The VOX Plus HT Accessory

Enjoy base station performance—with your HT!

by Mike Kossor WA2EBY

After a long, busy season of fleamarketeering, I managed to reallocate sufficient funds to finally invest in a 2 meter rig. With all the fine equipment available, the selection wasn't easy. I wanted a rig that I could take with me to hamfests, operate mobile, and use at home. The obvious choice? A full-featured handi-talkie, of course!

The handheld I chose was perfect for taking to hamfests. I added the optional speaker mike, plugged the external 12 volt DC power cable into the cigarette lighter jack, made a mounting bracket, and enjoyed excellent mobile operation as well. But when I tried operating the unit at home, it became apparent I was having to compromise.

Unhandy Talkie

During a recent VHF contest, I found myself joggling the HT, logbook, and pen, trying to log and call CQ. I did my best at making contacts running a mere 2.5 watts RF output. Being limited to a single mode, FM, took its toll on my score, since I was unable to make CW contacts worth bonus points. I did try operating MCW (Modulated CW) using the tone pad, but the battery started dying during the awkward QSO.

With the battery gone, and out of the contest, I had plenty of time to think about how nice it would be to operate VOX on the handheld, as I do on my HF gear. Logging would be so much easier. It would also be nice to operate MCW with a real key, and transmit the full 5 watt RF output available without having to worry about taxing the batteries to exhaustion.

It also occurred to me that an MCW mode would be especially useful to individuals with Technician Class licenses who only have FM transceivers. How could they upgrade without practicing CW?

My thoughts soon turned to action. My goal was to design an add-on accessory that could provide these desirable features, at a cost and complexity well within the realm of the average radio amateur.

Features of the VOX Plus

What evolved is the VOX Plus. This accessory uses the external microphone, speaker, and power jacks of a transceiver, and adds the features of VOX operation or break-in MCW. It uses a clean 800 Hz sine wave oscillator complete with sidetone. A programmable regulated power supply is also available to power transceivers requiring six to ten 500 mAh NiCd batteries, at full RF power output.

Photo A. The VOX Plus setup. (Photo by Eric Wagner.)

These features resolved the initial shortcomings of HT base station operation. However, since I was using an external speaker, I decided to add an active audio filter, too. This way I could separately adjust the low and high frequency response of the received audio. Compensating for poor frequency response of transmitted or re-transmitted signals, I could customize the received audio for optimum readability, and also use the filter to attenuate annoying CTCSS tones, if present. A 2 watt audio power amp was added to provide sufficient audio output.

One final feature I thought desirable was an audio tape interface for MCW. With this interface, taped bulletins or code practice can be sent with full break-in operation.

Circuit Overview

The VOX Plus circuit is a combination of transistor switches and common op amp circuits described in detail in many textbooks. Two good books on the subject are *Analysis and Design of Integrated Electronic Circuits*, by Paul M. Chirlian (chapters 13, 14 and 18), and *Basic Electronics*, by Michael M. Cirovic (chapters 14 and 15). The circuit does get a bit cumbersome when all the individual circuits are grouped together. However, Figure 1, a functional block diagram, should give you a general idea of how the system operates.

Referring to Fig. 1, VOX operation requires MODE switch S1 to be in the voice position. Switch S1A disables the MCW oscillator while segment S1B connects the transceiver's microphone input to the VOX Plus microphone amplifier. The circuit is considered to be in an idle state when the operator is not talking and the transceiver is not receiving any signal.

In this state, the positive input of comparator U2C is biased at 50% of the supply voltage, +0.5V, and the negative input is biased at +0.6V. The output of comparator U2C is low (0 volts) because the negative input is at a higher potential than the positive input. The re-triggerable monostable multivibrator (or "one-shot") is also in an idle or stable state with its output low because it has not received a positive trigger voltage from comparator U2C. PTT switch Q3, controlled by the one-shot, is in the open state, placing the transceiver in the receive mode.

Transmit Mode

When the operator begins talking, the voice is picked up by the internal VOX Plus electret microphone and amplified by U1A. The signal is then applied to the input of VOX amp U1B via switch S1B for further amplifi-

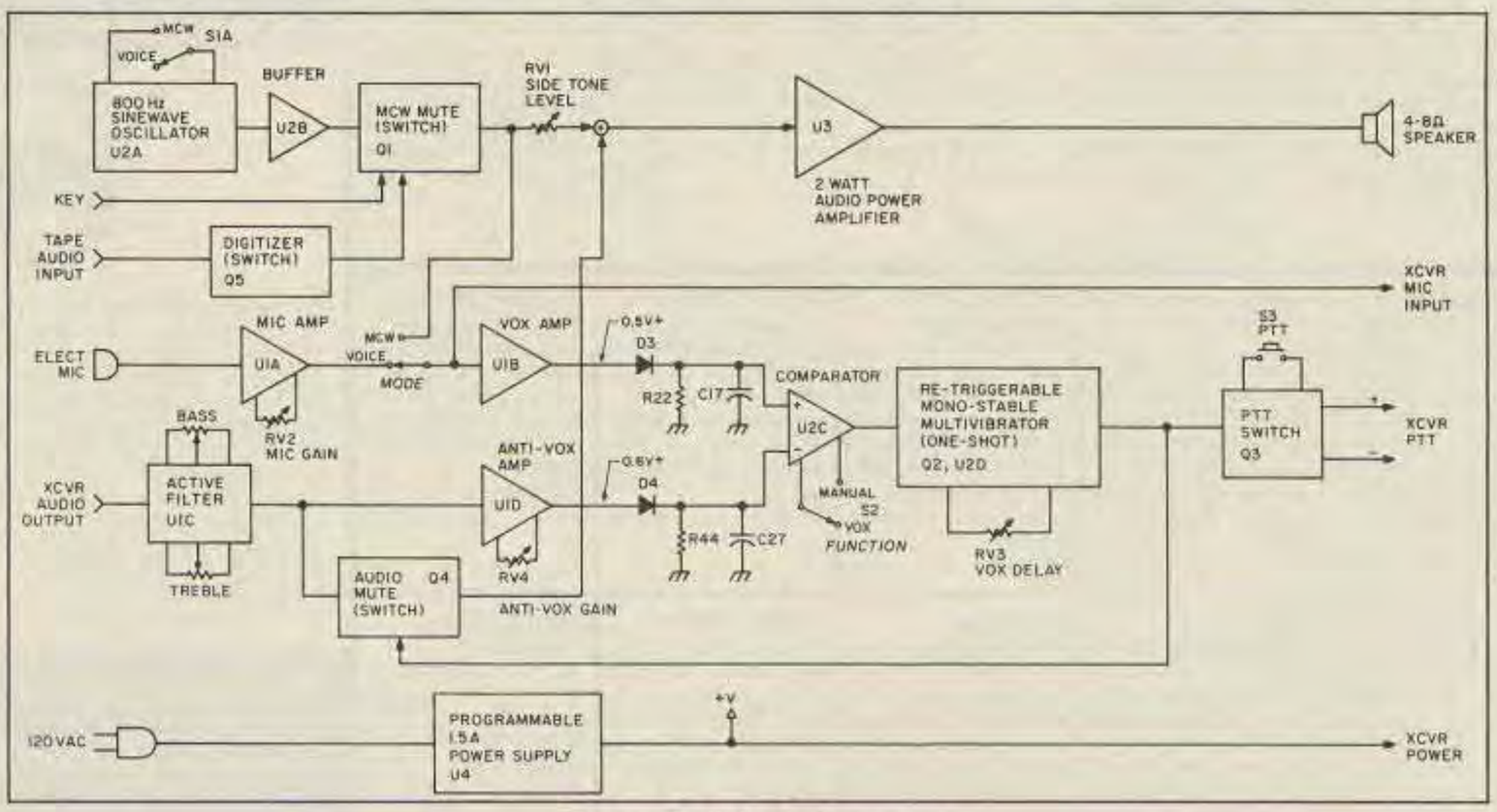

Figure 1. Block diagram.

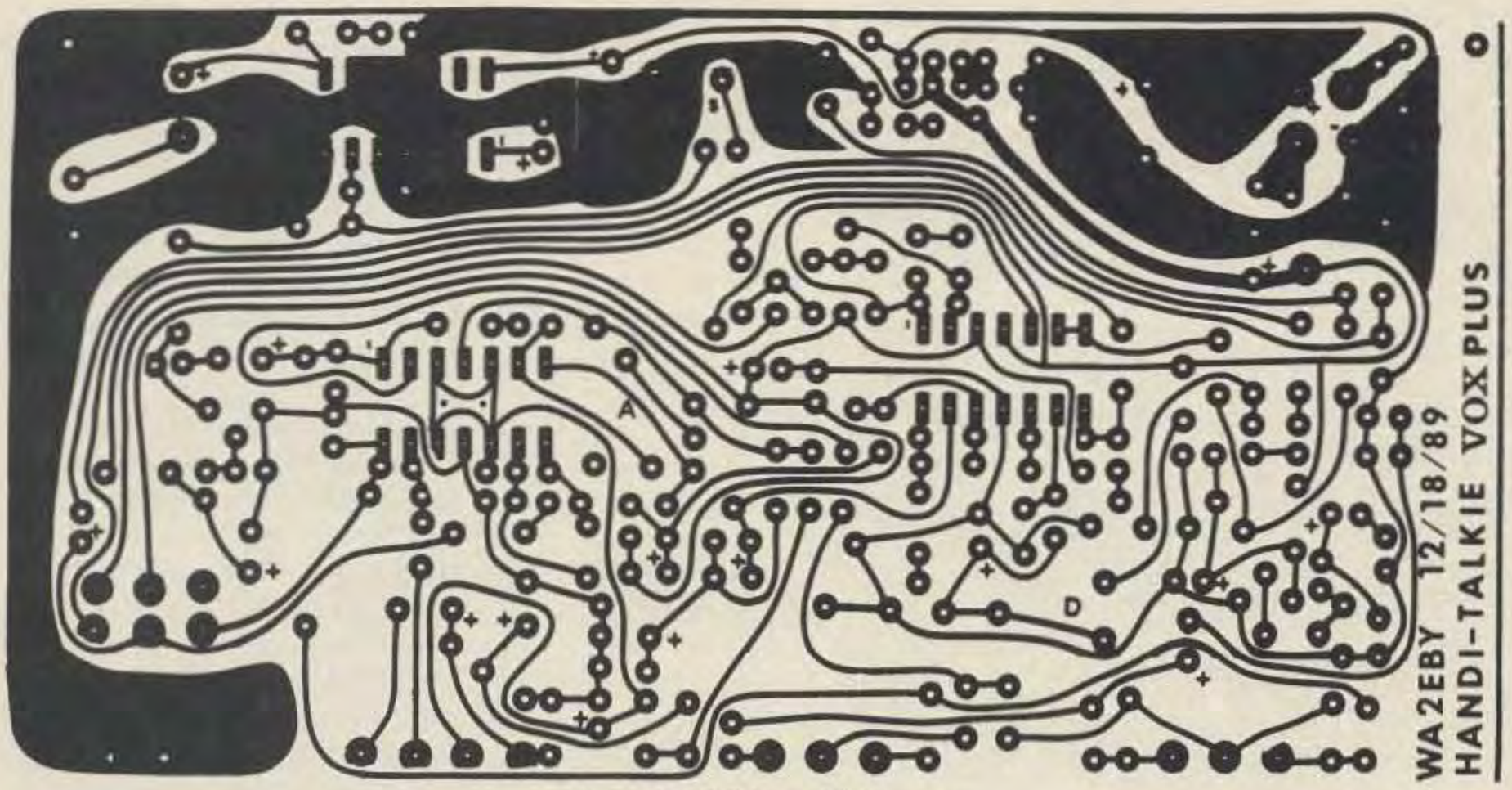

Figure 2. PC board foil pattern.

cation. The highly amplified voice signal at the output of VOX amp U1B is then rectified by diode D3.

The positive peaks of the rectified audio charge capacitor C17, which is connected to the positive input of comparator U2C. The +0.5V DC bias level normally present on the positive input of U2C increases in direct proportion to the amplitude of the operator's voice.

When the voltage level increases to about +0.7V, it exceeds the +0.6V value present on the negative input of U2C, and the comparator's output goes high (+V volts). This in turn triggers the one-shot and turns on PTT switch Q3, keying the transceiver. The output of the one-shot is also used to turn on audio MUTE switch Q4 to eliminate "pops" in the speaker when switching from receive to transmit and back to receive.

A sample of the operator's voice is fed to the microphone input of the transceiver and transmitted out. The transceiver will remain keyed as long as the operator's voice is of sufficient amplitude to keep capacitor C17 charged, maintaining the positive input of comparator U2C at a higher level than the negative input. When the operator's voice ceases, capacitor C17 discharges quickly through resistor R22, and the positive input of comparator U2C returns to its normal value of +0.5V.

Upon reaching its normal value, the circuit is back in the idle state, which causes the output of comparator U2C to return to low. Thus the trigger pulse to the one-shot is removed, allowing its output to return to low after a predetermined time delay set by VOX delay potentiometer RV3. PTT switch Q3 returns to the open state when the one-shot "times out," putting the transceiver back into the receive mode. If the operator pauses during his transmission and begins to speak before the one-shot "times out," the new positive trigger pulse from comparator U2C resets or re-triggers the one-shot circuit before it releases PTT switch Q3. The transceiver will drop out of

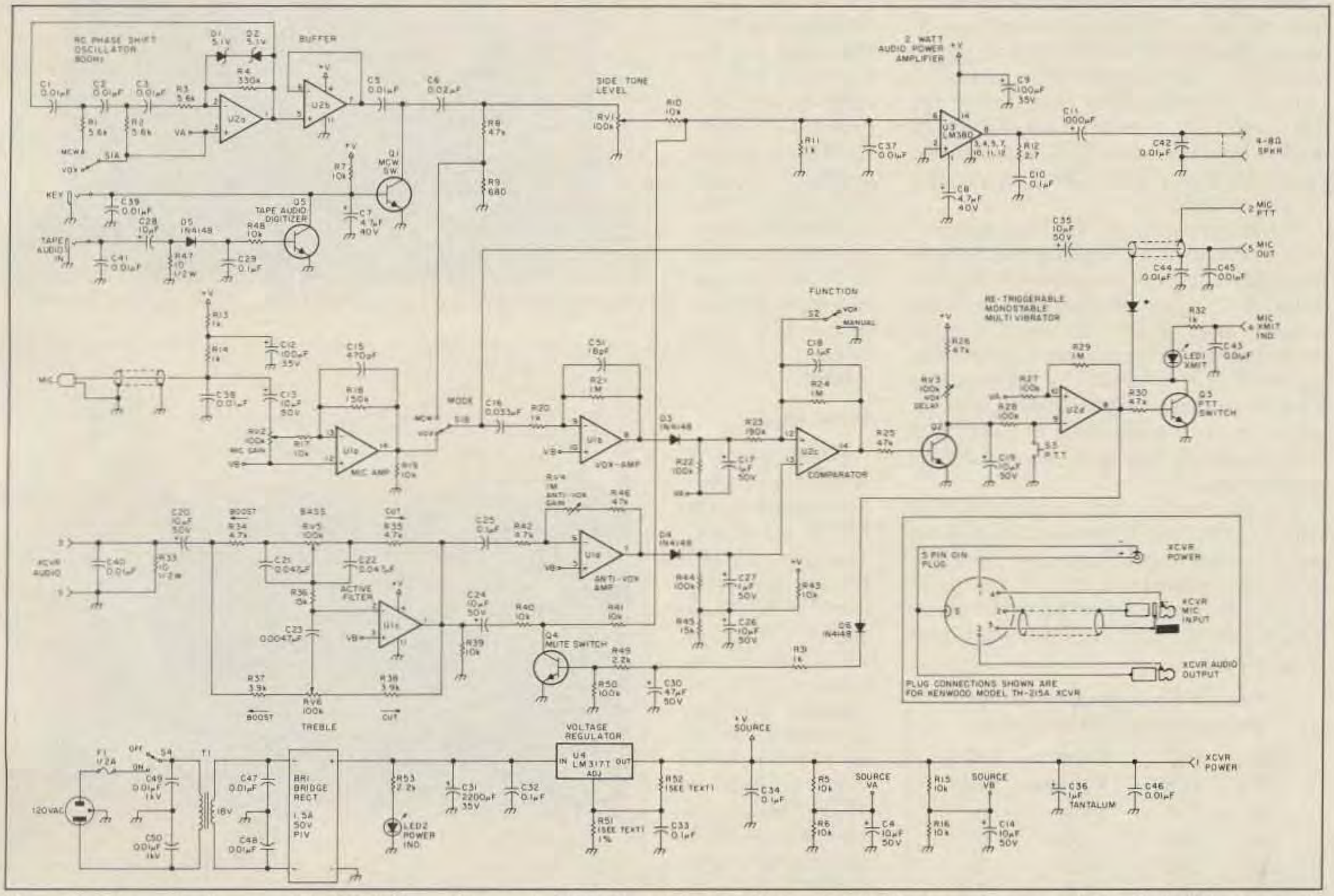

*Figure 3. Schematic diagram of the VOX Plus. (*To use the VOX Plus with other HTs, wire pin 2 for PTT when grounded and pin 5 for MIC audio out. For proper operation of the XMIT Indicator LED, attach pin 4 to +V and add a blocking diode in the PTT line as shown.)*

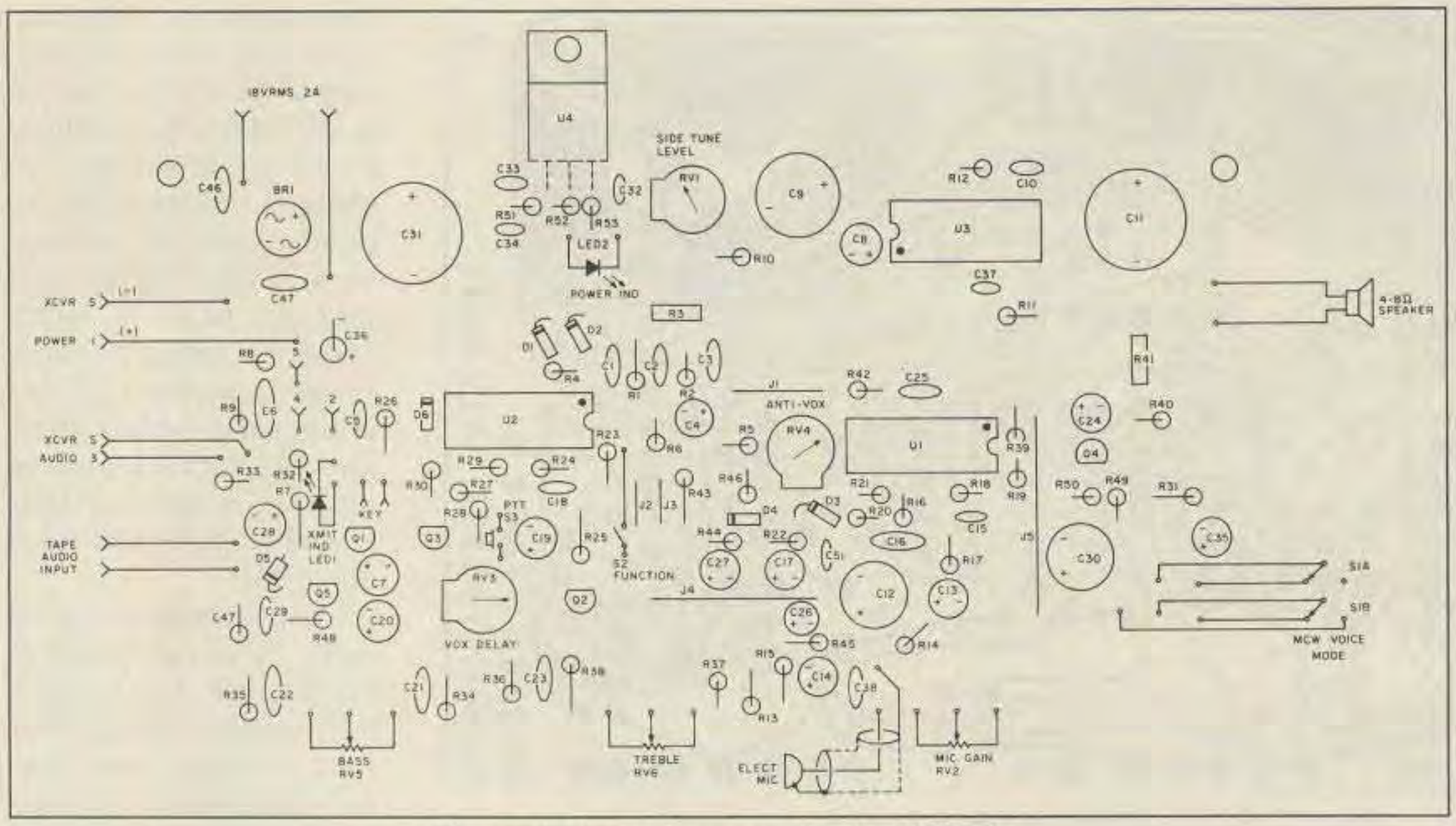

Figure 4. Parts placement for the VOX Plus.

transmit mode between words if the VOX delay is set too short.

Receive Mode

When the operator is not talking and an incoming signal is received, the audio signal from the transceiver is conditioned by active filter U1C, then passed to a 2 watt audio power amplifier capable of driving a 4- to 8-ohm speaker at a respectable level.

A sample of the transceiver's audio taken from the active filter output is used to cancel the effect of the audio picked up by the VOX Plus' electret microphone; this prevents the received signal from keying the transceiver. The transceiver's audio sample is taken from active filter U1C and amplified by anti-VOX amp U1D. Diode D4 rectifies the audio sample.

The positive peaks of the rectified audio charge capacitor C27, which is connected to the negative input of comparator U2C. The +0.6V DC bias level normally present on the negative input of U2C increases in direct proportion to the transceiver's audio. The anti-VOX gain, controlled by potentiometer RV4, is adjusted so that the bias level increase on the negative input of comparator U2C equals the bias level increase on the positive input.

The net result is that comparator U2C remains in its idle or low state because the negative input tracks the positive input bias level, and remains lower in level. The operator can still initiate a transmission by beginning to speak while an incoming signal is being received. The voice will cause an additional increase in the bias level only on the positive input of comparator U2C.

When the increase on the positive input of U2C exceeds the negative input, the VOX Plus will key the transceiver and operate as described previously. Resistor R44 is used to discharge capacitor C27 when transceiver audio ceases, returning the bias level on the negative input of comparator U2C to its normal value of +0.6V.

Table 1. Power Supply Voltage Programming Resistor Values

R51 (1%)	R52 (1%)	Output Voltage	NiCd Cells
4.7k	510	12.8V	10
3.9k	510	10.8V	9
2.2k	330	9.6V	8
2.7k	470	8.4V	7
3.9k	820	7.2V	6

MCW Mode

MCW operation is selected by placing switch S1 in the MCW position. This starts the 800 Hz sine wave oscillator, U2A, which applies a sample of its output to the transceiver's microphone input and disconnects the internal electret microphone. Break-in MCW operation is identical to VOX operation, except the 800 Hz sine wave signal takes the place of the operator's voice. The presence of the 800 Hz audio signal at the input to the VOX amp is controlled by MCW mute, Q1. A key or keyer activates MCW mute Q1 and allows the 800 Hz signal to reach the VOX amp. The same process takes place as described for VOX operation, using the MCW signal instead of the operator's voice.

A second method of controlling MCW mute Q1 is to use an audio tape player. Code practice, CQ, or CW message is recorded on audio tape. When played back into digitizer Q5, on/off keying pulses are generated, which control MCW mute Q1. Note that since the tape audio only generates on/off keying pulses, no tape hiss, hum, or background noise is heard. Taped code is QRM-free

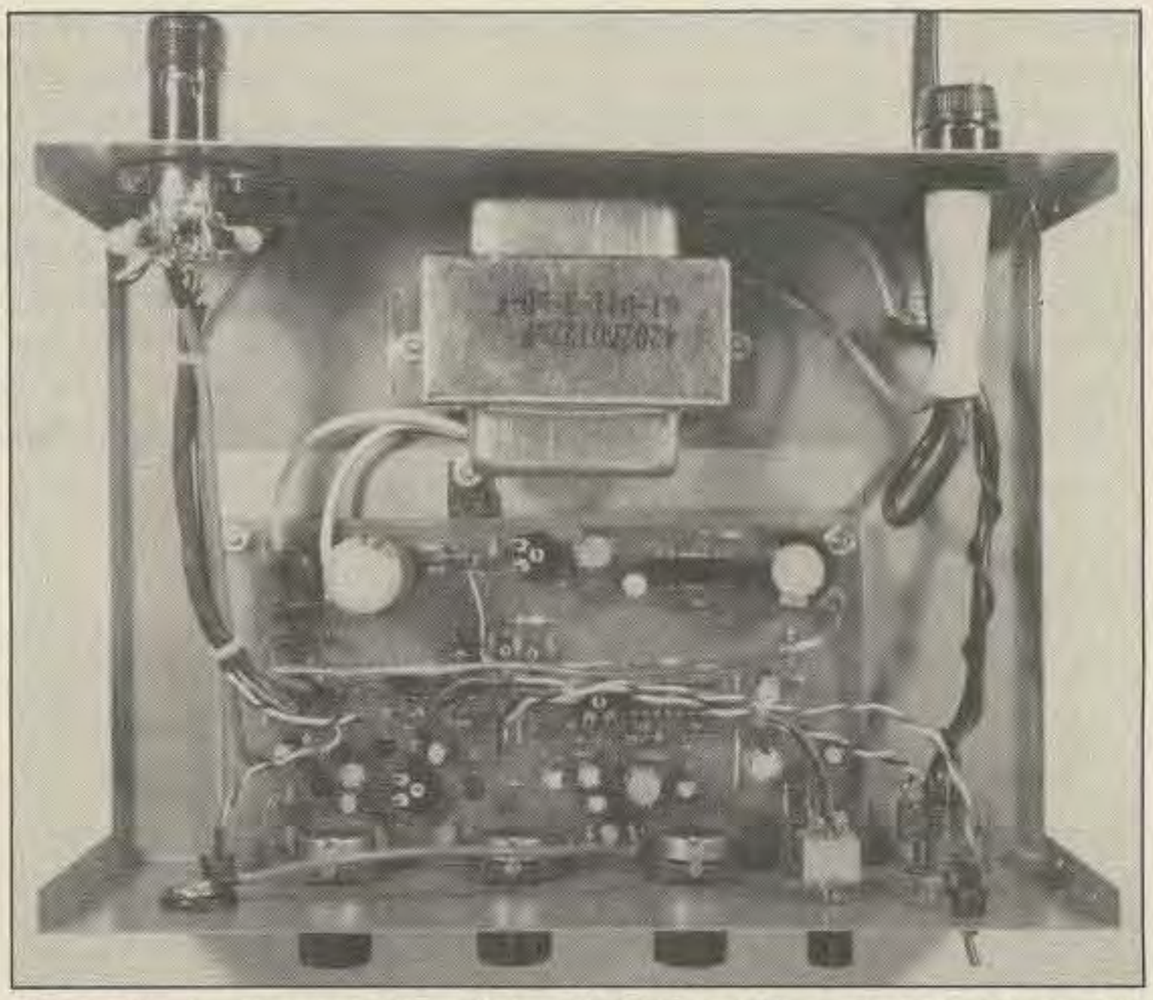

Photo B. An internal view of the VOX Plus. (Photo by Eric Wagner.)

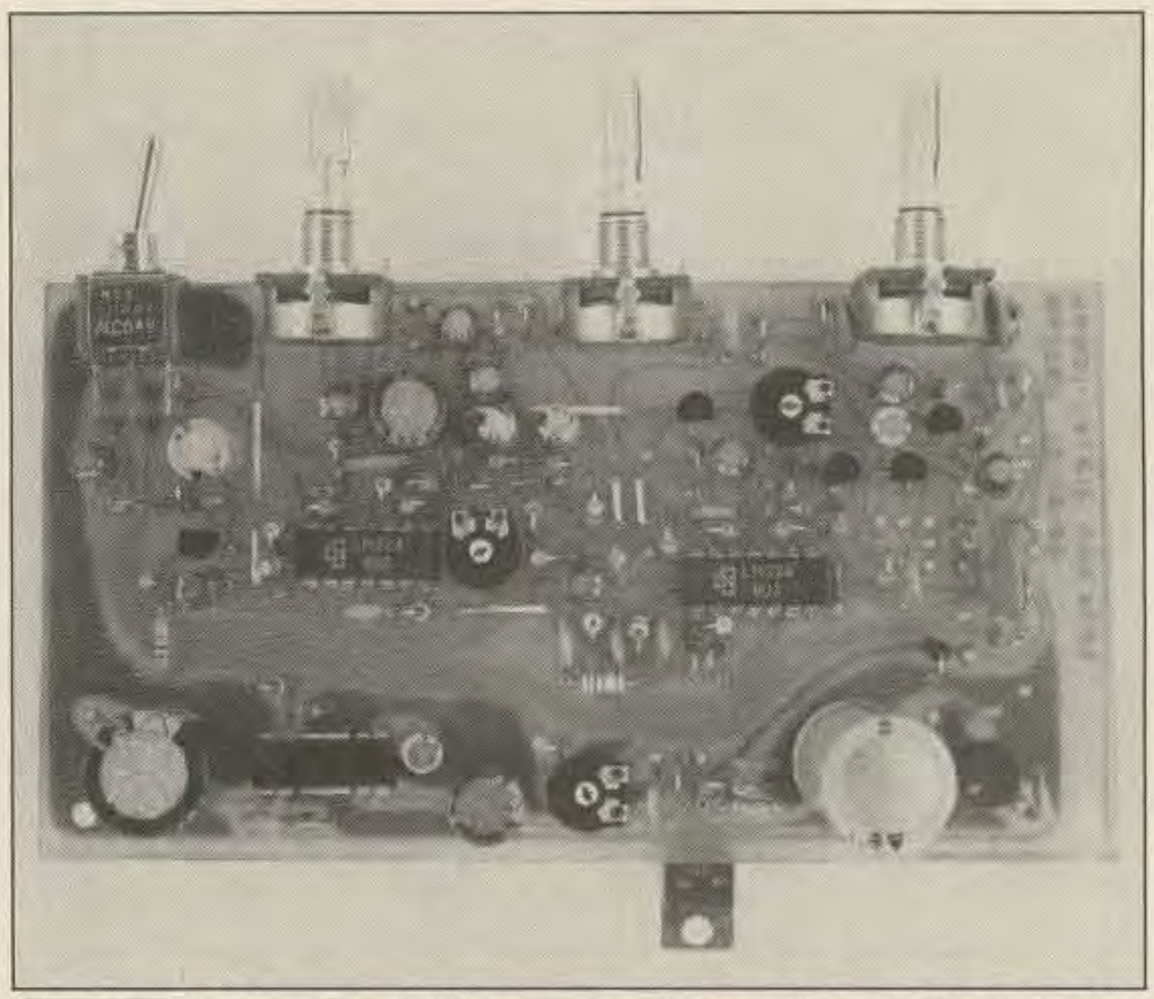

Photo C. Close-up view of the completed circuit board. (Photo by Eric Wagner.)

Table 2. Handi-Talkie VOX Plus

Resistors			
All resistors are ¼W, 5%, unless otherwise noted.			
R12	2.7	ohms	
R33,47	10	ohms	½W
R52*	510	ohms	1%
R9	680	ohms	
R11,13,14,20,31,32	1k	ohms	
R49,53	2.2k	ohms	
R37,38	3.9k	ohms	
R34,35,42	4.7k	ohms	
R51*	4.7k	ohms	1%
R1,2,3	5.6k	ohms	
R5,6,7,10,15,16,17,19, 39,40,41,43,48	10k	ohms	
R36,45	15k	ohms	
R8,25,26,30,46	47k	ohms	
R22,27,28,44,50	100k	ohms	
R18	150k	ohms	
R23	190k	ohms	
R4	330k	ohms	
R21,24,29	1	megohm	
RV1,3	100k	ohms	1 turn trimmer
RV4	1	megohm	1 turn trimmer
RV2,5,6	100k	ohms	linear taper pot
Capacitors			
C51	18	pF, 25V	ceramic disc
C15	470	pF, 25V	ceramic disc
C1,2,3	0.01	µF, 50V	ceramic disc, (NPO) or Mylar
C5,11,38,39,40,41,42, 43,44,45,46,47,48	0.01	µF, 50V	ceramic disc
C49,50	0.01	µF, 1 kV	ceramic disc
C6	0.02	µF, 25V	ceramic disc
C10,18,25,29,32,33,34	0.1	µF, 25V	ceramic disc
C16	0.033	µF, 25V	ceramic disc
C21,22	0.047	µF, 25V	ceramic disc
C23	0.0047	µF, 25V	ceramic disc
C17,27	1	µF, 25V	electrolytic
C36	1	µF, 25V	tantalum
C7,8	4.7	µF, 25V	electrolytic
C4,13,14,19,20,24,26, 28,35	10	µF, 25V	electrolytic
C30	47	µF, 25V	electrolytic
C9,12	100	µF, 25V	electrolytic
C11	1000	µF, 25V	electrolytic
C31	2200	µF 35V	electrolytic
Semiconductors			
BR1	50V, 1.5A		bridge rectifier
LED1,2	T1 style		red
D1,2	1N5231B, 5.1V DC		¼W zener diode
D3,4,5,6	1N4148		switching diode
Q1,2,3,4,5	2N3904		NPN, transistor
IC1,2	LM324		quad op amp
IC3	LM380		2.5W audio amp
IC4	LM317		adjustable voltage regulator
Other Components			
T1	18V, 2A		power transformer
S1	DPDT toggle switch		
S2,4	SPST toggle switch		
S3	normally open		push button
J1,2	mini-audio		jack
J3	5-pin DIN		jack
J4	RCA phono		jack
F1	½A fuse		with holder
Electret condenser microphone			
PC board			
AC power cord			
heat sink			
enclosure			
knobs			
5-pin DIN plug, mini-audio plugs (2), coaxial power plug.			

*See Table 1. for R51 & R52 values.

Parts kits are availalble from Micro Mart, 508 Central Ave., Westfield NJ 07090. Tel. (201) 654–6008. PC board and components are $29.95, plus $2.50 S&H; the parts kit, less enclosure, heat sink, and knobs, is $49.75, plus $3.75 S&H; the PC board only is $12.95, plus $2.50 S&H; and the power transformer is $4.75 plus $3.50 S&H.

and indistinguishable from hand-sent code.

Other Features

FUNCTION switch S2 disables comparator U2C so you can operate in manual mode. In this mode, you must use PTT switch S3 to key the transceiver. This feature is useful in voice mode when the room noise level causes false XCVR keying, or in the MCW mode to use the VOX Plus' sidetone as a code practice oscillator. A programmable regulated power supply is available for powering transceivers that operate from six to ten 500 mAh NiCd batteries. The output voltage is programmable by changing the value of resistors R51 and R52. See Table 1 for programming resistor values.

Design Details

A few words need to be said regarding some of the "basic" op amp circuits, since their physical implementation is slightly different from the theoretical description. The design of the RC phase-shift oscillator requires some practical modification to attain dependable operation.

In theory, the circuit will oscillate when the gain is set to a value of 1/29. This is a very critical value. If the value is slightly less, the circuit will not oscillate. If the value is slightly more, the output waveform will clip, resulting in distortion. This problem is overcome by adding amplitude compensation to the circuit.

Back-to-back zener diodes are placed in parallel with feedback resistor R4. The zener diodes decrease the gain of the oscillator as the output amplitude approaches the positive power supply rail to prevent it from clipping and distorting the waveform. Because of the zener diodes, you need more gain to get the oscillator started, thus the gain is higher than 1/29.

In theory, the frequency of oscillation of the RC phase-shift oscillator is given as: $f = 0.065/RC$. The addition of amplitude compensation using the zener diodes causes the actual frequency to be lower. It is difficult to predict the actual frequency of oscillation because zener diodes are nonlinear devices, and therefore, linear analysis can not be used to determine it. The theoretical equation does, however, give a good place to start.

A practical note pertains to the use of the LM324 op amp. For capacitively coupled loads, a resistor should be used from the output to ground to increase the class A bias current and prevent crossover distortion (see the National Semiconductor Corp.'s *Linear DataBook 1* 1988). This is the purpose of resistors R19 and R39. Notable distortion was present without them.

The one-shot circuit consists of transistor switch Q2 and comparator U2D. The trigger pulse is applied to the base of Q2 via R25, which limits the base current to a safe value. Each time a positive trigger pulse is applied to R25, Q2 discharges capacitor C19 to ground. The voltage across C19 is applied to the negative input of comparator U2D; the positive input of U2D is fixed at V/2. When C19 is discharged to ground, the voltage across C19

falls below V/2 and the output of comparator U2D goes high.

The output remains high until the voltage across C19 rises above V/2 volts. The charge time of C19 is controlled by the series combination of resistors R26 and RV3, VOX delay. The circuit is re-triggerable because capacitor C19 can be discharged repeatedly by a trigger pulse, effectively resetting its charge time. MUTE switch Q4 is activated by the output of the one-shot by charging capacitor C30 via diode D6 and resistor R31.

The voltage across C30 supplies base current to Q4 via base resistor R49. Q4 turns on and bypasses to ground the audio present at the junction of the voltage divider that consists of R40 and R41, preventing it from reaching the audio power amp U3.

Capacitor C24 provides DC isolation. When the one-shot times out, diode D6 prevents C30 from discharging immediately. MUTE switch Q4 remains on while C30 discharges through resistors R49 and R50, and keeps the audio path shunted to ground. In this way, the attack and decay of the MUTE switch are controlled, and the introduction of noise by the action of the mute circuit itself is prevented.

Construction

Only common components are used in this project. Most of them can be found in your junk box. If you don't have a junk box, you can get all the parts from *Micro Mart* (see parts list).

Due to the number of components, I chose PC board construction. You could also use point-to-point wiring. Photo B. shows the circuit board mounted in a Radio Shack steel enclosure. Note that voltage regulator U4 is mounted on the copper side of the board, keeping the leads as short as possible to minimize RF pickup and to maintain load regulation. This also simplifies access to the aluminum heat sink mounted to the bottom of the steel enclosure. The steel enclosure does not make a suitable heat sink because of its lower thermal conductivity. The dimensions of the aluminum heat sink are 6" x 2.5" x 0.0625".

Connect the transceiver's power, microphone, and speaker jacks with a 5-pin DIN plug, its receptacle mounted on the rear panel. Bypass capacitors C40, C43, C44, C45 and C48 are mounted at the 5-pin DIN receptacle to prevent RF from disrupting circuit operation. Access to the KEY input and TAPE AUDIO input are made with 3.5mm phone jacks. An RCA audio jack is used for the speaker output. Bypass capacitors C39, C41, and C42 associated with these terminals are also located on their respective jacks.

Setup and Operation

Check the circuit carefully before applying power. If all looks good, set the FUNCTION switch S2 to manual and set the MODE switch S1 to the MCW position. Set BASS and TREBLE to center position, and MIC GAIN control to minimum. Set sidetone level control RV1 to minimum by turning it CCW; then turn it ⅛ turn CW. Set VOX delay RV3 and anti-VOX gain RV4 to center position. Connect a 4- to 8-ohm speaker to the speaker jack and a telegraph key to the KEY input.

Before connecting the VOX Plus to your transceiver, turn on POWER switch S4 and check the programmed power supply voltage to ensure its value is correct, as selected from Table 1. The supply voltage should be within 5% of the selected value. Press the telegraph key and listen for the 800 Hz sidetone from the external speaker. Adjust sidetone level RV1 to the desired level.

Connect the transceiver to the VOX Plus. Be sure to use an external antenna to prevent strong RF fields from causing undesirable operation. Tune in a QSO and try varying the BASS and TREBLE controls. You should be able to make muffled signals or tinny signals more natural sounding, and attain better readability.

To operate break-in MCW, change FUNCTION switch S2 to the VOX position and start sending. The VOX Plus will automatically key the transmitter when you start sending code. The transceiver should remain in the transmit mode until about 1 second after you stop sending. If the transmitter drops out between letters or words, increase VOX delay RV3 by turning it CW.

To operate voice, change MODE switch S1 to the voice position, turn the MIC GAIN control to about ¾, and talk only when you what to transmit. Remember, you are now operating VOX, and you should turn the microphone gain down when you're not in a QSO. 73

Mike Kossor WA2EBY, 13 N. 12th St., Kenilworth NJ 07033