AUTOMATIC ELECTRIC

TECHNICAL JOURNAL

THE NEW
SPEAKERPHONE—EXECUTIVE MODEL

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GENERAL SYSTEM

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"Partial gain-switching" in this new telephone permits high signal levels without "singing" or "clipping"; a novel "floating baseplate" design improves appearance, doubles space for mounting components.

NUEVO "SPEAKERPHONE" (TELEFONO ALTOPARLANTE) — "MODELO EJECUTIVO"

En este nuevo teléfono, la conmutación parcial de la ganancia posibilita altos niveles de señalización sin "canto" ni mutilación. El empleo de la "base flotante" mejora su apariencia y duplica el espacio para la colocación de sus partes.

LE NOUVEAU TELEPHONE A HAUT PARLEUR — MODELE "EXECUTIVE"

Le controle automatique du gain de ce nouvel appareil permet une haute amplification sans amorcage ni distorsion. Le nouveau concept de base "flottante" permet de doubler l'espace réservé aux organes.

IL NUOVO TELEFONO CON ALTOPARLANTE — "EXECUTIVE MODEL"

Un sistema di controllo parziale del guadagno permette, in questo nuovo telefono, segnali ad alto livello con l'eliminazione dell'effetto Larsen e dell'innesco. Un nuovo sistema di montaggio a "base fottante" raddoppia lo spazio disponibile per i componenti.

For expanding a Rotary 7A2 exchange, and connecting it into the nationwide toll dialing network, Automatic Electric developed interconnecting equipment that requires no change in existing equipment.

CONEXION ENTRE EQUIPO STROWGER Y ROTATIVO

La Automatic Electric ha perfeccionado un equipo para la ampliación de una central tipo Rotativa 7A2 y su conexión a la red continental automática que no requiere cambios en el equipo existente.

INTERCONNECTION ENTRE CENTRAUX STROWGER ET CENTRAUX ROTARY

Automatic Electric a étudié un systeme d'interconnection permettant l'extension d'un central rotary 7A2 et sa liaison au réseau automatique interurbain national, sans la nécessité de modifier l'appareillage existant.

INTERCONNESSIONE FRA EQUIPAGGIAMENTI STROWGER E ROTARY

Per consentire l'ampliamento di una centrale Rotary 7A2 ed il relativo allacciamento alla rete di teleselezione nazionale, la Automatic Electric ha sviluppato equipaggiamenti di intrconnessione che non richiedono alcuna modifica alle apparecchiature della centrale esistente.

These coils will withstand a 10 kilovolt pulse between windings, and 20 kilovolts to ground. Designed for installation in re-enterable splice cases; also in lead cases for strand or pole mounting.

BOBINAS DE CARGA DE "ALTA TENSION"

Estas bobinas pueden resistir impulsos de 10 kilovoltios entre devanados y 20 kilovoltios a tierra. Proyectadas para instalarse en cajas de empalme accesible, así como en cajas de plomo para colocarse en cable mensajero o en postes.

Please address correspondence to the editor, Public Relations Department, Automatic Electric Company Northlake, Illinois, U.S.A.

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THE NEW SPEAKERPHONE—EXECUTIVE MODEL

By R. T. Cleary and T. G. Cannon
Automatic Electric Laboratories, Inc.

Figure 1. This new Loudspeaking Telephone, with its unique housing and simple controls, provides "no hands" operation for an individual or a group of people.

Loudspeaking telephones offer two obvious advantages over other instruments: (1) "No hands" operation, and (2) "Group conversation" (i.e., a number of persons gathered in an office, or an entire family around the telephone, can all hear and be heard at the same time). With these inherent advantages, it was felt that the market for such a telephone would be greatly increased if by means of voice-switching techniques it could be made acoustically satisfactory, and if by use of "human-factors" engineering it were made convenient to use, and given a distinctive appearance that would visually convey the idea of a loudspeaking telephone instrument.

Probably the greatest problem was to make a loudspeaking telephone which would give transmission at a normal handset level to the line, and yet not have loudspeaker-microphone acoustic feedback ("singing") or echo; with the decision to use gain-switching in the new telephone, we were on the way to solving this problem.

But there were other problems. Simple gain-switching usually results in the "clipping" of first syllables, and also makes it impossible for

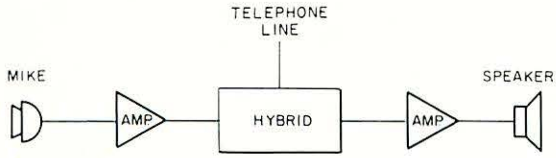


Figure 2. The basic circuit of every loudspeaking telephone includes amplifiers and a hybrid balancing network.

a listener to interrupt the speaker; under these handicaps, conversation is somewhat unnatural. Some modification of usual gain-switching techniques was therefore indicated. At the same time, although a loudspeaking telephone is inherently a more complex device than an ordinary telephone, it was necessary to make the new instrument as simple as possible to install and maintain. Automatic Electric's Speakerphone—Executive Model (see Figure 1) was designed with these difficulties in mind—and we feel that they have been almost entirely overcome.

Besides this, the new design departs from existing designs of telephone housings, not only to make a distinctive appearance but to actually *look* like a loudspeaking telephone!

Causes of Feedback and Echo Problems

A loudspeaking telephone in its most basic form consists of a microphone (or "mike"), a loudspeaker, and their associated amplifiers, connected to the telephone line via a hybrid balancing network (see Figure 2).

The hybrid network is a bridge circuit used to couple the microphone and loudspeaker amplifiers to the line while minimizing the electrical coupling between these amplifiers.

The ideal hybrid network should be exactly balanced against the impedance of the line, but since this varies with the characteristics of the particular line and its distant terminating impedance, some coupling always exists.

Loudspeaker and microphone placement, as well as room acoustics, also have a considerable effect on operation. If there is excessive loudspeaker-microphone coupling and an unbalanced hybrid network, the electro-acoustic feedback loop will cause singing. Even with a balanced hybrid, with the gain and acoustic coupling below the singing point, the distant party may still hear a delayed echo of his voice, because of acoustic coupling of loudspeaker and microphone. This is bothersome and hampers normal conversation.

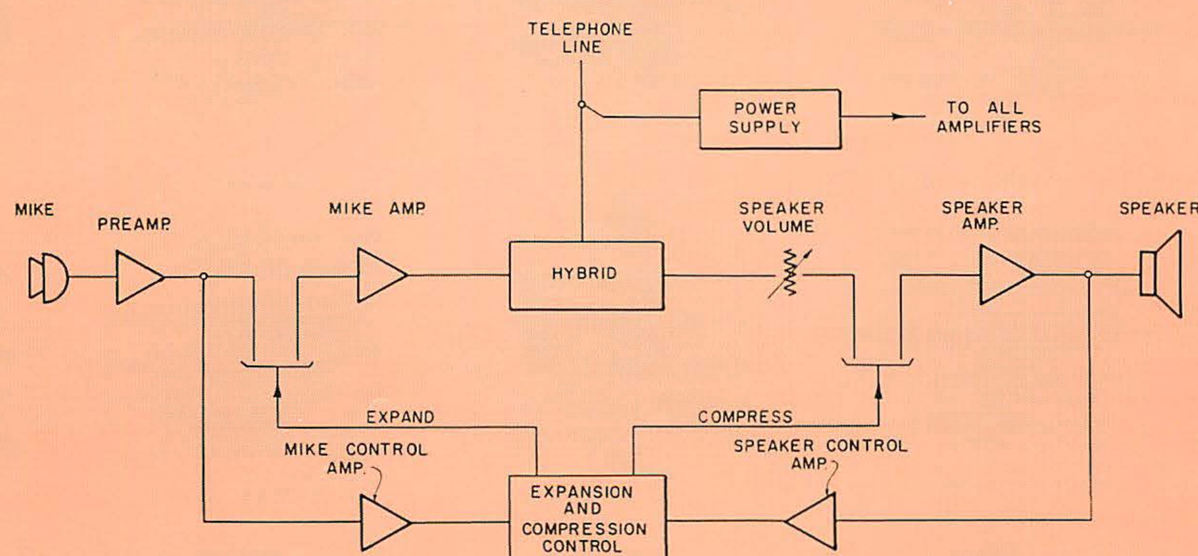
Singing and echo problems can be decreased by a reduction in amplifier gain, but of course this is not a satisfactory solution. Telephone users expect to hear at about a normal volume, and we set out to meet this requirement.

Voice-Switching Techniques

There are several criteria for a good voice-switching circuit:

1. It must have a fast "attack time" (the in-

Figure 3. The Speakerphone—Executive Model, has supplemental amplifiers and controls, to provide ample transmission volume without "singing".



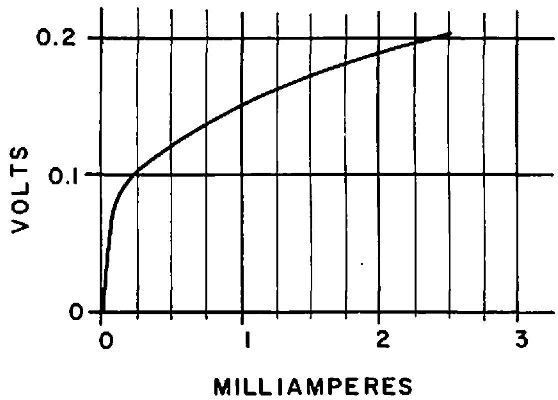


Figure 4. This curve shows that the current through a diode varies with the voltage drop across it.

terval beginning when a voice signal enters the mike or speaker channel and ending when that channel is operating at full gain). If the attack time is too slow, first syllables will be clipped.

2. It must have a slow enough "decay time" (beginning when the speech signal ends and ending when the channel is reasonably attenuated) so that switching does not occur between syllables, and so that stressed and unstressed syllables in speech are amplified at the same rates. On the other hand, if the decay time is too long, rapid back-and-forth conversation will not be possible, since the channels will remain active too long.

3. Switching should be smooth, with no click or other disturbing noises.

4. To make interruptions possible, the circuit should be arranged to prevent exclusive holding of a channel.

The above requirements were achieved with a great degree of success in the present design, by the use of diodes as nonlinear elements in the switching circuits.

Partial Gain-Switching

A block diagram of this novel telephone is shown in Figure 3. Under "no signal" conditions, the speaker amplifier operates at full volume and the microphone amplifier is attenuated. This insures good results, even on long toll circuits where the signal level is extremely low and would not reliably operate a gain switch. When the local party speaks, his voice is amplified by the mike preamplifier, and fed via the mike control amplifier to the expansion and compression control. The signal causes the microphone amplifier to be expanded (gain increased 20 db) while the speaker amplifier is compressed (gain reduced 20 db). Total loop gain can thus be increased 20 db over that of a non-gain-switched circuit, without increased singing and echo.

When the distant party speaks, his speech is amplified by the speaker amplifier and reproduced by the loudspeaker. Part of the signal is sent to the expansion and compression control via the speaker control amplifier. (Although the speaker amplifier is normally expanded, it is still necessary that a speaker control circuit be present. This control acts as a protective device, so that when the speaker channel is in use, noise and signal which may enter the microphone as speech will not cause speaker attenuation).

Diode Control Circuits

The forward characteristic of a typical germanium diode is shown in Figure 4. It is readily apparent that the resistance of the diode decreases as the d-c biasing voltage across it (in the forward direction) increases. If an incremental a-c voltage is superimposed on the d-c biasing voltage, the dynamic resistance (resistance to the a-c voltage) is increased as the d-c voltage decreases—(see Figure 5). Thus a diode can be used in an audio circuit to control the gain of that circuit, by using a d-c biasing voltage to change the dynamic resistance of the diode.

Compression

A practical circuit for attenuating a signal by increasing the d-c biasing voltage is shown in Figure 6. Figure 6A shows a T-network with a

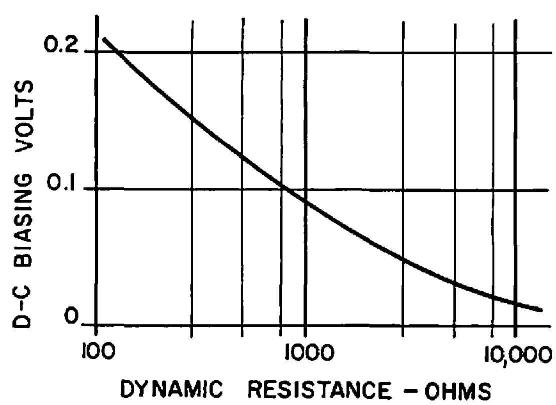
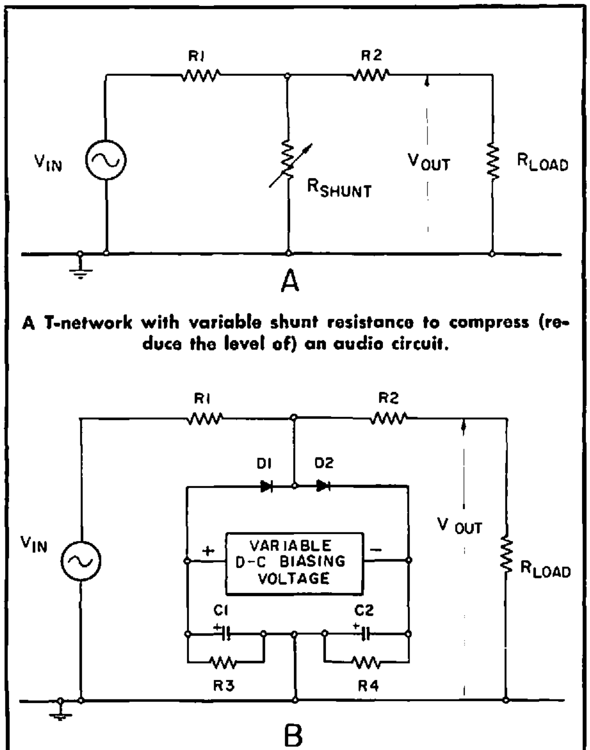


Figure 5. This curve shows that the resistance of a diode to a small a-c signal varies inversely with the d-c voltage across it.



A T-network with variable shunt resistance to compress (reduce the level of) an audio circuit.

The same network, with variable shunt replaced by diodes.

Figure 6. Principle of the audio compression circuit.

variable shunt element, R shunt. We now replace this shunt by diodes, D1 and D2 (Figure 6B). It must be remembered at this point that the a-c voltage is small (100 mv or less for germanium diodes) and therefore causes movement over only a small part of the dynamic resistance curve, resulting in extremely small nonlinear distortion. An increase in the d-c biasing voltage causes forward biasing of the diodes, decreasing their dynamic resistance and causing attenuation of the audio signal. Capacitors C1 and C2 bypass the audio to ground.

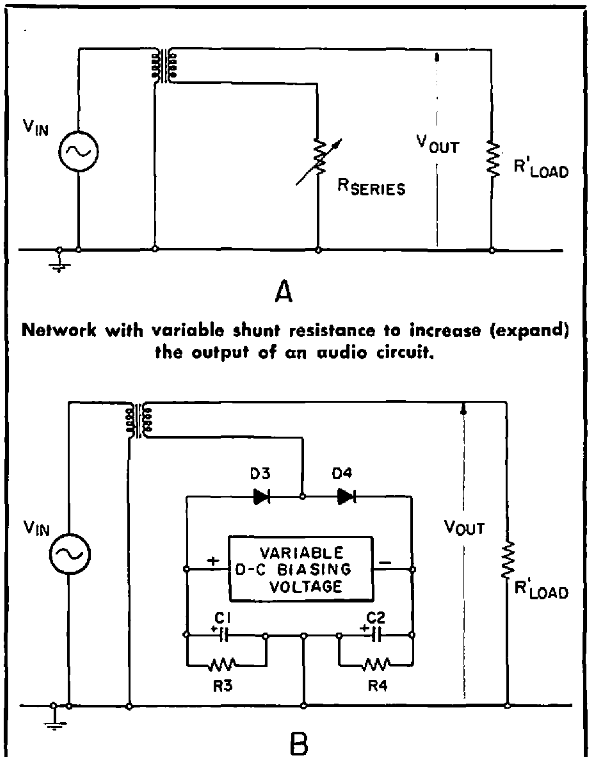
Elements D1, D2, R3, R4, C1, and C2 form a balanced bridge. This is a very important part of the circuit, since it allows a change in d-c biasing voltage without any change in d-c voltage at the junction of R1 and R2, thus permitting a fast attack time without any thump in the audio circuit caused by d-c switching transients.

Expansion

In a loudspeaking telephone using gain-switching, it is required that the d-c control voltage which compresses one channel expand the other. The method used is shown in Figue 7. Figure 7A shows how the audio output level is increased (expanded) when R series is decreased in resistance. Figure 7B shows how this is accomplished with diodes. Operation is identical with that of the compression circuit, except that decreasing the resistance of the diodes expands the signal rather than compressing it.

A signal in the speaker-control amplifier causes a d-c voltage which is subtracted from the mike-control d-c voltage. This prevents stray noises and speaker echo in the microphone channel from operating the expansion-compression circuit when the speaker channel is in use.

There are several interesting points to be noted about the combination of the expansion and compression circuits. This combination requires two diodes in the compression circuit, and four diodes in series in the expansion circuit (although only two are shown in the simplified diagram—Figure 7B). If two diodes were used in each circuit, total loop gain (microphone channel gain times speaker channel gain) would be increased during switching, causing feedback problems. With the



Network with variable shunt resistance to increase (expand) the output of an audio circuit.

The same network, with variable shunt replaced by diodes.

Figure 7. Principle of the audio expansion circuit.

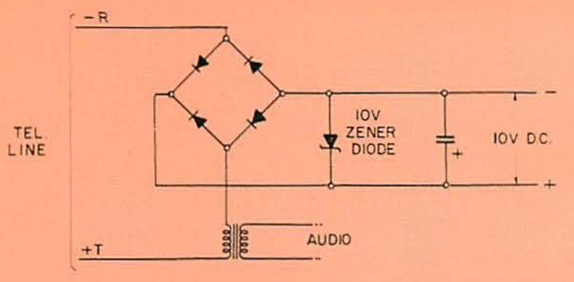


Figure 8. The telephone line supplies power as well as audio signal for the loudspeaking circuit. The diode bridge assures proper polarity, irrespective of line polarity.

present arrangement, more d-c voltage is required in the expansion circuit to produce the same dynamic resistance. This gives a very desired characteristic, and loop gain remains almost constant throughout the entire switching range.

Resistors shunted by 2 MF capacitors are used in series with the diodes, to "soften their knee". Their use is very important to smooth operation. The resistors limit diode current, and the capacitors are for audio bypass. Without these elements, operation is choppy, and stressed syllables are further stressed while unstressed syllables are made even softer.

Power Supply

Power for operation of the Type 880 telephone is derived from the telephone line, using an arrangement (see Figure 8) which is generally applicable to electronic telephone circuits. The diode bridge is used so that the output voltage will be of proper polarity even under reverse-battery conditions. A 10-volt power Zener diode holds the voltage within 3 per cent, from zero loop to 1000-ohm loop. Under certain conditions, such as greater than 1000-ohm loop, or certain high-resistance battery feed switchboards. (Western Electric 555, Leich L55), an external power supply, operated from commercial power, is used.

Flashing Lamp "On" Signal

Since the handset of a loudspeaking telephone remains in its cradle even while the telephone is in use, it would be very easy to leave the unit on after use, if no other indication were provided. Mechanical indicators have never been satisfactory, and usually not enough power is available from the telephone line to operate an incandescent lamp. A flashing neon lamp is therefore used in the new Speakerphone. The 10-volt supply powers a 50 KC transistor oscillator (3 ma current drain), the secondary of which provides 150 volts of 50 KC. This is rectified and filtered, and feeds a neon R-C relaxation oscillator that flashes the neon indicator (encased in the ON-OFF button) at a rate of 20 flashes per minute.

Electronic Ringer

The Type 880 Loudspeaking Telephone responds to ringing current of any standard frequency (16-66 cps), on single-party or two-party selective ringing lines. The ringing current is rectified and filtered, and the resulting d-c voltage is used to power a two-frequency oscillator, operating at 2,000 cps and quenched at 12 cps. The oscillator signal is amplified by the ringer output transistor, and is fed to the same loudspeaker used for loudspeaking operation.

Housing the "Speakerphone"

The elements of the "Speakerphone" which are most intimately related to the user are the dial, the ON-OFF switch, and the loudspeaker volume control; the handset is less closely associated with the user since, in a telephone of this type, it is used comparatively seldom. In

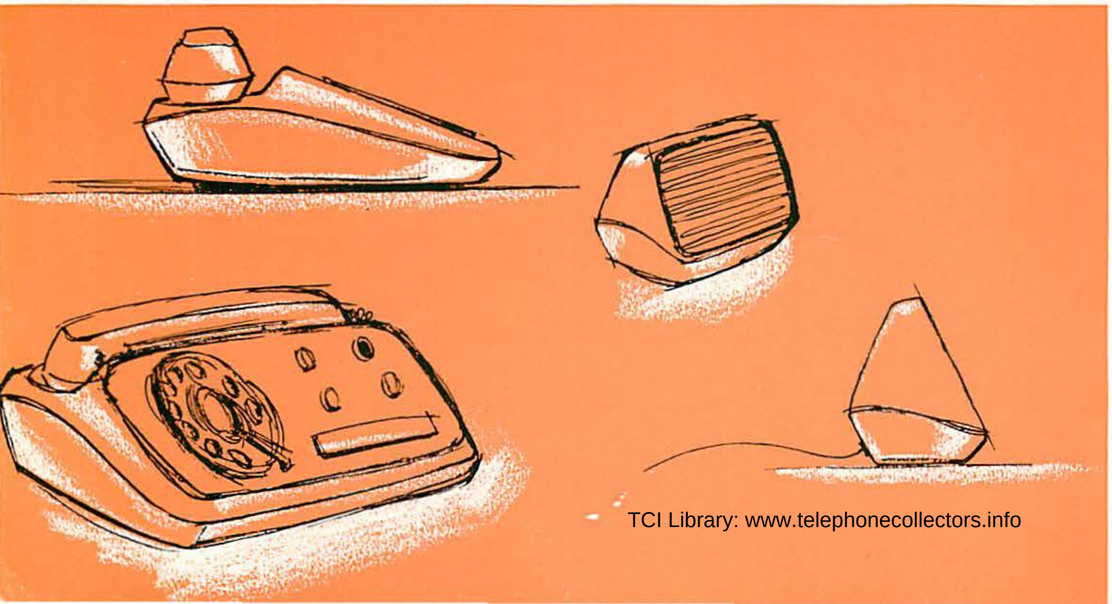


Figure 9. Designer's original sketch for the new Speakerphone.

arranging these elements, the dial and the loudspeaker controls were placed next to each other on an inclined panel, so they are equi-distant from the user and easily seen (see cover picture). The handset was placed back of this panel, making it of secondary importance to the loudspeaking feature, yet easy to reach with either hand. The long axis of the base was thus placed parallel to the handset, so the depth of the telephone could be reduced, while its length would be only that of the handset.

To decrease the time needed to get the new telephone into production, the housing was designed so it could be either injection-molded or vacuum-formed. The latter is a process which forms sheet plastic materials to a mold by the application of heat and air suction. Parts to be produced by vacuum-forming must have shallow draws and liberal draft, to prevent excessive thinning of the material. Angular forms which are difficult to draw were therefore avoided in favor of those with curves of larger radius, and since, with vacuum-forming, there is no opportunity to introduce reinforcing ribs, the continuously curved surfaces were designed to provide necessary rigidity in the housing.

The original sketch from which the Speakerphone was developed is shown in Figure 9. Note that the housing was split into upper and lower sections, so as to meet the requirement for shallow draws, and still provide enough vertical space for the components. This concept became the basis for the unique design of the Speakerphone.

When the Speakerphone is assembled, the shallow upper and lower housings cover the components, which are mounted to an aluminum center plate (see Figure 10), made by riveting two identical shallow-drawn "pans" back to back. The flanges on the edge of this center plate are then used for aligning the housings and covering their trimmed edges.

The lower housing is held in place by three screws which go into brackets mounted to the centerplate. These same brackets act as legs when the housings are removed for maintenance.

The upper housing is secured by the screws that fasten the brushed aluminum faceplate to the control mounting plate.

Particular attention was given to the type and arrangement of controls used. A large rocker switch was chosen as the ON-OFF switch, because it would be easy to operate and its function would be obvious even to a person unfamiliar with the telephone. The flashing lamp that is used to indicate a seized line was mounted in the rocker switch so their close relationship would be apparent, and the rocker switch was mounted at the bottom of the panel so it is closer to the user than the other controls. Above the rocker switch, a group of small holes in the faceplate indicate the location of the microphone. The speaker volume-control wheel, mounted with its edge pro-

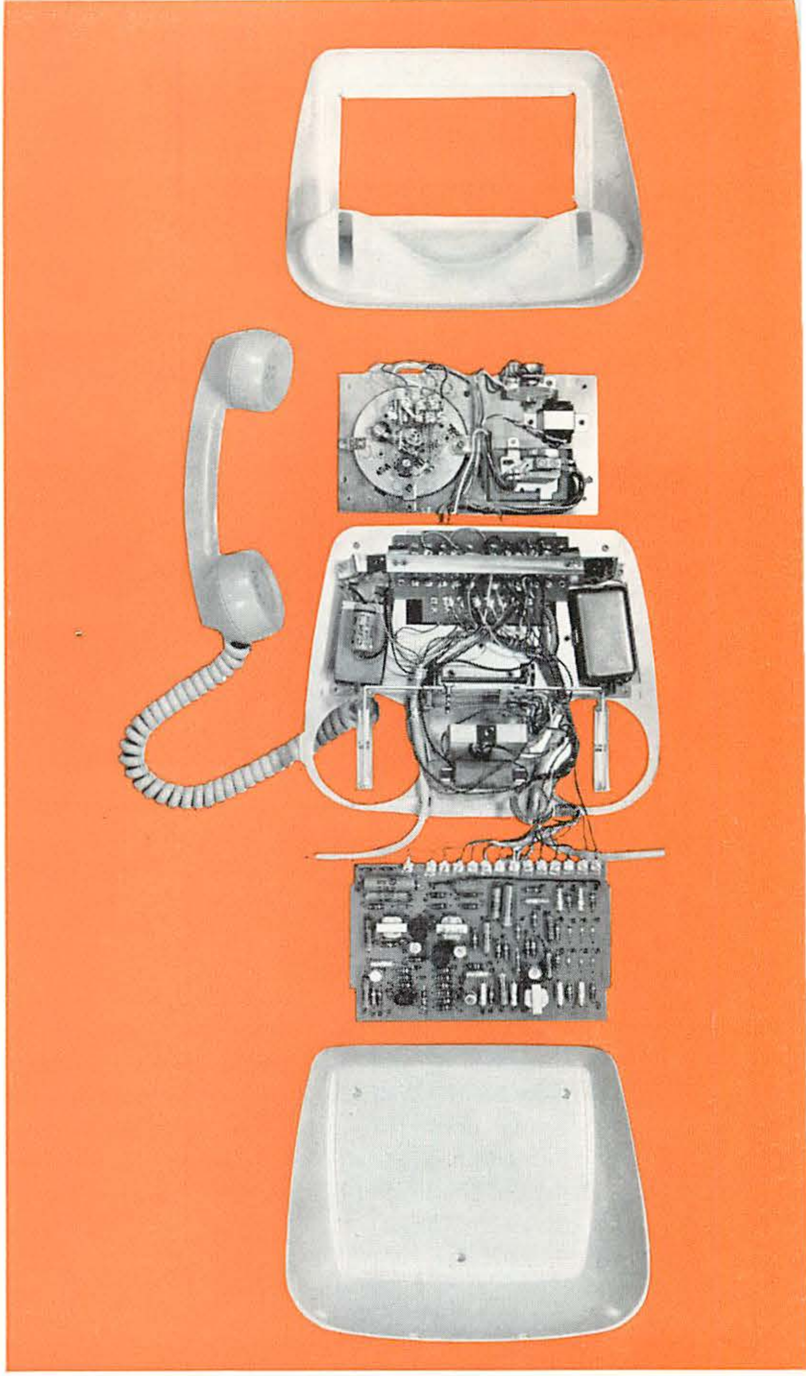
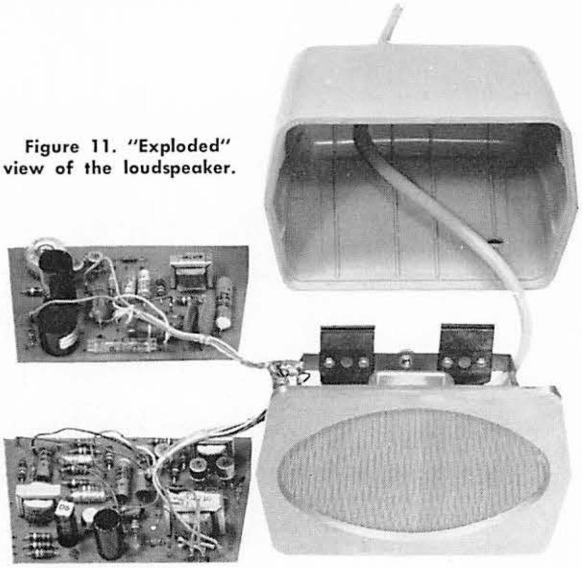


Figure 10. "Exploded" view of the Speakerphone. Working parts are mounted on the plate in the center, and on the faceplate and the printed wiring board which are connected to it. The two parts of the housing are shown at top and bottom.

Figure 11. "Exploded" view of the loudspeaker.



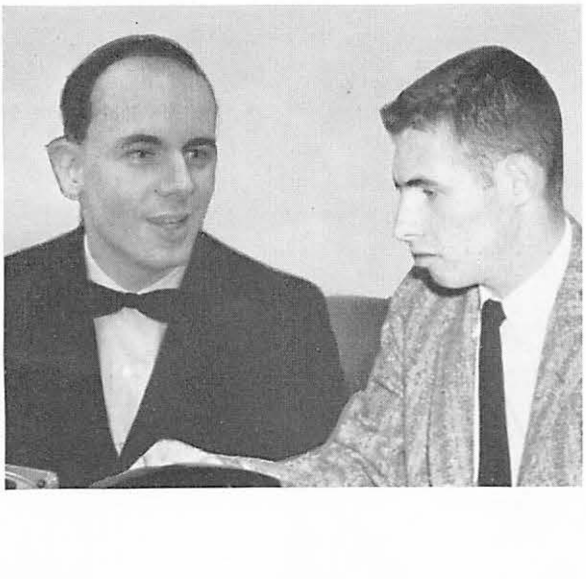
jecting through the faceplate, is above these holes, far enough away from the rocker switch to avoid being accidently moved, yet no further from the user than the uppermost finger-wheel hole.

Speaker Housing

The housing for the separate speaker holds a 3″ by 5″ speaker, the speaker-amplifier printed-wiring board, and the electronic-ringer printed-wiring board. With the shape of the speaker as a starting point, the printed-wiring boards were mounted on either side of the magnet to keep the height of the assembly at a minimum (see Figure 11). The tapering of the sides and top toward the rear gives the illusion of shallowness when viewed from the front, by eliminating any reference points which the eye might use to judge depth. A relationship to the main unit is created by the slight break about the middle of the speaker and by the use of a brushed aluminum faceplate. This diecast aluminum faceplate has studs in back, for mounting the speaker and holding the front edges of the printed-wiring boards. The rear edges of the boards are held by a clip that is mounted to the rear of the faceplate; a single screw, which goes through the back of the housing into this clip, draws the faceplate tightly into the housing.

Conclusion

Automatic Electric's Type 880 telephone, the "Executive" Speakerphone, was designed to overcome the difficulty experienced with other loudspeaking telephones, which sometimes sing because of feedback from the loudspeaker into the microphone. Partial gain switching obviates this problem, since with this new method the loudspeaker and the microphone are never "alive" at the same time—yet there is no "clipping" of syllabels, and the listener may interrupt the speaker at any time, as in normal conversation. All necessary controls are conveniently placed and clearly marked, and the design of the housing is so distinctive that it may well become a prototype of other telephones of the future!



Robert T. Cleary joined Automatic Electric Laboratories in 1960, after receiving a B.S. in E.E. from Illinois Institute of Technology. Since 1955, however, he had participated in the Co-operative Engineering program. Now in the Electronics Application Group of the Laboratories' Products Design Department, he has aided in the design of transistor loudspeaking telephones. He has four patents applied for in his own name, and another as co-inventor. At IIT he was student president of Rho Epsilon, honorary electronics fraternity.

Thomas G. Cannon received a B.S. in Industrial Design from I.I.T. Institute of Design in 1959. During summer vacations he had worked for the Laboratories' Product Design Department, and joined the Electromechanical Design Group of this Department, on an advanced telephone instrument development assignment. After his graduation, he developed the appearance designs of an electronic telephone exchange and of the Speakerphone-Executive Model. Now a member of the U.S. Army's First Support Group, he is stationed in New York.

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