JUNE 1951

RADIO-ELECTRONICS

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HUGO GERNSBACK, *Editor*

THE ELECTRIC VOICE — SEE AUDIO SECTION

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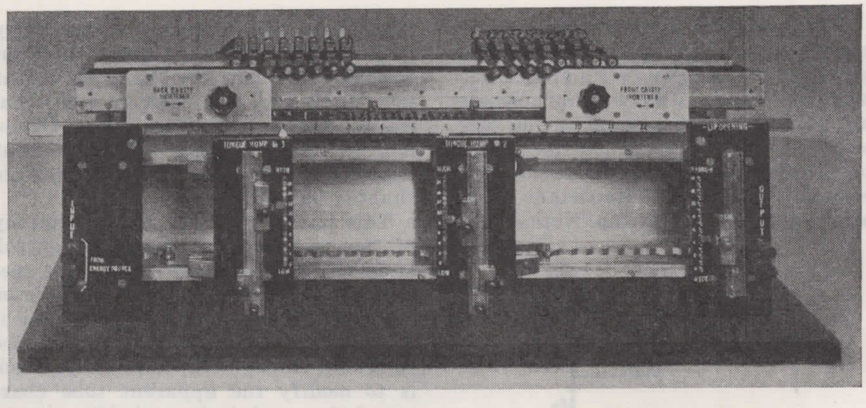
Cover Feature



A closeup photo of the equipment. The tongue hump and lip opening sliders are in front, and the contacts for the sliding cavity shorteners project on top.

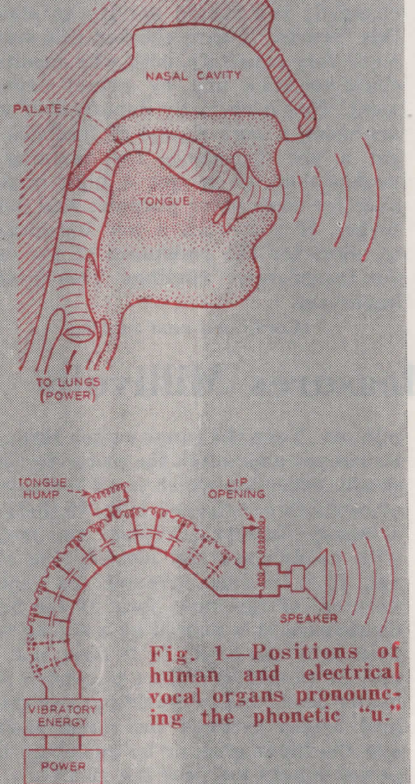


Fig. 1—Positions of human and electrical vocal organs pronouncing the phonetic "u."

ELECTRIC VOICE

This electrical analog of the human vocal apparatus produces good vowel sounds

By ERIC LESLIE

WE ALL used analogies when we learned radio. Current flow was illustrated by water flowing through a pipe. With a reciprocating pump added, alternating current was illustrated. Radio waves were (all too simply) represented by a stone thrown into water. Tesla even devised an "oscillator" with a weight for inductance and a spring for capacitance, with steam (from the building's heating circuit) as the source of power. So successful was the analogy that it not only oscillated furiously at a frequency set by the spring tension and the weight, but could also be "loaded," furnishing power for small workbench appliances. So we went through electricity and radio, getting acquainted with each new phenomenon with the help of familiar mechanical analogies.

As we learned more about electronics some of these phenomena turned out to be far more simple than the analogies used to explain them. It was by no means surprising that the analogies should reverse, and that engineers should study the action of a vibrating weight at the end of a spring with the help of an electrical circuit analogy. Radio engineers found it worthwhile to break down the mass, compliance, and friction of a loudspeaker into inductance, capacitance, and resistance, when studying the action of the cone. Books have been written devoted to describing mechanical actions in terms of electrical circuits.

The reason that such analogies are possible is that we can describe the behavior of both electrical and mechanical circuits with mathematical equations that look exactly alike. Thus in one equation the symbol for voltage may take the place of the symbol for force in the other; inductance is analogous to mass, etc. The same applies also to the equations of thermodynamics, acoustics, and other systems so that a circuit in one of these systems can have an analogy in any of the others. Engineers make frequent use of this fact.

The electric voice equipment shown on our cover is a recent and daring example of the analog-in-reverse. It was designed and constructed by H. K. Dunn and L. O. Schott of the Bell Telephone Laboratories, an organization which makes study of the human voice and human speech one of its chief activities. Since the human vocal apparatus can be represented with an electrical analog, they decided to set up one and feed it from oscillators which produce signals electrically equivalent in frequency and composition to those produced by the vocal cords. Then if its output were turned into sound by a loudspeaker,

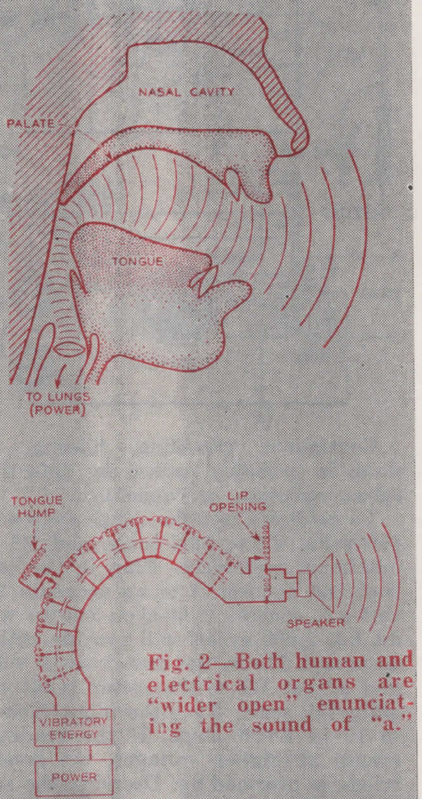
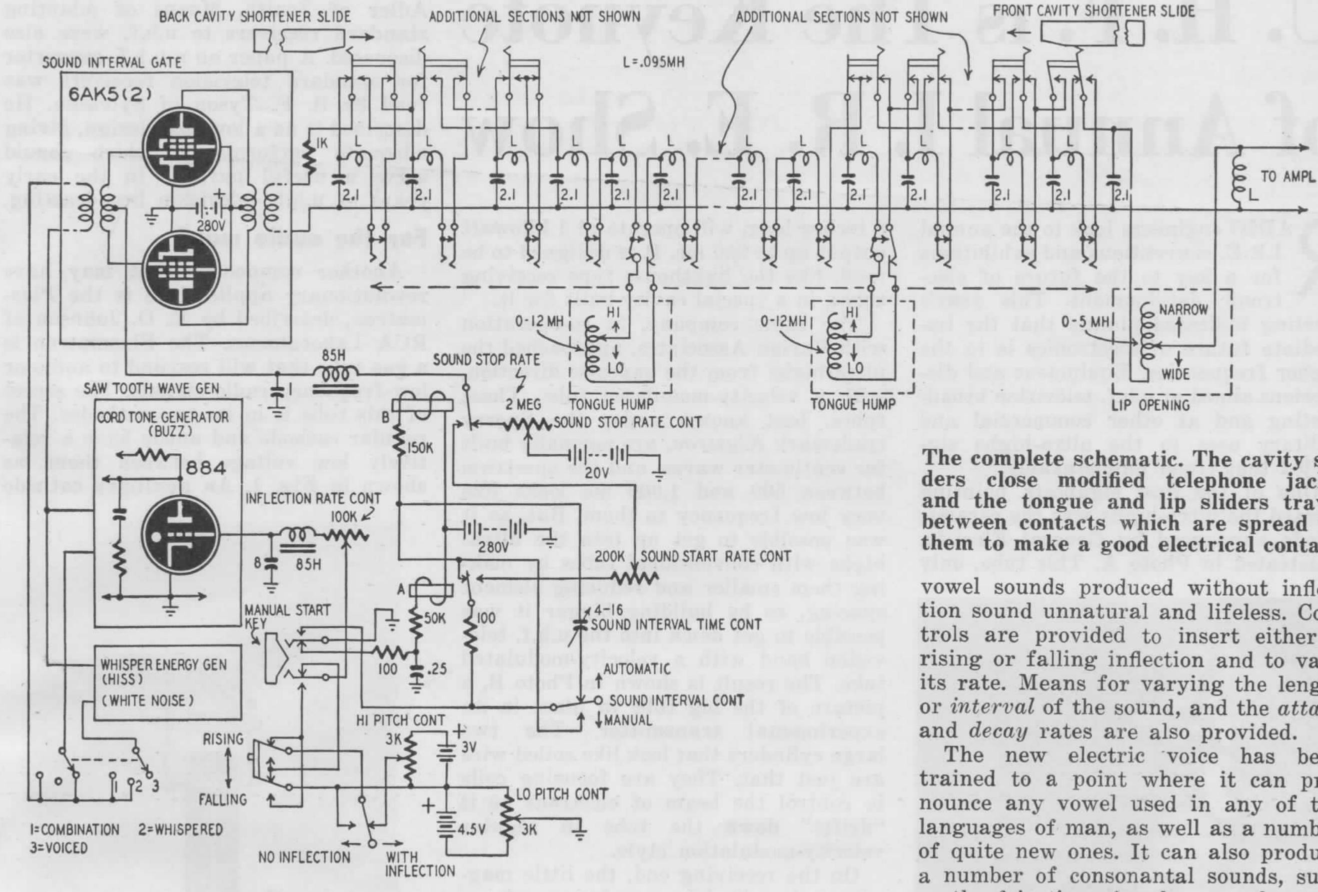


Fig. 2—Both human and electrical organs are "wider open" enunciating the sound of "a."



The complete schematic. The cavity sliders close modified telephone jacks, and the tongue and lip sliders travel between contacts which are spread by them to make a good electrical contact.

sounds similar to those of the human voice should be produced.

Several attempts to synthetize speech sounds have been made (see "Manufactured Speech," RADIO-CRAFT, August, 1939, for a description of the voder, or vocoder). Voice sounds were analyzed into their frequency components with a series of bandpass filters, like those shown in the illustration of visible speech equipment on page 235, RADIO-CRAFT, January, 1946. Then the frequencies which appear in a given sound were picked out—usually from a bank of tone generators—and mixed in the correct proportions to produce the sound.

That method dealt with the disembodied sounds, without reference to the mechanism which produced them originally. Dunn and Schott started out with the opposite approach, to produce an electrical analog of just that speech-producing mechanism.

The human vocal apparatus, consisting of the throat, tongue, and lips, can be represented by a cylindrical cavity about a square inch in cross-section and about five inches in length. The area and length of this cavity can be varied to some extent by the speaker's throat muscles. Its size and shape is still further modified by the back and tip of the tongue, and by the lips, any or all of which may be moved to pronounce a given sound.

The most exact analog of the human vocal apparatus would be a section of transmission line, with inductance and capacitance distributed along its length. A section of waveguide might be even more exact. But at voice frequencies such models would be too big to construct, so lumped constants (coils and capacitors) are used.

The vocal cavity is represented electrically by 24 sections of transmission line. The end sections of these are shown in the schematic. Sections can be cut off or added at either front or rear (or both) of the electrical cavity, varying the timbre from that of a baby to the voice of a bass singer.

Two variable inductors serve as the tongue hump (back of tongue) and tongue tip. The tongue hump divides the cavity into two parts, as the real tongue hump tends to do in speech. A similar inductor acts as the lip opening. High inductance in these circuits is equivalent to constricted throat passages and narrow lip opening; lower inductance represents wider vocal passages and a more open mouth. Fig. 1 is a representation of the human and electrical vocal tract while pronouncing the phonetic "u" (as in "rule"). Fig. 2 is the position while pronouncing the vowel "ah." (The drawings were made before the forward tongue hump had been added to the circuit.)

The "larynx" and control circuits appear at the left end of the schematic. A sawtooth oscillator and "white-noise" generator provide, respectively, the electrical equivalents of voiced and unvoiced sounds from the vocal cords. An important part of the circuit is the inflection control. The human voice does not maintain exact pitch while pronouncing even short vowel sounds, and vowel sounds produced without inflection sound unnatural and lifeless. Controls are provided to insert either a rising or falling inflection and to vary its rate. Means for varying the length or *interval* of the sound, and the *attack* and *decay* rates are also provided.

The new electric voice has been trained to a point where it can pronounce any vowel used in any of the languages of man, as well as a number of quite new ones. It can also produce a number of consonantal sounds, such as the fricatives *f* and *v*, *s* and *z*, and the sounds of *l* and *r*, though some of these require certain additional apparatus not shown in the schematic. Work has been in progress to make it possible to pronounce more of the consonants, but has had to give way, for the moment at least, to projects considered more vital to the national interest. So the time when we will have an artificial voice which can recite "Mary's Little Lamb" is still far in the future. Meanwhile the equipment is a valuable device for studying human speech sounds and their formation in detail.

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GUIDED MISSILE RECORDER

Magnetic recorders using a metal tape 6 inches wide and 150 feet long will be placed in the noses of guided missiles to record data that ordinarily is automatically sent out by radio. As the rockets penetrate the atmosphere above the earth, there is often difficulty with reception of the automatically transmitted signals. The magnetic recorder, announced recently, is manufactured by United Aircraft for the Navy's Bureau of Ordnance. Weighing only 46 pounds, the machine can record 200 pieces of information simultaneously and continuously. The tape is led into an armored cylinder that withstands the shock of dashing into the ground. The tape, played back through a transcriber, enables personnel to make graphs of air pressures, temperatures, and so on. The device was developed by the Armour Research Foundation.