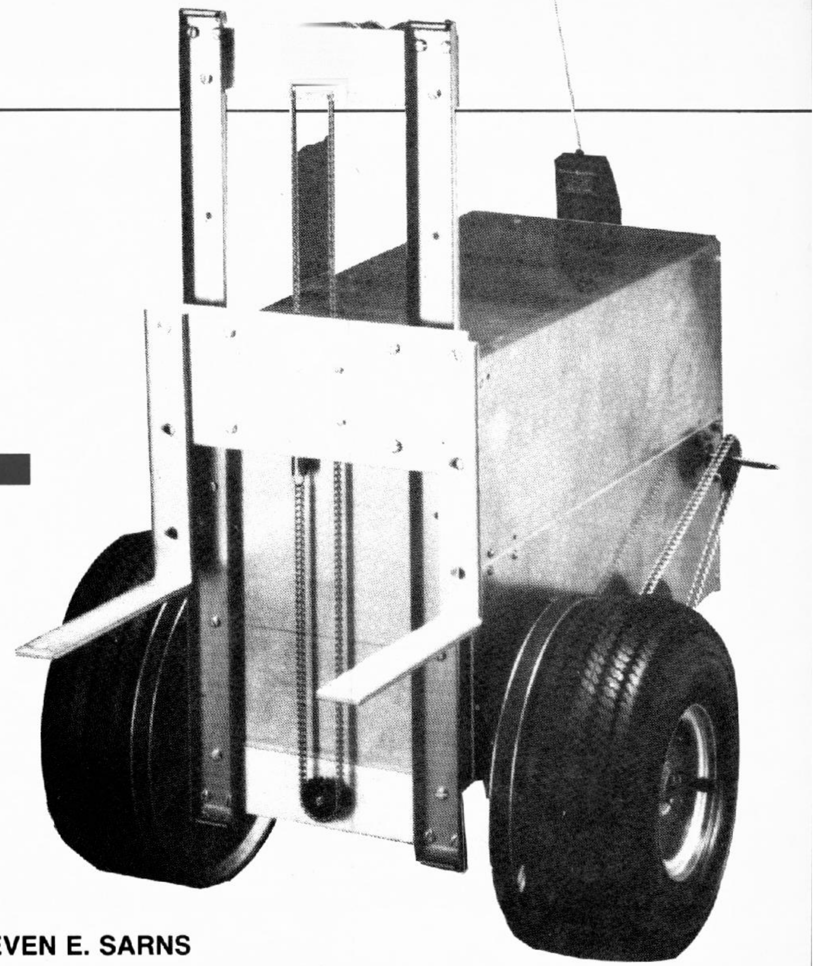
R-E ROBOT



Adding some "sense" to the robot.

STEVEN E. SARNS

Part 13 LAST TIME, WE looked at an electronic eye for the robot. However, we had no way to connect the eye to the robot. This month, we'll take care of that by showing you a head unit that serves as an interface for the navigational and sensory circuits, including the eye. The head unit also controls the movement of a small rotating platform that it and its associated sensors are mounted on. The advantage of using a rotating platform is that it allows for more accurate angular movements and measurements than trying to step the robot through ½-degree angles.

The specific functions that the head unit will support are:

- Stepper-motor drive for horizontal scanning.
- Optional stepper drive for vertical scanning.
- Ultrasonic range finder.
- Interface to the light-sensitive eyes that we discussed last time.

Mechanical design

We decided to design the head assembly in such a way that the entire unit, including the motors, etc., is detachable. That means that mounting the motors in the base unit and using a pulley system is out. Instead, a rather simple mechanical design has been used, one that relies on two key components for easy solutions to tough problems. That design is shown in Figs. 1 and 2.

As shown in Fig. 1, a 78-tooth timing-belt pulley serves as a mounting base for the entire head assembly. The timing-belt pulley is secured to the base unit, but the pulley does not rotate. Instead, the head rotates around it, driven by a motor in the head assembly. A "lazy-susan bearing" attaches the head to the pulley, providing a large diameter access hole in the middle through which all of the control wires can pass. Those bearings are used in barstools and are available at most hardware stores.

The driving motor is mounted on the bottom and inside the head, with the drive belt on the bottom. A 12-tooth timing pulley on the motor results in a 6.5:1 gear-reduction ratio for the assembly. The result is a self contained, detachable, rotating head. The assembly can be mounted either to the top of the robot's chassis or to the top of the arm unit.

The entire head-drive unit is mounted within a 10 × 6.6 × 4.5-inch aluminum case. (The case is available from the supplier mentioned in the Sources Box that is elsewhere in this article.) One .062-inch removable aluminum side is used as the bottom and all of the drive components are mounted to that flat plate. See Fig. 2. Once the unit has been tested, the remainder of the case is slipped back over the plate and re-

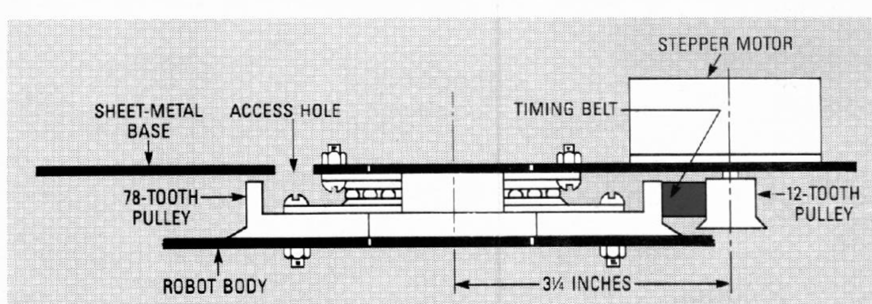


FIG. 1—THE HEAD UNIT mounts on a 78-tooth pulley. The pulley is secured to the base unit and does not rotate; instead the head rotates around it.

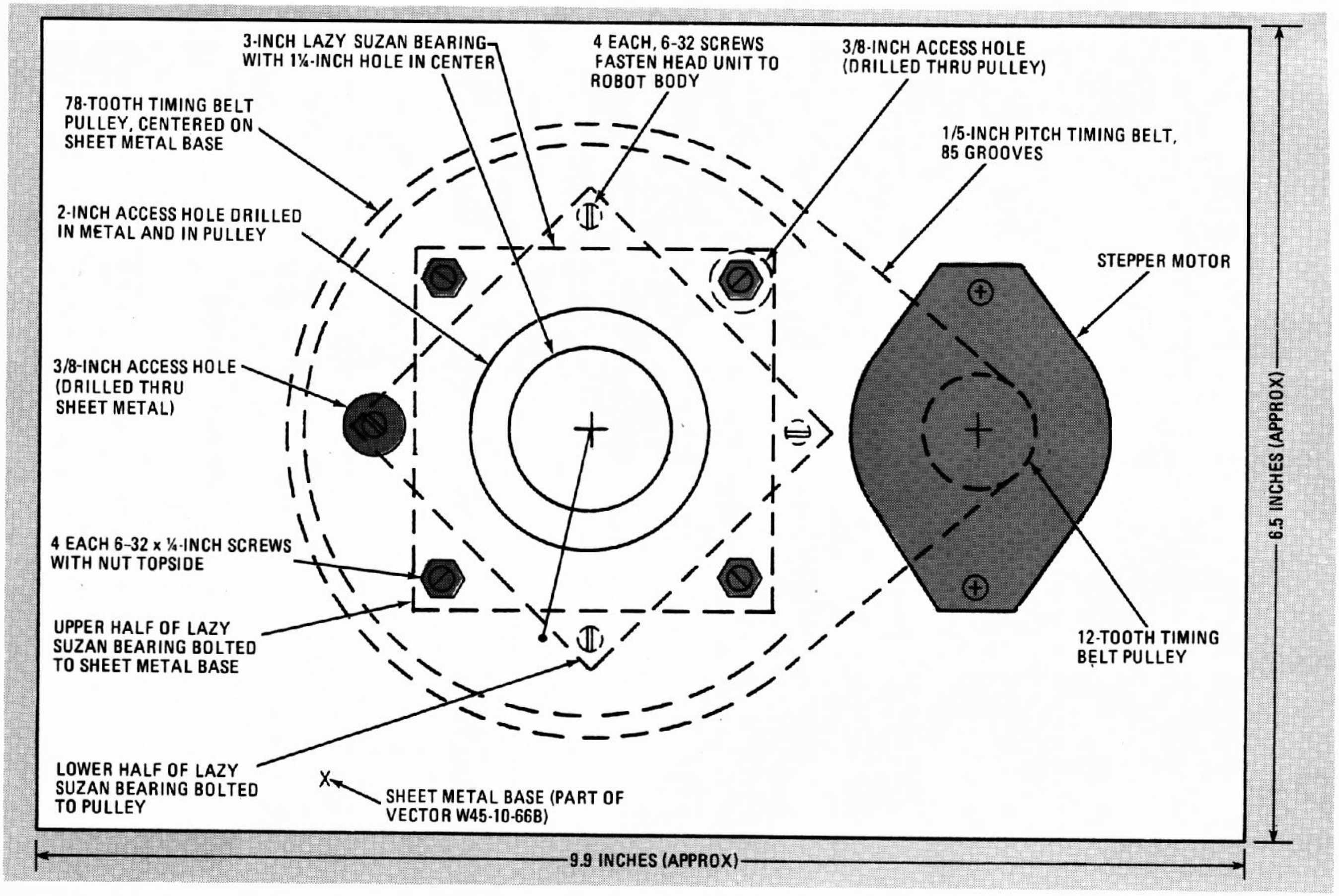


FIG. 2—THE HEAD'S DRIVE-TRAIN is detailed in this top view.

fastened. The case is ample enough to allow a 3.5-inch disk drive to be mounted in the head assembly.

User-bus interface

The schematic of the head-unit electronics is shown in Fig. 3. The head-unit circuit attaches to the bi-directional user bus via PL1. The head unit is mapped at location 0FH and consists of the peripheral functions listed in Table 1.

The peripheral address of 0FH is decoded with a single 74LS138 decoder, IC1. User-bus address lines A0 through A2 are connected to that IC's A0 through A2 inputs (pins 1–3); the fourth address line, A3, is connected to the active-high ENABLE input (pin 6). The output is taken from pin 7, the O7 output. Thus, all inputs must be high for the output to go low. You can use that decoding scheme to map other peripherals on the user bus.

Upon examination, you will notice that the 74LS138 actually decodes the 8 addresses between 08H and 0FH, each one appearing as an active low on its 8 respective outputs. If you connect address line A3 to an active-low enable, you can decode addresses 00H to 07H.

The active-low output of the address decoder is connected to the enable input of a 74LS377 output latch, IC3. The clock input is activated by the $\overline{\text{WRITE}}$ signal on the user bus. Thus we can write a byte of information to the output latch by setting up the data on the 8 data lines, setting up the address on the 4 address lines, and then strobing the $\overline{\text{WRITE}}$ line low to clock the data into the 74LS377 latch.

Inputs are read in a similar fashion. The output of the address decoder is applied to one $\overline{\text{ENABLE}}$ input of a 74LS541 buffer, IC2. The other $\overline{\text{ENABLE}}$ input is activated by the $\overline{\text{READ}}$ signal on the user bus. A byte of data is read from our head peripheral unit by setting the address lines to 0FH, bringing the $\overline{\text{READ}}$ strobe low, reading the byte on the data lines, and then returning the $\overline{\text{READ}}$ strobe high.

TABLE 1

Input	Function	Ouput	Function
DØ	Left eye, high freq	DØ	Horz stepper step
D1	Left eye, low freq	D1	Horz stepper enable
D2	Right eye, high freq	D2	Horz stepper direction
D3	Right eye, low freq	D3	Sonar echo initiate
D4	Sonar echo return signal	D4	Vert stepper step
D5	Limit sensor 0	D5	Vert stepper enable
D6	Limit sensor 1	D6	Vert stepper direction
D7	Limit sensor 2	D7	Sonar blank inhibit

Stepper-motor control

Stepper-motor control can be achieved in a number of ways. One is to use a microprocessor-intensive approach by driving each coil of the stepper with a single-bit output of the microprocessor. That means that each step of the stepper is accomplished by

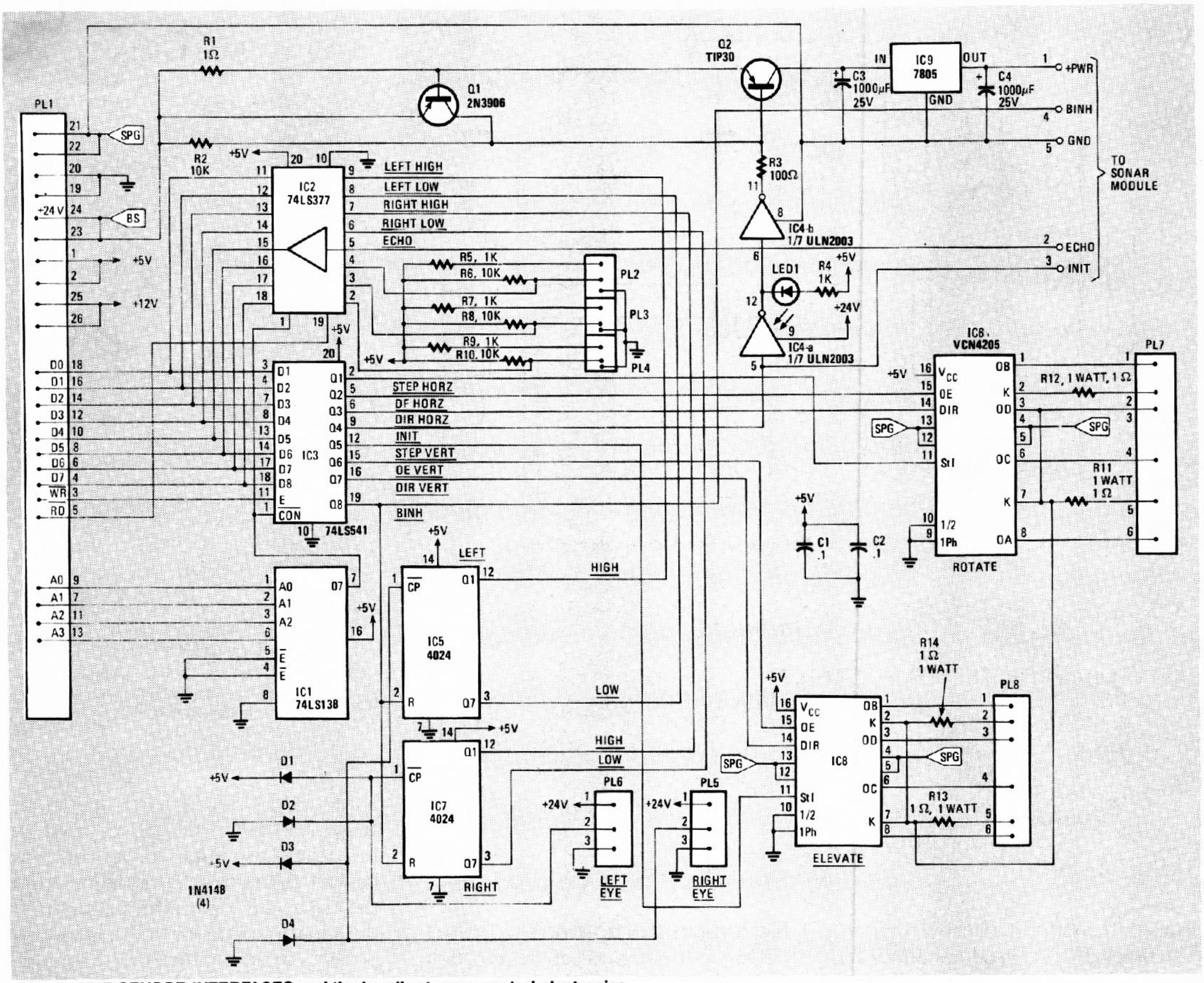


FIG. 3—THE SENSOR INTERFACES and the head's stepper-control electronics.

code look-up tables that contain the state of the phases for each step for both directions. On the other hand, you could use a motion-control IC such as the Hewlett-Packard HCTL-1000. Once the desired final position for the stepper is input to that device, it accelerates the motor, maintains its speed, and decelerates the motor as needed without further instructions from the microprocessor.

The microprocessor-intensive approach is inexpensive, but generating the code required would take quite some time. On the other hand, motion-control IC's are expensive, costing between $40 and $250.

There is another approach that is in-between those two extremes. If we use a stepper-motor control IC and service that IC with the microprocessor, our cost does not rise much and we can greatly cut the time we would need to generate the code.

That approach fits nicely into our requirements for the head unit because the tasks asked of the motor-control circuit are actually pretty simple: step a few times and wait for the sensors to accumulate new data. Step rates and acceleration will not be a major factor.

The Sprague UCN4205B-2 is used as the stepper-motor controller. That IC was chosen for its hefty motor-drive rating of 1.5 amps at up to 30 volts.

During periods of head inactivity, we will de-energize the stepper motor coils, thus conserving power. Drive-sequence selection is accomplished by grounding pin 10 for two-phase drive, or open circuiting pin 10 for half-step drive. Two-phase drive spins the head around faster, but half-step gives smoother operation. Either can be used, depending on your preference or application.

Note that two stepper controllers are included in the circuit. One, IC6,

SOURCES BOX

The following are available from Vesta Technology (7100 W. 44th Ave., Suite 101, Wheatridge, CO 80033, 303-422-8088): Bare head unit PC board; $19; fully assembled and tested head-unit PC board (not including sonar ranging unit), $89; Texas Instrument sonar-ranging module; $29. CO residents must add appropriate sales tax. Other components for the R-E Robot project are also available from Vesta Technology.

Stock Drive Products (55 S. Denton Ave., New Hyde Park, NY 11040, 516-328-0200) can supply the drive-train components for the head unit:Timing Belt, 0.2-inch pitch, 85 grooves (part no. 6G3-85-037); pulley, 12 tooth (part no. 6A3-12H3708); pulley, 78 tooth (part no. 6K3-78SF03712). Contact Stock Drive Products directly for pricing and shipping information.

Stepper motors suitable for the head (12-volt, 36-ohm coil) are available from United Products Corporation (1123 Valley St., Seattle, WA 98109-4425, 206 682-5025) for $6.95 each. Ask for part number Copal SP-57. **R-E**

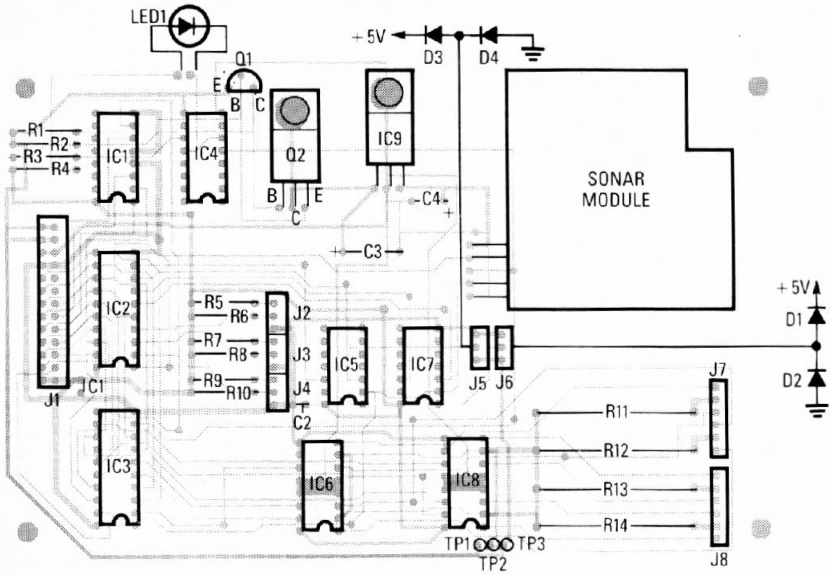


FIG. 4—ALL OF THE HEAD'S ELECTRONICS are mounted on one double-sided PC board.

LISTING 1

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(HEAD UNT—STEPPER MOTOR TEST)
HEX                                 VARIABLE HEAD-POS
: M+     9 F PCX!                     1 HEAD-POS +!          8 F PCX!
: M–     D F PCX!                    –1 HEAD-POS +!          C F PCX!
: MØ     A F PCX!
: TEST
    BEGIN
        M+     1Ø DELAY  KEY?
    UNTIL MO ;
```

PARTS LIST

all resistors ¼-watt, 5%, unless otherwise noted
R1—1 ohm
R2, R6, R8, R10—10,000 ohms
R3—100 ohms
R4, R5, R7, R9—1000 ohms
R11–R14—1 ohm, 1 watt
Capacitors
C1, C2—0.1 µF, ceramic disc
C3, C4—1000 µF, 25 volts, electrolytic
Semiconductors
IC1—74LS138 1-of-8 decoder
IC2—74LS541 octal buffer/line driver
IC3—74LS377 octal D flip-flop
IC4—ULN2003 seven-inverter IC
IC5, IC7—4024 7-stage binary ripple counter
IC6, IC8—UCN2005 stepper controller
IC9—7805 5-volt regulator
Q1—2N3906 PNP transistor
Q2—TIP30 NPN transistor
D1–D4—1N4148 diode
LED1—red LED
Other components
PL1—26-pin, dual-row male header
PL2–PL6—3-pin male header
PL7, PL8—6-pin male header
Miscellaneous: PC board, case (Vector W45-10-66B or equivalent), mechanical components (see text), wire, solder, etc.

is used to control the head's rotation. The other, IC8, is used to control the head's elevation. Since vertical scanning is an optional function, the second controller is optional. In any event, both stepper-motor controllers work in an identical manner. For simplicity, we will only discuss the operation of IC6.

The stepper controller is connected directly to the four coils of its associated stepper motor via PL7. The common wires of the two pairs of coils are returned to the power supply through optional resistors R11 and R12. Direct shorts could be used in place of those resistors in most cases. However, in some cases the use of the resistors will allow you to use a higher coil-drive voltage. That drives the stepper in the current mode, enabling a higher step rate due to the reduced effect of coil inductance. Since both 12- and 24-volt supplies are available, steppers with 12- or 24-volt coils can be used. We suggest using steppers with 24-volt coils if possible since the 12-volt regulator on the robot's main board can only supply about 1 amp total.

Motion-control software

Our software must set the direction of rotation and enable the control bits. It then must apply a pulse to the controller's step input, which causes the device to output each of the four phase-drive sequences to the motor. The top speed of our motor will be limited by the ability of the software to output the step commands, but that will not be a problem because the head must stop every few steps to accumulate data. We will not attempt to accelerate the motors, merely step them at a low speed.

As the code in Listing 1 demonstrates, the software required to rotate and test the head unit is very simple. (It is assumed that you have the PCX! and PCX@ words installed. Those were defined in Part 8 of this series, which appeared in July, 1987.)

The word M+ rotates the motor one step clockwise and increments the value in the variable HEAD-POS; the word M– rotates the motor counterclockwise. The word M0 turns off the coils. TEST can be rewritten to rotate in the opposite direction by substituting M– for M+. In operation, the 10 DELAY would be replaced by the analog-to-digital conversion process of the optical information from the eye or the sonar information from the sonar module (or both) as well as possibly releasing the Forth-83 multitasker to another task. The following word will rotate the head a given number of steps while maintaining the current relative position in HEAD-POS.

```
: CW  ( STEPS — )  Ø
  DO
     M+3Ø DELAY
  LOOP MØ :
```

Sonar interface

Sonar ranging modules are available from Texas Instruments and Polaroid. The TI module is the latest generation and offers improved noise-rejection characteristics. Either module will work in the circuit as will ranging devices that do not use the Polaroid transducer. We have simply designed the circuit board with a mounting area for the module and the control lines ready to wire to the module. See Fig. 4.

That's all for this month. Next time we'll show you how to use the TI module, connect the eye, build the head, and more! **R-E**