shown at left; component layout at right.

How Scrambling Works. The block diagram in Fig. 1 shows how the scrambler works. The incoming audio signal is filtered to remove all frequency components above 3 kHz as shown at (A). The signal is then used to modulate a 3.5-kHz oscillator signal, with a linear four-quadrant multiplier as the modulator. The output (B) of the multiplier includes the sum and difference frequencies and any remaining 3.5-kHz carrier, leaving only the difference frequencies as shown at (C).

It is interesting to note that, in the output, the voice channel from 300 to 3000 Hz is contained in a single-sideband signal from 3200 to 500 Hz. It can be recorded or transmitted like any other voice signal, but the frequency spectrum of the output is an inversion of the input. (For example, an input frequency of 300 Hz is 3200 Hz in the output and an input of 2500 Hz is 1000 Hz in the output.) The inversion thus makes the voice message unintelligible.

When the scrambled signal is coupled to the input of a similar unit, the signal is re-inverted and the original audio comes out in unscrambled form as shown at (D) and (E) in Fig. 1.

Circuit Operation. The complete schematic of the voice scrambler is shown in Fig. 2. Integrated *IC1* is used as a high-input-impedance buffer amplifier to prevent loading on

the signal source. Resistors *R2* and *R3* control the gain of the buffer. An active low-pass filter with a cutoff frequency of 3000 Hz is provided by *IC2* and *IC3*. The shape of the filter is controlled by the feedback components (*R4-R7* and *C2-C7*) and the circuit is designed to provide a four-pole Chebyshev filter characteristic with 1 dB of ripple in the passband and a sharp roll-off. Integrated circuit *IC5* is a stable square-wave oscillator operating at a frequency determined by *R16, R17,* and *C9*. Potentiometer *R17* is used to adjust the oscillator frequency so that two or more units can be matched. The oscillator output is attenuated by resistors *R18* and *R19* and modulated by the output of *IC3*, the filtered input signal. The balanced modulator is *IC4*. Trimpots *R27* and *R28* provide balancing adjustments for the modulator. When they are properly adjusted, only the sum and difference frequencies of the two inputs will appear at the output. Integrated circuits *IC6* and *C7* form a low-pass filter to pass only the desired output signal.

The output of *IC7* can be used to drive load impedances as low as 2000 ohms. It can be used with most amplifiers, for speaker applications, or a set of 2000-ohm headphones.

Construction. To ensure that the active filters are properly tuned, it is recommended that 5% resistors and capacitors be used for the critical components (*R4-R7, R21-R24, C2-C7, and C12-C17*). The gain-controlling resistors for the multiplier (*R10-R13*) should also have 5% tolerances.

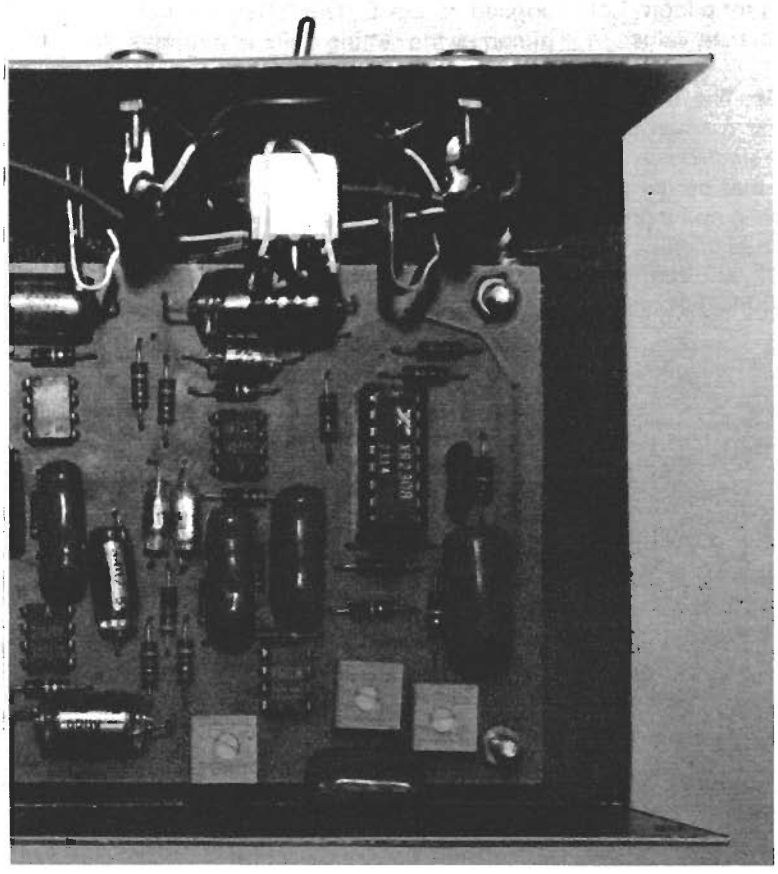


Photo shows how the prototype was assembled. Batteries are at left, but an extended supply can be used if desired.

Although the circuit can be wired point-to-point on perforated board, it is preferable to use a pc board such as that shown in Fig. 3. Be sure to observe the notch codes on the IC's and the polarities of the electrolytic capacitors so that they are properly installed.

In using a pc board, note that 8-pin DIP 741 op amps are required. If point-to-point wiring is used, other versions of the 741 (round, 14-pin DIP or dual) can be substituted.

Mount the batteries in holders in any convenient location in the chassis. If desired, the power can be obtained from an external supply between ±6 and ±15 volts. The supply voltage is not critical as far as circuit operation is concerned, but the maximum input signal level and the overall gain will vary for different supply voltages. The gain can be adjusted by changing the values of *R3* (raising it to increase the gain) and *R18* (lowering it to increase oscillator signal level).

The input and output connectors on the front panel must be chosen to suit the application.

Adjustment. For the proper operation, the oscillator should be adjusted to 3500 Hz. If an accurate counter or oscilloscope is available, *R17* can be adjusted while monitoring the output of *IC5* (pin 3). An alternate method of adjustment based on the accuracy of the lowpass filter can be used if necessary. With the input shorted to ground and *R17* turned fully counterclockwise, adjust *R28* to get an output of 0.15 volt on an ac voltmeter. Now adjust *R17* until the output voltage falls to 0.026 volt. The oscillator is now adjusted to approximately 3500 Hz.

To balance the multiplier, it will be necessary to adjust *R27* and *R28* while monitoring the scrambler output with an ac voltmeter or a set of headphones. With no signal input, adjust *R28* for minimum output (near the middle of its range). To adjust *R27*, it is necessary to disable the oscillator by shorting across capacitor *C9*. With an input signal of about ½ volt (1000 to 3000 Hz), adjust *R27* for minimum output signal. The scrambler is now ready for use.

Use. A crystal microphone can be connected to the input of the scrambler with the output (with unity gain) connected to the MIC input of a tape recorder or transmitter. If headphones are used, the scrambled signal is connected between the recorder preamplifier and speaker amplifier (or receiver detector and audio amplifier).

The multiplier portion of the circuit can be used as a single-sideband modulator. The multiplier can be modified to operate with carrier frequencies as high as 5 MHz. Pins 13 and 14 of *IC4* should be shorted to pin 4, with *R10* through *R13* removed, a 5100-ohm resistor connected between pins 4 and 15, and pin 2 connected to pin 16. With *IC5* removed, the desired carrier signal can be coupled into pin 4 (using about 1 volt). The output of *IC4*, from pin 15, can be coupled into a SSB filter to remove the unwanted sideband.

The multiplier can also be used as a variable-gain amplifier, or remote volume control. If the oscillator is removed, the gain of the multiplier can be controlled by varying the dc level on pin 5 of *IC4* from 0 to 5 volts. One way to accomplish this is to include a 100,000-ohm potentiometer in series with a 100,000-ohm resistor across the positive supply. Remove *IC5, R18*, and *R19*. Connect C10 from *IC4* (pin 5) to ground. Connecting the wiper from the potentiometer to *IC4* (pin 5) will provide the desired variable voltage. For wide-band or hi-fi use, remove the two active filters. A control range of 50 dB can be obtained with low distortion. ◈