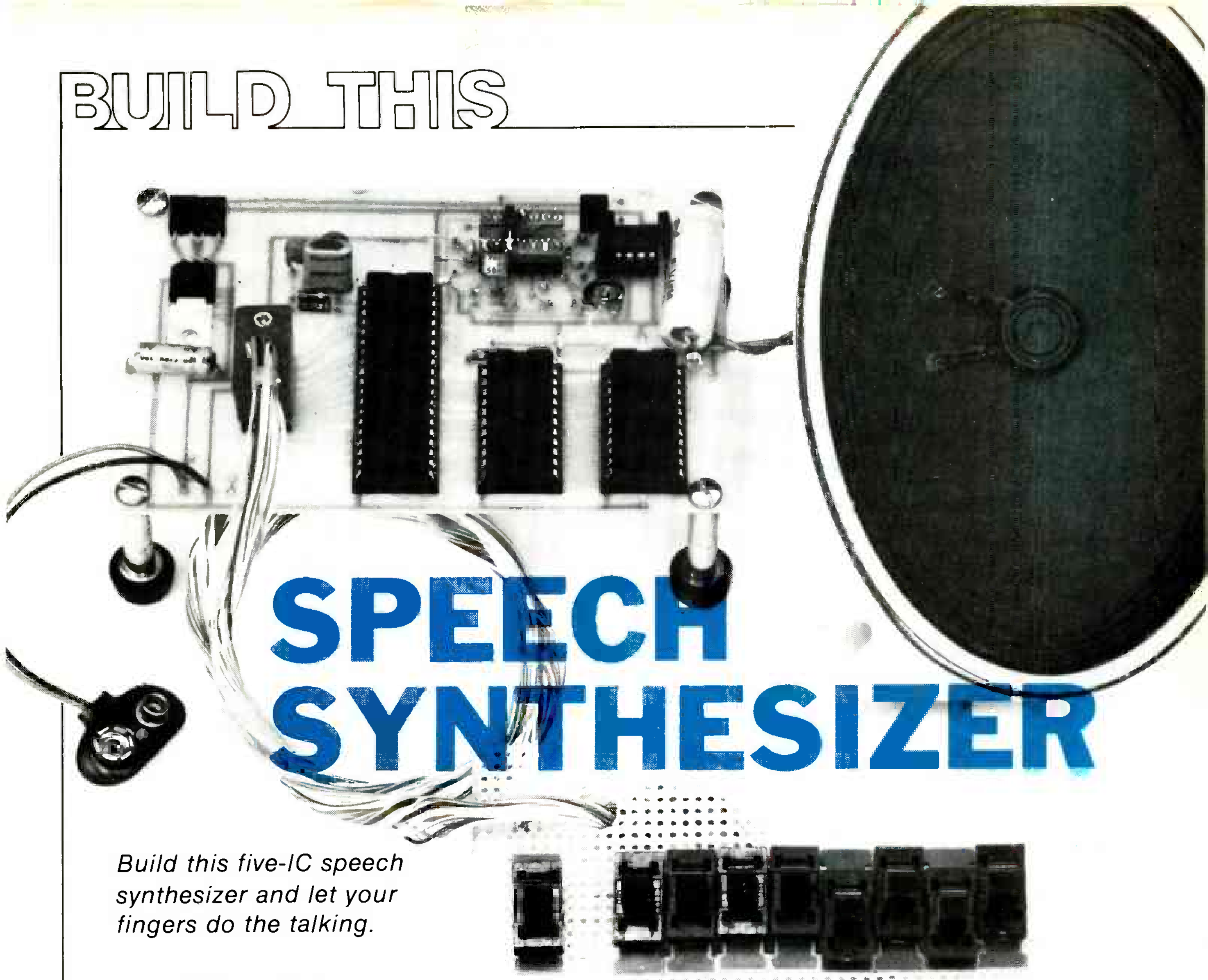
BUILD THIS



SPEECH SYNTHESIZER

Build this five-IC speech synthesizer and let your fingers do the talking.

L. STEVEN CHEAIRS

WHETHER THEY'RE USED FOR INSTRUmentation or for practical applications, many electronic devices provide us with visual readouts. Those can range from simple indicator lights to complex LED or LCD arrays, up to and including alphanumeric displays.

Frequently, though, it would be useful to have the information without having to look at the device. There are already DMM's that provide an audible continuity-test function using a tone, but wouldn't it be convenient if the meter could tell you what voltage was being measured so you wouldn't have to take your eyes off your work? Or, how about your own talking clock—one that *really* "tells time?"

What's required for devices of that sort is speech synthesis. And while speech synthesizers have been with us for a while, it is only recently that they have been reduced to a couple of IC's and their cost come down to a reasonable level. One such speech-synthesis system is the *Digitalker* from National Semiconductor.

About the circuit

The *Digitalker* system consists of three N-channel MOS integrated circuits. The main IC is referred to as the *S*peech-*P*rocessor *C*hip, or SPC; its pinout is shown in Fig. 1. The other two IC's (see Fig. 2) are ROM's containing the speech data that is processed by the SPC to produce words or phrases. Add a power supply, clock network, filter, and an audio amplifier to the *Digitalker* IC's and you will have a system that produces high-quality speech. That synthesized (actually, reconstructed) speech has the natural inflection and emphasis of the original speech. Male, female, and children's voices can be reproduced easily. (Some other speech-synthesis systems have had difficulties in reproducing the higher frequencies required for other than male voices.)

The *Digitalker's* ROM's store only those speech elements that the ear needs to hear. (The vocal tract also generates sounds that do not convey any intelligible information.) The techniques used by National to process a speech waveform are broken into two basic categories: digitization and compression.

Recordings of actual speech are sampled for digitization (turning analog values into binary numbers) at a rate at least twice that of the highest frequency in the waveform's pattern. If the highest frequency to be used were 3000 Hz, the sampling frequency would have to be at least 6000 Hz. That sampling frequency is called the Nyquist rate.

To minimize the storage space needed for the speech information, Dr. Forrest S. Mozer developed four compression schemes. The first removes all redundant (unnecessarily repeated) pitch

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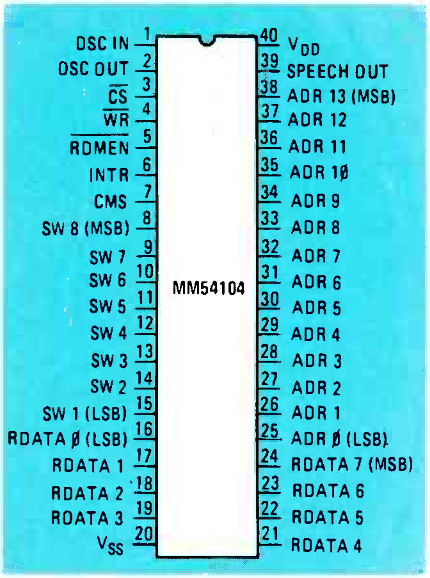

FIG. 1—THE HEART OF THE SPEECH synthesizer is National Semiconductor's MM54104.

periods and portions of certain other pitch periods. Redundant phonemes (individual sounds that, when strung together, make up speech) are also removed at this stage.

The second stage of compression, adaptive delta-modulation, involves storing the arithmetic differences of successive wave-amplitudes. By using that technique, rather than storing the amplitude values themselves, storage requirements are further minimized.

The third compression technique removes the direction component of the speech waveform. That is done by a process called phase-angle adjustment. The ear doesn't use that component, so its removal will not affect speech quality.

The last compression technique allows the amount of ROM required to store the speech data to be reduced by 50%. It does that by reducing the low-amplitude portion of a waveform to silence.

The result of using multiple compres-

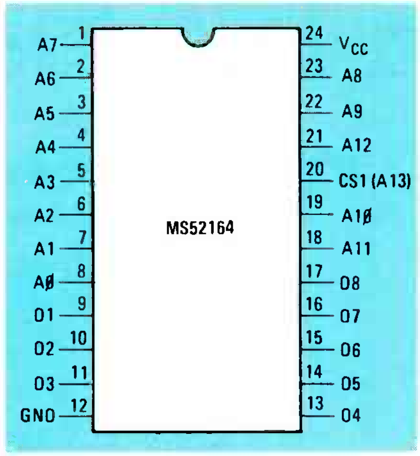

FIG. 2—THE MM52164 is a 8192 × 8 ROM used to contain speech data.

TABLE 1

Word	8-bit binary address S8 S1		8-bit binary address S8 S1		8-bit binary address S8 S1
THIS IS DIGITALKER	00000000	Q	00110000	IS	01100000
ONE	00000001	R	00110001	IT	01100001
TWO	00000010	S	00110010	KILO	01100010
THREE	00000011	T	00110011	LEFT	01100011
FOUR	00000100	U	00110100	LESS	01100100
FIVE	00000101	V	00110101	LESSER	01100101
SIX	00000110	W	00110110	LIMIT	01100110
SEVEN	00000111	X	00110111	LOW	01100111
EIGHT	00001000	Y	00111000	LOWER	01101000
NINE	00001001	Z	00111001	MARK	01101001
TEN	00001010	AGAIN	00111010	METER	01101010
ELEVEN	00001011	AMPERE	00111011	MILE	01101011
TWELVE	00001100	AND	00111100	MILLI	01101100
THIRTEEN	00001101	AT	00111101	MINUS	01101101
FOURTEEN	00001110	CANCEL	00111110	MINUTE	01101110
FIFTEEN	00001111	CASE	00111111	NEAR	01101111
SIXTEEN	00010000	CENT	01000000	NUMBER	01110000
SEVENTEEN	00010001	400HERTZ TONE	01000001	OF	01110001
EIGHTEEN	00010010	80HERTZ TONE	01000010	OFF	01110010
NINETEEN	00010011	20MS SILENCE	01000011	ON	01110011
TWENTY	00010100	40MS SILENCE	01000100	OUT	01110100
THIRTY	00010101	80MS SILENCE	01000101	OVER	01110101
FORTY	00010110	160MS SILENCE	01000110	PARENTHESIS	01110110
FIFTY	00010111	320MS SILENCE	01000111	PERCENT	01110111
SIXTY	00011000	CENTI	01001000	PLEASE	01111000
SEVENTY	00011001	CHECK	01001001	PLUS	01111001
EIGHTY	00011010	COMMA	01001010	POINT	01111010
NINETY	00011011	CONTROL	01001011	POUND	01111011
HUNDRED	00011100	DANGER	01001100	PULSES	01111100
THOUSAND	00011101	DEGREE	01001101	RATE	01111101
MILLION	00011110	DOLLAR	01001110	RE	01111110
ZERO	00011111	DOWN	01001111	READY	01111111
A	00100000	EQUAL	01010000	RIGHT	10000000
B	00100001	ERROR	01010001	SS	10000001
C	00100010	FEET	01010010	SECOND	10000010
D	00100011	FLOW	01010011	SET	10000011
E	00100100	FUEL	01010100	SPACE	10000100
F	00100101	GALLON	01010101	SPEED	10000101
G	00100110	GO	01010110	STAR	10000110
H	00100111	GRAM	01010111	START	10000111
I	00101000	GREAT	01011000	STOP	10001000
J	00101001	GREATER	01011001	THAN	10001001
K	00101010	HAVE	01011010	THE	10001010
L	00101011	HIGH	01011011	TIME	10001011
M	00101100	HIGHER	01011100	TRY	10001100
N	00101101	HOUR	01011101	UP	10001101
O	00101110	IN	01011110	VOLT	10001110
P	00101111	INCHES	01011111	WEIGHT	10001111

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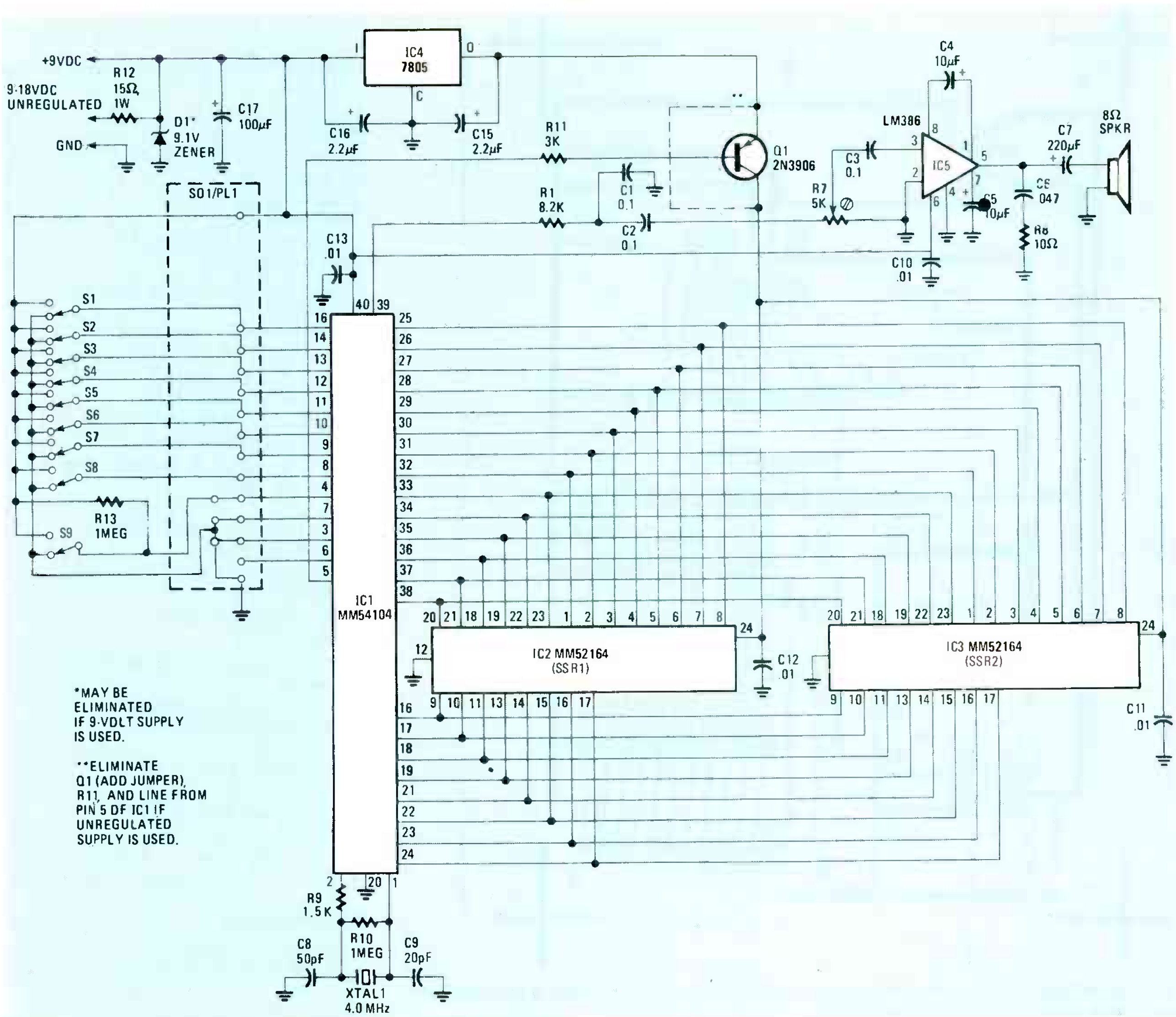

FIG. 3—SPEECH SYNTHESIZER can be operated from either a 9-volt battery or an unregulated DC-supply. See text for more details.

sion-techniques is a system capable of storing and reconstructing a word or phrase with high quality.

How it works

The complete speech-synthesizer circuit consists of the speech processor IC (SPC), plus the speech ROM's, power supply, filter, and audio amplifier. The speech data is mask-programmed into the ROM's by National Semiconductor, starting from an ordinary analog tape containing the words and phrases required.

The speech waveforms are time-domain compressed, eliminating a great deal of the number-crunching required by other techniques to reconstruct the digitized word. Because of that, the SPC can operate at lower clock-frequencies, and the speech-reconstruction circuit becomes simpler to build. Inside the SPC there is a programmable frequency-generator and a variable-gain D/A converter. Together, they produce the intonation and inflection that make for realistic-sounding speech.

The ROM set specified in the Parts List is programmed with a vocabulary (see Table 1) consisting of 136 words, one complete phrase, two tones, and five different silence durations. The words are in a male voice and the phrase is in a female voice. Each word or phrase to be synthesized is assigned an 8-bit address. Address 81H (the "H" indicates that the number is hexadecimal) is the "ss" hissing sound; it is used after a word to make it plural. All addresses higher than 8FH are invalid and will result in garbled sounds.

The circuit, shown in Fig. 3, is quite simple to build. It can be powered either by a 9-volt transistor battery connected to the REGULATED DC input or from 9 to 18-volts DC applied to UNREGULATED input. Resistor R12 and Zener diode D1 are used to obtain 9-volts if an unregulated source is used; they may be omitted if a 9-volt battery is used. The 9-volts is used by the SPC and the audio amplifier.

Power for the ROM's (5-volts) is derived from the 9-volt supply by IC4, a 7805 5-volt regulator. That power can be switched on or off by the SPC's ROMEN line using resistor R11 and transistor Q1, a useful feature for extending battery life. If an unregulated supply derived from a transformer is used you can omit R11 and Q1 and add a jumper between the pads for what would have been Q1's collector and emitter.

A clock network—resistors R9 and R10, capacitors C8 and C9, and XTAL1—is used with active components inside the SPC IC form a 4-MHz clock. The remaining circuits are the filter and audio amplifier.

The filter is a simple passive R-C circuit whose component values are chosen for a 200-Hz rolloff frequency. The output of the filter is supplied to a voltage divider, which acts as a volume control. The signal is then amplified by IC5, which drives a 8-ohm speaker. (Use a fairly large speaker—small 2¼-

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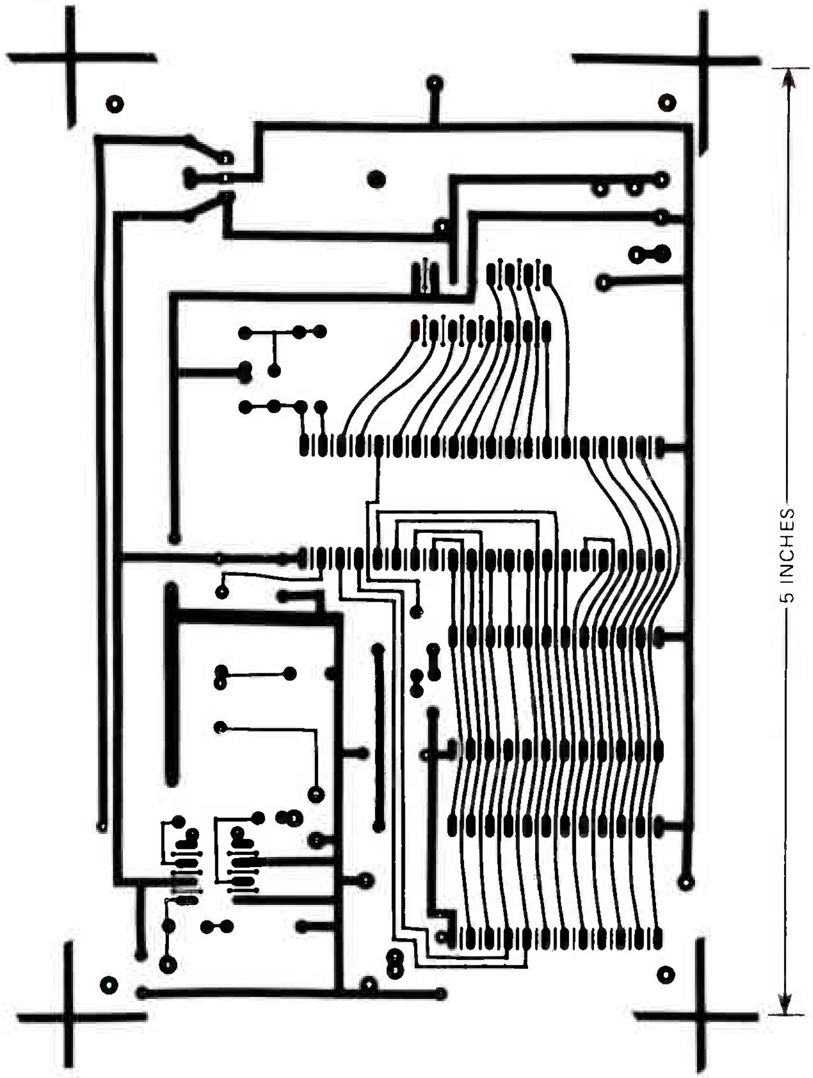

FIG. 4—**SYNTHESIZER IS CONSTRUCTED** on single-sided PC board. You may wish to eliminate feed-through traces between IC pins to prevent shorts.

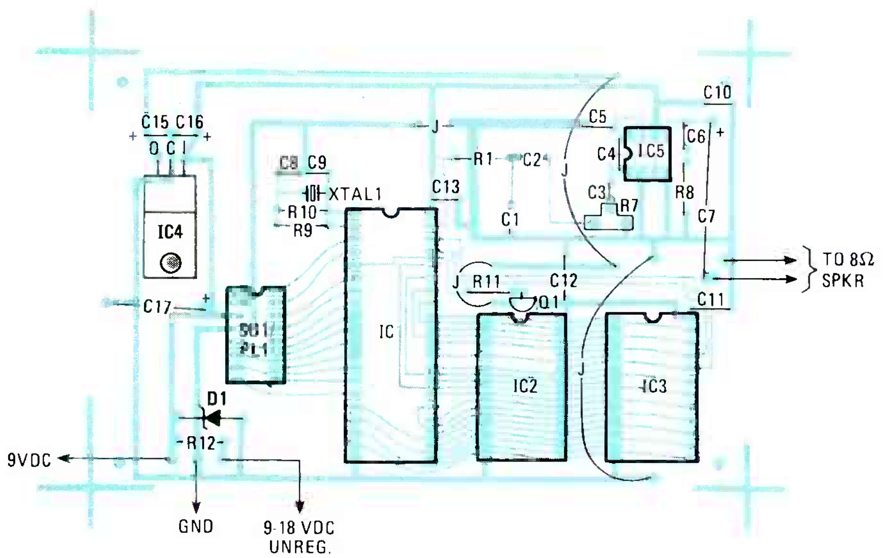

FIG. 5—**PARTS-PLACEMENT DIAGRAM** shows board with components for both 9-volt battery and unregulated-DC operation. Refer to text for information on which parts can be eliminated.

inch ones tend to distort the sound.)

Construction

A foil pattern for the circuit board is provided in Fig. 4. An already etched-and-drilled board is also available; see the Parts List. Install the IC sockets, together with the jumpers required for your configuration, as shown in Fig. 5. Then install and solder the resistors, capacitors, and crystal. Finally, install the diode, transistor, and IC4. You are now ready to test the synthesizer.

Before inserting the rest of the IC's in their sockets, apply power to the board. The sockets for IC1 and IC5 should have 9-volts at their V_{CC} pins (pins 40 and 6, respectively). Pin 3 of IC4—its output—should read 5 volts. If you used Q1, pin 24 (V_{CC}) of IC2 and IC3 will be at ground potential. If you ground pin 5 of the SPC (IC1) socket, 5-volts should appear on pin 24 of the two IC's. If everything checks out, disconnect power and discharge the filter capacitors.

Connect the speaker and install all the IC's in their sockets. Connect the switches as shown in the schematic

continued on page 110

PARTS LIST

All resistors ¼ watt, 5% unless otherwise noted
R1—8200 ohms
R2-R6—not used
R7—5000 ohms, PC-mount trimmer potentiometer
R8—10 ohms
R9—1500 ohms
R10, R13—1 megohm
R11—3000 ohms
R12—15 ohms, 1 watt (see text)
Capacitors
C1-C3—0.1 µF, ceramic disc
C4, C5—10 µF, tantalum
C6—0.047 µF, ceramic disc
C7—220 µF, electrolytic
C8—50 pF, ceramic disc
C9—20 pF, ceramic disc
C10-C13—0.01 µF, ceramic disc
C14—not used
C15, C16—2.2 µF, tantalum
C17—100 µF, electrolytic
Semiconductors
IC1—MM54104 speech processor IC (National)
IC2—MM52164 SSR1 speech ROM (National)
IC3—MM52164 SSR2 speech ROM (National)
IC4—7805 5-volt regulator
IC5—LM386 audio amp
Q1—2N3906
D1—9.1-volt Zener
XTAL1—4.0 MHz crystal
SO1—16-pin DIP socket
PL1—16-pin DIP header
S1-S8—SPDT slide or toggle switch
S9—SPDT momentary slide or toggle switch
Miscellaneous: PC board, switch-mounting board, 8-ohm speaker, IC sockets, 9-volt battery, or 9–18-volt DC power supply, etc.

The following are available from Quest-Star Electronics, 2820 Howard Dr., Las Vegas, NV 89107: IC1-IC3, $105.00; PC board, $12.95; kit of all parts, $149.95. Add $1.75 for shipping and handling; NV residents please add tax. Allow 6-8 weeks for delivery. For information on other speech-ROM sets, send an SASE to Quest-Star Electronics.

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SPEECH SYNTHESIZER

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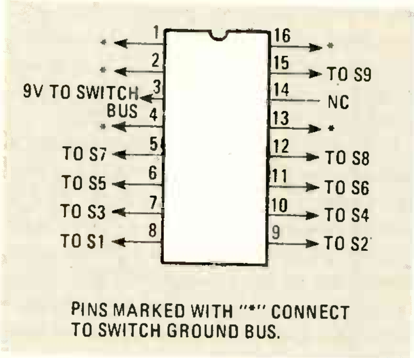

FIG. 6—CONNECTIONS FROM PL1. This same arrangement can be used for connection to a computer's parallel port.

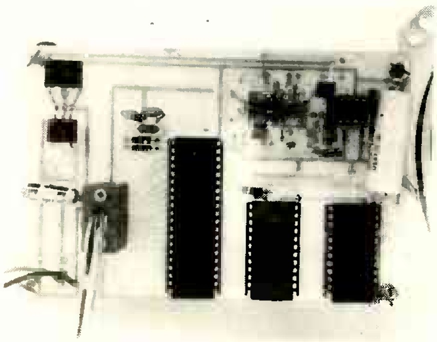

FIG. 7—PROTOTYPE OF the speech synthesizer. DIP header at top of board is not used in version described here.

(Fig. 3) and Fig. 6, using a DIP header for PL1 to mate with SO1 on the board. The completed board is shown in Fig. 7.

Apply power to the circuit and set S1 through S8 in the logic-zero (grounded) position. Now throw switch S9. You should hear a female voice say, "This is *Digitalker*."

Set switch S1 in the logic-one (9-volts) position, throw S9 and you will hear in a male voice say, "One." As you increment the switch address in binary fashion and throw S9 each time, the count will continue, "...two, three, four," etc. Table 1 shows the contents of each binary address; using that table to set the switches, you'll be able to put the synthesizer through its paces.

After you've had enough of throwing switches, you can unplug them and connect the board to your computer via a parallel port. Now, with a simple program your computer will be able to say things like, "TIME IS UP. PLEASE TRY AGAIN." You will quickly learn how to combine *pieces* of the pre-programmed words to form new words, as well; since output stops each time you access the SPC, it is a simple matter to slice phonemes out of several words and recombine them. R-E

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