BUILD A VOCAL "TRUTH" ANALYZER

BY COLLEEN McNEICE AND ROGER COTA

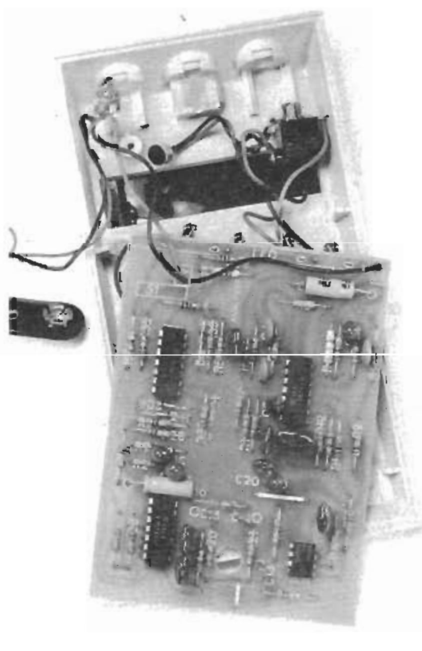
Hand-held LED-display instrument is said to detect voice stress

SO-CALLED "electronic lie detectors" have become controversial items. Some workers in the fields of security and law-enforcement swear by them, while others (including some psychologists) hold that the principles on which the devices are based are ill-founded and unscientific. Still other individuals denounce the application of lie detectors as an invasion of privacy.

Actually, the best that these detectors can do is measure psychological stress. Even then, the measurement is indirect. Basically, the device makes its determination by sensing an effect of one type or another that many researchers believe is an accurate indicator of stress. Validation studies have been used to compile an impressive record of successes, but it should be remembered that a high degree of interpretational skill is required and there is always an appreciable probability for error in using such an instrument.

One popular indicator of stress has been the relative amplitude of certain vocal modulations in a person's speech. The Voice Stress Analyzer described here is a small, readily portable unit. It is designed to operate on the principles pioneered by Dektor and other companies in the field whose products have received wide acceptance.

Basic Theory. Extensive military research and wartime counterintelligence work have yielded several theories and devices that have been used during interrogation in an attempt to separate truth from falsehood. One of these theories is that human voices, which have fundamental frequencies ranging from about 90 to 200 Hz, are normally modulated by an 8-to-12-Hz "microtremor" signal. The latter's effect is usually masked by other voice components: but, according to these researchers, reasonably simple electronic circuitry can detect and measure the microtremors.



LEDs are positioned in window area, miniature microphone is put in center cutout at top of case.

(continued on page 68)

When a person is under stress, says the theory, normal vocal microtremors diminish greatly in amplitude. The autonomic nervous system, preparing the body for emergency reactions, causes the pupils to dilate, blood to rush away from the limbs, and the muscles to tense. Since the vocal chords are principally muscular tissue, they, too, tighten and decrease the amplitude of microtremors. Thus, it is claimed, measuring the relative amplitude of vocal microtremors gives an indication of stress. The waveform of a human voice with microtremor, indicating no or very little stress, is shown in Fig. 1A, its spectral content in Fig. 1B.

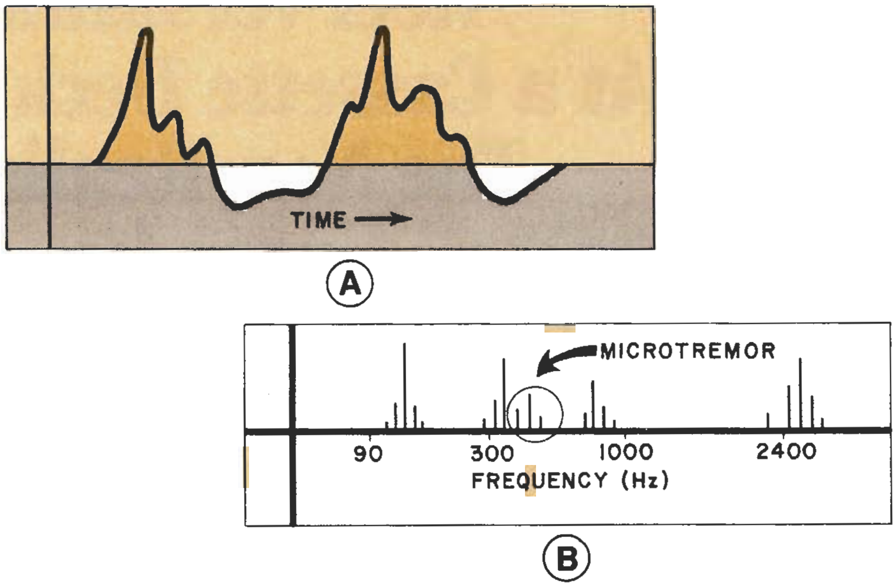


Fig. 1. Waveform of the human voice with microtremors is shown at (A), spectral content of voice is at (B).

System Operation. Basic operation of the Voice Stress Analyzer is shown in Fig. 2, while Fig. 3 illustrates typical waveforms (not drawn to scale) that occur in the circuit.

The input voice signal in Fig. 3A illustrates the somewhat closer peak spacing attributed to microtremors as compared with the "normal" spacing of the peaks in the voice signal. After amplification, the composite voice signal goes to a voice-frequency bandpass filter to remove extraneous noise. Then the signal input is half-wave rectified. In a 150-Hz low-pass filter, the higher voice frequencies are attenuated, leaving only the lower frequencies, including those of the microtremors (Fig. 3B). The positive-going output then toggles a Schmitt trigger (Fig. 3C) to produce a squared-off waveform. The latter is suitable for toggling a one-shot multivibrator that then produces the 1.5-ms pulses shown in Fig. 3D.

As the 8-to-12-Hz microtremor modulates the fundamental, spacing between pulses changes. Pulses from the one-shot then pass through a 20-Hz low-pass filter and an 8-to-12-Hz filter, after which it is rectified and integrated to form a smooth voltage. This signal may rise above a preset threshold when the microtremors are closely spaced, in a manner similar to that of the vertical-sync scheme used in a TV receiver. When the integrated output is above the threshold, it causes the LEDs to come on in a particular sequence (Fig. 3E).

The Circuit. Figures 4 and 5 illustrate the complete schematic diagram of the Voice Stress Analyzer. The *IC2D* circuit (Fig. 5) supplies the ground tap required by the op amps. Resistors *R1* and *R2* and capacitor *C1* provide power from battery *B1* for the condenser microphone. Jack *J1* is a transfer type that disconnects *MIC* when an external audio source is plugged into it. (The external source can be a telephone pickup, dynamic microphone, or output from a tape recorder.)

Audio amplifier *IC1A* operates close to its open-loop gain whose output goes to the *IC1B* bandpass-filter circuit. Recti-

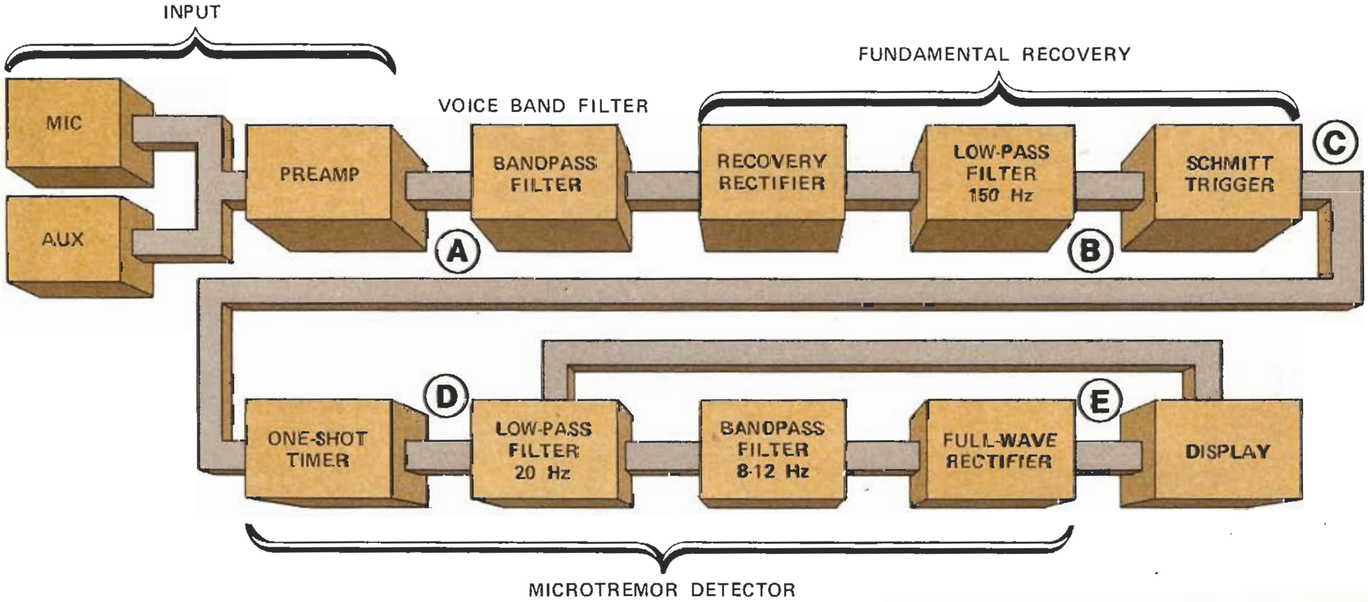


Fig. 2. The analyzer circuit is designed to extract the 8-to-12-Hz microtremor from the voice input and use the resultant signal to turn on a LED display.

fier *D1* half-wave rectifies the signal to recover the fundamental modulating frequency. Higher harmonics are removed by *IC1C*, an 18-dB/octave filter that passes only those frequency components below 150 Hz.

Schmitt-trigger circuit *IC1D* converts the recovered fundamental into steep rising and falling edges that are suitable for driving timer *IC4*. As shown in Fig. 3C and D, the Schmitt trigger's sharp rise time toggles the timer, which produces a 1.5-ms pulse.

The generated pulse train goes through low-pass filter *IC2A* to remove the waveform's sharp edges and amplify any frequencies below 20 Hz. Bandpass filter *IC2B* is "tuned" to the 8-to-12-Hz microtremor frequency and amplifies any signal within this range.

Full-wave rectifier *IC3A/IC3B* accepts this signal and produces a dc output voltage that is proportional to the amplitude of the microtremor (Fig. 3E). This voltage is developed across *C19*, which is constantly being discharged by time-constant resistor *R32*.

Display drivers *IC3C* and *IC3D* are

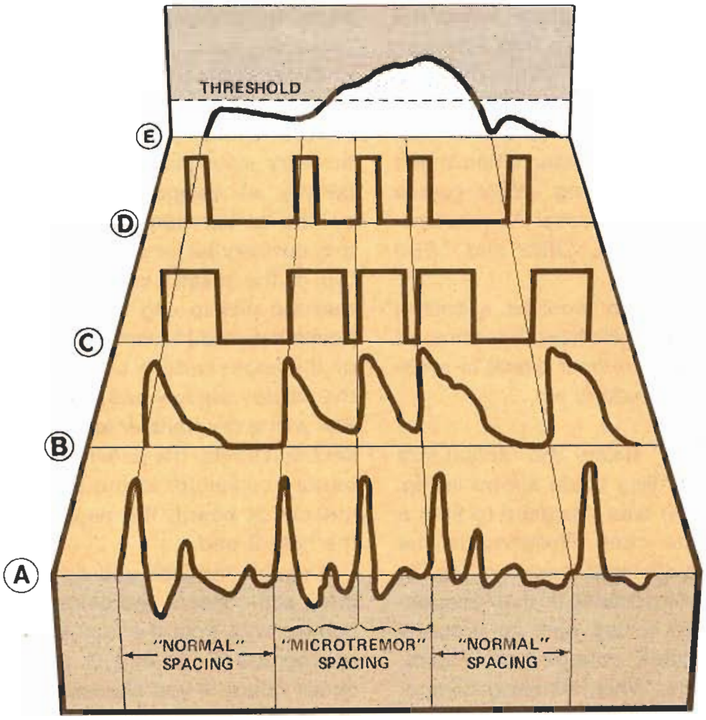


Fig. 3. Typical waveforms within the analyzer. According to the authors, the "trick" lies in detecting the presence of the narrower microtremor peak spacing within the voice frequencies. Integrated one-shot pulses derived from these signals are used to toggle the readouts.

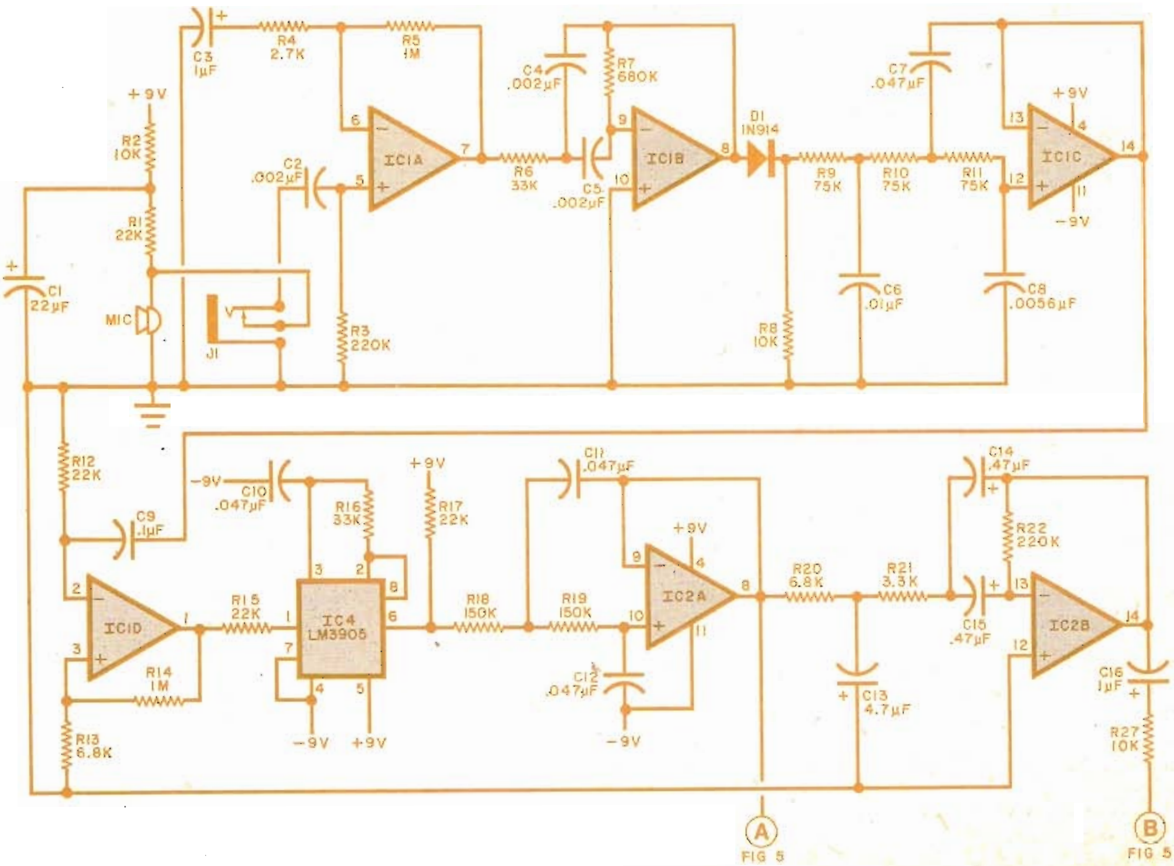


Fig. 4. The voice processing circuits of the analyzer result in 20-Hz signals from IC2A and 8-to-12-Hz signals from IC2B. These signals drive the rectifier/display section shown in Fig. 5.

connected as comparators, using the voltage generated across *R33*, *R34*, and *R35* as the reference. The comparators then drive the LEDs. When *LED1* comes on, presence of microtremors is indicated, meaning no stress. When these frequencies are missing, *LED4* comes on to indicate high stress. As microtremors come and go, *LED2* and *LED3* come on.

The display also receives a control signal from the 20-Hz filter that turns off the LEDs when no input signal is present, conserving battery life.

Construction. Using the actual-size etching and drilling guide shown in Fig. 6, the Analyzer was designed to fit in a calculator-type case. Referring to the component-placement guide in Fig. 6, mount the components in their respective locations, taking care to properly orient the diodes, polarized capacitors, ICs, and LEDs. When installing components on pc board, be sure to properly orient diodes, LEDs, ICs, and electrolytic capacitors, as shown in the component placement guide.

With exception of the microphone, auxiliary input jack, power switch, and battery, all components mount directly on the circuit board. The microphone and auxiliary jacks mount in holes at the top of the plastic case. (Make certain that the pickup end of the microphone points outward.) Mount the power switch on the upper surface of the case, below the display window and label its ON position with a dry-transfer lettering kit. Connect and solder the positive lead of *B1*'s battery connector to the hole A-pad on the circuit board, the negative lead to the hole B-pad.

Examine the jack and schematic diagram and connect and solder lengths of hookup wire from the jack's lugs to the appropriate E, F, and G pads on the circuit board. If you choose a rechargeable battery for *B1*, mount a suitable power jack on the plastic case and wire it to the battery.

Now, use a dry-transfer lettering kit to label the LEDs in the display. Label *LED1* NORMAL and *LED4* STRESS. Leave transitional *LED2* and *LED3* without legends. This completes construction.

Construction. Using the actual-size controls, it should be operational as soon as power is turned on. As you speak into the microphone, you should note that the LEDs flicker, with the NORMAL LED on most of the time.

A number of tests were performed on the Voice Stress Analyzer by one of the authors. Using the audio from a TV-network news broadcast, it was noted that when the newscaster spoke, the NORMAL LED was on most of the time. When actors and actresses were speaking their roles, basically the same results were observed. However, when

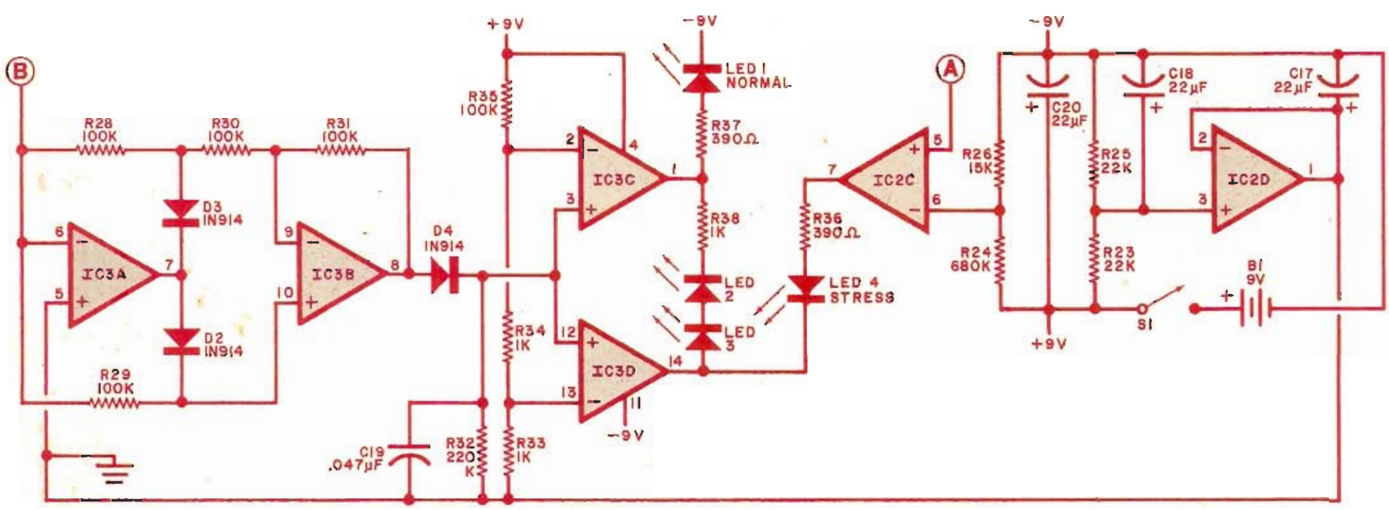


Fig. 5. The 8-to-12-Hz signals are rectified in IC3A and IC3B, integrated in C19 and used to turn on a comparator (IC3C, IC3D) that causes the LED (s) to glow. IC2C shuts down the LEDs when there is no 20-Hz signal, while IC2D creates a bipolar supply from a single 9-volt battery.

PARTS LIST

B1—9-volt battery
C1,C17,C18,C20—22-µF, 16-volt tantalum
C2,C4,C5—0.002-µF, 100-volt Mylar
C3,C16—1-µF, 100-volt electrolytic
C6—0.01-µF, 100-volt Mylar
C7,C10,C11,C12,C19—0.047-µF, 100-volt Mylar
C8—0.0056-µF, 100-volt Mylar
C9—0.1-µF, 100-volt Mylar
C13—4.7-µF, 35-volt tantalum
C14,C15—0.47-µF, 35-volt, tantalum
D1 through D4—1N914
IC1,IC2,IC3—LM324 quad op amp
IC4—LM3905 precision timer
J1—subminiature phone jack with switch
LED1 through LED4—red LED
The following are ¼-watt 5% resistors:
R1,R12,R15,R17,R23,R25—22,000 ohms
R2,R8,R27—10,000 ohms
R3,R22,R32—220,000 ohms
R4—2700 ohms
R5,R14—1 megohm
R6,R16—33,000 ohms
R7,R24—680,000 ohms
R9,R10,R11—75,000 ohms
R13,R20—6800 ohms
R18,R19—150,000 ohms
R21—3300 ohms
R26—15,000 ohms
R28 through R31,R35—100,000 ohms
R33,R34,R38—1000 ohms
R36,R37—390 ohms
Misc.—suitable enclosure, battery clip, hook up wire, mounting hardware, etc.

Note: The following is available from Logical Systems, 3314 H St., Vancouver, WA 98663 (Tel: 206-694-7905): complete kit including microphone, battery clip, pc board, case, and manual for $79.00. Also available separately: etched and drilled pc board at $9.00; hand-held case, battery clip with power jack and condenser microphone at $18.00. Please add $3.50 for postage/handling. Washington state residents, please add 5.1% sales tax. Allow four weeks for delivery.

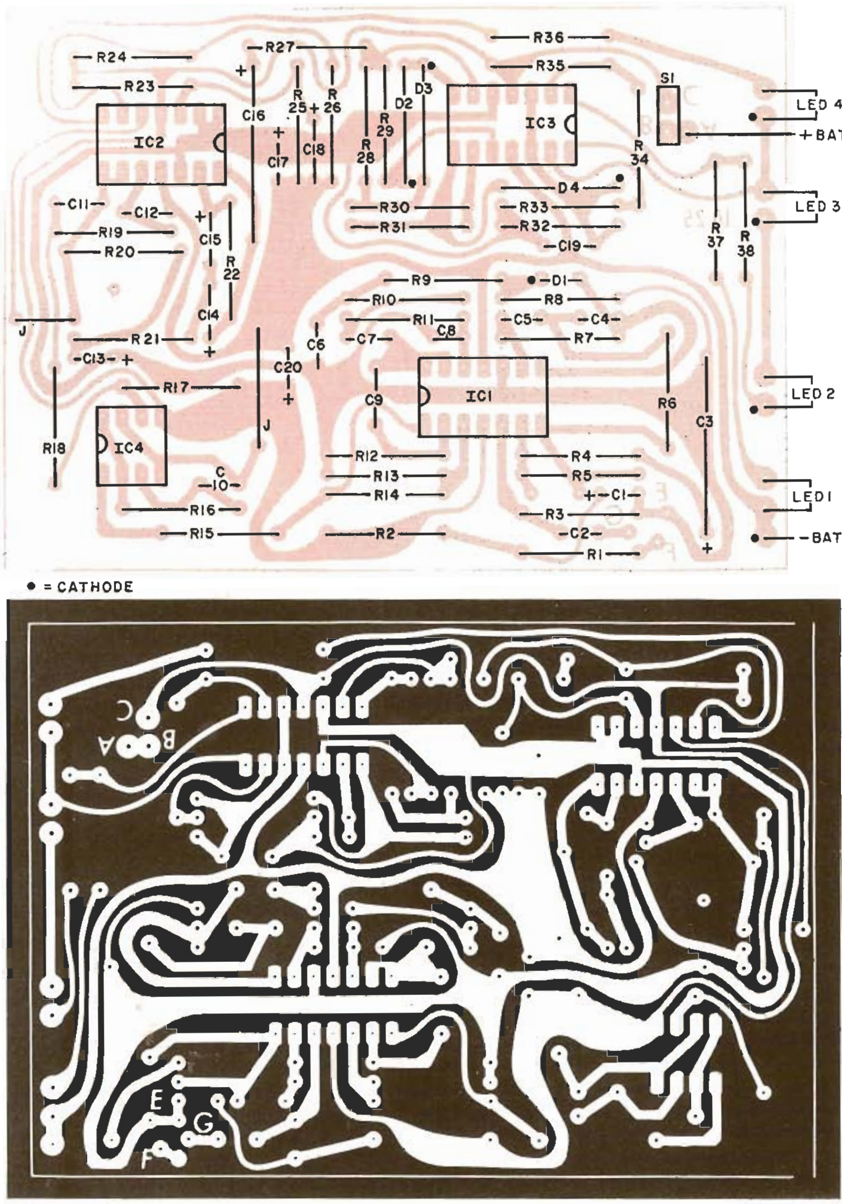


Fig. 6. Actual-size foil pattern and component placement guide for the voice analyzer. Be sure to observe polarities of electrolytic capacitors and diodes and orientation of ICs.

various advertising announcers' voices were monitored, it was interesting to note that the other LEDs had a tendency to flicker on, with the STRESS LED coming on quite often. The same was true when monitoring a number of phone-in radio programs. Finally, a number of situations were rigged, using various people as test subjects, all instructed to lie in answer to certain questions. The results were inconclusive. The results might have been pointedly different if the subjects being monitored were not aware that vocal stress tests were being conducted. Too, it should be kept in mind that voice characteristics differ among different people and even with the same person over a short period of time.

Psychologists at one U.S. university have stated that there is no conclusive evidence that microtremors actually exist in the vocal chords. One report, prepared by a psychologist on behalf of the U.S. Army's Land Warfare Laboratory at Aberdeen Proving Ground, concluded that results obtained with voice stress devices are "no better than chance." Moreover, American Civil Liberties Union suits have been presented alleging such devices constitute invasion of privacy.

Whether or not voice stress analyzers do what is claimed of them is a debatable point. However, they are interesting devices with which to experiment. ◊