

TECHNICAL PAPERS

The following 11 articles have been selected from the 28 finalists as representative of the diverse ideas that were submitted by the contestants. The papers by H. Levitt, M. Friedman *et al.*, and R. Hight were awarded first, second, and third prize, respectively.

HEARING, SPEECH, AND LANGUAGE

TELECOMMUNICATIONS DEVICES FOR THE DEAF

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The teletypewriter is an extremely valuable communication aid for deaf persons. It does, nevertheless, have several practical disadvantages, including the high initial purchase cost and subsequent maintenance costs (which include telephone charges). Teletypewriters also have a low rate of communication, are relatively inflexible in their mode of operation, and are of limited portability. A low-cost, mass-produced pocket computer has been programmed to resemble a teletypewriter but with the additional advantages of both memory and logic. The system is not only more powerful and more convenient to use than a conventional teletypewriter (especially since it is pocket sized) but is also less expensive.

Introduction

The teletypewriter was invented well over half a century ago, yet its potential benefit as an aid for the deaf was only begun to be realized in the past decade. This delay was not due to any lack of technological capability but rather to a slowness in recognizing its value as an aid for the deaf and in making such devices available to deaf persons in large numbers. An

important contributing factor was the relatively high cost of early telecommunication devices.

A turning point in the history of the teletypewriter for the deaf came in 1974 when a profoundly deaf physicist developed an acoustic-inductive coupling system that enabled two teletypewriter machines to communicate with each other over a standard telephone line.¹ This invention opened the door for profoundly deaf persons to the nation's vast telephone network, yet reaction to this development was slight at first. Teletypewriters were relatively expensive in those days, particularly for a deaf person whose earnings, on the average, were well below the national norm. Despite this inauspicious start, a national association was formed (Teletypewriters for the Deaf, Inc., Washington, D.C. 20013) and a Telecommunications for the Deaf network grew steadily. Since these devices do more than simply serve as teletypewriters, they are now referred to more generally as Telecommunication Devices for the Deaf (TDD).

A major increase in the rate of growth of the TDD network occurred in the late 1960's. Many of the components used in a TDD (e.g., keyboard, modem, acoustic coupler) are the same as those used in a computer terminal, and the growing large-scale mass production of the latter produced significant reductions in the cost of a TDD. Devices that once cost well over \$2000 were reduced to under \$1000. With this reduction in cost, many more deaf persons were able to afford a TDD, resulting in a sharp increase in the size of the TDD network.

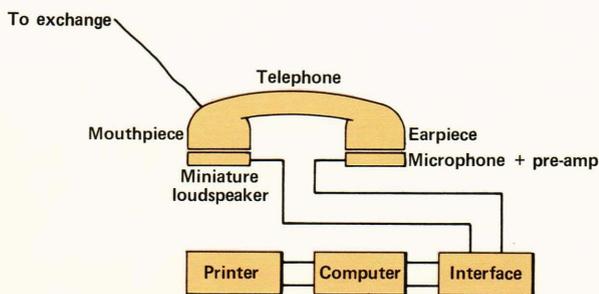
Despite its popularity and growing use, the TDD has several disadvantages. Most of the existing devices are heavy, relatively expensive pieces of equipment, but this appears to be a temporary situation. Recent innovations in microprocessor technology have brought down both the size and cost of a TDD, and inexpensive devices of small size are now reaching the market. A more serious problem is that TDD's are relatively slow, the rate of message transmission being determined primarily by the user's typ-

ing speed. Also, the mode of operation of TDD's is relatively inflexible and they have limited message-handling capabilities. Because of such limitations, TDD's make inefficient use of the telephone channel and hence are unnecessarily expensive in terms of telephone-connect time. The cost of buying and maintaining a TDD is probably still the largest single factor limiting the growth of the TDD network.

The time taken to communicate by means of typed messages is perhaps the most fundamental limitation of existing TDD's. Deaf users of a TDD have developed a variety of codes and communication strategies for reducing the excessive time spent in transmitting and receiving hand-typed messages. Hearing persons who are not adept at communicating by teletypewriter find the process frustratingly slow. Although there are groups and organizations that have installed TDD systems as a service device (e.g., direct TDD access to police, fire, and ambulance services, catalog shopping by TDD, and TDD links to government agencies), relatively few hearing persons use the TDD network. At present the network is still primarily a deaf-users group, with few links to the larger, hearing community.

The inconvenience and the practical problems associated with the use of conventional TDD's have resulted in only distinct and relatively limited use of the nation's vast telephone network by deaf persons. In contrast, because of the convenience of communication by telephone, hearing persons use the telephone system in many different ways for many different purposes.

A particularly important form of communication is the urgent or unanticipated call made from an unexpected place. Hearing persons typically use the nearest public telephone for this purpose — a possibility denied to the deaf person unless a TDD happens to be conveniently accessible. One way of circumventing this problem is to use the buttons of a conventional push-button telephone as a keyboard for transmitting messages,² but this approach requires the use of some form of coding since there are nearly three times as many characters in the English alphabet as there are buttons on a push-button telephone. A special decoder is also necessary for reading any messages transmitted in this way.



Pocket computer and interface enable a deaf person to communicate from any standard telephone.

Another possibility is to treat the TDD in much the same way as a much-valued credit card and "never leave home without it." One of the marvels of modern technology is that fairly sophisticated, inexpensive calculators are now being manufactured that have the dimensions of a wallet-sized credit card. These devices include a keyboard and display panel. Pocket-sized TDD's using many of the components of mass-produced hand-held calculators have recently been introduced,³ although the impact of these devices on the market has yet to be felt.

Development of a Pocket Computer Aid for the Deaf

The purpose of this paper is to show how a modern off-the-shelf pocket computer can be programmed to serve as a pocket teletypewriter, but with the additional advantages of memory and logic. The program described is one of several written for the Radio Shack TRS-80 pocket computer and is designated TTY-1. Two types of program are stored in the computer memory — the main program, which stores and organizes the messages to be transmitted, and a set of 10 reserve programs, each of which is accessed directly by the touch of a single button. Each reserve program performs a specific function.

A special plastic template is fitted over the keyboard so that each of the reserve buttons used in calling up a reserve program can be given a convenient label. For example, the button labeled M3 is associated with message number 3 stored in memory. Pressing this button in calling up a reserve program will recall the message from memory, display it momentarily on the screen, and then transmit it. If the wrong message is displayed (e.g., the wrong button is pressed), transmission can be forestalled by pressing the BREAK button, which interrupts the program. A second pressing of the BREAK button returns the program to its starting point.

Table 1 shows the labels assigned to the 10 reserve programs and their associated operations when the appropriate reserve button is pressed. Note that the reserve buttons are all uppercase; i.e., the SHIFT key must be used prior to pressing a reserve button.

When the reserve program for writing a message (WR) is activated, the user is provided with helpful instructions (e.g., when to enter the message, an indication whenever a line of 21 characters is completed, and a warning whenever the memory is within one line of being filled completely). When in the WRITE mode, any button on the keyboard can be used. These include the English alphabet, numerals from 0 to 9, punctuation marks, several mathematical symbols, and special keys for correcting typing errors. It is not advisable to use the full keyboard if compatibility with conventional TDD systems is a goal. For communication with other TRS-80 pocket computers, there is no limitation as to which symbols can be used. For convenience, a removable plastic template (of the type used to label the reserve but-

Table 1 — List of reserve programs.

<i>Button Label</i>	<i>Operation</i>
M1	Retrieve, display, and transmit message No. 1 (one line)
M2	Retrieve, display, and transmit message No. 2 (one line)
M3	Retrieve, display, and transmit message No. 3 (one line)
M4	Retrieve, display, and transmit message No. 4 (one line)
M5	Retrieve, display, and transmit message No. 5 (one line)
M6	Retrieve, display, and transmit message No. 6 (one line)
RD	Read message currently in temporary memory (up to 13 lines)
WR	Write message into temporary memory (up to 13 lines)
OUT	Transmit message in temporary memory
IN	Receive and display message from sender, store in temporary memory (can be reread)

tons) can be used to identify those symbols compatible with conventional TDD use.

The reserve programs are the ones most commonly used and hence have been designed to be particularly easy to activate, i.e., only one button need be pressed in addition to the SHIFT key. The system can perform many additional operations, the most important of which are shown in Table 2, together with a brief description of each operation. Two types of instructions are shown in the table: those that are program instructions (i.e., instructions that are specific to the TTY-1 program) and those that are control instructions for the TRS-80 pocket computer.

When the ENTER RUN 500 instruction is used, a message is displayed asking the user to identify, by pressing the appropriate reserve button, which message is to be stored. When this is done, the message can then be entered. The computer counts the number of lines entered and warns the user of memory overflow.

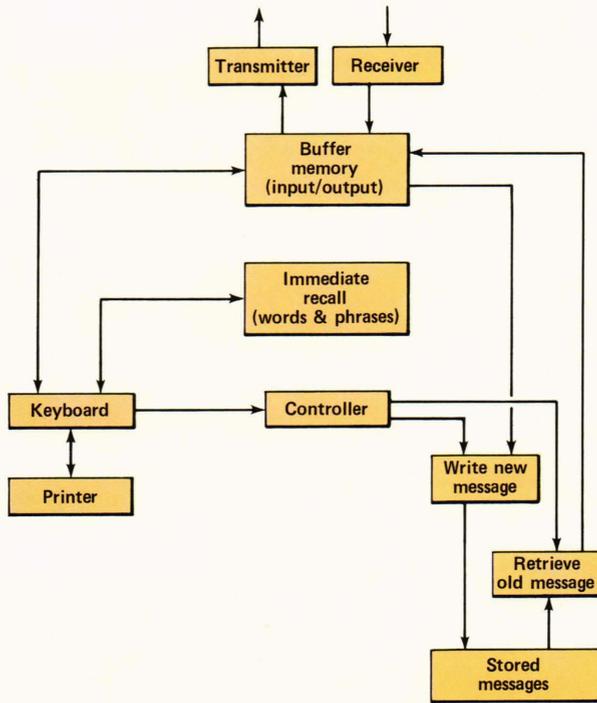
In addition to the instructions shown in Table 2, there are several more complex operations that an experienced user can employ. These operations include editing or correcting errors in messages to be transmitted, storing in memory or on an audio cassette tape a message that has just been received, composing longer messages by concatenation of several shorter previously stored messages, using audio cassette tape for the preparation of very long messages, and transmitting only a selected section of a stored message. Such capabilities open up the possibility of using the system as a text editor.

The computer can also be used for the purpose for which it was designed — computing. At any point where a break occurs in the program (e.g., immediately after a transmission or after pressing the BREAK key twice), the computer can be used for computational purposes, using all of its available mathematical functions. The only limitation is that a specific subset of registers should be used as memory so as to avoid overwriting any of the stored messages.

The program described here (TTY-1) is structured to store three one-line messages, three three-line messages, and one 13-line message. Each line has been programmed to consist of three seven-letter words (i.e., 21 characters). A revised program (TTY-2) can store one long message of over 50 lines instead of several short messages. Special reserve buttons are also used to store commonly used words or phrases that can be inserted, at the touch of a button, into the text of the message being prepared for transmission.

Table 2 — Instruction set.

<i>Instructions</i>	<i>Operation</i>
<i>PROGRAM INSTRUCTIONS</i>	
SHIFT	Recall and run reserve program number i (see Table 1)
Key #i ENTER RUN 500	Write and store message in memory (instructions appear on display, as needed)
ENTER	
<i>CONTROL INSTRUCTIONS</i>	
ON (also labeled CA/BREAK)	Switch on computer if power is off; interrupt program if computer is on; if pressed twice, interrupt and restart program
CSAVE "TTY-i"	Transmit program
ENTER	
CLOAD "TTY-i"	Read and store new program labeled TTY-i; i can be any character
ENTER	
CLOAD? "TTY-i"	Check whether a program being read in is identical to the one currently stored in the computer
ENTER	



Flow diagram showing access to messages stored in a pocket computer memory.

Programs TTY-1 and TTY-2 have been displayed for persons having no knowledge of computers. These programs provide helpful hints and instructions to the user and are protected against misuse. The cost of providing a user-oriented program is that much of the computer memory is taken up by the program. The word-processing capabilities of the program are also limited (because of memory limitations). A much more powerful program (labeled TTY-3) is for persons having some experience with computers. In this case, the program can be lost or damaged by the user, but replacing the program is neither difficult nor time consuming. With this system, the user has much more flexibility in storing, retrieving, and editing phrases, sentences, or even whole paragraphs, thereby facilitating the process of preparing typed messages.

It is a relatively simple matter to change programs, as is shown by the instructions in Table 2. It is important, however, when communicating with another TRS-80, that the programs in both computers are compatible. A simple way of ensuring this is to always start a communication with a common program (e.g., TTY-1) and then, if the situation requires a special-purpose program, read that program as needed into both computers. The new program can be read in from an audio cassette tape or from another TRS-80 pocket computer.

The transmission of signals to and from the TRS-80 pocket computer is simple. A plug is available for reading signals into or out of the computer. A miniature interface, available from the manufacturer, converts these signals into a train of tone pulses that can be recorded using a conventional audio cassette re-

recorder or, with a slight modification, transmitted over a telephone line. An optional accessory is an inexpensive line printer that produces hard copy of all signals transmitted from or received by the computer.

“The TRS-80 pocket computer costs only \$150, and an inexpensive modem plus coupler should cost about \$50.”

At present, the code used by the TRS-80 pocket computer is not compatible with either of the two standard codes in current use (ASCII or Baudot). A converter could be developed to allow the TRS-80 pocket computer to communicate with other standard telecommunication devices, but it would be much simpler and more economical in the long run if the design of the pocket computer were modified to include a standard communication code.

The system described above has many advantages. It facilitates and speeds up communication by means of stored messages or components of messages (e.g., commonly used words). The basic instrument is pocket sized, thereby allowing the deaf user to have it readily available at all times. Further, messages can be prepared before making the telephone call (e.g., while traveling on a bus or train), and messages can be sent and received from any available telephone. The system is also upwardly expandable. An additional pocket computer or a personal home computer can be added to the system either to increase memory or to increase transmission speed by using one computer as a buffer while messages are prepared on the second. A personal home computer can also be used to strengthen the word-processing capabilities of the system.

A remarkable aspect of the system described here is its low cost. The TRS-80 pocket computer costs only \$150, and an inexpensive modem plus coupler should cost about \$50. Two useful, but not essential, accessories are a miniature line printer (currently available at \$150) and a cassette recorder of reasonable quality (typical cost, \$50). The cost of an entire system, including optional accessories, is less than that of a conventional TDD. An additional financial advantage of the computer system is that, since messages are sent from a buffer memory, packets of information can be sent in short bursts to reduce the cost of telephone-connect time.

Future Developments

In terms of future developments, two exciting possibilities are immediately apparent. One is to use the pocket computer to control a conventional TDD at the user's home so that it behaves as an intelligent communication terminal. Another is to use the computer as an intelligent buffer for a touch-shorthand typewriter (e.g., the type of instrument used by court reporters). In this way messages can be typed, trans-

mitted, and received at rates comparable to those of normal speech.

Perhaps the most important advantage of all is that the use of a pocket computer as a convenient, inexpensive communication device introduces the deaf TDD user to the concept of an intelligent, computer-based communication system of almost unlimited scope and flexibility. Breaking the cost barrier should be regarded as only the first step in developing considerably more powerful communication tools for

the deaf. Devices such as these could do much to help break down the communication barriers between deaf and hearing users of the telephone system.

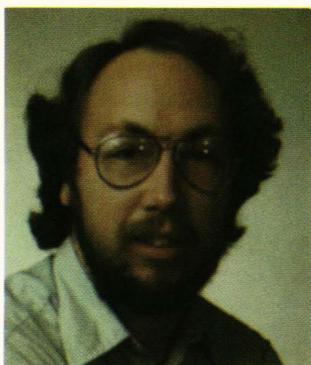
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LIP-READER TRAINER

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Lip reading is the most difficult method of communication for the hearing-impaired person to learn. Once learned, however, it provides the hearing-impaired person with an important and valuable means of communicating with others. This paper presents an experimental software package that has been developed as a training aid to assist the parent or instructor in teaching lip reading to the hearing-impaired child or student. This article discusses the need for such a program, considerations of program design, a general description of the program, and future directions for the Lip-Reader Trainer.

Need for Assistance

Verbal communication between people is based on the transmission and reception of sound patterns that have been assigned definite meanings. These sound patterns are called words, and the sound segments that make up the words are called phonemes. When words are heard by a person, they are individually matched in memory to previously learned word patterns and assigned meanings. Lip reading requires a similar translation process for communicating except that, instead of matching auditory patterns with ideas or meanings, visual patterns are substituted. The visual patterns are formed during the utterances

of the phonemes that create the words being spoken. Although there are over 60 phonemes in the English language, as few as 18 produce visually identifiable shapes. The rest either exhibit no visual features or take on the appearance of other phonemes. It is apparent that learning to associate phoneme shape patterns with words is quite difficult. Generally, an instructor or person knowledgeable in the correlation of phoneme shape to the phoneme is needed to teach the student. Further, much time is required to teach a person to lip-read, and an even greater amount of time is required for practice. Practicing also requires a willing and patient partner.

The Lip-Reader Trainer is an experimental software package for the Apple II microcomputer that converts typed sentences into animated mouth movements. It provides the instructor or parent with a training aid that presents the correct correlations of mouth configuration to phoneme, and easy-to-use animation controls. It also provides a flexible means to animate any words or sentences. In addition, the Lip-Reader Trainer is a patient partner who has as much time as the user wishes to take.

Design Criteria and Program Development

The design of the Lip-Reader Trainer had three main criteria: (a) to produce correct correlations of lip, teeth, and tongue configuration to phoneme; (b) to keep program memory requirements under 48K; and (c) to keep the programs easy to use. The first was the most difficult. Phoneme shapes are very personal in that everyone talks differently, even though they produce the same words. The position of the mouth, teeth, and tongue must form a certain configuration for each phoneme, yet the way that a phoneme appears can vary widely for different people. The phoneme shapes that were designed for the Lip-Reader Trainer are idealized and stylized shapes that clearly represent each of the 18 phonemes. Further, the shapes are presented from a straight-on view with the mouth at eye level.