A speakerphone permits a user—alone or in a group—to converse without holding the handset. The 4A, with all-new integrated circuits, is smaller and easier to install than previous models; it improves conference calls, sounds better, and picks up voices more clearly.

The 4A Speakerphone—A Hands-Down Winner

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"NO HANDS" TELEPHONE CALLING is bringing benefits to a variety of telephone users, both singly and in groups. For larger groups—business conferences and university extension classes, for example, involving as many as 30 people—the need is met by the Portable Conference Telephone (see *Conferences and Classes Via PCT: If You Can't Come, Call,* RECORD, *April 1973*). But for individual users and groups of up to, say, seven or eight people, a speakerphone is more convenient. A stenographer taking dictation from an on-the-road salesman, a printer marking proofs with corrections called in by a customer, a small group of business people discussing problems with a regional manager—all have appreciated the efficiency of using one of the various models of speakerphones produced in recent years by the Bell System.

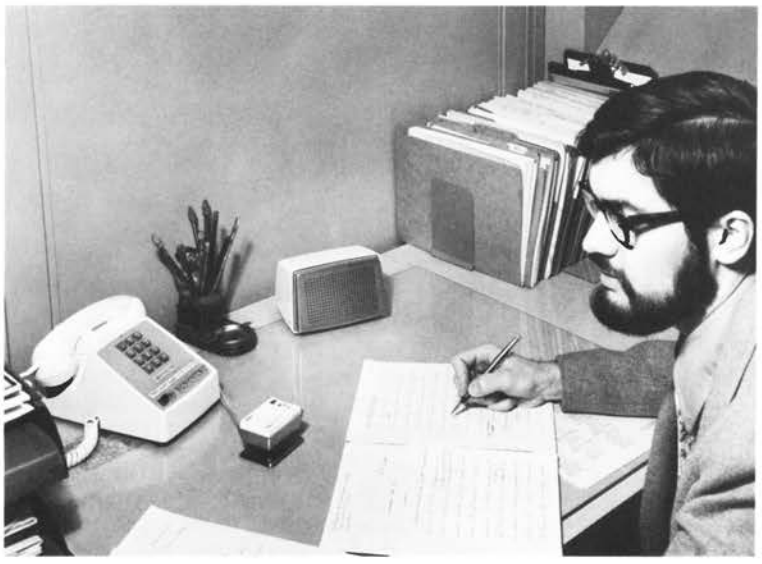
Now Bell Labs engineers at Indianapolis have developed a new model—the 4A speakerphone (see lower photo, page 234)—that offers several advantages over preceding models. The new speakerphone is smaller and easier to install; it simplifies conference calls; and it has better sound fidelity and improved pickup of voices. Used along with an ordinary telephone, the 4A consists of two units—a control pad and a loudspeaker unit. The control pad contains the volume control, the microphone, and the on-off rocker-switch control (which also cuts off transmission for the "quiet" mode of operation). The loudspeaker unit contains most of the circuitry for the speakerphone, as well as the loudspeaker itself. The control pad and the loudspeaker come in a variety of decorator colors to match the associated telephone.

To use the 4A speakerphone, a customer presses the ON OR QUIET control on the rocker-switch control pad and waits for dial tone, dials the number, and then speaks when the called party has answered. To answer an incoming call, the user simply presses the ON OR QUIET control and speaks. If he wishes, he may adjust the volume of the distant party's voice from the loudspeaker, but he need not pick up the handset or raise the volume of his voice above its ordinary level. Although he will sound best to the other party when he is close to the microphone, he is free to move about the room to retrieve files, for example, or open a window.

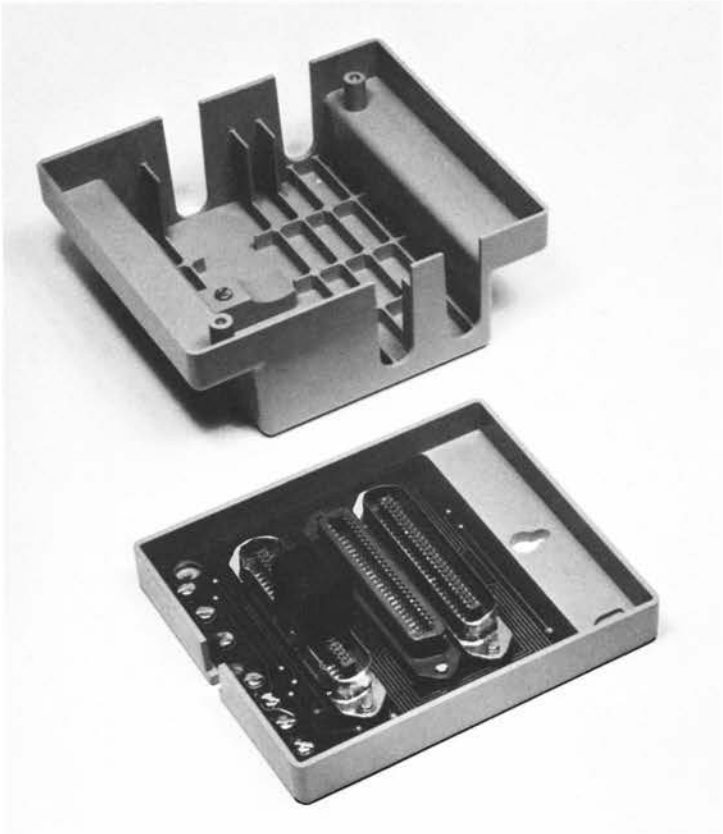
If the user wishes to prevent transmission of a private conversation or of a disturbing noise in his room, he presses and holds the ON OR QUIET control. This action—which is equivalent to putting a hand over the microphone of a handset—does not interfere with his reception of the distant speaker's voice. If either customer wishes to keep the distant party's speech private, the speakerphone user simply picks up the handset, thus automatically turning off the speakerphone. To transfer from handset to speakerphone, he depresses the ON OR QUIET control while replacing the handset in its cradle.

Preceding speakerphone models have a third component—a wall-mounted unit (about 7 by 7 by 4 inches) containing the circuitry. But the silicon

Members of the TOUCH-TONE® *and Speakerphone Department at the Indianapolis Laboratory participate in a conference call using a 4A speakerphone. The conference participants do not have to crowd to one side of the table to be heard because the 4A's new omnidirectional microphone in the control pad/transmitter (center of table) picks up sound equally well from all directions.*



Depressing the ON OR QUIET *control on the control pad/transmitter activates the 4A speakerphone. Since it is not necessary to pick up the telephone handset for either dialing or talking, Bob Lindsay of the Speakerphone Group at Bell Laboratories' Indianapolis location can comfortably take notes or refer to his records during a conversation.*



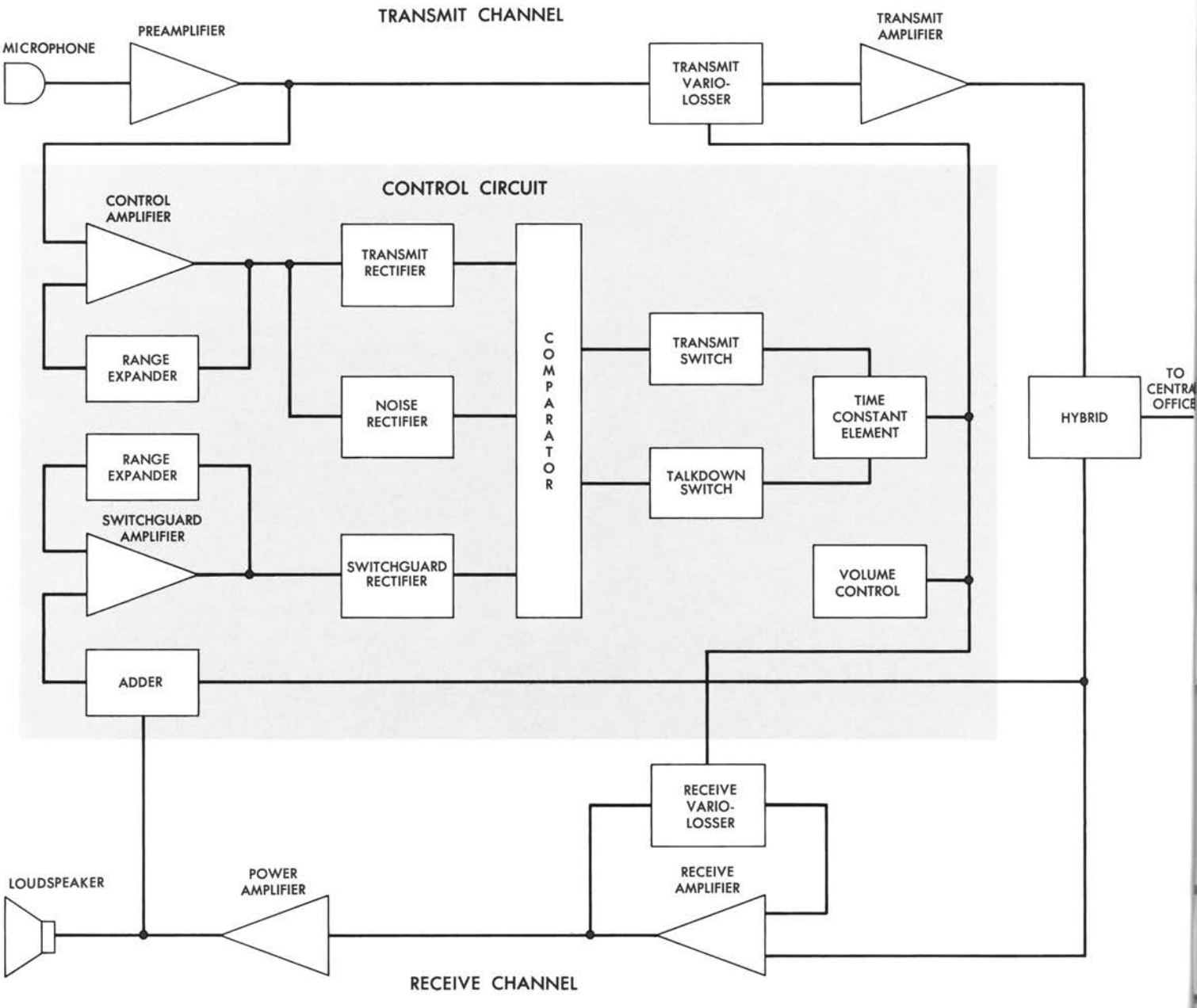
With this newly designed 82A connecting block (shown with its cover removed), installing the 4A speakerphone is almost as easy as plugging in an electric toaster. The cords from the loudspeaker and the transmitter plug into a single receptacle (left), along with a small plug (shown in place) that permits certain connection options. The center receptacle is for the cord of the telephone set, and the other connects to the telephone network. Since each plug has a distinctive shape matching that of its receptacle, no cord can be incorrectly connected.

integrated circuits developed for the 4A speakerphone are so small that we were able to place all the circuits inside the control pad and the loudspeaker unit, eliminating the wall unit. The major significance of the newly designed circuitry, however, lies in the service improvements that we were able to achieve. Primary among these is the improvement in voice switching—using the speaker's voice volume to determine whether the speakerphone will transmit or receive at a given moment. With voice switching, only one party, or group, can speak at one time. If both the local and the distant speaker try to talk simultaneously, the louder voice will determine the direction of transmission. When a distant speaker stops talking, the circuitry stays in the receive mode, since that is the speakerphone's "at rest" mode. But when a speakerphone user pauses, his speakerphone returns to the receive mode after a predetermined hold time.

But how long is the ideal hold time? The most satisfactory length will prevent switching during the local speaker's natural pauses but will trigger switching when the distant user begins to talk. A relatively long hold time is desirable to avoid choppy outgoing speech and eliminate unnecessary switching, provided that the distant party does not interrupt frequently. If he does interrupt, then a very short hold time is desirable to avoid the loss of his first syllable. The 3B speakerphone, the most recent model, uses a fixed hold time—a compromise resulting in slight choppiness in the initial outgoing word and occasional clipping of incoming interruptions. But the 4A adapts the length of its hold time to prevailing conditions. When the distant party does not interrupt, the hold time is relatively long; when he interrupts, the hold time is shortened. The result is an appreciable improvement in intelligibility for both the speakerphone user and the distant party. (For more detailed circuit information, see "The Inside Story," pages 236-237.)

The new control pad/transmitter departs significantly from previous designs. To raise the quality of transmitted speech closer to that obtained via a standard telephone, we reduced the sound level of the lowest-frequency signals. Softening the lowest frequencies also helps reduce the "barrel effect" that some people have found objectionable in earlier speakerphones. (This effect is the hollow sound caused by sound waves, mostly at low frequencies, reflected from the walls and furnishings of a room and picked up by a microphone that is some distance away from the talker.) Acoustic considerations require a small control pad/transmitter to eliminate sound-wave reflections, but small size is to the user's advantage. The 4A control pad can easily be moved about the room for conferences, or kept close at hand for easy use and better sound fidelity without taking up much space. We mounted the microphone face down toward the supporting surface. Oriented this way, the microphone can pick up sounds equally well from all directions. Thus, participants in a speakerphone conference no longer have to group themselves in front of the transmitter. They can merely place the control pad in the center of the room and remain as they were (see upper photo, opposite).

The 4A speakerphone uses a light-emitting diode (LED) as an on-off indicator lamp—one of the first Bell System applications of LEDs (see *Crystal Lamps are Lighting Up the Bell System*, RECORD, *November 1972*). The LED is superior to the incandescent lamp used in the 3B speakerphone because the LED is easier to see, yet uses less power. Other goals that we achieved in design-



ing the control pad were to protect the microphone from damage by making it almost completely inaccessible, and to make the rocker-switch control responsive to a user's touch. We also marked the control for "quiet" use to remind users that they have the option of temporarily turning off the microphone to keep a private conversation from being transmitted.

The new loudspeaker housing is slightly larger than that of preceding models because of the control circuitry packaged inside. But increasing the size of the enclosure, sealing it, and fitting it with a better loudspeaker have all helped to improve the sound fidelity of the new speakerphone. Since the loudspeaker unit does not need to be accessible, a user may place it in any convenient out-of-the-way location within 7 feet of the connecting block. (An optional cord increases this distance to 14 feet.)

As demonstrated in the field trial at Indianapolis, an installer can set up the 4A speakerphone in about half the time it takes for the 3B. First, there is no control unit to be mounted or connected. And second, the installer can connect the control pad, the loudspeaker, and a rotary-dial or TOUCH-TONE® key telephone simply by plugging their connectors into the new 82A connecting block designed for the 4A speakerphone (see the photo on page 235). Connecting a transformer to the screw

The Inside Story

Newly developed circuitry in the 4A speakerphone improved its performance over preceding models in several ways. The 4A's control circuit, for example, provides a variable hold time—the interval between "talk" and "listen" modes. In this circuit (color area in diagram opposite), signals from the microphone and the distant party's telephone line (upper left) are amplified and then passed to the rectifiers. The transmit rectifier and the switchguard rectifier produce dc voltages proportional to the audio level in the transmit and receive channels, respectively. The noise rectifier includes a special filter circuit that produces an output voltage for sounds remaining steady over long time periods (low-level sounds made, for example, by fans, air conditioners, and background traffic) but not for speech or other sounds varying rapidly in level. The comparator (center) then uses the outputs from the three rectifiers to determine whether the speakerphone should be in the transmit or receive mode and how fast the modes should change. This is how the comparator works:

- When a speakerphone user begins to talk, the voltage produced by the transmit rectifier becomes the largest of the three rectifier outputs. The comparator responds by activating the transmit switch, rapidly putting the transmit and receive variolossers into the transmit mode. (The variolossers work together as an automatic loss-control circuit—when the transmit variolosser inserts loss, the receive variolosser removes loss, and vice versa.)
- When the speakerphone user has stopped speaking but the distant party remains silent, the voltage from the noise rectifier becomes the largest output. In response, the comparator deactivates the transmit switch, and the time-constant element automatically allows a long hold time—a slow return of the variolossers to the receive mode.
- When the distant party begins to speak, the voltage from the switchguard rectifier becomes the largest output. In this case, the comparator deactivates the transmit switch and activates the talkdown switch, which allows only a short hold time—a rapid return of the variolossers to the receive mode. The variable hold time thus permits ready interruption of a speakerphone user's speech, along with a very smooth-sounding transmit mode, free of clipping on all syllables except the first.

We also redesigned the variolossers, which serve an important role in controlling gain during the mode changes just described. If gain were allowed to build up in the entire transmit/receive acoustic loop, the distant party would hear an echo of his own voice, and eventually oscillation or "singing" would occur. It is important, therefore, to maintain an unvarying total loop gain regardless of whether the speakerphone is transmitting, receiving, or holding. The variolossers—one in the transmit channel and one in the receive channel—maintain this constant gain by inserting equal loss or gain in one channel to balance a change in the other; the gains are said to "track inversely." In the 4A speakerphone, we ensure excellent inverse tracking by using identical variolossers, fabricated side by side on a single slice of silicon.

New integrated circuits to meet the 4A's design criteria were developed for other elements of the circuitry. The control and switchguard amplifiers, for example, were designed to add enough gain to low-level incoming signals to ensure a sufficiently strong input for the rectifiers to operate. The range expanders in the feedback paths of the control and switchguard amplifiers are nonlinear networks that greatly increase the dynamic range of the two amplifiers to ensure correct operation of the control circuit at all expected voice levels. As in earlier speakerphone designs, the volume control restricts the total amount of loss switched between the transmit and receive channels, particularly at low volume-control settings where the speakerphone operates under normal conditions. This restriction minimizes clipping and transmitted background noise.

terminals on the connecting block and plugging in the transformer complete the installation. For custom installation—when the associated telephone is not a plug-ended key set with six buttons—a newly designed 223A adapter is available.

Some key telephones ring—even if the phone is in use—whenever a call comes in on another line connected to the key set. The 82A connecting block has a small option plug that breaks the connection to the ringer when the speakerphone is in use. If this option is not needed, the installer merely reverses the option plug. This reversed position is also used for any installation that requires an auxiliary relay—for example, to switch on a "speakerphone in use" signal lamp at a secretary's desk. The same options are available with the 223A adapter.

The first production units of the 4A speakerphone went to Southern Bell for installation about mid-1973. A six-month appraisal study there is expected to clear up any related problems and provide enough Operating Company feedback so that the 4A can go into full production.

A small, inexpensive, easy-to-install speakerphone with transmission quality equal to that of an ordinary telephone has been a goal of the Bell System for a long time. The 4A speakerphone is a significant step in that direction.