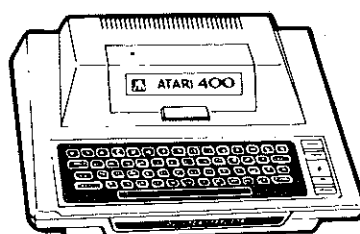


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**SOLID-STATE DEVELOPMENTS**

By Forrest M. Mims

**Solid-State Speech**

**B**Y NOW, you have probably heard samples of solid-state speech produced by such devices as the Speak & Spell® educational trainer manufactured by Texas Instruments or the Voice Challenger® chess game by Fidelity Electronics. If not, you are in for a treat—amazing progress has been made in the field of digital speech generation.

My first exposure to solid-state speech occurred in 1975, when two companies demonstrated talking calculators at a conference on electronic aids for the blind. Both machines produced intelligible spoken renditions of the symbols and numbers marked on their keys as well as visual displays.

The speech quality of Speak & Spell is at least as good as that of the talking calculators. This is true even though Speak & Spell requires considerably less memory per spoken word. This is the

result of highly sophisticated circuits that model the human vocal tract.

The latest speech-generation circuits are highly complex. The need for this complexity is explained by the nature of the human vocal tract. An in-depth dis-

cussion of the mechanism that converts streams of exhaled air into intelligence-bearing sounds is beyond the scope of this column. Suffice it to say that speech is generated by intricate cooperation of the diaphragm, lungs, vocal cords, air passages, resonant cavities (both fixed and adjustable ones), and the lips, tongue and teeth.

**Generating Solid-State Speech.** There are three major methods of generating solid-state speech. The first is the equivalent of the magnetic tape recorder. Spoken words are digitized by an analog-to-digital converter (ADC) and stored directly in memory. Solid-state speech is produced when the contents of the memory are clocked out of the mem-

(Continued on page 72)

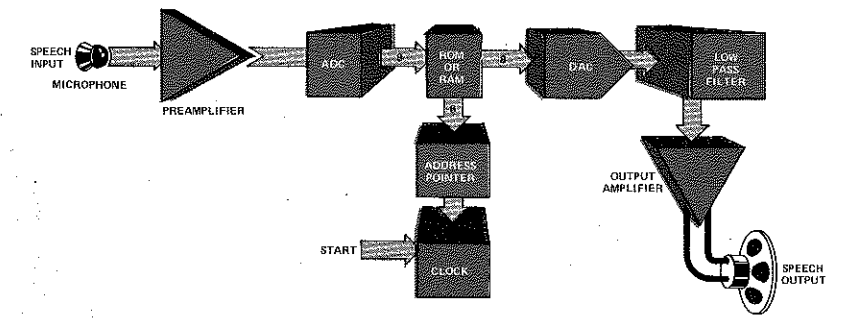


Fig. 1. Direct storage of speech in solid-state memory.

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ory, processed by a digital-to-analog converter (DAC) and then smoothed by a low-pass filter and amplified. A block diagram of this appears in Fig. 1.

This direct-storage method was used very effectively in the first talking calculators. Unfortunately, however, considerable memory space is required for even small amounts of speech. For example, a system of this type might store speech in 8-bit samples loaded into memory at a clock rate of 8 kilohertz. One second of speech, therefore, would require 64,000 bits of memory.

The required amount of memory can

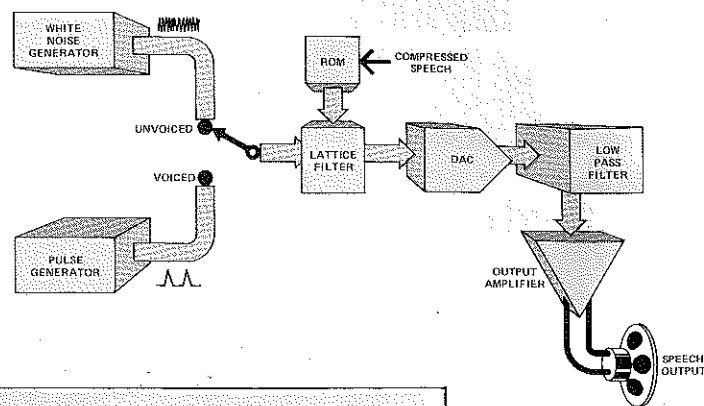
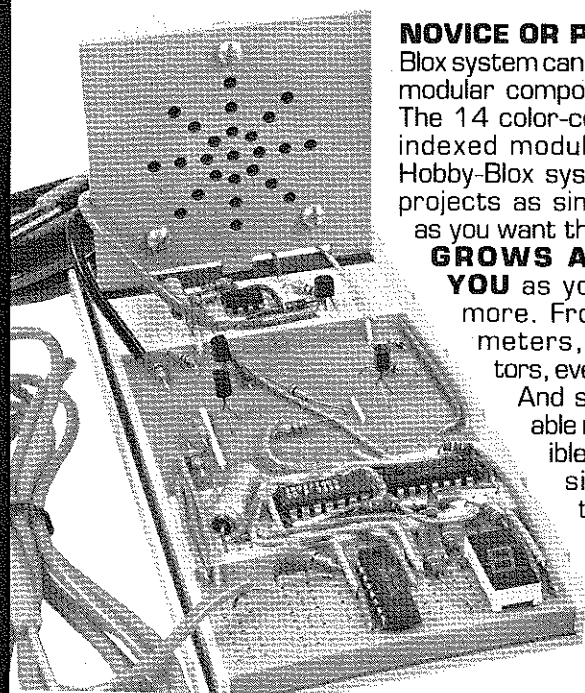


Fig. 2. The linear predictive coding method of speech synthesis.

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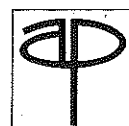


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be considerably reduced by storing only the relatively small number of basic speech sounds or *phonemes* required to produce any spoken word. This is what is done in the second major form of speech generation. Stored phonemes are electronically combined to produce any desired word in any language.

Unlike the method in which entire words are stored, the phoneme storage and reconstruction method provides truly synthesized speech. It also provides a virtually unlimited vocabulary. Unfortunately, as computer enthusiasts who have tried this method have found, stringing together phonemes produces unnatural, "robotic" sounding speech.

The third method of speech generation is also a form of synthesis. In this method, words are analyzed for distinguishing features that are quantized and stored in digital form. The compressed words are then reconstructed by sophisticated electronic processing.

Individual words consist of a small number of frequency and amplitude variations followed by intervals of redundant signal. By extracting the key frequency and amplitude variations and the time intervals between them and ignoring inconsequential signal, a word can be electronically dissected and compressed. Speech processed in this way can be loaded into much less memory than otherwise would be required. The procedure used for compression and conversion is called *parametric speech analysis* and requires sophisticated computer techniques and a good deal of human effort.

Two of the methods used to recreate compressed speech are *linear predictive coding* (LPC) and *adaptive predictive coding* (APC). The former, LPC, is the method used by Texas Instruments in its Speak & Spell, Speak & Read® and Speak & Math® learning aids. It is also used by General Instrument in its *Orator* SP-0250 speech processor chip.

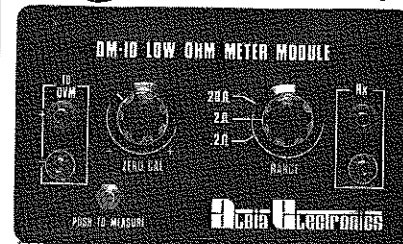
An LPC synthesizer circuit (Fig. 2) is an electronic analog of the human vocal tract. In operation, a periodic train of pulses or a white-noise signal is applied to a sophisticated, digital lattice filter which, under the control of the compressed-speech data stored in the memory, reproduces the original speech pattern. A digital-to-analog converter transforms the digital output of the fil-

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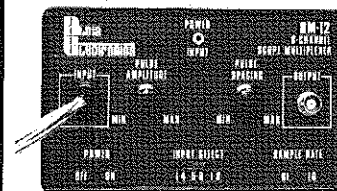
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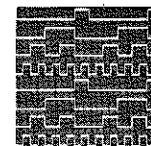
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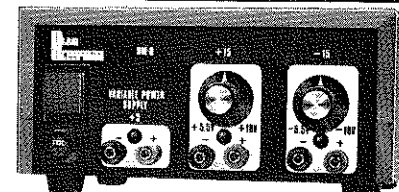
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solid-state developments

ter into an analog signal, which is then smoothed by a low-pass filter and used to drive a speaker.

The LPC method synthesizes speech at rates from 1200 to 2400 bits per second. Texas Instruments implements LPC with a three-chip set consisting of a TMC 0280 synthesizer, a TMC 0350 16,384 x 8-bit ROM and a TMC 0270 microprocessor-controller.

National Semiconductor has recently introduced a speech-synthesizer chip set that uses a somewhat simpler approach. Words are compressed and stored in a standard 16K, 32K or 64K ROM and reconstructed by a special-purpose,

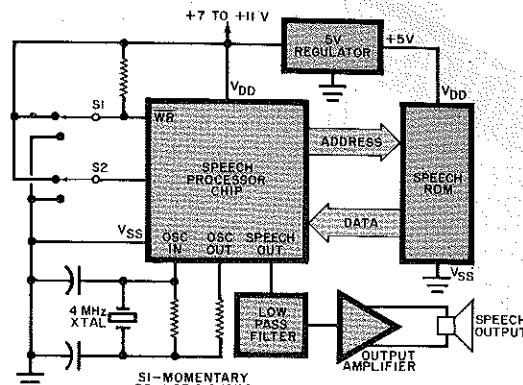


Fig. 3. National Semiconductor's speech processing system.

speech-processor chip. The latter contains a programmable frequency generator and a variable-gain DAC.

National's speech-processor chip can directly address up to 256 words or expressions stored in up to 128K of ROM. Much larger vocabularies can be obtained by cascading additional ROMs.

A simplified circuit diagram of a complete synthesizer made from National's speech-processor chip and an external ROM is shown in Fig. 3. This chip is available with a custom-encoded ROM or preassembled into National's DT1000 DIGITALKER®.

The DT1000 comes on a single circuit board complete with a speech-processor chip, a ROM, a microprocessor, and an output amplifier. It can generate any of 144 preprogrammed words, selected by a self-contained keyboard.

The DT1000 sells for \$495. If that seems high, consider the fact that National charges \$599 to custom encode just one word of male speech. Female speech requires a higher data rate, and the cost is \$700 per word! The customer supplies a high-quality tape recording of the desired words or phrases, and National compresses and loads the digitized version in the ROM. The synthesized output preserves the original inflection, emphasis, and timbre of the speaker's voice.

**Summing Up.** If you have yet to hear a sample of solid-state speech, be sure to visit a store that sells Speak & Spell or similar talking products. For a sample of National's very realistic-sounding synthesized speech, dial 408-737-3939 (a toll call). You'll hear an assortment of common phrases such as "Please call your office," "Going up," "The temperature is . . ." and others in male, female and children's voices.

Soon, it seems, electronic speech will be a common part of everyday life. You can already buy talking clocks, calculators, toys and games. Next will come talking vending machines, elevators, appliances, test equipment, aids for the blind, automobiles and many other devices which now convey information to their users via analog or digital meters, readouts or gauges.

**For More Information.** If you are interested in solid-state speech, rather than directing your inquiries to this column, it would be better to contact di-

solid-state developments

rectly the companies that produce various kinds of electronic-speech generators. These devices employ sophisticated hardware and software, and some of the firms that make them have prepared information and specification sheets explaining their products in detail.

Some of the manufacturers of solid-state speech modules and chips are:

**Texas Instruments**  
M/S 308  
Box 225012  
Dallas, TX 75265

**National Semiconductor Corp.**  
2900 Semiconductor Dr.  
Santa Clara, CA 95051

**Microelectronics Div.**  
General Instrument Corp.  
600 West John St.  
Hicksville, NY 11802

**Telesensory Systems, Inc.**  
3408 Hillview Ave.  
Box 10099  
Palo Alto, CA 94304

**Stynetic Systems, Inc.**  
Flowerfield Buildings 1  
Saint James, NY 11780

**Votrax Division**  
Federal Screw Works  
Troy, MI

Other firms are also involved with or preparing to enter the speech-synthesis business. As developments occur, they will be described here.

**New Products.** Datal-Intersil (11 Cabot Blvd., Mansfield, MA 02048) has introduced a miniature 3½-digit LED digital panel meter that sells for \$38.50 in single-unit quantities. The new meter, designated the DM-31, measures only 3.5" x 2.0" x 0.5" and utilizes large (0.56" high) digits. It reads from 0 to ±1.999 volts dc. Write to the company for additional specifications.

National Semiconductor (2900 Semiconductor Dr., Santa Clara, CA 95051) has introduced a new voltage-regulator chip, the LM330, that it claims has a lower minimum input-to-output differential voltage than any other fixed-output regulator—0.32 volt at 150 milliamperes. Conventional 5-volt regulators require an input of at least 7 volts. The LM330, however, will provide a 5-volt output even if the input voltage falls to 5.32 volts.

The LM330 offers the possibility of longer operating intervals between cell replacement or recharging in battery-powered equipment. It also makes it possible to power such equipment with a 6-volt battery.

The automotive version of the LM330 is the LM2930. Both these new chips are made using a new, deep-diffusion process. They are protected against reverse-polarity connection and will be available for under a dollar. Write to National for additional information. ♦

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