Important factors leading to Alexander Graham Bell's invention of the telephone were his devotion to the problems of the hard of hearing and his knowledge of the nature of speech and hearing. At the Laboratories, continuing studies of the fundamentals of sound and hearing have led to better telephone instruments and to more effective devices to help those whose hearing is impaired. In the 532-type telephone set there is a self-contained transistor amplifier — independent of local batteries — that offers improved service to these customers.

The New Volume Control Telephone

A. J. CHASE *Station Apparatus Development*

The junction transistor has made possible an entirely new approach to the design of a telephone set for the hard of hearing. Capable of operating as a high efficiency amplifier at low voltages, the junction transistor uses but a small fraction of the central office power supplied to the instrument at a customer's premises. Now for the first time it is possible to operate a practical receiving amplifier in a telephone set without the use of local batteries.

Over the years a number of developments have provided telephone service for those with impaired hearing. Some 50 years ago mechanical repeaters were used at the customer's premises, and by the late twenties an electron tube amplifier was available.* By 1941 the miniature mechanical amplifier developed for hearing aids was provided in a combined set.† Although some 50,000 installations of this set indicate some service improvement, performance limitations and manufacturing difficulties stimulated new design. Development of an electron tube replacement set was discontinued when the imminence of transistors indicated a more desirable solution.

When point-contact transistors became available, their small size and low power requirements prompted the development of a two-stage transistor amplifier. Despite reduced power requirements in this design, local batteries again had to be used to supply the biasing voltages of approximately 20 volts dc needed for satisfactory operation.

The introduction of the junction transistor not only reduced power requirements still further but also assured satisfactory operation of the amplifier at voltages low enough to eliminate the need for local batteries. Ideally suited, too, were such characteristics of the junction transistor as its small size, its long life expectancy, and its freedom from the effects of shock and mechanical vibration. Its low operating power and voltage levels facilitated packaging of the amplifier by permitting such miniaturization of all circuit components that in the final design the amplifier is housed in a cubic space approximately one inch on each side. Figure 1 shows one of the amplifiers with the metal case removed.

The circuit schematic of Figure 3 shows the junction transistor amplifier inserted in the receiver circuit of a 500-type telephone set. This amplifier provides adequate gain in a single stage, and the input impedance of the transistor is suitable for direct coupling into the receiver circuit shown at terminals R and GN. Resistor R1 and capacitor C1, shunted across the input, provide stabilization of the input impedance and suppression of radio interference. The transistor collector circuit is coupled to the U1 receiver by a miniature output transformer, whose impedance ratio is designed for maximum power gain with the low collector voltages available – usually 2 to 4 volts. The 20,000-ohm base resistor, R2, has been selected to provide transistor current which

* RECORD, *October*, 1931, *page* 46.
† RECORD, *October*, 1942, *page* 45.

ranges from about 5 milliamperes on the shortest customer loops to two milliamperes on the longest.

Power for the amplifier is obtained by diverting a small fraction of the carbon transmitter current, causing a loss in transmitting level of less than one db. This operating current is filtered by a small inductor, L1, and by-pass capacitor, C2.

The voltage gain available in this single stage is too small to permit the use of stabilizing negative feedback when the amplifier is operating at full gain, but for operation at less than full gain, the volume control potentiometer provides negative feedback by inserting resistance in the emitter circuit.

At minimum gain, therefore, the resistance of the volume control in the emitter circuit is high enough to insure negligible speech distortion and serves to stabilize and minimize variations in transistor characteristics. Because performance at minimum gain is effectively that of a standard 500-type set, the design of the set is simplified and its maintenance minimized by omitting the customary arrangement for switching the amplifier out of the circuit when additional gain is not required. The expected long life of transistors justifies the use of the amplifier whenever the set is in use, irrespective of whether additional gain is required.

Since the bridging diodes at the input of the talking circuit protect the transistor against battery reversals or the accidental applications of manual ringing voltages on the line, the transistor is always biased properly for operation.

The design objective for the junction transistor amplifier was to provide a continuous range in gain from substantially 0 to at least 20 db. Power supply

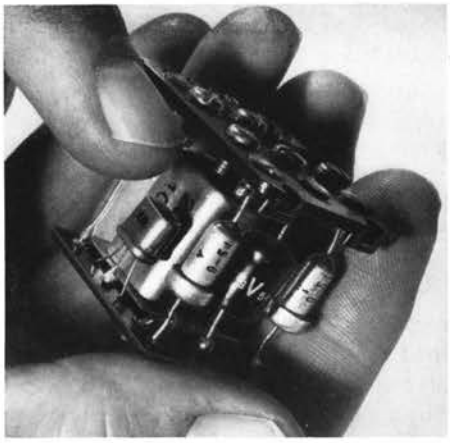

Fig. 1 — The heart of the 151A amplifier is the junction transistor shown just beneath the pointing finger.

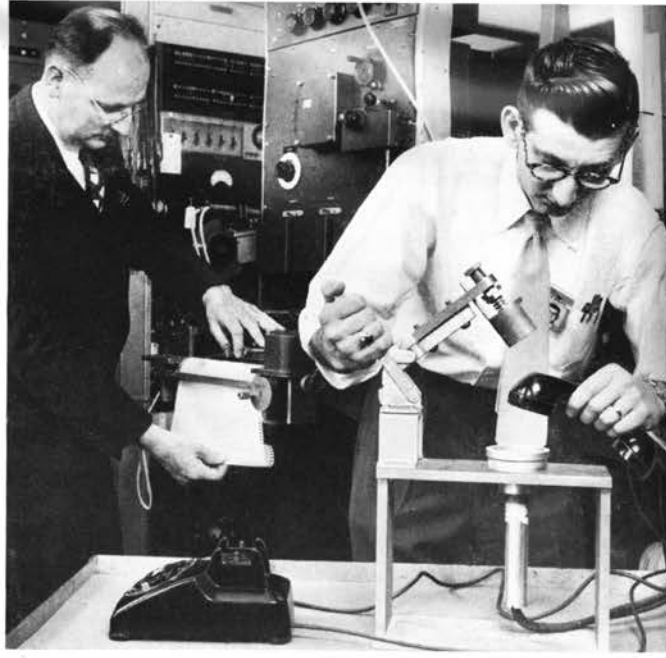

Fig. 2 — J. R. Ouellette couples the receiver to the "artificial ear" while the author prepares the level recorder for operation.

variations due to differing customer loop lengths have little effect on the maximum gain available.

The curves of Figure 4 illustrate the performance of the set in terms of sound pressure delivered to the ear by a close-coupled telephone receiver. Measurements were made by means of the "artificial ear" shown in the foreground of Figure 2 and the level recorder in the background. The lower curve of Figure 4 represents pressures delivered by a standard 500-set receiver over the important portion of the audio range when a steady signal is applied to the line at a typical incoming level. When the amplifier is adjusted for maximum gain, the sound pressures are raised as indicated; the slight increase in gain at the higher frequencies is a desirable characteristic. The top curve shown by the dotted line represents the "threshold of feeling," beyond which sounds are felt rather than heard; it is obviously desirable that sound pressures in the ear be kept below this level. Since both the overload characteristic of the transistor amplifier and the click-reducing characteristic of the varistor built into the receiver serve to limit sound pressures in the ear, safe operation is assured regardless of the level of incoming sounds or sharp clicks on the line, and the pressures on the ear cannot exceed those shown in Figure 4 by more than a few db.

A model of the new set has been designated as the 532-type. (The illustration at the head of this article shows Mrs. M. S. Aamodt operating the plastic knob to adjust the volume of this set.) The ampli-

fier is housed in a metal case riveted to the base of the set, with all components mounted to the terminal plate which forms the cover of the case. The diode bridge, the 419A varistor, is housed in the terminal plate cartridge mounted between the legs of the dial bracket, and the potentiometer gain control mounts in the corner of the set for easy access. In outward appearance the set resembles a single-button key set.

Assembly of this transistorized set is simplified by the fact that all components may be readily added to the base plate of a standard 500-type set. The amplifier housing mounts in holes originally provided for the filamentary type equalizer of the earlier 500-type series; the potentiometer bracket utilizes holes provided for the key in the 510-type set; and the varistor assembly replaces the terminal strip of that set. All other components are standard with the sets in the 500-type series, and installation of the set is as simple as that for the 500-type. Another type known as the 533 is available for selective ringing party service.

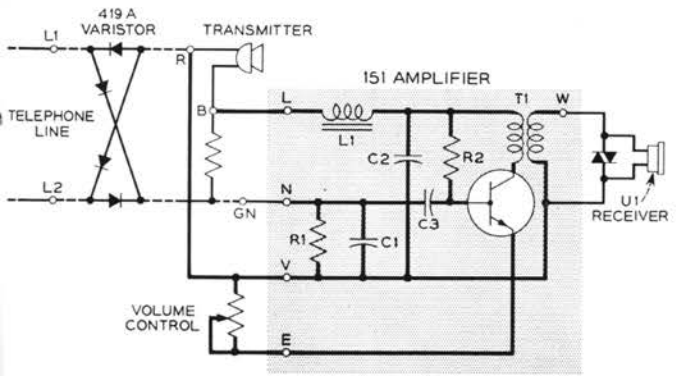

Fig. 3 — Simplified schematic of the 151A amplifier inserted in the receiver circuit of a 500-type telephone set.

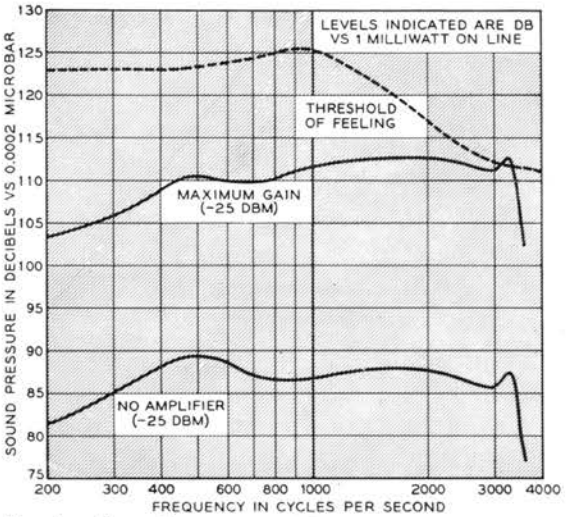

Fig. 4 — Sound pressures delivered to the ear by a close-coupled telephone receiver.

Measurements made at the San Francisco World's Fair in 1939 revealed that about 0.7 per cent of the people tested had hearing losses which experience has indicated require some amplification for satisfactory hearing over the telephone. Assuming that this distribution applies to the telephone population and that there are an average of two telephone users for each of the fifty million stations in the United States, it would appear that there might be 700,000 customers with impaired hearing, who would benefit by such a telephone set.

In this regard the potentialities of the set are evident, including the fact that it is simpler to install and maintain than previous types. It is the first of many applications of the junction transistor to the station set which will undoubtedly be made to improve service for the customer.

THE AUTHOR

A. J. CHASE joined the Laboratories in 1930. Until 1938 he was concerned primarily with telephone transmitter carbon tests and transmitter maintenance, and from 1938 to the start of the war he was engaged in economic and maintenance studies of the station dial. During World War II Mr. Chase took part in the design, development, and testing of underwater sound reference instruments and an electronic-mechanical system for guiding torpedoes. Since the war he has been responsible for the maintenance of appraisal facilities for special tests of telephone apparatus and has engaged in the design, development and maintenance of service observing equipment. Mr. Chase received a B. of E.E. degree from New York University in 1938.