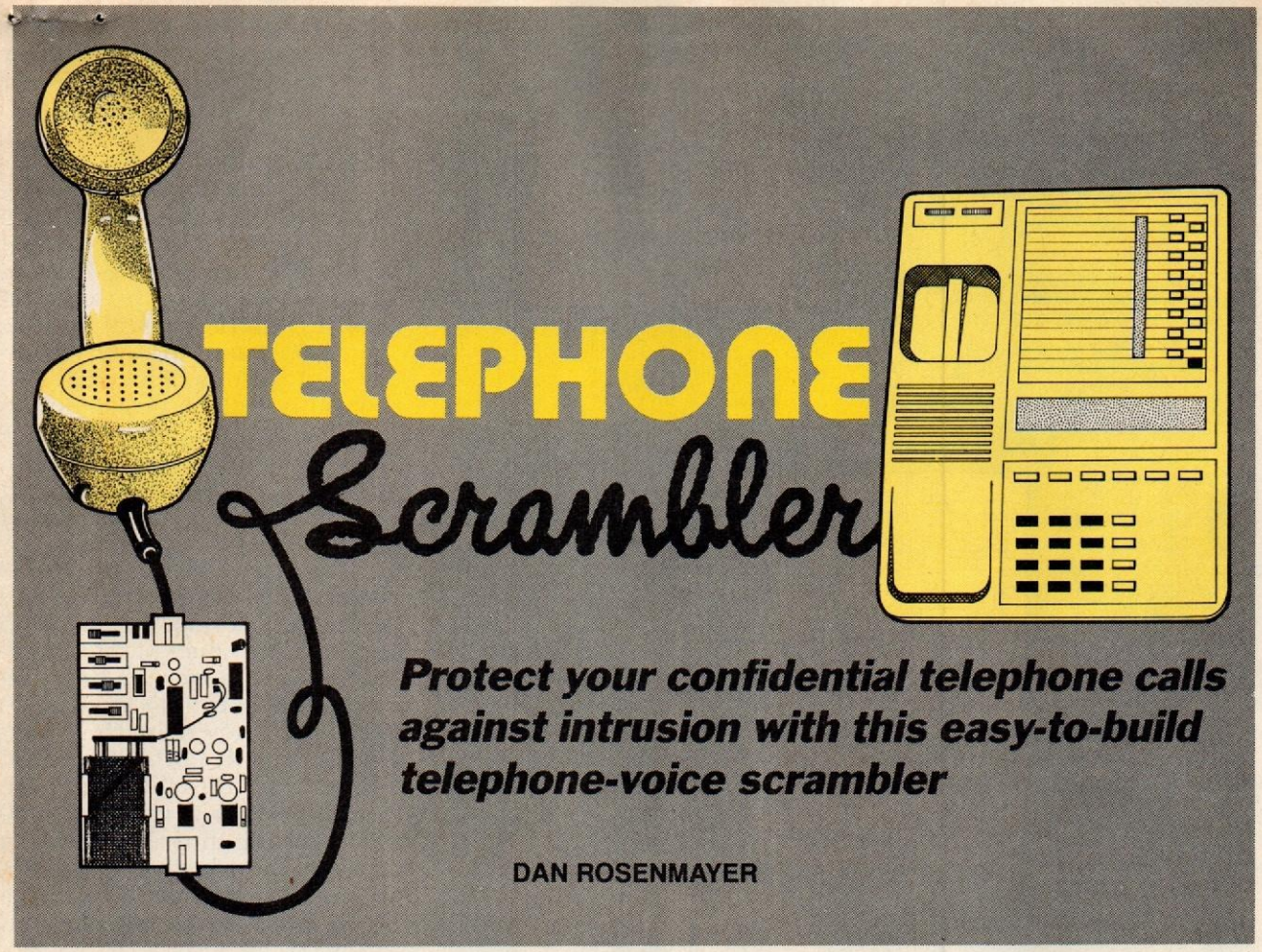


TELEPHONE Scrambler

Protect your confidential telephone calls against intrusion with this easy-to-build telephone-voice scrambler

DAN ROSENMAYER

TELEPHONE-VOICE SCRAMBLING IS the most effective method for eliminating unwanted eavesdropping on your confidential phone calls. It should be considered if you have reason to believe that unauthorized persons are or could be listening in on your telephone conversations. A system consisting of two compatible telephone-voice scramblers will permit normal conversation between you and your intended listener, while making all speech unintelligible to anyone listening on extensions at either end of the line. Only a person with a compatible unscrambler will be able to understand what is being said.

Many circuits are available that can monitor your phone line and detect intentional or unintentional removal of handsets from their hooks on any extension. Because they're easily defeated, those circuits could lull you into a false sense of security. Even if you detect an unauthorized listener "horning in," you have only two choices: hang up or be on guard against saying anything that you don't want to be heard by an unauthorized third party.

Matched telephone voice scramblers enable you to carry on conversations without guarding your speech. They also eliminate the threat of wiretapping and covert tape recording, unless the intruder has the necessary circuitry to unscramble your garbled conversations.

In the past, factory-made telephone voice scramblers were expensive and difficult to find. Today scramblers are more readily available and their prices have fallen because of the availability of low-cost voice scrambler/descrambler IC's. However, those scramblers might include certain features that you don't want such as a briefcase housing. This article will permit you to build inexpensive, compact, and effective voice scramblers in the form of loaded circuit boards.

Figure 1 shows the TVS250 voice scrambler coupled between the headset and base of a standard telephone. It is half of a complete telephone security system. Connections between the scrambler circuit and telephone are easily made with standard telephone cords terminated with standard modular plugs. A second voice scrambler would be similarly connected to another telephone to form the secure telephone system shown in Fig. 2.

Theory of operation

The heart of the TVS250 is the COM9046, a voice scrambler/descrambler IC made by Standard Microsystems Corp. Figure 3 is a simplified block diagram of that dedicated chip. The IC contains two identical speech channels that permit full-duplex operation when connected between two telephones. Each channel is capable of scrambling and descrambling voice communications.

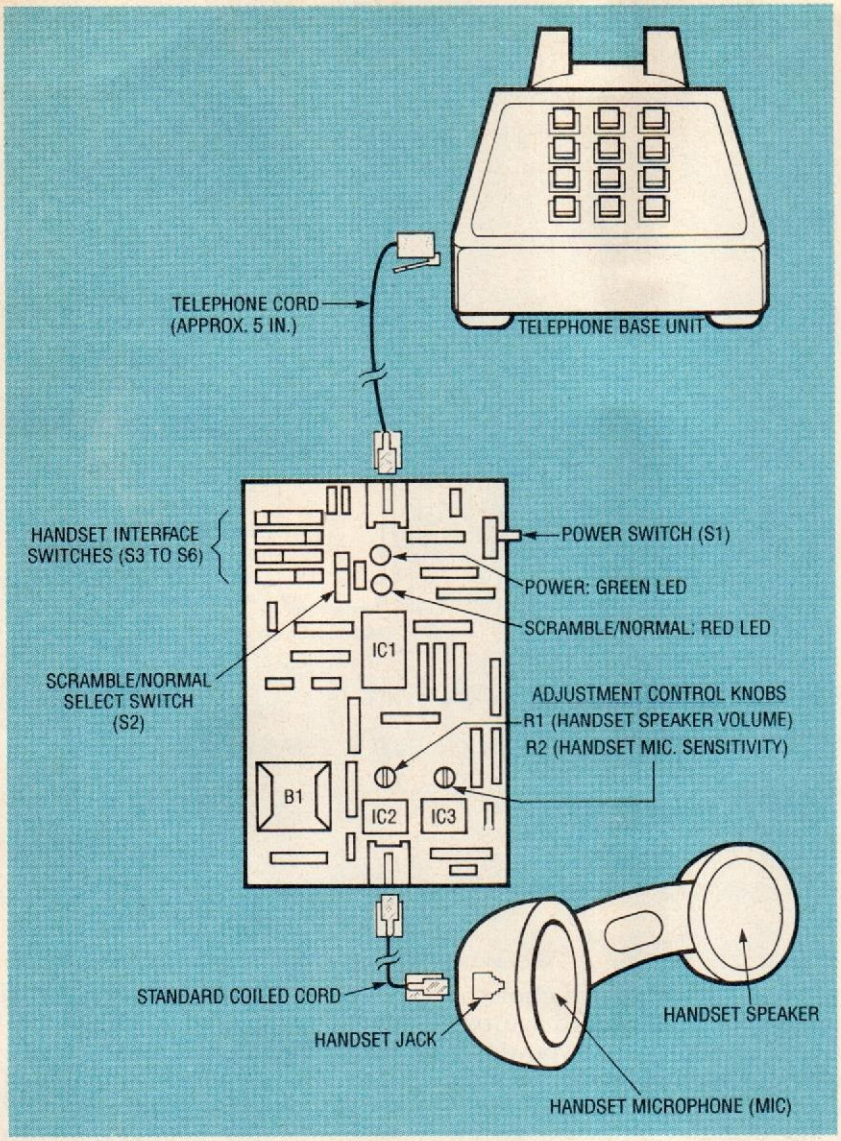


FIG. 1—ONE END OF A SECURE TELEPHONE SYSTEM, a TVS250 scrambler circuit coupled between the handset and the base of a telephone with standard jacks and cord.

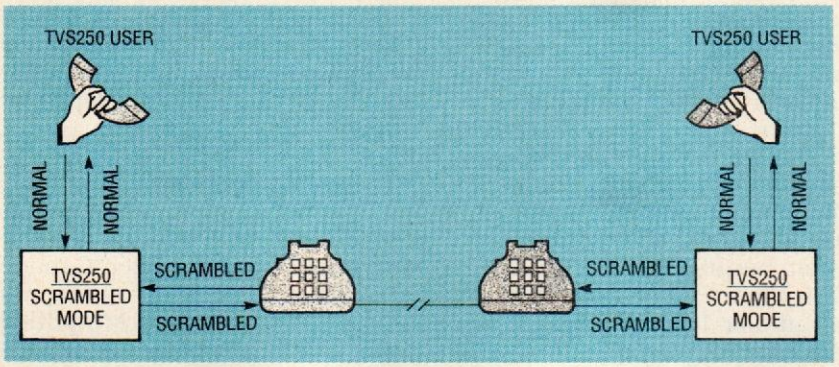


FIG. 2—COMPLETE TELEPHONE SECURITY is obtained with a TVS250 at both ends of the phone line forming a duplex scrambler/descrambler system.

To render the speech channels unintelligible, the incoming audio signal is inverted by the IC's internal double-sideband modulator. While one channel accepts the normal frequency spectrum from the handset microphone, inverts and transmits it, the other channel accepts the incoming inverted signal, normalizes and sends it to the handset speaker.

Circuit design

The COM9046 voice scrambler/descrambler IC contains a crystal oscillator that controls system timing. The on-chip oscillator requires an external 3.58-MHz crystal that is commonly used in TV color-burst applications. The chip also contains switched-capacitor filters, so input speech must be filtered by an anti-aliasing single-pole, low-pass filter before it is applied to the audio input at pins 5 and 11.

The filter's 3-dB cutoff point is determined by the resistors and capacitors connected to pins 5 and 11. The values of those components were selected so that the cutoff point is less than 20 kHz. As shown in the schematic, Fig. 4, both R5 and R6 have values of 3.9 K, and both C11 and C12 have values of 2200 pF. Applying those RC values to the equation for filter cutoff frequency, $F_O = (2\pi RC)/2$, yields a 3 dB cutoff frequency of about 18.5 kHz.

The COM9046 was designed to operate on ±2.6 volts (+2.6 volts at pins 9 and 7, and -2.6 volts at pins 3 and 8). This operating voltage is measured with respect to a ground reference at pin 4 of the IC. However, the TVS250 operates from a single 9-volt transistor battery so it is necessary to obtain the required ±2.6 volts from a unipolar 9-volt transistor battery. Those voltages are measured with respect to the IC's analog reference at input pin 4.

The 9 volts can be reduced to 5 volts by IC4, a 78L05A low-voltage regulator, as shown in schematic Fig. 4. The 5-volt input is applied to a voltage divider consisting of R16 and R18. Pins 7 and 9 of IC1 are connected to the 5-volt source. Pins 3 and 8 are connected to the supply ground (0 volts). The midpoint of the two resistors R18 and R16 is connected to pin 4 of the IC. Because the two resistors are of equal value, their junction produces +2.6 volts.

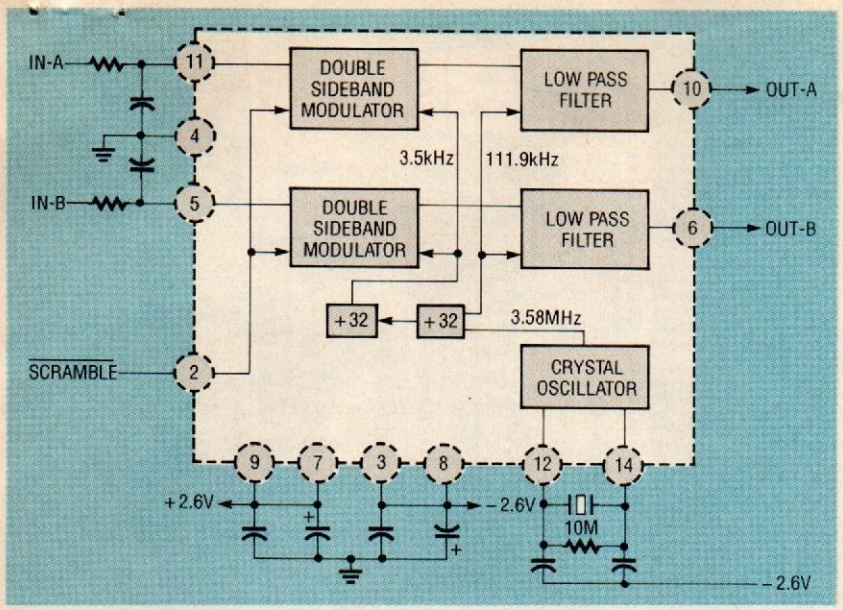


FIG. 3—SIMPLIFIED DIAGRAM OF THE COM9046 SCRAMBLER/ DESCRAMBLER IC and some peripheral components that are the heart of each TVS250 voice scrambler.

the telephone base passes IC1, it drives the handset speaker. The audio output signal from pin 6 of IC1 is filtered by an active low-pass filter consisting of IC3-b, R14, R15, C13, and C14.

Inserting those RC values in the low-frequency cutoff equation given earlier will show that the filter can pass all frequencies below 3.1 kHz. The filter greatly reduces high-frequency noise, especially that produced by clock feedthrough from IC1's internal oscillator.

The output from this low-pass filter is applied to the audio amplifier IC2 which acts as a low-power differential driver connected to the handset speaker. Potentiometer R1's resistance value of 100 K will permit volume adjustment of the handset speaker.

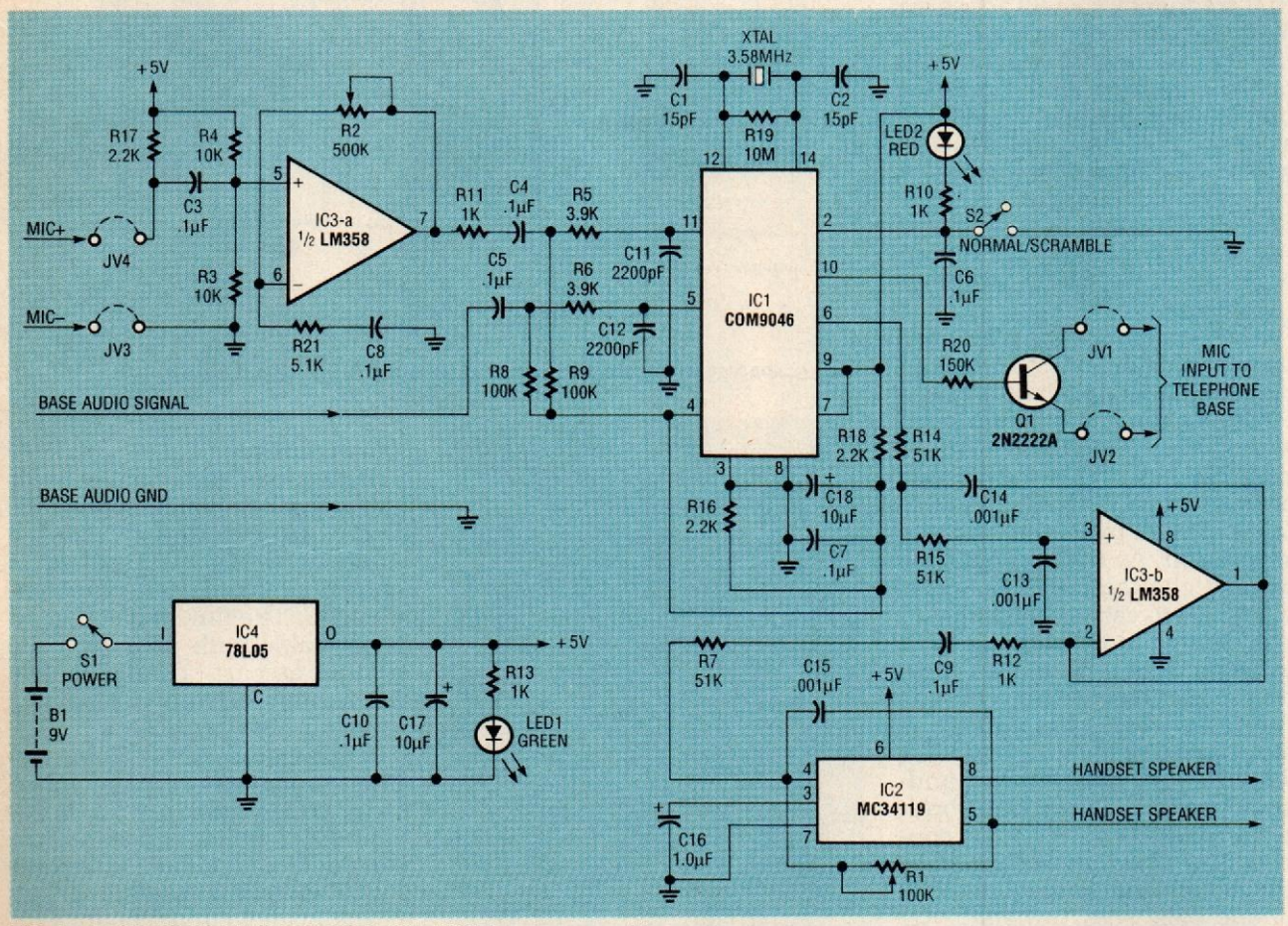


FIG. 4—SCHEMATIC DIAGRAM FOR THE TVS250 voice scrambler.

Now, with respect to pin 4, pins 9 and 7 are at +2.6 volts, and pins 3 and 8 are at -2.6 volts as shown in Fig. 3. Both of those values are within the acceptable limits for IC1.

The scrambler/descrambler IC1 can be interfaced with a standard telephone. The audio output from the base of the telephone is AC coupled to IC1 via C5. After the audio signal from

The equivalent circuit for the handset microphone is a potentiometer that changes its resistance with applied input audio signals. In quiet periods, its effective resistance is constant,

but when audio input is applied, its resistance changes linearly with the varying input frequencies.

Because the microphone can be considered as equivalent to a potentiometer, a voltage divider can be formed with R17 as one resistor and the handset microphone as the other one. As the microphone's resistance changes, the voltage at JU4 will follow. That voltage is AC coupled by C3 to the amplifier circuit that includes IC3-a.

Filter resistor R21 and capacitor C8 form a high-pass RC filter for the amplifier circuit that will attenuate low-frequency noise and prevent DC bias amplification. Applying the values of this filter to the cutoff frequency equation yields a high-frequency cutoff point of 312 Hz. Below that frequency C8 will act as an open circuit, effectively removing R21 so that the signal will not be amplified. At frequencies higher than 312 Hz, C8 will act as a short, and amplification will be determined by the values of feedback potentiometer R2 and filter resistor R21. The output of the amplifier stage is then AC coupled to IC1 via coupling capacitor C4.

The audio input from the handset microphone goes to IC1, and the output audio at pin 10 of that IC must be interfaced with the telephone base. This is done by applying it to the base of transistor Q1. The current to Q1 is limited by R20 to prevent saturation. As the applied base voltage changes, Q1's collector current will vary accordingly.

A change in collector current causes a direct change in collector-to- emitter voltage across the transistor. This voltage is similiar to the voltage at JU4 which was derived for the handset interface. Lines from both collector and emitter of Q1 connect the microphone input to the telephone base. The telephone base sees transistor Q1 as a microphone.

The resistance of potentiometer R2 was selected as 500 K to permit varying the amplification of the audio input. That potentiometer varies the audio applied to the base of Q1. The circuit permits the user to adjust the transistor drive as well as compensate for internal circuit differences in telephones.

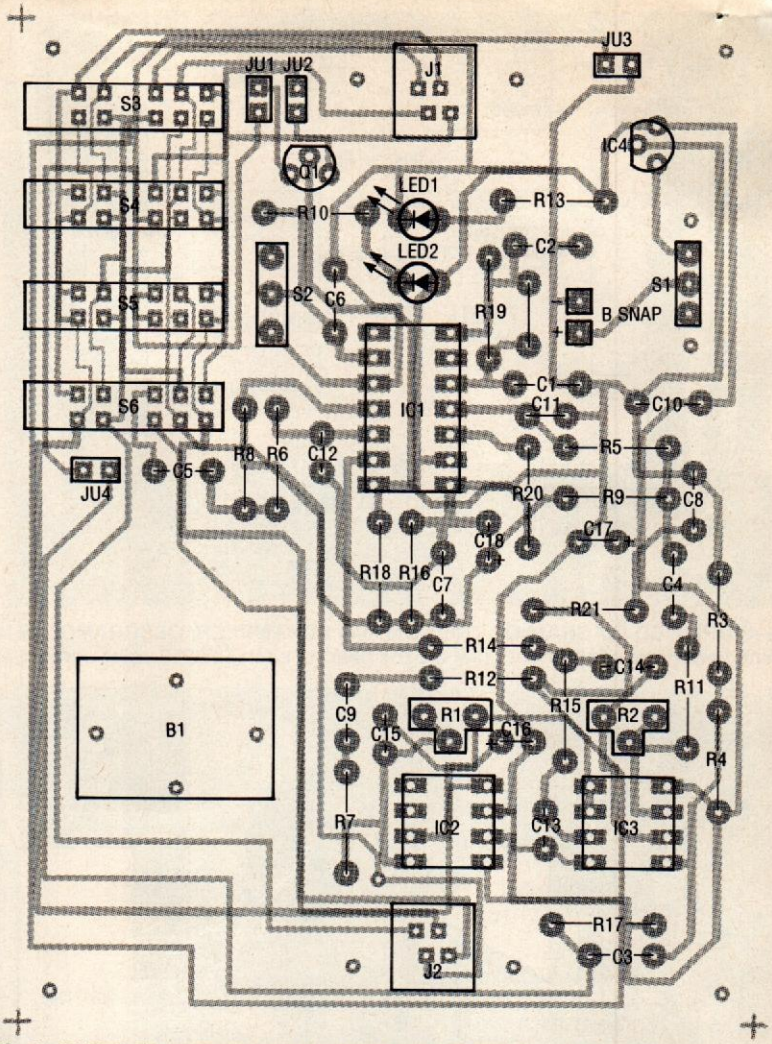


FIG. 5—PARTS PLACEMENT DIAGRAM for the TVS250. voice scrambler.

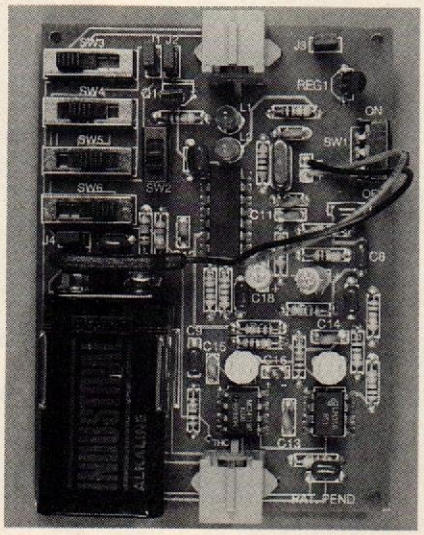


FIG. 6—PHOTOGRAPH OF LOADED BOARD for the TVS250.

Construction

Because of the complexity of the telephone voice scrambler, the double-sided PC board made with the foil patterns shown in this article is recommended. The finished PC board is available both as a separate item or as part of the complete kit available from the source given in the Parts List.

Begin the assembly of the telephone voice scrambler by inserting and soldering fixed resistors R3 to R21 where shown on parts placement diagram Fig. 5. (Figure 6 is a photograph of the loaded circuit board.) Insert and solder potentiometers R1 and R2. Do the same for nonpolarized capacitors C1 to C15. Next, insert and solder polarized capacitors C16 to C18, noting their polarity. Trim all excess lead lengths.

PARTS LIST

All resistors are ¼-watt, 5 %, unless otherwise noted

R1—100,000 ohms, PC-mount potentiometer, screwdriver adjust
R2—500,000 ohms, PC-mount potentiometer, screwdriver adjust
R3, R4—10,000 ohms
R5, R6—3900 ohms
R8, R9—100,000 ohms
R10–R13—1000 ohms
R7, R14, R15—51,000 ohms
R16–R18—2200 ohms
R19—10,000,000 ohms
R20—150,000 ohms
R21—5100 ohms

Capacitors

C1, C2—15 pF, ceramic disc
C3–C10—0.1 µF, metal film
C11, C12—2200 pF, ceramic disc
C13–C15—0.001 µF, ceramic disc
C16—1µF, 35 volts, tantalum
C17, C18—10 µF, 16 volts, electrolytic, polarized

Semiconductors

IC1—COM9046 voice-scrambling IC, (Standard Microsystems)
IC2—MC34119, audio amplifier driver (Motorola or equiv.)
IC3—LM358 dual operational amplifier, single supply
IC3—78L05A, 5-volt regulator (Texas Instruments or equiv.)
Q1—2N2222A, NPN transistor
LED1—green light-emitting diode, T1, 5mm
LED2—red light-emitting diode, T1, 5mm

Other components

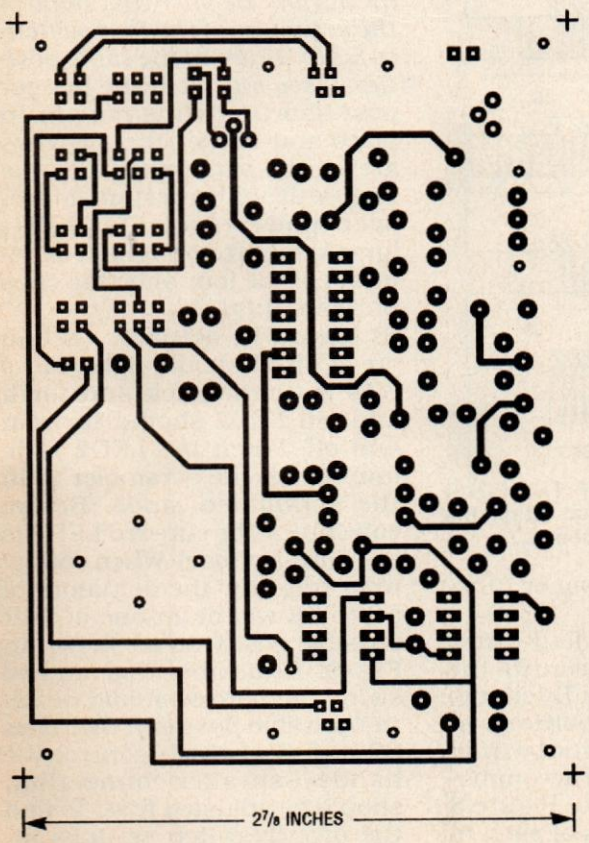
S1—SPST slide, PC-mount, side-actuated switch
S2—SPST slide, PC-mount, top-actuated switch
S3–S6—STS2400 PC, 2P4T slide, PC-mount, top-actuated (Augat/Alcoswitch or equiv.) switch
J1, J2—telephone jack, 4-4, Type 616, PC-mount
JU1–JU4—two-post jumper, 3/32-inch-on-centers with insulated shorting clips(see text)
XTL1—crystal 3.579545 MHz, metal case (ITT 4183 or equiv.)
B1—9-volt transistor battery, alkaline, standard

Miscellaneous: TVS250 PC board, 5-inch length of telephone cord terminated with standard telephone plugs, 9-volt transistor-battery clip-type holder (Keystone No. 79 or equiv.) with two 2-56 screws and nuts, 9-volt transistor battery terminal snap with leads, four rubber or plastic PC board feet (see text), and solder.

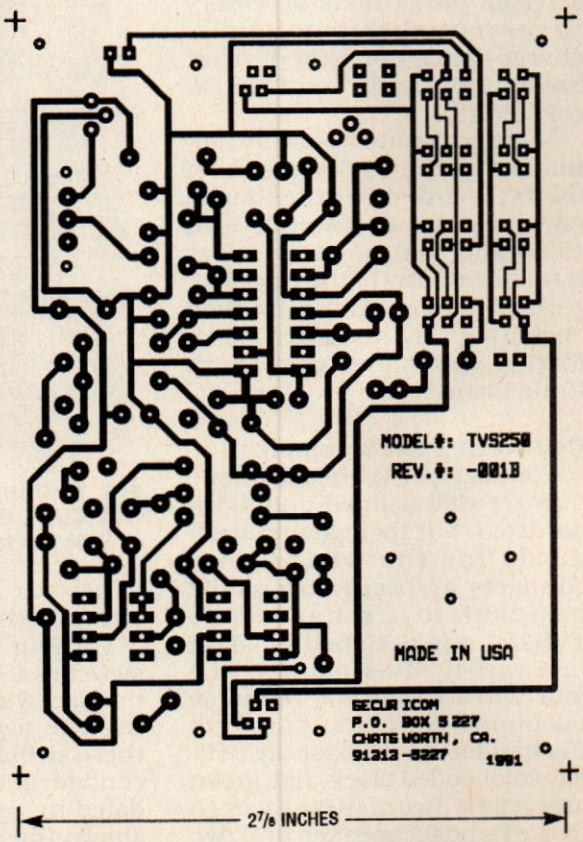
Note: The following parts are available from Securicom, P.O. Box 5227, Chatsworth, CA 91313-5227 (818)-710-0110

- **COM9046 scrambler/descrambler IC only—$18.00**
- **Double-sided, silk-screened and drilled PC board—$20.00**
- **A complete kit including PC board, all components, and 5-inch plug-terminated phone cord—$59.95**
- **Assembled and tested TVS250 with user's manual—$79.95**

Check, money order, and Mastercard orders accepted. Please add $3.75 for postage and handling. California residents must add 8.5% sales tax.



TOP LAYER (COMPONENT SIDE) of telephone voice scrambler PC board shown actual size.



BOTTOM LAYER (SOLDER SIDE) of telephone voice scrambler PC board shown actual size.

Then insert the jumper posts, switches, LED's, crystal, and telephone jacks where shown on Fig. 5. (Place the shorting clips (see Fig. 7) on the jumper posts JU1 to JU4 to prevent losing them.) All switches can be inserted in only one position. Orientation is not critical for inserting the crystal XTAL1. Note that the flats at the base of LED1 and LED2 are next to their cathodes. Solder all leads or wires and trim excess lengths.

Assemble the 9-volt battery holder to the PC board with screws and nuts. Insert the red and black insulated wires of the battery terminal snap in the PC board with the black wire in the hole marked "-" and the red wire in the hole marked "+" as shown in Fig. 5. After soldering the wires, trim their ends.

Insert all semiconductor devices (IC1 to IC4 and transistor Q1) where shown in Fig. 5 last. Be sure to note the dots or notches that indicate the pin 1 positions on IC1 to IC3, and the orientation of IC4 and Q1. Observe all precautions necessary to prevent electrostatic discharge damage of these devices. Solder their leads and trim excess lengths.

Make a careful visual examination of the soldered side of the PC board to be sure that all connections are sound and clean and that no stray solder has shorted any of the traces together. Remove any unwanted "bridging" by standard desoldering techniques or a sharp knife blade.

Connecting the scrambler

Connections to the telephone line are well defined and standardized, but there are no standards for the wiring that connects a specific telephone handset to its base. The TVS250 was designed to adapt to a variety of telephones. The four wires inside the retractile telephone cord that connects the handset to the base are usually color coded black, red, green and yellow. Two of these wires go to the handset speaker, and two go to the handset microphone. Unfortunately, telephone manufacturers have not agreed on

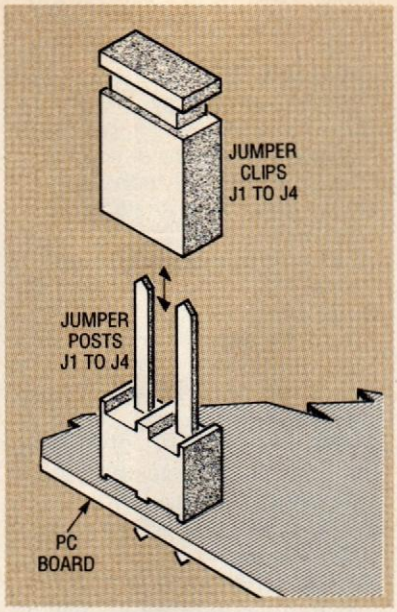


FIG. 7—SHORTING CLIPS ON JUMPER POSTS are removed while adapting the TVS250 to a specific telephone.

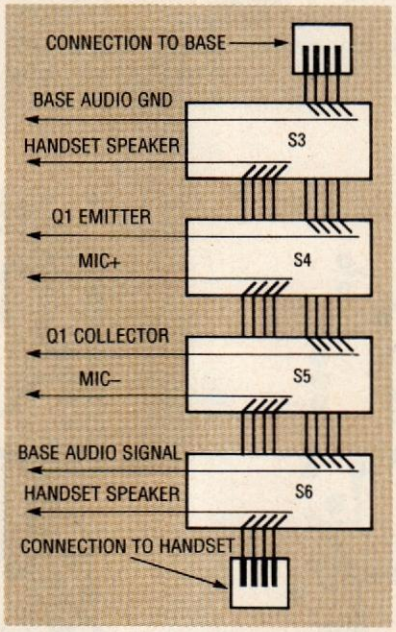


FIG. 8—FUNCTIONS OF THE FOUR SWITCHES S3 to S6 that adapt the TVS250 to a specific telephone.

either the color coding or function of those wires.

The four two-pole, four-throw switches (S3 to S6) control the handset wiring order. By changing the actuator positions of these switches, any cord wiring configuration can be accommodated by the TVS250. Figure 8 shows the functions of each of those four switches.

After some experimentation, it should take only a minute or so to arrange the switch actuators to accommodate variations in cord wiring. The easiest method for connecting the TVS250 to your particular telephone is as follows:

1) Set the midpoints of potentiometers R1 and R2 by turning their control knobs with a screwdriver so that their arrows point toward the bottom of the PC board.

2) Switch S1 to its OFF position. Attach the terminal clip to the 9-volt transistor battery and snap the battery into its spring holder on the circuit board.

3) Connect the TVS250 to your telephone by plugging one end of the five-inch phone cord into the telephone base and the other end into phone jack J1. Then plug the retractile cord that normally connects the handset to the base into jack J2 and hang up the phone.

4) Remove the shorting clips from posts JU1 to JU4. This removes switches S4 and S5 from the circuit (see Figures 4, 5, 6, and 7).

5) *Caution: Be sure that none of the actuators of the four switches S3 to S6 are in the same positions (see Fig. 9).* If the jumper post shorting clips remain in place and two of the switches are in the same position, the unit will malfunction. Moreover, power indicator LED1 (green) might not light. The removal of the four shorting clips prevents this.

6) Move S1's actuator ON and green LED1 should light. Move S2's actuator back and forth and red LED2 should turn on and off. When red LED2 is illuminated, the scrambler is in the *scrambled mode*. Before continuing, be sure red LED2 is off (*normal mode*). When configured properly, the actuators of S3 to S6 will be in one of four possible positions as shown in Fig. 9. *Remember that no two switch actuators should be set in the same position.* Switches S3 and S6, which control the handset speaker connection, should be adjusted first. To find the proper switch settings for the handset speaker, listen for the phone's dial tone.

7) Set S3's actuator to position

1, pick up the phone, and listen normally. Now move S6's actuator in sequence to positions 3, 4 and then 5. If you hear a dial tone in any of those actuator positions, leave it there. If no tone is heard, move S3's actuator to position 2 and again try S6's actuator in the other three positions. Continue this procedure until the dial tone is heard.

While the complete procedure should take only about a minute, remember that if a handset is left off of its base (hook) for more than about 15 seconds, the dial tone will automatically turn off. Hang up the phone between actuator settings to be sure that a dial tone is present when the right combination is found.

8) With the dial tone present, adjust potentiometer R1 to the desired volume.

9) Turn the TVS250 off (green LED1 is off). Place the shorting clips on all four jumper posts. After the dial tone is heard, the handset microphone switches S4 and S5 can be adjusted. For this step ask someone to assist you by listening in on an extension to your phone.

10) Set the actuator of S4 to one of the positions not used by S3 or S6, and set S5's actuator to the last available position. Turn the TVS250 on after making sure that it is set for *normal mode* (red LED2 is off). Ask your assistant on the extension to pick up the handset and key in any number to eliminate the dial tone before proceeding. Then speak normally into the handset. Your assistant can tell you if the sound volume is within normal limits. Then adjust potentiometer R2 for the best speech quality.

If, after adjusting R2, you cannot obtain quality speech, it is probable that the actuators for switches S4 and S5 are in reversed positions. (This can be determined if your assistant's voice seems distant or incomprehensible even after you have turned R2 both completely clockwise and counterclockwise. A screeching sound might also be heard.) If this is the case, simply switch the actuator positions of S4 and S5 and repeat the adjustments to R2 while speaking to your assistant.

The positioning of actuators of S3 and S6 is critical. If you still cannot get quality speech from your phone after performing the previous procedure, the positions of actuators of S3 and S6 are reversed. Exchange their positions and repeat step 10.

Although the TVS250 is rugged and will not require special handling, the unprotected circuit board must not be placed in any position where conductive

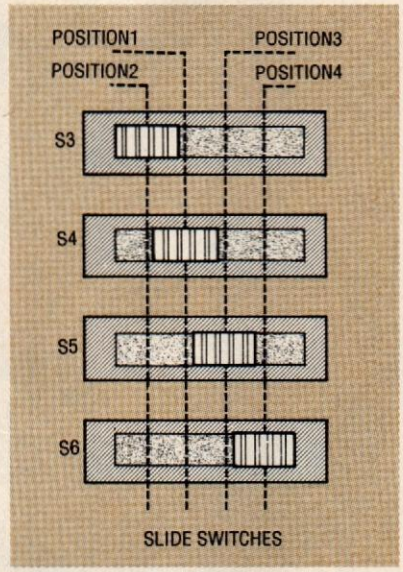


FIG. 9—FOUR POSSIBLE ACTUATOR SETTINGS of the two-pole, four-throw slide switches S3 to S6 that adapt the TVS250 to a specific phone.

surfaces could short out unprotected soldered connections on the underside of the board. The insulating feet at the corners of the PC board's underside will help to prevent damage from this cause by elevating it above any flat surface on which it is positioned. However, you might also want to enclose your scrambler in an insulated protective case for more protection.

After the fine adjustments have been made, your voice scrambler will be ready for use, but, of course, two scramblers are needed to form a system. Make the following simple test:

- Turn on the TVS250 with S1 noting that green LED1 is on.
- Pick up the handset and listen for the dial tone.
- Switch S2 to the scrambled mode (red LED2 is on).
- Listen for the scrambled dial tone.
- Change back to normal mode and phone someone.
- Speak normally into the phone with the scrambler mode off (green LED1 is always on when using the phone).
- Switch the unit into the scrambled mode (red LED2 is on).
- As the other party speaks, you will hear his scrambled speech and he will hear yours.
- Switch back and forth from the scrambled to the normal mode as often as necessary to check out a single unit.

When two tested scramblers on the same line are in the scrambled mode, both your voice and that of the person you called will sound normal. Anyone listening on extensions to either phone will only hear garbled speech.

Scramblers should be turned off when a call has been completed to conserve battery power. In continuous operation, a 9-volt alkaline battery will provide about 30 hours of scrambler operation.

Answering and call waiting

The scrambler can leave secure messages on an automatic answering machine. Turn on your scrambler and speak normally to any telephone with both a compatible scrambler and answering machine. When a receiving party plays back your message and hears the garbled speech, he turns on his scrambler and listens to your normalized speech through his handset.

The TVS250 can be switched back and forth from scrambled to normal mode at any time during a conversation. If you have call waiting, you could be in a secure conversation with another party whose telephone has a compatible scrambler when you are interrupted by another caller. To answer the call waiting signal, simply switch your scrambler to its normal mode and answer the call as usual. After the call is completed, return your unit to the scrambled mode and continue your secure conversation. **R-E**