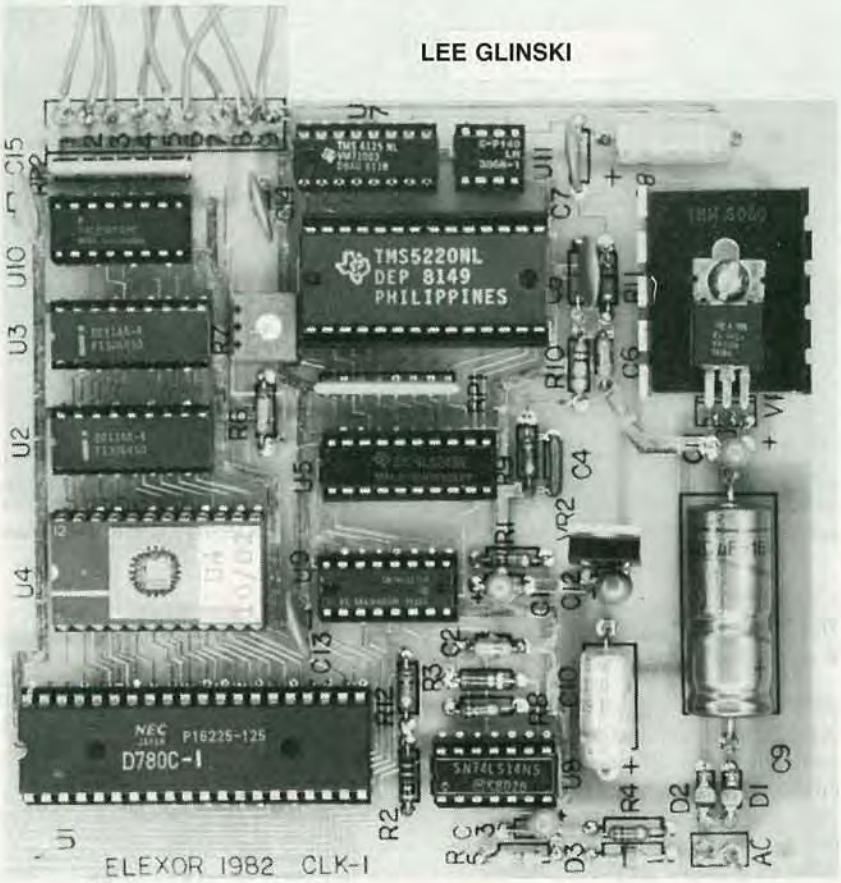
BUILD THIS

TALKING ALARM CLOCK

When you need to know what time it is, this clock tells you—literally.

LEE GLINSKI



Part 2 WE HAVE ALREADY DISCUSSED the theory behind how this clock talks. (See the May 1983 issue of **Radio-Electronics**.) Now we'll discuss how to build the clock, and how to operate it.

Hardware description

Please refer to the block diagram (Fig. 2), and the schematic diagram (Fig. 3) of the talking clock as we discuss its internal operation.

The entire clock is controlled by a Z80 microprocessor, IC1. It keeps track of the time, reads all the switches, and controls the speech synthesizer. The control software for the processor is stored in a 2516 or 2716 EPROM, IC4, with a capacity of 2K bytes. The microprocessor also uses two 1K × 4 2114 RAM's (IC2 and IC3).

The six mode and set switches, S1–S6, are connected to the microprocessor through a Tri-State buffer IC10.

A 74LS139 address decoder, IC9, connected to the microprocessor's address and control lines, generates the various strobe pulses that control reading and writing from and to the memory, speech synthesizer, and the switch buffer.

The voice-synthesis processor is the TMS5220, IC6, which is connected to the microprocessor bus through a 74LS245 bidirectional octal buffer, IC5. The buffer is needed to isolate the TMS5220 from the microprocessor data bus.

In operation, the TMS5220 and the microprocessor operate at different speeds—the TMS5220 is a very slow device. Therefore, the microprocessor has to be slowed down whenever it does a read or write from or to the VSP. That is accomplished by using a special line coming out of the voice synthesizer—the READY line. That line is connected to the microprocessor's WAIT line. When the microprocessor reads or writes from or to the VSP, the READY line indicates when the TMS5220 has finished its data transfer. The VSP will take the microprocessor's WAIT line low to signal the microprocessor to temporarily stop and wait until it (the VSP) has completed its data transfers. As soon as the data transfer is complete, the VSP releases the Z80, and program execution continues.

Speech data for time announcements is contained in ROM IC7, a Texas Instruments VM71003 that is preprogrammed with a clock vocabulary. It is connected to the TMS5220 by means of a dedicated interface bus.

The audio output of the voice processor IC is fed to a simple, passive, low-pass filter consisting of R9–R11, C5, and C6. The filter is needed because the speech waveform coming from the D/A converter contains some digitizing noise and must be smoothed out to produce a clean analog waveform. The filtered waveform is fed to audio amplifier IC11, an LM386 audio amplifier capable of delivering over 100 mW—more than enough for most purposes.

The power supply uses a wall-plug-type transformer, T1. The nine-volts AC from the transformer is rectified by diodes D1 and D2. The rectified voltage is filtered by capacitors C9 and C10 and then goes to two 3-terminal regulators, IC12 and IC13, which regulate it to +5 and −5 volts, respectively. The clock draws under 500 mA from the +5-volt supply, and under 50 mA from the −5-volt supply.

The transformer also supplies the 60-Hz reference frequency used for the timekeeping function. A 60-Hz sinewave is taken from the transformer and rectified by diode D3. The signal is then dropped to TTL levels by a voltage divider made up from R4 and R5. That TTL-level signal is buffered by a Schmitt trigger (IC8-c) and applied to the non-maskable-interrupt (NMI) line of the microproces-

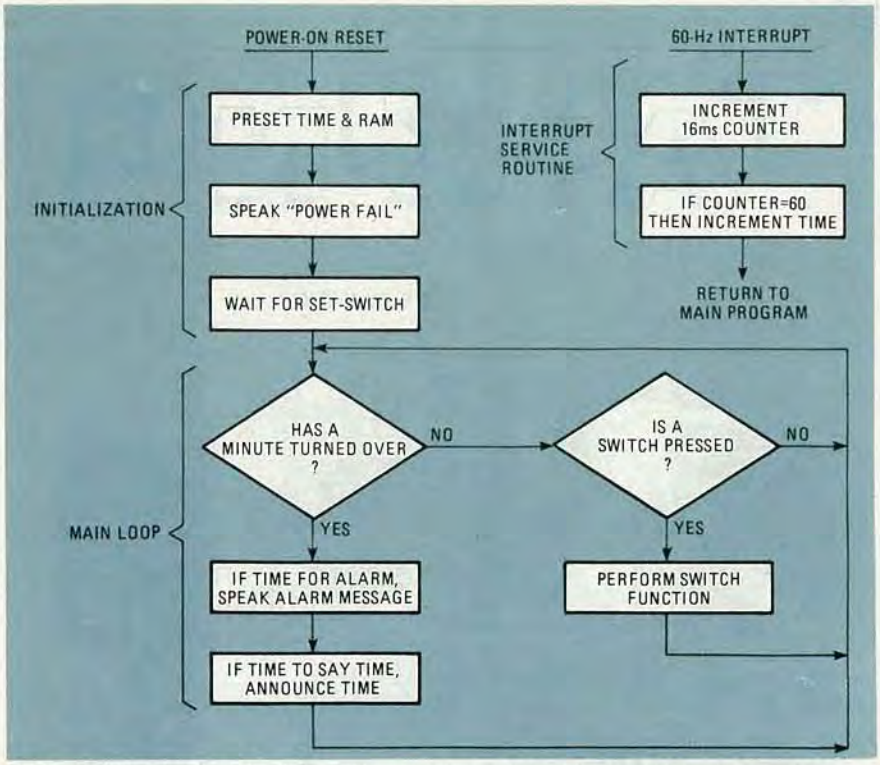


FIG. 4—MAIN LOOP IN LOGIC DIAGRAM handles coordination of timekeeping and speech functions.

(1/60-second), a count of 60 will indicate precisely one second. So, every time the counter reaches 60, the time of day is incremented by one second. The only action performed at the time the interrupt takes place is the incrementing of the time counters; resetting of the clock functions is done in the main loop of the software.

As shown in the flowchart, the primary function of the main loop is to decide when to perform certain operations.

Whenever the minute-point is reached, the software checks to see whether the alarm is on, and whether the time of day matches the alarm time. If the alarm is on and the two times match, then an alarm message is spoken.

The software also checks to see whether it's time to speak the time in the auto-speak mode. Once it decides that the time is to be spoken, it composes a phrase containing the appropriate "hour" and "minute" words. That phrase is then spoken by the voice processor.

Another function of the program's main loop is to continuously check on whether one of the pushbutton switches is pressed. If it finds one of the SET switches pressed, it increments the time, thus allowing the user to set the time of day. If

sor. Capacitor C3 across the input of the buffer filters out high-frequency noise that might give false interrupts.

Software

As mentioned earlier, the entire clock is software-driven. There are routines to keep track of time, check whether switches are pressed, compose phrases for speaking, and control the voice synthesizer to generate speech.

As indicated in the flowchart, Fig. 4, the microprocessor takes care of all timekeeping functions, as well as causing the speech synthesizer to speak words and phrases.

When power is applied to the clock, the microprocessor RESET line is activated, and the microprocessor performs a power-on initialization routine. That routine presets the time and the alarm to 12:00 AM, as well as initializing some internal registers. It then alerts you to set the time by first beeping and then announcing, *"Power fail. Set the time,"* twice. During initialization the normal time-speaking function is inhibited. That's done to prevent false time-indications. When the TALK button is pressed, instead of announcing the time, the clock will tell you to *"set the time."* The normal speaking-function is enabled only after the time has been set.

The 60-Hz line frequency provides the time reference for the clock. The 60-Hz power-line signal is applied to the nonmaskable-interrupt line of the microprocessor. Every time the interrupt occurs, the microprocessor increments a counter. Since the interrupts come every 16.67 ms

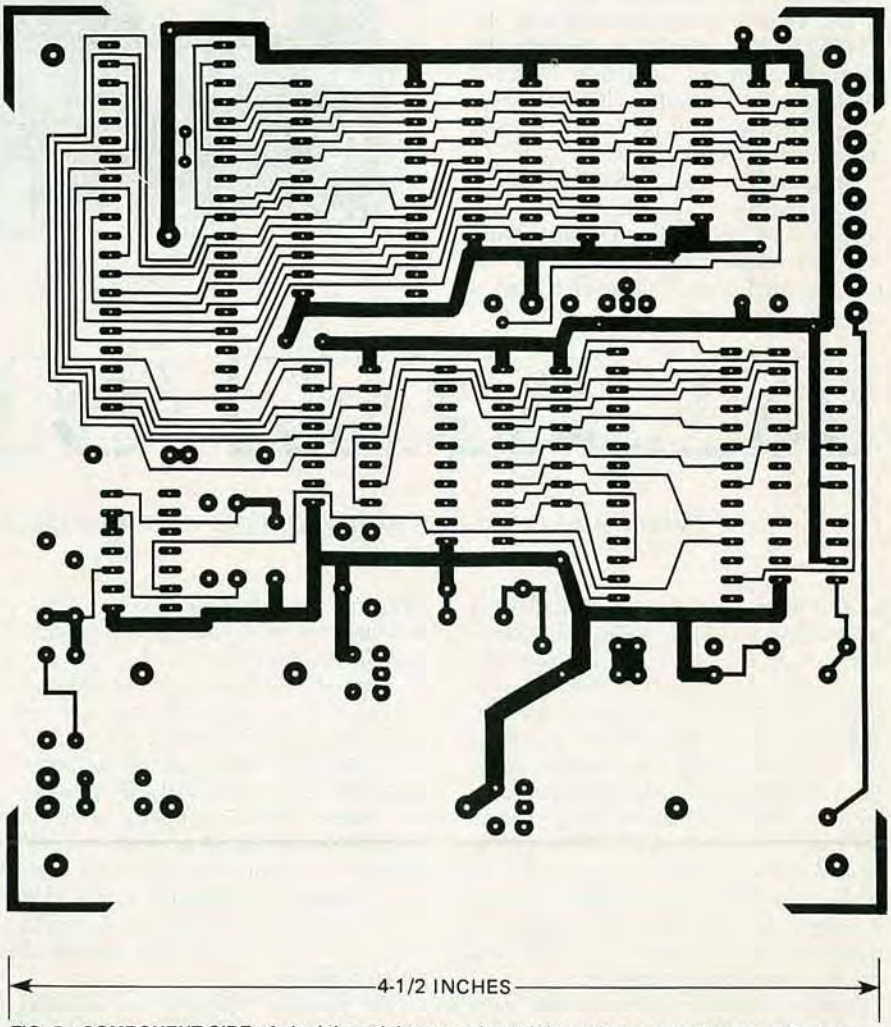


FIG. 5—COMPONENT SIDE of clock board. Large pads at right are for connections to switches and speakers.

the SPEAK TIME switch is found pressed, the software composes a phrase containing the current-time information, and announces it.

Construction

The talking clock should be built using a double-sided printed-circuit board with plated-through holes. A foil pattern for the component side of the board is shown in Fig. 5, and one for the "foil" side in Fig. 6. A professionally made silk-screened board can be obtained from the source shown in the Parts List.

PARTS LIST

All resistors ¼ watt, 5% unless otherwise noted
R1, R11—10,000 ohms
R2—330 ohms
R3—620 ohms
R4, R8, R9, R12—1000 ohms
R5—470 ohms
R5—180,000 ohms
R7—100,000 ohms, PC-mount trimmer potentiometer
R10—100,000 ohms
R13, R14—8 × 1K SIP (*S*ingle *I*n-line *P*ackage) resistor pack

Capacitors
C1—330 μF, 10 volts, electrolytic or tantalum
C2—0.001 μF, ceramic disc
C3, C11, C12—2.2 μF, 10 volts, electrolytic or tantalum
C4—0.05 μF, ceramic disc
C5, C7, C13–C15—0.1 μF, ceramic disc
C6—0.01 μF, ceramic disc
C8, C10—100 μF, 16 volts, electrolytic
C9—680 μF, 16 volts, electrolytic

Semiconductors
IC1—Z80 microprocessor
IC2, IC3—2114 1K × 4 RAM
IC4—2516 or 2716 2K × 8 EPROM, preprogrammed
IC5—74LS245 octal bus transceiver
IC6—TMS5220 voice-synthesis processor
IC7—VM71003 clock-vocabulary ROM
IC8—74LS14 hex inverting Schmitt trigger
IC9—74LS139 dual 2/4 decoder
IC10—74LS367 hex Tri-State bus driver
IC11—LM386 audio amplifier
IC12—7805 5-volt positive regulator
IC13—7905 5-volt negative regulator
D1–D3—1N4001
T1—9 VAC, 600 mA, wall-plug transformer
S1–S3—SPST slide or toggle switch
S4–S6—SPST N.O. pushbutton switch

Miscellaneous: PC board, speaker, IC sockets, heat sink for +5-volt regulator, enclosure, wire, solder, etc.

The following are available from ELEXOR, PO Box 246, Morris Plains, NJ 07950: double-sided plated-through PC board, $12.50; IC4, $7.50; IC6 and IC7, $25.00; kit of all parts (less enclosure) $69.50. Please add $2.50 for postage and handling as well as applicable state and local sales tax(es).

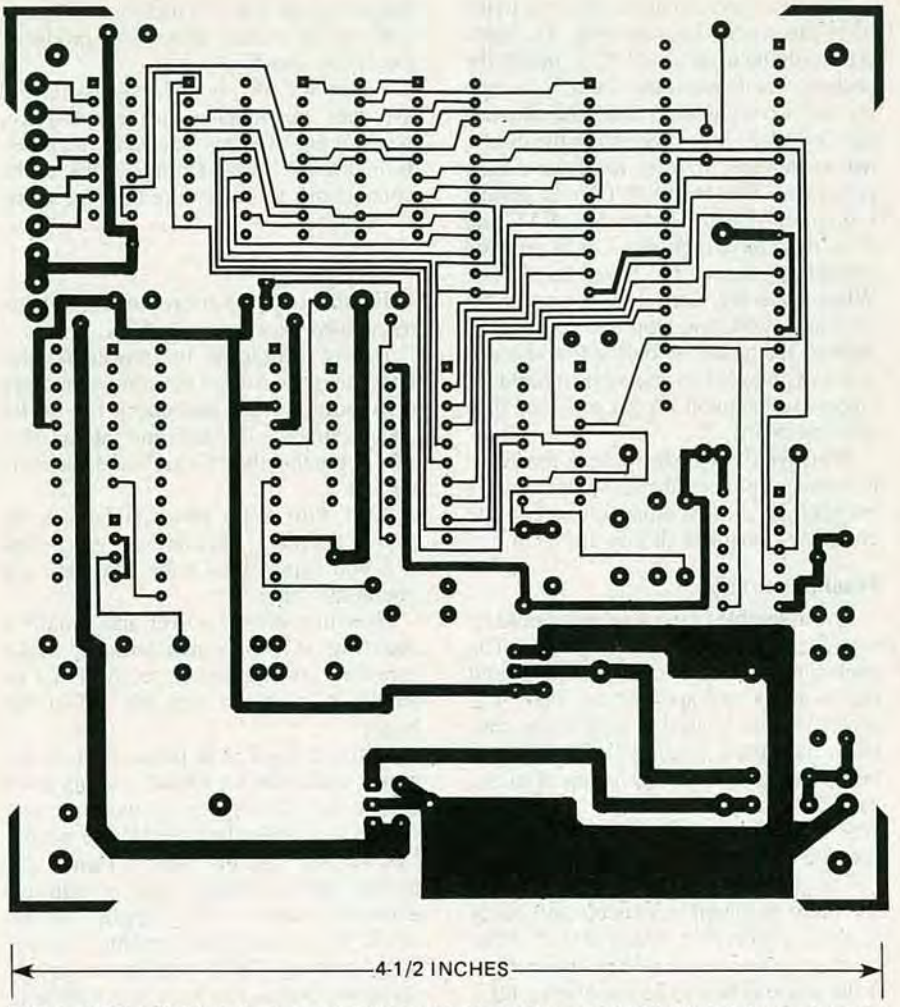


FIG. 6—"FOIL SIDE" of clock board. Double-sided board uses plated-through holes and can be ordered from supplier indicated in Parts List.

Hand-wired breadboard construction can also be used if a great deal of care is taken. The layout should follow the PC-board design. Use heavy wire for the ground and power lines, and make sure the audio section is away from the other IC's to eliminate noise-pickup by the amplifier.

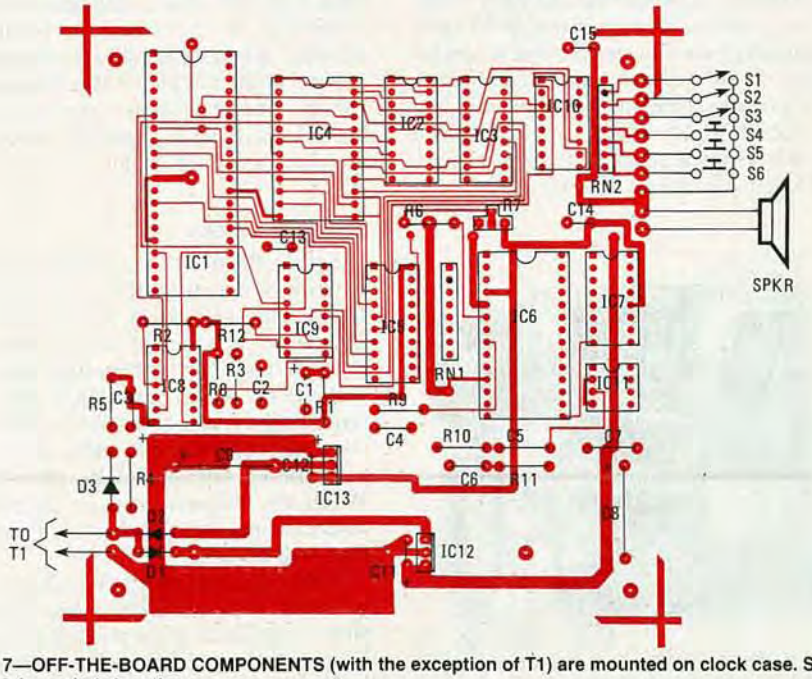


FIG. 7—OFF-THE-BOARD COMPONENTS (with the exception of T1) are mounted on clock case. See Fig. 3 for switch functions.

When assembling the board refer to the parts-placement diagram (Fig. 7). Sockets should be used for all IC's. Install the sockets, but do not insert the IC's (except for the two regulators) until after the initial checkout. When mounting the diodes and capacitors, be sure to observe their polarities. The two SIP (*S*ingle *I*n-line *P*ackage) resistor-networks, R13 and R14, must have their pin-1 ends oriented toward the top of the board as shown. When soldering, use a low-power (about 25 watts) soldering iron and contact the pads on the board for only a few seconds at a time to avoid excessive heat buildup. Excessive heat will lift the pads and thus ruin the board.

When you've finished, check the board to make sure there are no solder bridges between IC pins or adjacent traces. The completed board is shown in Fig. 8.

Final assembly

The assembled circuit board should be housed in some type of an enclosure. The enclosure should be large enough to hold the switches and speaker, as well. The prototype was housed in a toy-clock case (with the insides removed). The "alarm bells" could be mounted on top of such a case and could contain two pushbutton switches (S6) connected in parallel to activate time speaking.

The SPEAK TIME pushbutton switch should be mounted in a visible and easily accessible place like the top or front of the case, since the switch will be used often. If the alarm is also to be used frequently, then the alarm ON-OFF switch should be mounted in an easily accessible place. The MODE and SET switches should be mounted on the rear of the box to keep curious fingers from disturbing the time setting.

The speaker can be any type with an impedance between four and eight ohms. The quality of the speech output is highly dependent on the speaker and its enclosure. Some experimentation can be performed to get the most natural sounding voice. Best performance will be obtained when using a speaker with good low-frequency response. The speaker used in the prototype was 2¾ inches in diameter and, in its plastic enclosure, produced excellent sound.

After the PC board, speaker, and switches are mounted in the enclosure, connect the switches, speaker, and transformer to the board. Double check all the connections to make sure they go to the right places.

Checkout

For this step, the entire clock should be assembled except for the IC's.

Before turning on the power double-check to make sure all the components are oriented correctly, and check the solder pads again for cold joints and shorts. Also make sure that the off-the-board wiring is correct.

Next, turn on the power and check the power supplies. Measure the +5- and −5-volt supplies to make sure they are operating correctly.

Now turn off the power and (finally!) insert the IC's into their sockets. Make sure they are oriented correctly. Pin 1 of all the IC's should face the top of the board.

With all the IC's in place, turn on the power and listen for sounds coming from the speaker. If everything is working, you should hear a beep followed by the words, *"Power fail. Set the time."* That is the power-fail message and is spoken whenever power is first applied to the clock. If you don't hear anything, something is wrong. The first thing to do is turn off power and re-check the board for cold solder joints and shorts. Make sure that all the IC's are inserted correctly, all the parts are the correct values, and that the power supply is working.

Calibration

Calibration of the clock consists of adjusting the clock frequency of the TMS5220 (it has a built-in oscillator) with R7. It should be 640 kHz (measured at pin 3 of the IC) for the speech to sound natural. The adjustment is not very critical, and can easily be made by listening to the clock's speech output.

Using the clock

Setting the time is performed by using the two SET TIME pushbutton switches. One advances the hours, and the other the minutes. When the SET HOURS switch is depressed, the current hour is announced. (For the SET MINUTES switch it's the current minute.) As the switch is held down, the time will count up, with each increment being announced by the clock. When the desired hour or minute is reached simply release the switch and the time will be set.

If the MINUTE/HOUR SET switch is depressed momentarily, the current MINUTE/HOUR is announced, but is not incremented. At the same time, a counter inside the microprocessor is cleared to zero. That counter is used to count time in seconds, and every time it reaches 60 the time-count will increment by a minute. Thus, momentarily depressing the SET switch will synchronize time to the second.

If the clock is just plugged in without the time being set, every time the SPEAK TIME pushbutton is pressed, the clock will say, *"Set the time"* as a reminder that the time has not yet been set.

The position of the ALARM switch determines whether the time or the alarm is to be set. If the switch is off, the time of day will be set. If it's on, the time the alarm goes off will be set. The alarm is set just like the time, except that the ALARM switch must be in the ON position. Remember that whenever the switch is on, the SET switches will set the alarm time and not the time of day. The current alarm setting can be heard by throwing the ALARM ON/OFF switch from the OFF to the ON position. Every time that's done, the clock will announce the alarm setting.

To use the alarm, first set the time you want it to go off, as described above. Then set the ALARM ON-OFF switch to the ON position; that will enable the alarm circuitry. When the alarm time-setting time matches the time of day, you'll hear the following: *"Good morning. The time is seven twenty-six AM. Time to get up."* The time announced is the actual time of day, and the "good morning" changes to "good afternoon" or "good evening," depending on the time of day.

After using the alarm several times I found it much more effective and pleasant than the conventional buzzer. If you are a heavy sleeper and don't wake up to turn off the alarm, it will repeat the alarm message every minute until it is turned off. Once the alarm is tripped, it can be shut off either by pressing the SPEAK switch, or by setting the alarm switch to the OFF position.

Switches S1 and S2 are used to select the auto-speak mode of the clock. In that mode the time will be announced automatically at predetermined intervals. The settings are shown in Table 1.

If you choose not to use the auto-speak mode, you can make the clock tell you the time simply by pressing the TALK button. If the button is held down, the time will be announced continuously. **R-E**

TABLE 1

S1 Mode 0	S2 Mode 1	Function
OFF	OFF	Speak time every minute
OFF	ON	Speak time on the hour
ON	OFF	Speak time on the quarter hour
ON	ON	Auto-speak disabled

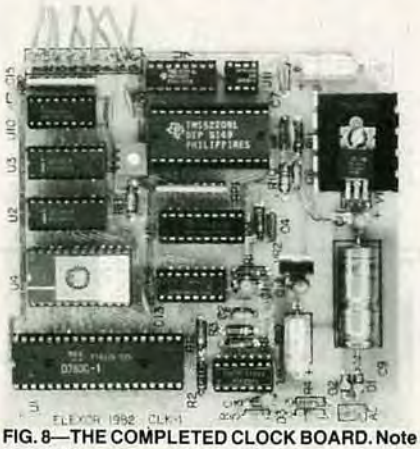


FIG. 8—THE COMPLETED CLOCK BOARD. Note that IC12 requires a heat sink.