The Tone Ringer

F. L. CRUTCHFIELD
Transmission Engineering
J. R. POWER
Station Apparatus Development

The transistor, because of its small power requirements, has tended to shift technological interest toward low-voltage, low-current circuits. This is particularly true, for instance, in the new electronic telephone switching systems and other transistorized equipment being developed to operate economically at low power levels. A new transistor-operated tone ringer has also been designed at Bell Telephone Laboratories as a possible replacement for the conventional telephone bell to provide equal or superior performance in supplying a pleasant but attention-attracting sound.

The ringer used in the 500-type telephone set is a direct descendant of those used 70 years ago. One reason for the persistence of this basic design is that each new ringer has had to be interchangeable with those already in service. Such compatibility is obviously desirable, but it may now have to be abandoned because in many of the switching and transmission systems currently being proposed for general use, it would be more economical to operate ringers at lower levels of power, rather than use the 90-volt, 20-cycle power presently required. This is especially true of the electronic switching system* now under intensive development at the Laboratories and, to a lesser degree, of line concentrators.

This break with the past offers a unique opportunity to make a fresh start and use modern techniques and components in the design of a ringer that will meet future requirements. Exploratory development along these lines is now underway, and the most important design objectives may be simply stated. First, the sound output must be equal or superior to that of the conventional ringers in attention-attracting qualities and in acceptance by the public. Next, the ringing signal should be within the voltage and frequency range normally provided for speech transmission in order not to impose any additional requirement on the transmission system. Another desirable characteristic would be that eight-party, full-selective ringing be available (so that each user on an eight-party line would hear only the ringing signal of his own telephone and none other). It is also desirable that this selectivity not require any ground connection at the user's telephone, because ground connections usually provide a path for the introduction of unwanted noise into the telephone line.

"Tone ringers" are being investigated as one means of meeting these requirements. On lines using

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such ringers, each party is assigned one of eight frequencies spaced between 478 and 1,000 cycles per second. When it is desired to ring a customer, his assigned frequency is sent out from the central office at about a + 8 dbm level. This signal excites a resonant circuit in his tone ringer which, in turn, drives a transistor amplifier. The amplifier output is converted into sound by a small loudspeaker or "sounder." The tone is given a distinctive character by interrupting the ringing voltage, and thereby the tone, about twelve times per second. The ringers of the other parties on the line remain silent because their resonant circuits do not respond to this particular ringing frequency.

A number of tone-ringer circuits are possible. They differ in detail and each is best adapted to one or another type of telephone equipment, but all perform the same functions and contain the same major elements. The most experience with field conditions and with user reaction has been obtained with the design developed for trial with the Type-P (rural) carrier system, and this ringer will be described in enough detail to illustrate the principles involved in all of them.

The circuit is shown schematically in Figure 1. The inductor L1 and capacitors C1 and C2 form a parallel resonant circuit that determines the operating frequency of the ringer. An installer can adjust this circuit to any one of the eight frequencies by making the right coil-tap and capacitor connections in the set. The ringing signal reaches the resonant circuit through a chain of components that includes the diodes CR1 and CR2 and the resistor R3. For the moment the diodes may be considered in their low impedance state, so that the controlling impedance of the chain is the resistor R3, (8,200 ohms). Near resonance, the impedance of the resonant circuit is high compared with R3, and most of the ringing signal is available to drive the resonant circuit. Under these conditions, the positive peaks of the voltage wave on the base of the transistor are greater than the sum of the forward breakdown voltage of the transistor and of the diodes CR3. A pulse of current then flows through the transistor and, in fact, its collector is driven to saturation. These pulses of current also flow through the sounder and generate the ringing tone. If resistance R4 is added in the collector circuit, it absorbs some of the available power and the sound level is reduced. Volume control is provided by making this resistance variable.

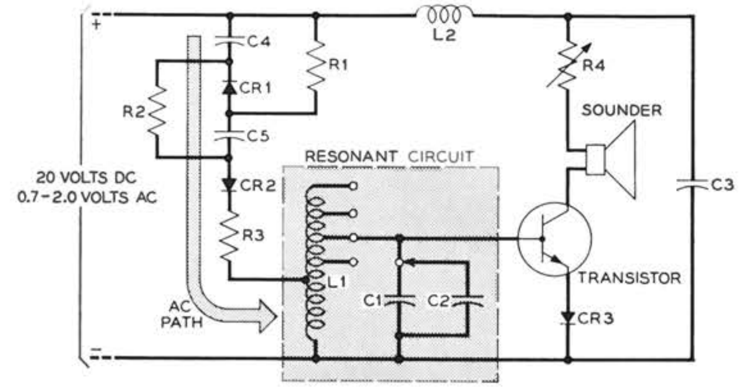

Fig. 1 — One of several possible tone-ringer circuits; different coil and capacitor taps indicated in the shaded area provide resonance to one of eight frequencies.

Fig. 2 — The sounder of the tone-ringer circuit — receiver is shown in palm of hand and double tube resonator appears above.

At a signal frequency differing widely from the resonant frequency, the impedance of the resonant circuit is low compared to R3 and the voltage developed at the base of the transistor is not sufficient to produce current in it. The ringer will then remain silent. However, ringer frequencies are only 10 per cent apart, and at this spacing the change in resonant circuit impedance is not by itself sufficient to assure complete selectivity when maximum signal voltage is present on the line (the "zero loop" condition, approximated when a telephone is geographically very close to the central office). It is therefore necessary to regulate the current that can flow through the input circuit. This is the function of the diodes CR1 and CR2. A 60-microampere direct current flows through these diodes via R1, R2 and R3. If the peak signal current is less than 60 microamperes, the diodes have a low impedance and have negligible effect on ringer operation. However, if the signal current tries to exceed this level, the net current in one or the other diode is driven to zero and the diode blocks. As a result the maximum signal current is a clipped sine wave, approaching a square wave, with 60-microampere amplitude. When the signaling frequency is within 2 per cent of the resonant frequency, this current is sufficient to generate a tone of the same sound power as that of a conventional ringer. However, at the frequencies of the adjacent parties, it will not activate the transistor and the tone ringer remains silent.

The sounder is shown in Figure 2. It consists of a modified telephone-type receiver coupled to a double-tube acoustic resonator. Its response is characterized by three peaks, one due to the receiver and two to the double resonator. This characteristic is shown in Figure 4. The sounder achieves good efficiency over the frequency band from about 850 to 2,400 cycles per second. Most of the signaling frequencies are below this band, but the pulses of current delivered by the amplifier to the sounder are very rich in harmonics. It is these harmonics that are converted into sound. This permits the use of smaller resonators than would be required to radiate the fundamentals (i.e., the 478-1,000-cycle signaling frequencies). It also places the sound energy in a range where it is less likely to be masked by background noise. The tone still sounds low in pitch, however, because the ear and brain partially restore the missing fundamental.

The amplifier network, sounder and volume control are mounted in a 500-type telephone set as

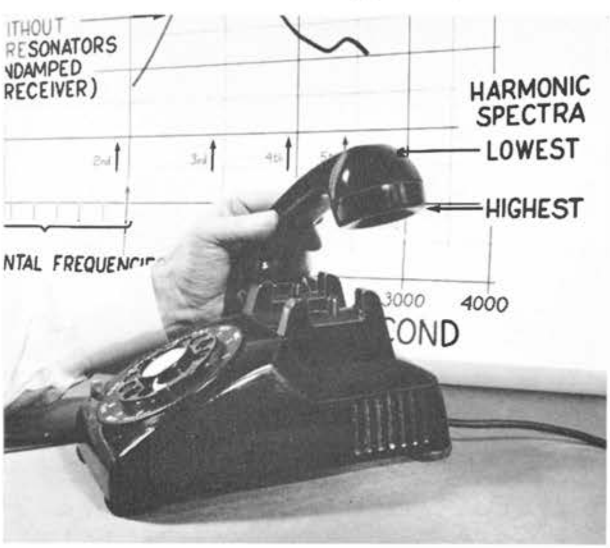

Fig. 3 — 500-type set modified for tone-ringer operation; sounder is behind louvres in base.

shown in Figure 3. The only innovation in external appearance is the row of slots in the side of the housing. These provide free egress for the sound. The volume control appears as a knob in the front lefthand corner.

The sound emitted by the tone ringer does not resemble the familiar sound of the telephone bell except that the 2-second ON, 4-second OFF repetitive cycle has been retained. In a change of this sort, it is essential to know whether there have been any important changes in such acoustical factors as audibility, clarity, distinctiveness and acceptability.

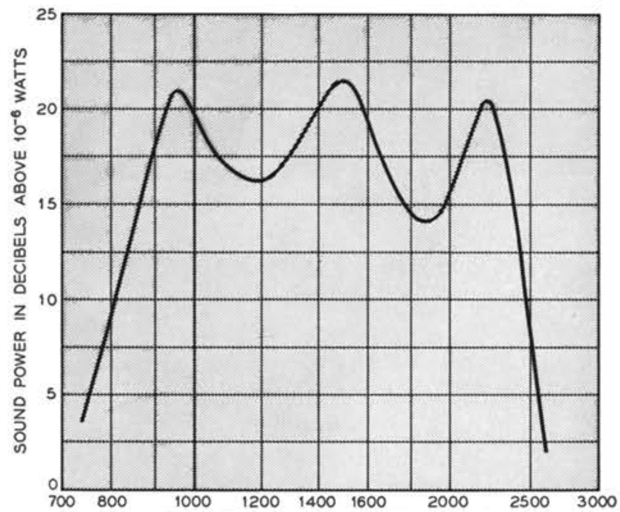

Fig. 4 — Frequency response of the sounder — the three peaks result from the telephone-type receiver and the two acoustic resonator sections.

A preliminary check of these factors was made in the Laboratories.

Models of the tone ringer were compared with a conventional ringer in the presence of background noise having an energy pattern simulating observed room noise. The level was adjustable to provide a range of noise conditions. In these tests, the masking effect of the noise was judged to be approximately the same for both ringers.

A second laboratory test was made in which the tone ringer was operated near one end of a long hallway. The observer walked away from the source until he reached a point where the signal was indistinct. The distance traversed was a measure of carrying power. Repeating the test with the conventional ringer gave a comparison in which the tone ringer was found to be somewhat more effective than the conventional ringer.

In another test, more than 200 Laboratories people served as a jury listening to the quality of the several ringer tones and expressing their opinions

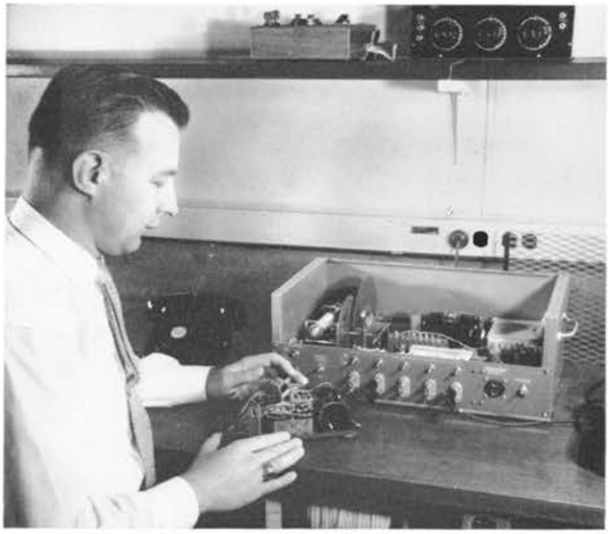

Fig. 5 — J. Kocan observes the operation of an experimental photo-electric signal generator that supplies the complex tone ringer signal voltages for the development laboratory.

of them. The over-all reaction of this group was favorable to the tone ringer, but the two highest-pitched tones were less popular than the others.

After these tests, tone-ringer sets were supplied as replacement telephones to 25 people in the Laboratories for a period of two weeks and their reactions were obtained. Here the results were even more favorable to the tone ringer; they indicated that the user's preference for it increases as he becomes better acquainted with it.

At about this time a field trial of the Type-P rural carrier system was in progress in Americus, Georgia. The low-voltage, voice-frequency signaling feature of the tone ringer suggested compatibility with the carrier system, and the Laboratory tests indicated that the tone ringer could be expected to perform well. Consequently, a small-scale field trial of the tone ringer was added to the carrier trial to determine the technical possibility of incorporating a tone-ringer system in a commercial plant and to obtain further telephone-user reaction to the tone-ringer signals.

At Americus, the P-carrier installation served 28 telephones on four rural 8-party lines, ranging in length from 12 to 18 miles. A standby voice-frequency circuit was provided for each line. Normal operation in this area employed divided-code ringing (i.e., each user hears the ringing signals of four telephones). This grade of service was retained. The full-selective ringing feature of the tone ringer was therefore not tested in this trial. A tone generator capable of supplying any two of the eight ringer tones was installed at the central office for each line served — one tone corresponding to conventional ringing on one conductor of the line (the tip side) and the other tone corresponding to ringing on the other conductor of the line (the ring side). Battery voltage for both talking and ringing was supplied from the outlying terminal of the carrier system for both carrier and voice-frequency operation.

Tone-ringer sets were installed in all 28 homes and provided telephone service for 69 adults and 13 children for a period of two to six months. The opinions of the customers were obtained by interviews conducted at the beginning and at the end of the trial period. The tone ringer was preferred to the conventional ringer by 70 per cent of these people. Their reasons for their preference were that it could be heard farther, was clearer and more easily recognized. Also, to use phrases obtained in the interviews, its "calm sound" was "not as rowdy as" or was "less terrifying" than the bell.

The interviews also gave data on the relative effectiveness of the two types of ringers. Only 72 per cent of the Americus people could hear the conventional ringer in all parts of their house while 91 per cent could hear the tone ringer in all parts of the house. Thirteen customers pointed out locations where they had heard and recognized their ring and where the telephone ringer was previously in-

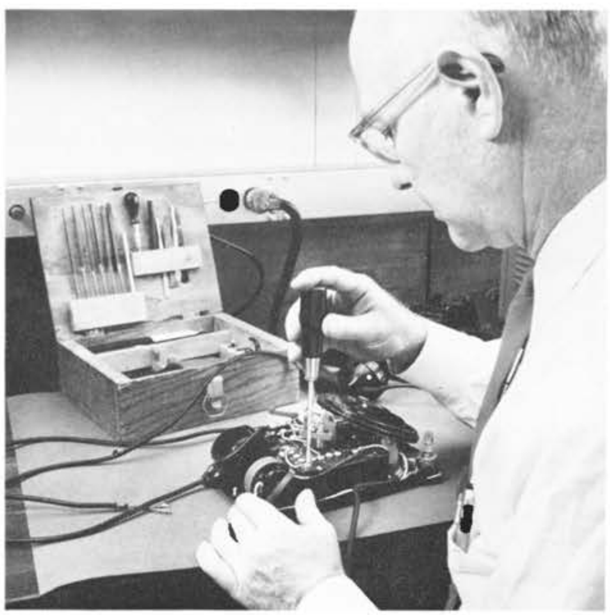

Fig. 6 — J. R. Power demonstrate how connections establish correct resonant frequency.

audible. Several of these locations were 300 feet or more away from the telephone instrument.

The Americus trial thus demonstrated that tone ringers can be operated over carrier lines or over long open-wire lines and that they are well liked by our customers. The economies in the case of a few carrier channels, however, are not favorable for general use at this time. A larger installation of tone ringer sets is undergoing a field trial at Crystal Lake, Ill., to establish the possibility of their use with an electronic switching system where the economic advantage would be considerable.

THE AUTHORS

F. L. CRUTCHFIELD received a B.S. degree from Guilford College in 1925. In 1926, he received an M.S. degree in Physics from North Carolina State College and joined the staff of Bell Telephone Laboratories that year. His first assignment was the development and standardization of the thermophone as a basic reference in electro-acoustic measurements. For several years, he was engaged in the design of apparatus for measuring telephone transmission and for testing telephone instruments. In 1936, he transferred into the group responsible for the design of telephone instruments. During World War II, he was concerned with the design of communication instruments for special uses by the armed forces. In 1954, Mr. Crutchfield joined the newly formed station systems engineering group which deals with the application of new arts to telephone station apparatus.

J. R. POWER received a B.S. degree from the Carnegie Institute of Technology in 1927 and joined the staff of Bell Telephone Laboratories in that same year. He was initially engaged in the development of precision voltage and speed regulators, primarily for use in the sound picture field. Following this he spent several years on miscellaneous acoustical problems and then on the electro-magnetic development of telephone ringers. During World War II he was engaged in the development of high power audio systems. After the war, he worked on hearing aids, audiometers and artificial larynges. In 1948 he returned to station apparatus development and is now concerned with the exploratory development of transistorized telephone sets.

Claude E. Shannon Receives Research Corporation Award

Dr. Claude E. Shannon, research mathematician at the Laboratories, has been awarded the 1956 Research Corporation Award for his work in establishing a mathematical theory of communications. His philosophic concept, known as "Information Theory," was developed by Dr. Shannon at the Laboratories. The theory has many applications in wire and radio communications and in computing machines, as well as more diverse fields.

The award consists of an honorarium of $2,500, a plaque and a citation. Dr. Shannon is the 21st recipient since the award's inception in 1925. The award honors individuals who have made notable scientific contributions which have not already received substantial recognition.

Dr. Shannon has been a member of the technical staff of the Laboratories since 1941. In January, 1956 he was appointed Visiting Professor of Electrical Communications at Massachusetts Institute of Technology. Dr. Shannon was recently appointed Professor of Communications Sciences in Electrical Engineering and Professor of Mathematics at M.I.T. He continues as a part-time member of the Laboratories.

Other award winners have included: Robert B. Woodward, Vannevar Bush, Percy W. Bridgman, Ernest O. Lawrence, Bruno Rossi, Edwin M. McMillan, Edward C. Kendall, Samuel A. Goudsmit, George E. Uhlenbeck, and H. S. Black. Mr. Black, a member of the Laboratories, received the prize in 1952 for his invention and development of the negative feedback system which is fundamental to much of science and industry.

Dr. Shannon received the Morris Liebmann Memorial Prize of the I. R. E. in 1949 and in 1955 the Franklin Institute awarded him the Stuart Ballantine Medal. He is a member of the National Academy of Sciences.