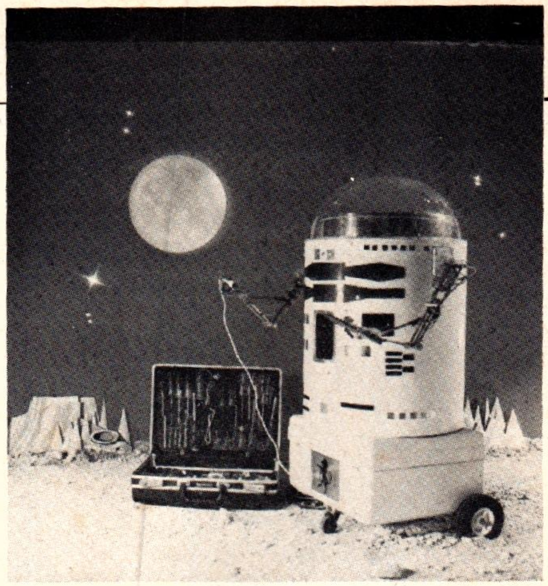
BUILD THIS

UNICORN-1 ROBOT



Assembling the Body

Part 4—Here's the first of two installments dealing with how to construct a body for the robot. This part describes the body frame and rotation mechanism.

JAMES A. GUPTON, JR.

SO FAR, WE'VE DISCUSSED THE DESIGN and construction of the *Unicorn-1* robot's manipulators (arms), end effectors (hands) and mobility base (legs). We are now past the most difficult aspects of its construction. This part of the series will deal with the body, and that is where the robot will begin to look like a robot.

Body frame

As shown in Fig. 27, *Unicorn-1*'s body dimensions allow plenty of interior space for whatever hardware—up to, and including, a computer—you desire to add. The prototype body is 19 inches in diameter and about 20 inches in height. That has been more than adequate for the author's needs, but does not restrict you from using other designs; after all, one of the aims of this project is to allow you to use your own ingenuity. The skin of the robot will be made of *Formica* (which comes in standard widths of 30 inches) so you will easily be able to make a body 30 inches in height, if it suits you. That is an increase of 50% in height over the original specs.

And, of course, you don't have to be restricted to the *R2D2* format. You can use just about any shape you desire.

If you haven't already done so, take an evening or two to decide what your robot will finally look like. That will not require any significant changes in the frame of the body, the principles of which we'll discuss here, but may affect you in the long run.

In any event, your robot's body will need a supporting structure, and a mechanism to turn it from side to side. That's what this section is about.

Whether the ultimate form of the body is cylindrical or otherwise, a reinforcing structure will be needed. What's shown here is for a cylindrical body, although it can easily be adapted to other shapes. Figure 28 illustrates the top and bottom bulkheads, along with the locations of the eight supporting columns. The bulkheads are made from 5/8-inch particle board, cut to dimension with a saber saw. If you have no saber saw, inscribe the circumference of the bulkheads on the board, and drill a closely-spaced series of 1/4-inch holes along its *outside* as shown in Fig. 29. After those holes are drilled, the piece can be knocked out with a chisel. Whichever way you proceed, allow a bit extra for wastage—that part of the material that gets turned into sawdust or is chipped away in the process.

When the bulkheads have been rough-cut, they can be dressed to their final dimensions with a wood rasp. Who says that robots are made entirely of metal!

If you make the effort, you will probably be able to find pieces of particle board at your local lumberyard as scrap at a very reasonable price. Should you have to purchase brand-new material, you may be able to get a "special cut," if you tell the person in charge exactly what you need.

The dimensions for the interior bulkheads for *Unicorn-1* were given in Fig. 28. The top bulkhead is nothing more than a ring-shaped section of particle board, while the bottom bulkhead has a three-legged shape, to support the body during rotation. The larger bulkhead opening in that bottom part permits maximum freedom for the cables running between the body and the mobility base.

After the two bulkheads have been cut to their final shape, the locations of the bulkhead support-columns should be marked (refer again to Figs. 27 and 28). First, draw a pencilled line completely around the bulkheads' circumference. That should be done .040-inch from the perimeter. The holes drilled along that line will be used to attach the columns to the bulkhead. Figure 28 identifies the specific holes that will be required.

Some of those holes, as has been indicated, will have to be countersunk (Fig. 30). That allows the screw heads to sit flush with the outside surface, and eliminates awkward bumps or bulges when the skin is fitted.

The eight wooden bulkhead-support columns are attached to the bulkhead with wood glue or epoxy, wood screws, and aluminum angle-braces. We don't take any chances.

After drilling the bulkheads for the support columns, drill "lead holes", top and bottom, to start the wood screws. That will help prevent splitting the columns. The lead holes should be about one-third the diameter of the wood screws themselves. Then, drill *through* those holes for attachment of the aluminum braces shown in Fig. 27. Lubricate the screws with soap to permit them t

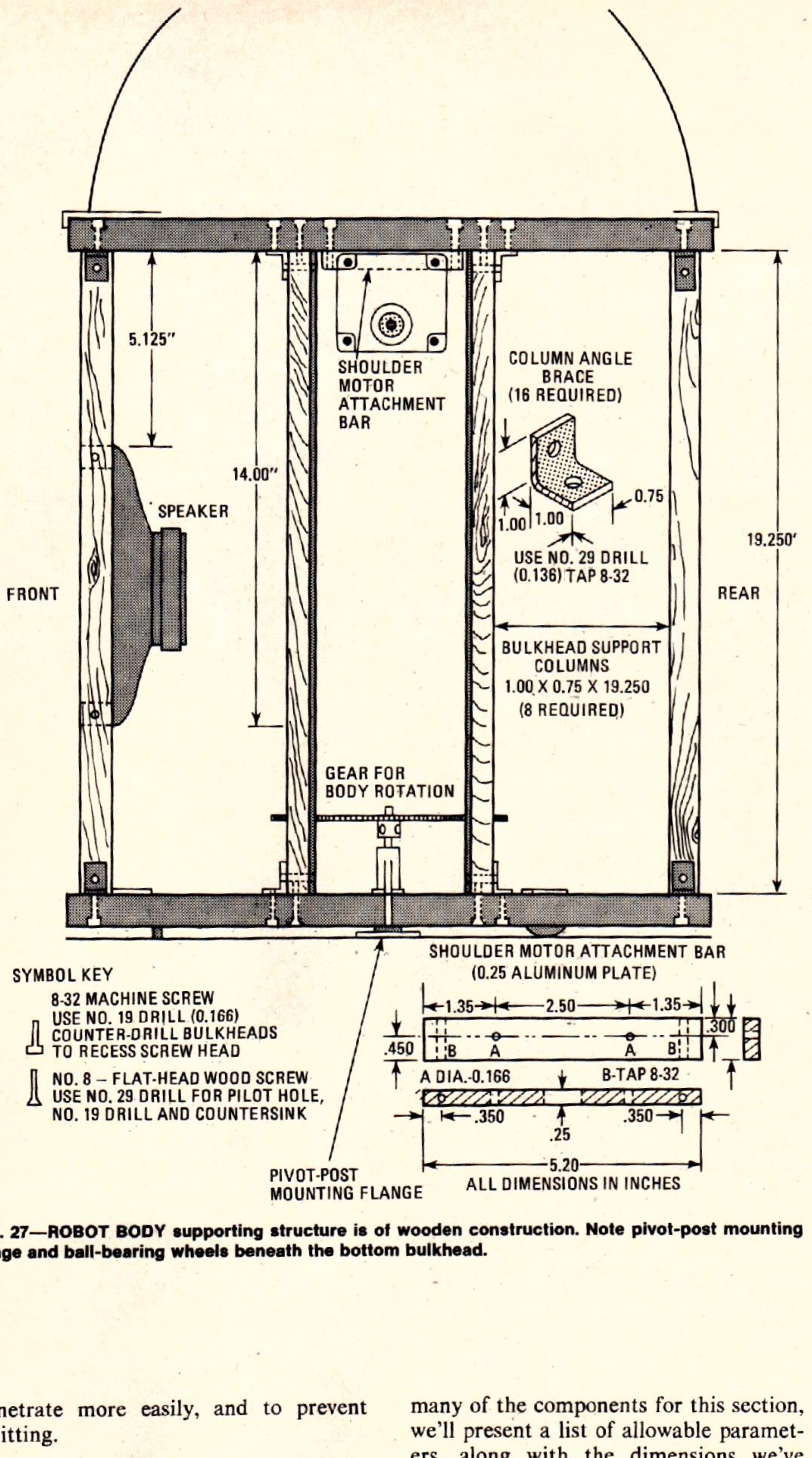


FIG. 27—ROBOT BODY supporting structure is of wooden construction. Note pivot-post mounting flange and ball-bearing wheels beneath the bottom bulkhead.

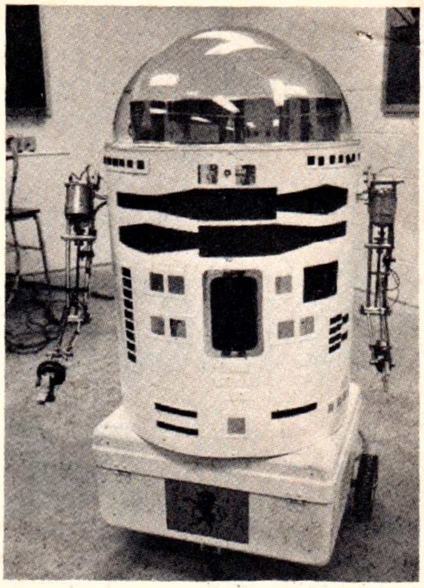
penetrate more easily, and to prevent splitting.

Body rotation

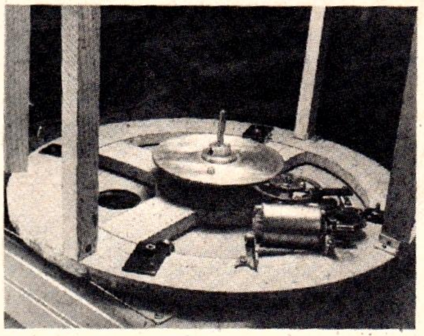
Unicorn-1's body turns on ball-bearing wheels that ride on the steel plate forming the top of the mobility base. The size of those wheels is not particularly significant, as long as the body maintains its clearance from the base. The units used in the original *Unicorn-1* had a diameter of .875-inches, giving the bulkhead a clearance of .125-inch from the mobility base. One of these is shown in Fig. 31.

As we have done previously, we stress the fact that nothing about this robot is critical. Since you may be "scrounging" many of the components for this section, we'll present a list of allowable parameters, along with the dimensions we've found to be most satisfactory.

1. **Ball-bearing wheels:** .375-inch to 1.125-inches diameter. For wheels larger than .5-inch, turn the mounting plate upside down (bearing mounting-flange facing up).
2. **Pivot-post mounting flange:** .062-inch to 1-inch thick. Mount any flange thicker than .125-inch inside the top of the mobility base.
3. **Pivot-post diameter:** .250-inch to 1-inch (.250-inch to .375-inch preferred).



BENEATH THIS RUGGED EXTERIOR lies a frame of wood. Next installment will describe skin.



COMPLEX GEAR TRAIN used to slow 10,000-RPM motor to 11-RPM for body rotation.

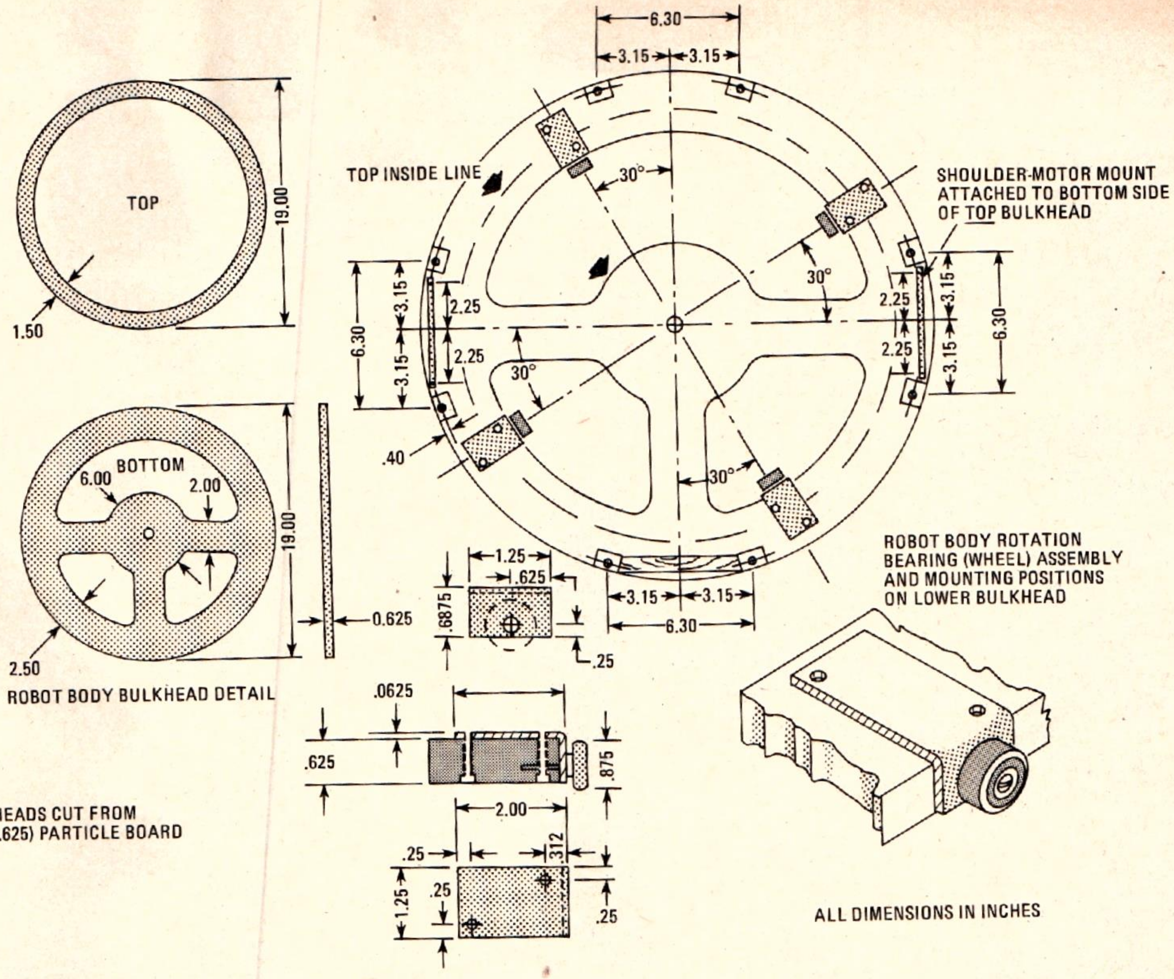
4. **Gear-shaft bore diameters:** .125-inch to .750-inch (.250-inch preferred).
5. **Body rotation speed:** 4 to 22 RPM (10 to 12 RPM preferred).

Just as in the design of the mobility base, there is a choice of methods to drive the body. An inexpensive, high-speed motor may be used if its speed is reduced through a series of gears. A speed-reduction of about 1000:1 is required with this method to obtain a rotational speed of 11 RPM. That, it should be obvious, requires several gears.

The amount of speed reduction is a factor of the number of teeth on each gear. If one gear has 16 teeth and another has 48, the gears have a ratio of 1:3 and driving the second gear with the first will reduce the speed by that factor (the second gear will only make one revolution for each three made by the first). A train of such gears would eventually reduce the small motor's 10,000 RPM to a useable rate, but, as Fig. 32 shows, could turn out to be somewhat complex.

Also, the speed of rotation will be affected by the weight of the load (the robot's body, in this case)—the motor speed could be slowed by 10 to 20 percent by that factor.

As in the case of using gears to drive



NOTE: BULKHEADS CUT FROM
5/8" (0.625) PARTICLE BOARD

ALL DIMENSIONS IN INCHES

FIG. 28—TOP AND BOTTOM BULKHEADS are cut from particle board. Bottom bulkhead is sturdier to bear body weight. Bearing mounting brackets are made from 1/16-inch aluminum.

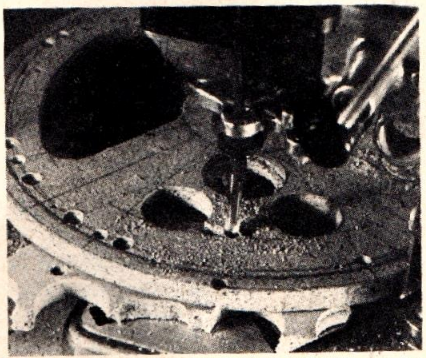


FIG. 29—A SERIES OF SMALL HOLES can be drilled to rough-cut bulkheads to shape.

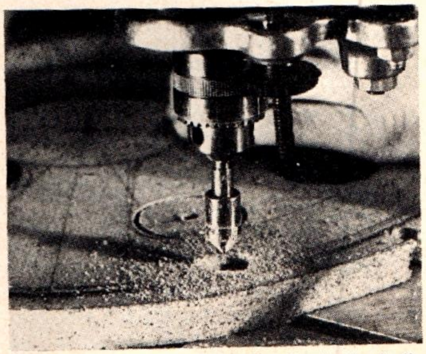


FIG. 30—COUNTERSINKING holes in the bulkhead prevents screwheads from protruding.

the mobility base, this method presents more problems, perhaps, than it solves.

A much simpler method uses the same type of low-speed gear motor that was used to drive the mobility base. As shown in Fig. 33, this motor can be mounted directly on the bottom bulkhead and its shaft connected directly to the pivot post and/or the pivot-post mounting flange, located on the mobility base.

Mounting of this type of motor is fairly straightforward and presents the least number of complications. A 22-RPM gearmotor may be used, or, if you can locate it, a slightly slower-speed one (about 10 or 12 RPM) may prove to be preferable.

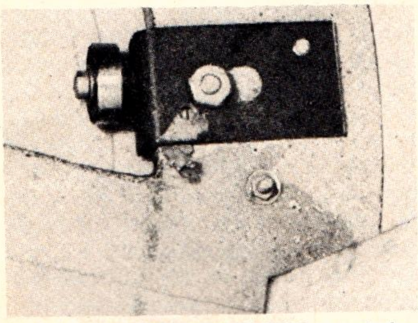


FIG. 31—BALL-BEARING WHEELS mounted on bottom bulkhead support body as it rotates.

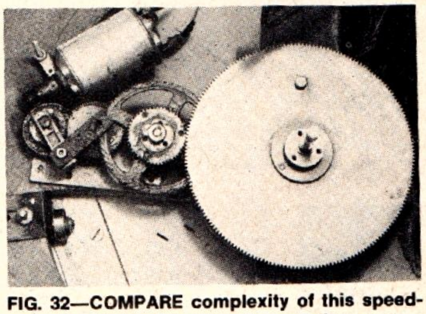


FIG. 32—COMPARE complexity of this speed-reduction train with drive shown below.

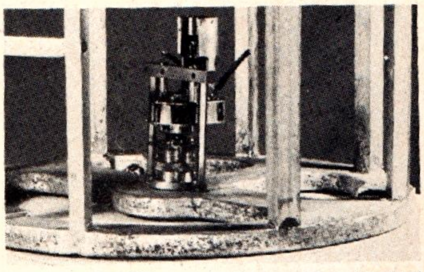


FIG. 33—22-RPM gear motor provides simplest and most direct means of rotating body.

Motor connection will be made to a small terminal strip mounted in the body.

Shoulder motors

When the manipulators and end effectors were described, the robot was given

PARTS LIST

Item	Size	Quantity	Supplier's part no.	Supplier
Particle board	19 × 19 in. minimum	2		Local
Wood strips	.25 × 1 × 19.25 in.	8		Local
Aluminum plate	.25 × .75 × 5.2 in.	2	AP52	Ⓐ or local
Aluminum angle	.0625 × 1 × 1 × .75 in. (make from .0625 × 1-in. angle, 13 in. long)	16		Local
Aluminum sheet	.125 × 1.25 × 3 in.	4	AS3	Ⓐ or local
Ball bearing wheels	.875 in. diameter, .375 in. shaft diameter	4	B11-10	Ⓐ,Ⓑ
	or			
	.625 in. diameter, .25 in. shaft diameter	4	B11-9	Ⓐ,Ⓑ
Wheel mounting screws (known as "shoulder screws")	To fit wheel centers	4		Local
Shoulder motor mounting screws	8-32	4		Local
Gearmotor mounting screws	8-32, length as needed	4		Local
Machine screws	8-32 × 1, Fillister-head	44		Local
Wood screws	#8 flat-head × 1 in.	20		Local
Precision spur gears (for use with high-speed motor)	48 pitch, 23 teeth, ⅛-in. face, ¼-in. bore	3	C48A18-023	Ⓐ,Ⓑ
	48 pitch, 120 teeth, ⅛-in. face, ¼-in. bore	3	C48A18-120	Ⓐ, Ⓑ
Pivot post	See text. Length to suit design	1		Local
Pivot-post mounting flange	See text	1		Local
Body motor (high-speed)	3-amp, split phase, 12 volts DC	1	61.085	Ⓒ
	or			
Body motor (22-RPM gearmotor)	22-RPM gearmotor, 12 volts DC	1	715-900153	Ⓐ, Ⓓ
Shoulder motor	22-RPM gearmotor, 12 volts DC	2	715-900153	Ⓐ, Ⓓ

SUPPLIERS

Ⓐ **The Robot Mart**
Room 1113
19 W. 34th St.
New York, NY 10001
(Catalog $3.00)

Ⓑ **Winfred M. Berg, Inc.**
499 Ocean Avenue
E. Rockaway, NY 11518

Ⓒ **Edmund Scientific Co.**
101 East Gloucester Pike
Barrington, NJ 08007

Ⓓ **Gledhill Electronics**
P.O. Box 1644
Marysville, CA 95901

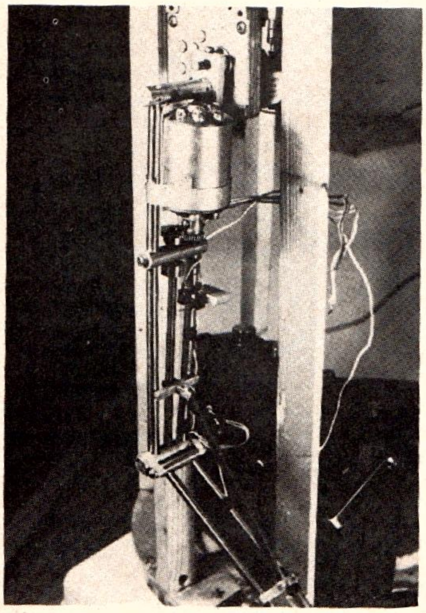


FIG. 34—SHOULDER MOTOR mounting plate is visible at very top of photograph. See Fig. 27 for body location.

the ability to bend his arms at the elbow and to open and close his hands. It would be useful to add another degree of freedom, which would allow the arms to be raised and lowered. That is easily accomplished with the same 22-RPM gearmotors we've already used.

A five-ohm, 20-watt resistor can be used to drop the motor's supply-voltage, thus slowing it down to a more suitable speed. (The same can be done for the body motor.)

The last cross-bar rod (at the shoulder hinge) on the manipulators has already been drilled to accept a shaft of the type found on these motors (refer back to Part 1, August 1980 issue). A simple bracket, shown in Fig. 27, allows the motor to be attached to the body. An actual installation of that sort is pictured in Fig. 34. Be sure that the mount is positioned so the surface of the gearmotor will be flush with the surface of the top bulkhead since, when the robot's skin is attached, a cutout will have to be made for the shoulder gearmotors, and their faces should be flush with the skin's surface.

Again, the shoulder-motor wiring will be connected to a local terminal strip.

Alternatively, the manipulators may be affixed to .250-inch rods that are attached to the body frame, without motors. The motors can always be added later.

Bear in mind that, although the skin will be removable, as much interior work as possible should be completed before it is attached. Some of the things that remain to be added are:

1. "Local" terminal strips for motor wiring and connections from them to the master terminal strip in the mobility base.
2. Speaker and LED installation.
3. Installation of supports and brackets for radio control and/or computer equipment.

In the next section of this series, we'll complete the work described above and attach the skin. In addition, we'll describe the construction of the control box that will allow you to operate the robot by means of a cable running to the mobility base. **R-E**

UNICORN-1 ROBOT

Part 6—Add some pizzaz to your robot with two different sets of flashing lights. For the more serious-minded, there's also a twist-of-the-wrist end effector.

JAMES A. GUPTON, JR.

YOU SHOULD HAVE YOUR OWN VERSION OF Unicorn-1 in action by now, and have probably been using this time to practice controlling the robot.

In this section, we'll not only describe some simple electronic circuits that will give the robot a more impressive appearance but will provide you, as well, with one of the options promised earlier—a rotatable end-effector.

The next installments of this series will provide circuits that can be used either for radio control (R/C) and/or for computer control—the computer being either part of the robot or external to it and transmitting commands via a radio link.

Before we get involved, though, we'd like to correct an error that crept into Part 2 of this series (September 1980) and that was brought to our attention by several readers: The red and green wires between switch S1 and the barrier strip were transposed in Fig. 18. The red wire should go to ground at the bottom-right of the switch, and the green one to +12-volts at the top right.

It's good to see so many readers taking such an interest in the project!

Electronic embellishments

Flashing lights always attract attention and—you can admit it—that's what you'd like your version of Unicorn-1 to do. We'll consider two different LED-indicator circuits: one to show that the arms are in motion, and in what direction they're moving; the other (just) to attract attention by announcing that Unicorn-1 is "alive."

The first circuit, which shows that the shoulder-motors have been activated, is presented in Fig. 42. You'll remember

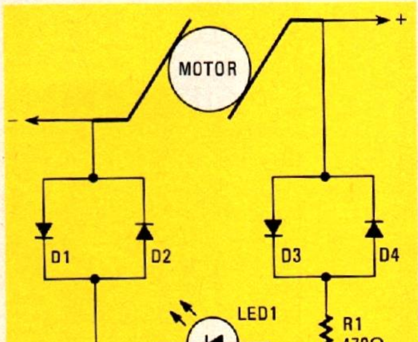
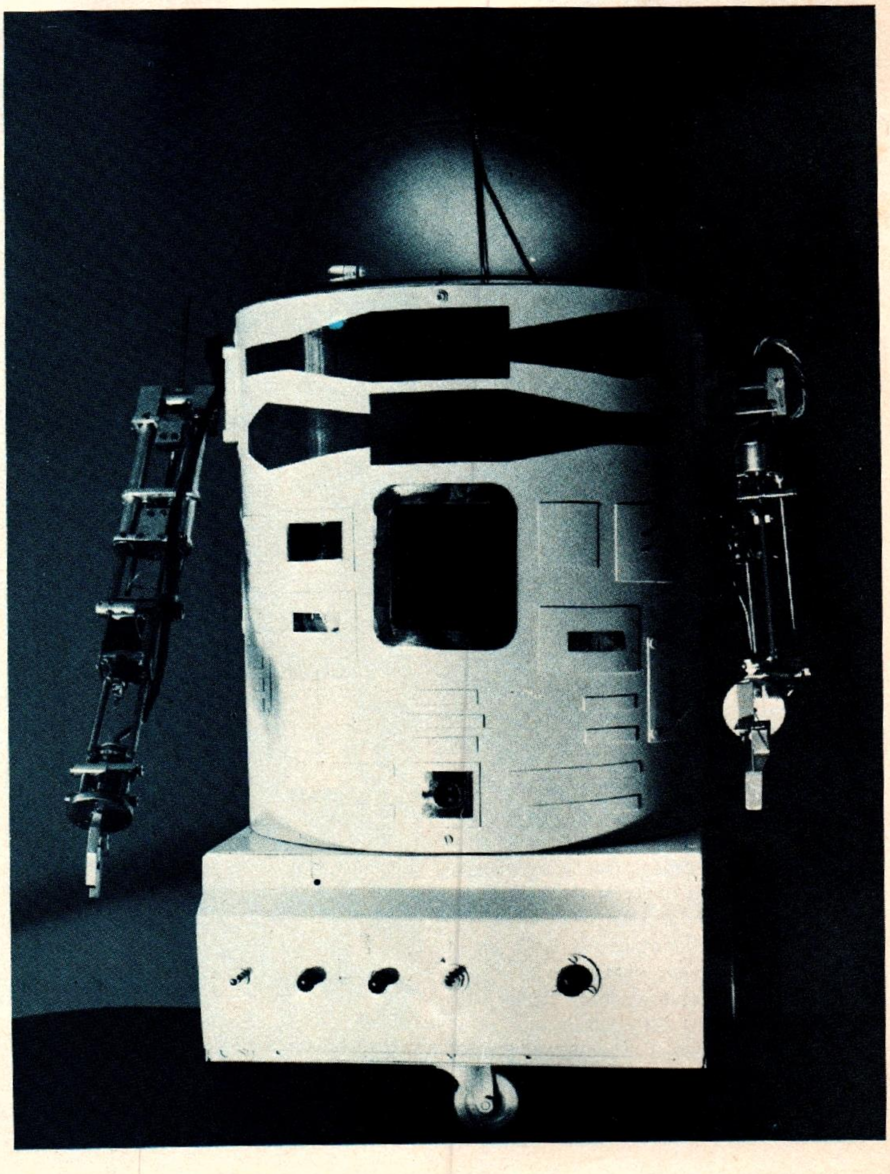


FIG. 42—MOTOR-DIRECTION INDICATOR uses twelve volts. Diodes and resistor reduce voltage and current to safe levels for LED's.



PARTS LIST—MOTOR-DIRECTION INDICATOR

R1—470 ohms, ¼ watt
D1-D4—1N4001
LED1, LED2—jumbo LED's (different colors)

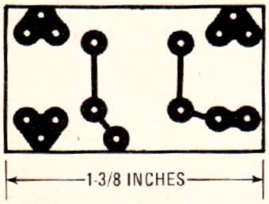


FIG 43—WHEN YOU MAKE THIS BOARD, be sure that pads *do not touch* rectangular border.

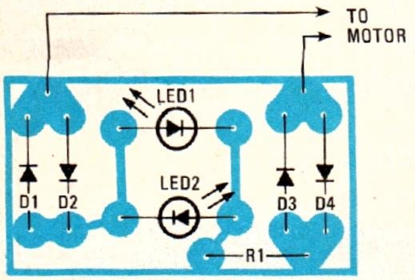


FIG. 44—PC BOARD for motor-direction indicator was designed for rectangular LED's. Circular ones will need their leads bent a bit.

that the direction of motor rotation is changed by reversing the polarity of the current used to power the motor. That circuit detects which way the current is flowing and indicates it via LED's.

Looking at the schematic for the circuit, it can be seen that—if we assume the right-hand terminal to be positive and the other one negative—a stream of electrons will flow through diode D2, LED1, and through D3, causing LED1 to light. (Remember, though, that the current flow is from the positive pole to the negative.) Also bear in mind, as you consider the schematic, that, in a LED—or in any other diode, for that matter—current flows from the cathode to the anode.

Current-limiting resistor R1 is used to prevent burning out the LED's. A value of 470 ohms will be about right to provide the LED with the 20 mA it needs, based on a 12-volt system.

If a command is given to reverse the current flow—where what was previously positive becomes negative—current will then flow through diodes D4, LED2, and D1. Use different colored LED's for LED1 and LED2 so you can tell at a glance which way the motor, and its associated mechanism, is moving.

A foil pattern for the circuit is shown in Fig. 43, and the parts-placement diagram in Fig. 44. Two of those can be built on one board to take care of both arms (see Fig. 45). The LED's used on the board shown in the foil pattern were rect-

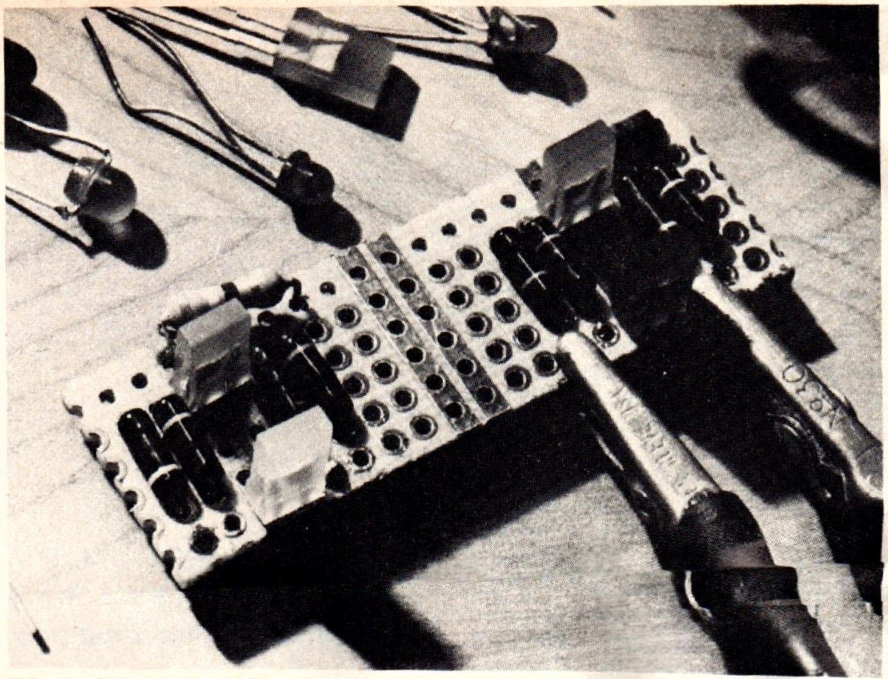


FIG. 45—ONE SMALL PIECE of board holds two complete motor-direction indicators. Current-limiting resistor is visible at top-left of board, above LED.

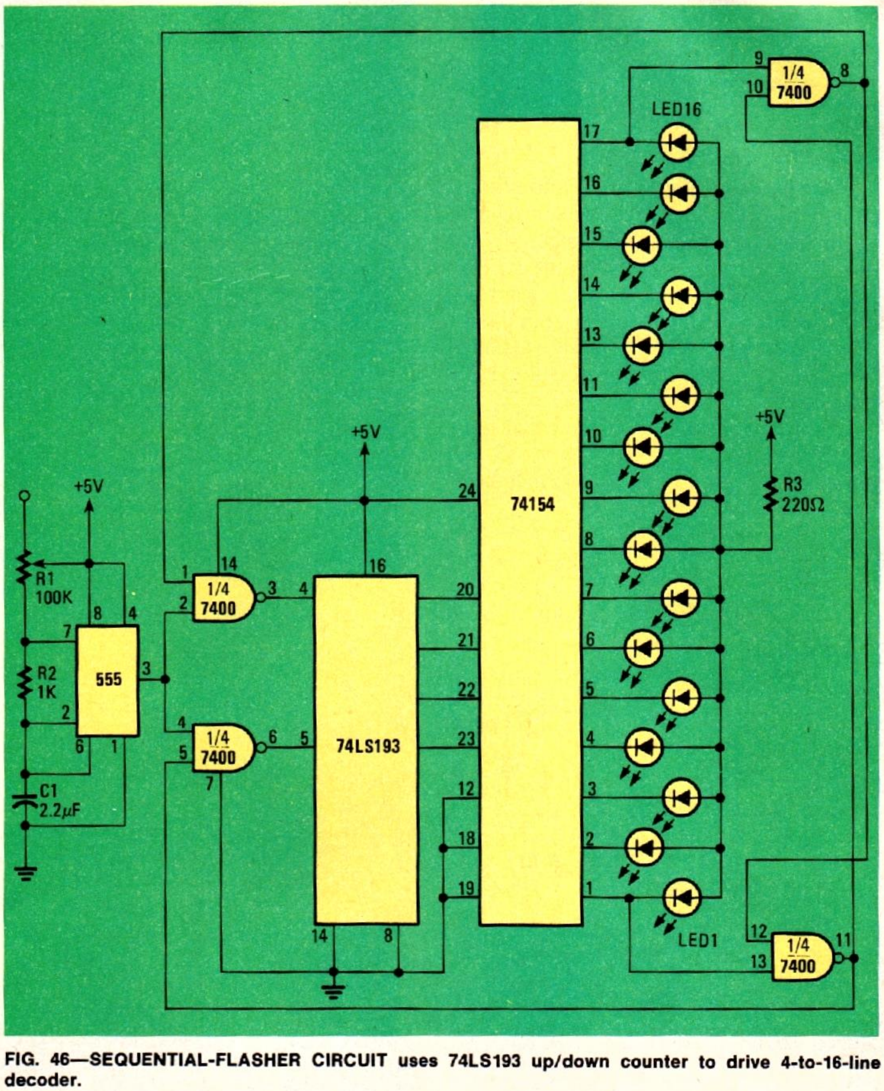


FIG. 46—SEQUENTIAL-FLASHER CIRCUIT uses 74LS193 up/down counter to drive 4-to-16-line decoder.

PARTS LIST—LED FLASHER

All resistors ¼ watt, 5%
R1—100,000 ohms, trimmer potentiometer
R2—1000 ohms
R3—220 ohms
Capacitors
C1—2.2 μF, 16 WVDC, electrolytic
Semiconductors
IC1—555 timer
IC2—7400 quad NAND gate
IC3—74LS193 up/down counter
IC4—74154 4-to-16 line decoder
LED1-LED16—jumbo red LED
Miscellaneous: 7805 voltage regulator with heat sink

angular, which explains the wide spacing of the pads. Round LED's would probably be better, since it is easier to drill round holes in the skin for displays than it is to drill rectangular ones.

One of the best attention getters is an array of flashing lights. One such LED circuit appears in Radio Shack's *ARCHER Engineer's Notebook*, and is the one described here. A display that creates a more random pattern was described in **Radio-Electronics**' Hobby Corner department in the December 1980 issue.

The sequential-flasher circuit in the original Unicorn-1 uses four IC's and five external components to operate 16 LED's. Its schematic is shown in Fig. 46. Resistors R1 and R2, working together with capacitor C1, determine the rate at which the 555 timer IC will cause the LED's to light, and R3 is the current-limiting resistor for the LED's.

The LED's are arranged in five columns of three each (see Fig. 47) with the sixteenth LED at the bottom of the middle column. In operation, they will light starting from the bottom-right, going up the column, then jump to the bottom of the next column, etc. When the last LED has lit, the process will reverse itself, working from left to right and finishing up at LED1.

Although a foil pattern and parts placement diagram (Figs. 48 and 49) are provided, the circuit, and the motor-direction indicator, are both easy enough to build on perforated construction board using wire-wrap techniques. If you have never done any wire-wrapping before, this would be a good place to start because of the simplicity of the circuits. (Articles on wire-wrapping techniques and materials appeared in the August 1979 and March 1980 issues of **Radio-Electronics.**)

You'll need nine jumper wires on the LED-sequencer board. Those can be made from wire-wrap wire, stripped at both ends and tack-soldered to the wiring- or foil-side of the board.

A few words about power supplies for those circuits: TTL IC's are very particular about their working voltage—it should be five volts, ±5% (4.75–5.25 volts). While five volts can be derived

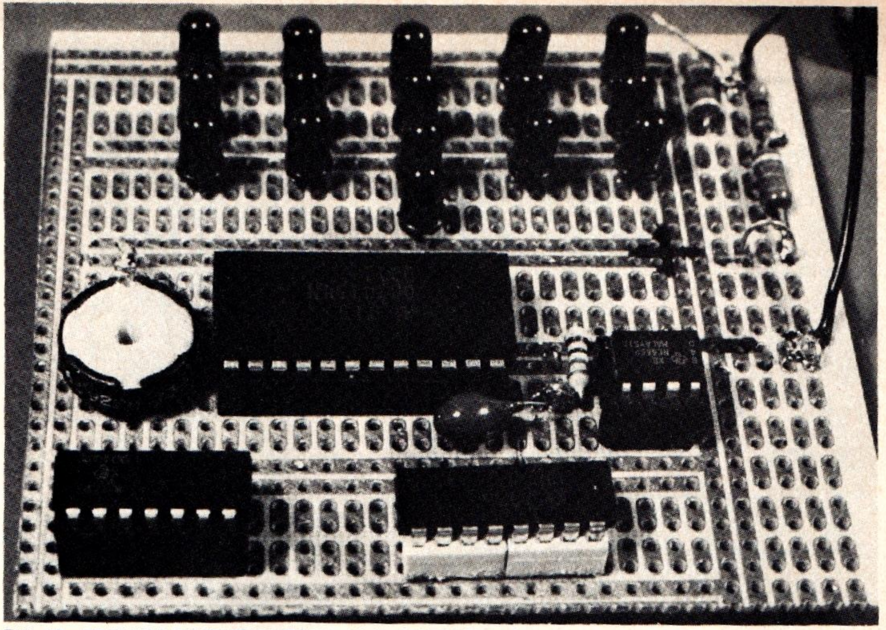


FIG. 47—TRIMMER POTENTIOMETER at left of 74154 IC varies rate at which LED's flash. Mount board so LED's are visible through opening(s) in skin of robot.

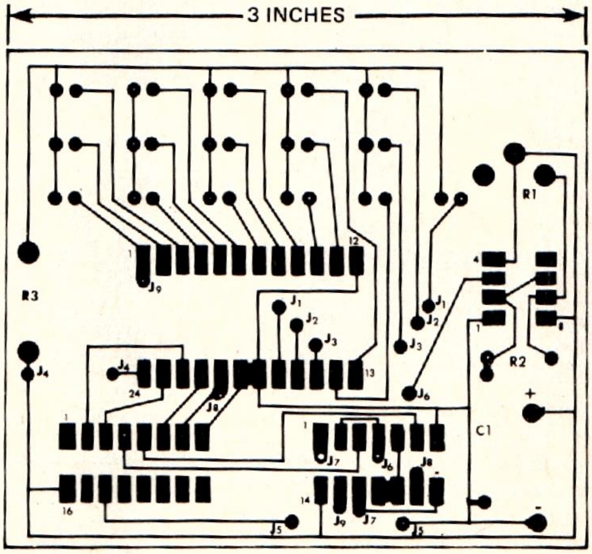


FIG. 48—PC BOARD for sequential-flasher circuit shown in prototype-version above.

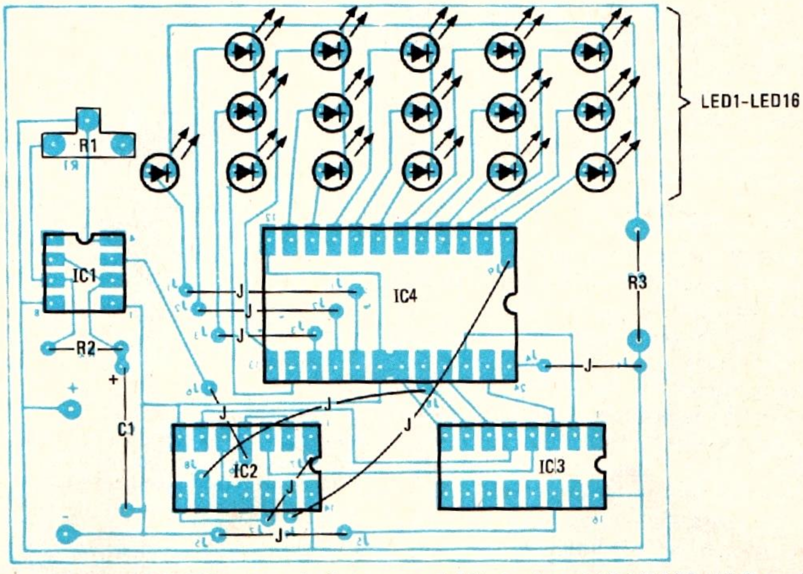


FIG. 49—NINE JUMPER WIRES are required on sequential-flasher board. "Odd" LED at left can be ommitted without upsetting anything if symmetrical layout is desired.

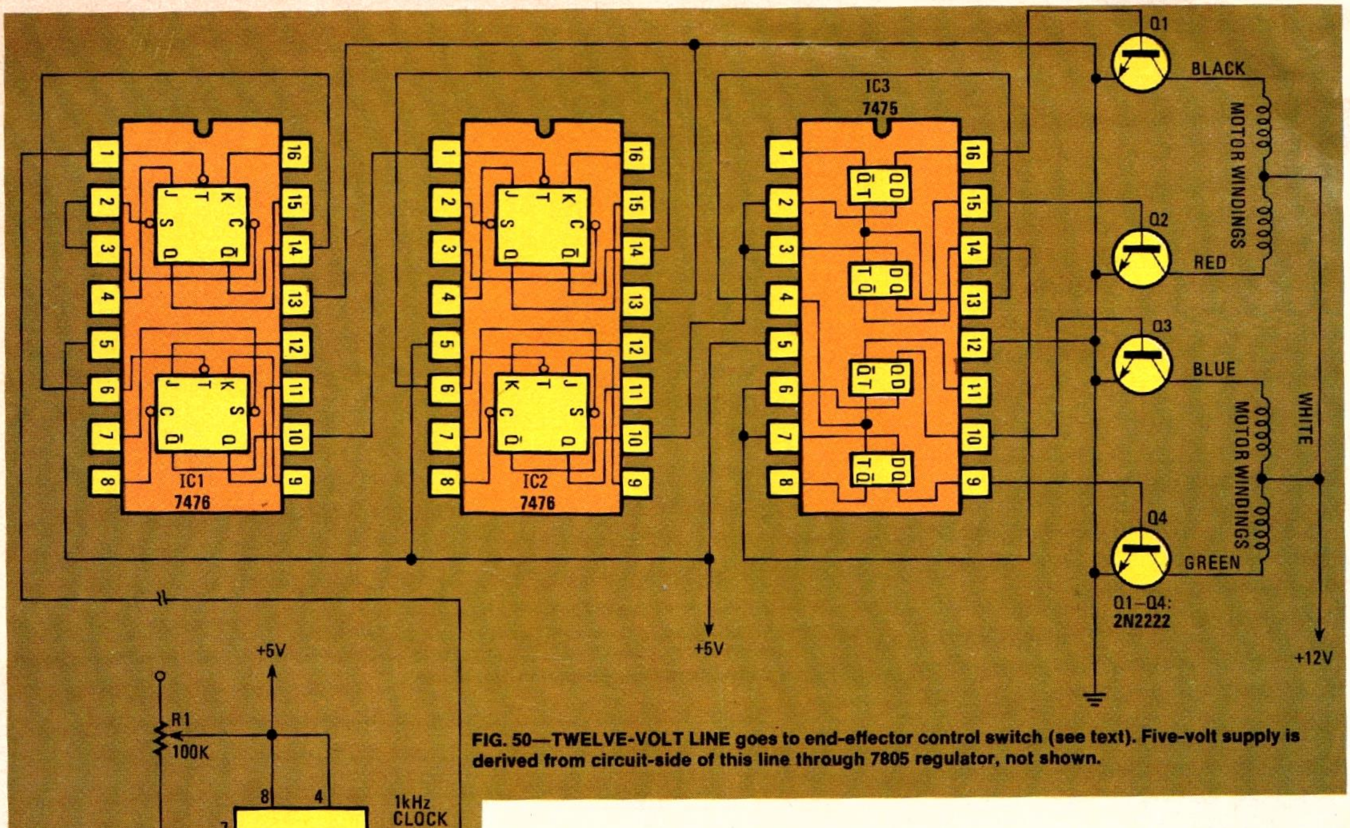
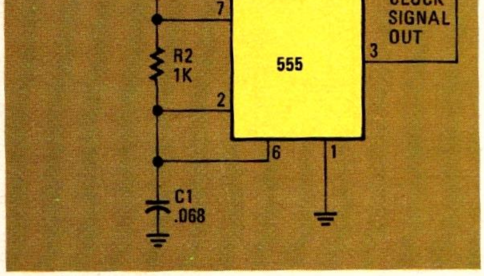



FIG. 50—TWELVE-VOLT LINE goes to end-effector control switch (see text). Five-volt supply is derived from circuit-side of this line through 7805 regulator, not shown.

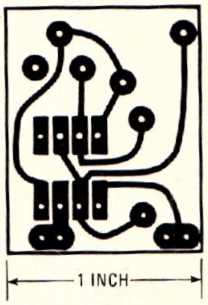


FIG. 51—CLOCK-SIGNAL GENERATOR board for stepper motor controller.

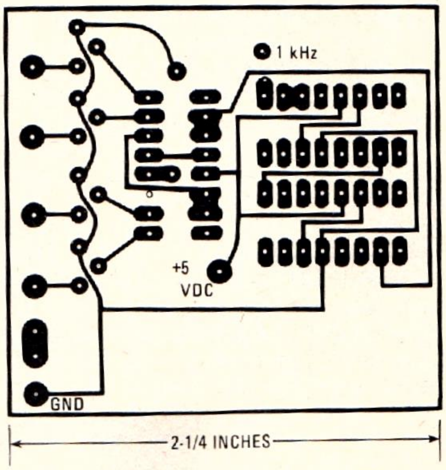


FIG. 53—DIVIDER CHAIN AND LATCHES are located on separate PC board.

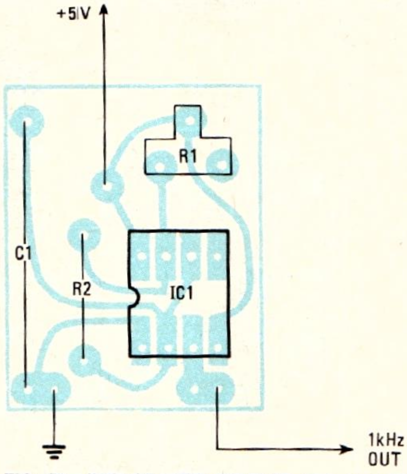


FIG. 52—INTEGRATED CIRCUIT, IC1, is a 555 timer (shown at lower-left in Fig. 50). One-kHz clock signal is fed to second PC board.

from the 12-volt supply by means of a dropping resistor, that method leaves itself open to fluctuations, depending on how much of a load the rest of the robot's electrical and electronic parts present to the battery at any given time. It's better to derive the five volts through a 7805 regulator, well heat-sinked to dissipate the heat generated in dropping the twelve volts to five The addition of an intermediate resistor to drop the 12 volts to eight would ease the load on the regulator.

Other TTL circuits will be described later and they, too, will benefit from a regulated five-volt power supply.

A twist-of-the-wrist

One of the options hinted at earlier in our series was an end-effector (hand) that could be rotated at the "wrist" to give an additional degree of freedom.

That "twist-of-the-wrist" end-effector uses the claw-type mechanism described in Part 2 (September 1980) but, rather than being firmly attached to the manipulator (arm), it is attached to the shaft of a stepper motor. A stepper motor is a motor whose shaft turns just a little bit each time an electrical pulse is applied to its windings.

Figure 50 shows a circuit that generates those pulses and drives the motor. The circuitry actually consists of two parts. The first, used to generate the pulses, is identical to the 555-IC section of the LED sequencer board, except for the values of R1 and C1, which are chosen to give an output of one kHz.

The second uses two 7476 IC's to divide that one-kHz signal by four (giving an output of 250 Hz), and that output is applied to a 7475 quad latch that feeds driver transistors Q1-Q4. Those transistors are connected so as to provide 12 volts to the four windings of the stepper motor.

Figures 51-54 show foil patterns and parts placement diagrams for the two-board circuit. The 12-volt and 5-volt (through a 7805 regulator, not shown) supplies are derived from the wiring to the solenoid of the end-effector mounted on the stepper motor's shaft.

PARTS LIST—STEPPER MOTOR CONTROLLER

All rsistors ¼ watt, 5%
R1—100,000 ohms trimmer potentiometer
R2—1000 ohms
Capacitors
C1—0.068 μF, 10 WVDC, any type
Semiconductors
IC1, IC2—7476 dual J-K flip-flop
IC3—7475 quad latch
IC4—555 timer
Q1-Q4—2N2222 or equivalent
Miscellaneous: 7805 voltage regulator with heat sink

PC boards for the above are available from PPG Electronics Co., Inc., 14663 Lanark St., Van Nuys, CA 91402. (213) 988-3525: Motor Direction Indicator and Stepper Motor Oscillator, $3.00 each, LED Flasher, $5.00, Stepper Motor Controller, $5.00. Please add $1.00 per order for shipping and handling. CA residents add 6% tax. MC and Visa accepted.

PARTS LIST—STEPPER MOTOR ASSEMBLY

Item	Size	Quantity	Supplier's part no.	Supplier
Stepper motor	12 VDC, 0.9°-step	1	Haydon 31612 or 31618, or equivalent	Ⓛ
Shaft	3/16-in. diam. × 1 inch	1		Ⓚ
Bearing	3/16-in. I.D.	2	B2-9	Ⓐ, Ⓑ
Gear	.593-in. diam., 36-T, 64 pitch, 3/16 I.D.	1	P64A19-36	Ⓐ, Ⓑ
Note: small mating gear comes with stepper motor				
Solid steel wire	20 gauge	5 inches		Ⓚ

SUPPLIERS

Ⓐ **The Robot Mart**
Room 1113
19 W. 34th St.
New York, NY 10001
($3.00 for catalog)

Ⓑ **Winfred M. Berg, Inc.**
499 Ocean Avenue
E. Rockaway, NY 11518

Ⓚ Local hardware or building supplies store

Ⓛ **Haydon Switch & Instrument, Inc.**
1500 Meriden Rd.
Waterbury, CT 06705
(Write for list of distributors)

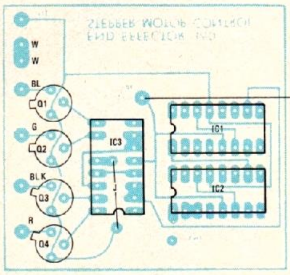


FIG. 54—COLOR CODES shown here should correspond with those on motor wires.

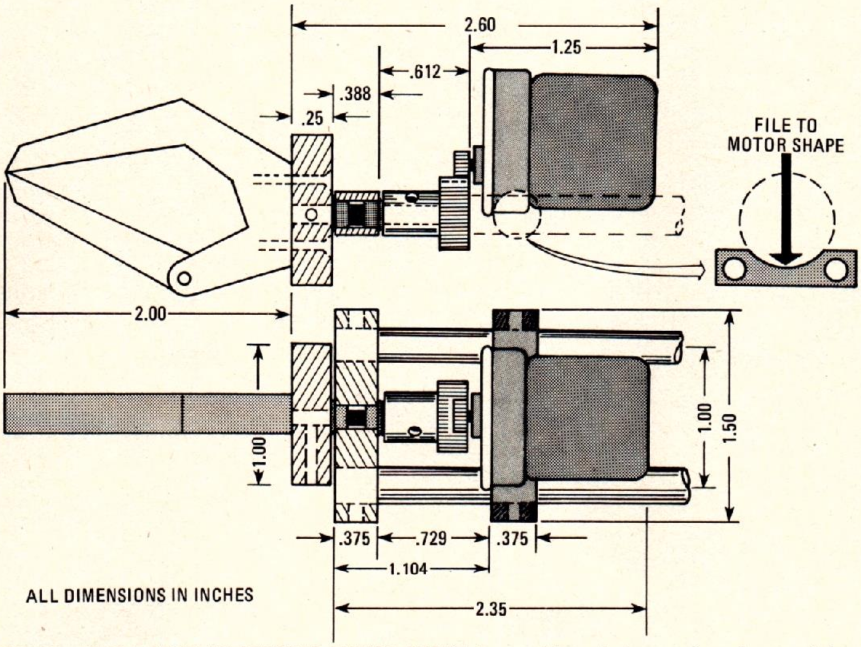


FIG. 55—SMALL GEAR ON STEPPER-MOTOR SHAFT does not have to be purchased separately—it comes with the motor. Note use of bearings through first cross-bar rod.

In practice, when the switch controlling that end-effector is thrown, the "hand" closes and the wrist begins to turn. Returning the switch to the "off" position stops the motor and opens the end-effector. The next time the circuit is activated, the end-effector closes again, but the wrist turns the other way.

The end-effector and wrist actions can be made independent of each other by the addition of another switch to the control console.

Several stepper motors that have been found to work well in this application are indicated in the parts list. The attachment of the motor to the robot's end-effector and manipulator is shown in Fig. 55. A 9-T (nine-tooth), 64-pitch gear is mounted on the shaft of the stepper motor and drives a 36-T, 64-pitch gear attached to the end-effector mounting flange by means of a 3/16-inch diameter shaft passed through two flange bearings in the end cross-bar rod. Not shown in the mechanical drawing is a hole bored through the axis of the shaft to pass the wire that operates the claw. Fig. 56 shows the assembled rotatable end-effector with the 20-gauge solid wire pivoted where it is attached to the solenoid to allow free rotation.

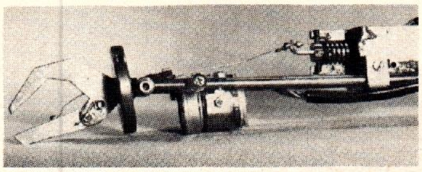


FIG. 56—COMPLETED rotatable end-effector mounted on forearm shows modified connection to solenoid using solid steel wire.

To mount the stepper motor and rotatable end-effector, the end cross-bar rod has to be drilled for the bearings and shaft, and the next cross-bar rod up should be filed to accept the shape of the motor. The motor is clamped and/or bolted to the arm assembly.

In the next installment, in preparation for radio- and computer-control, we'll describe motor-control circuits that operate from logic-level signals, and start making radio-control system. **R-E**

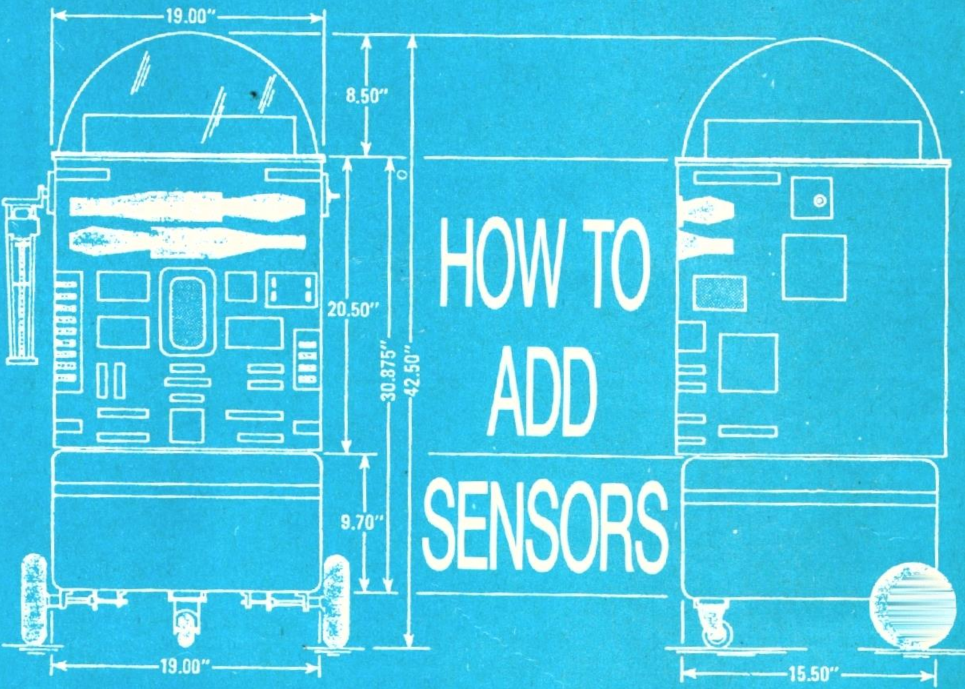
BUILD THIS

Part 11—The better your robot can respond to the world around it, the more useful it will be. Here are two sensors that will enable the robot to "see" and "feel" objects that are in its vicinity.

UNICORN-1 ROBOT

JAMES A. GUPTON, JR.

HOW TO ADD SENSORS



UP UNTIL THIS POINT, ANY REACTION THAT the robot has shown to events happening around it have actually been those of its operator. Radio- or computer-control has been possible only to the extent that the operator could observe the robot's environment and make the robot react to it. And, even operating in that way, there has been the danger that the robot could "stumble" into something that could not be seen by the operator.

In this installment of the Unicorn-1 series we'll describe two types of sensors that will enable the robot to detect objects in its immediate vicinity and to react to them.

The first is a contact-type sensor that will give the robot a limited sense of "feel" and allow it to know when it has bumped into something.

There are times, though, when it would be better for the robot to be able to sense when it was *about to bump into* something—running into brick walls is one thing; running into people, another!

The second sensor, then, will be of the proximity-type, giving the robot a rather restricted sort of "vision."

Contact sensor

The robot should be equipped with two contact-sensors—front and rear. They are extremely simple in design, as can be seen from Fig. 86, consisting of lever-actuated switches that are connected to rods projecting from the mobility base. Note that the rear sensor-rod is about twice as long as the one for the front sensor. This compensates for the fact that the large driven wheels of the mobility base may project behind it and, naturally, we want the sensor to come into contact with an obstacle before any part of the robot does.

The sensor rods are made from pieces of wire coat hanger, with the paint or lacquer removed to permit good solder joints. The front rod is about 1½-inches long and the rear rod about twice that length. The compression springs can be "liberated" from dried out ball-point pens. The springs are held in place by 4-40 washers soldered to the rods.

A 4-40 cap nut (the kind with a rounded end) can be soldered to the end of each rod to prevent it from scraping or impaling whatever it may come into contact with. Better protection can be provided by applying a liberal amount of silicone sealant to the cap nut to provide a soft, protective surface.

Even better, a small bumper, with a soft covering made from a piece of foam rubber or inner tube, can be constructed and affixed to the end of the sensor rod.

The bushings that fit into the mobility base and allow the sensor rods to move in and out are nothing more than 10-32 × ⅜ machine screws that have been drilled out with a No. 42 drill bit (use a drill press and vise, if you possibly can) and had their heads filed flat to remove the screwdriver slot. Leave enough head, though, to hold the screw in place. Use 10-32 nuts to secure the bushings to the mobility base.

A helpful hint: Fig. 86 shows a half-inch brass washer soldered to the "inside" end of each sensor rod. (The washers are especially necessary if more than one switch is used for each sensor—see below.) *Those* washers should be the last part to be attached.

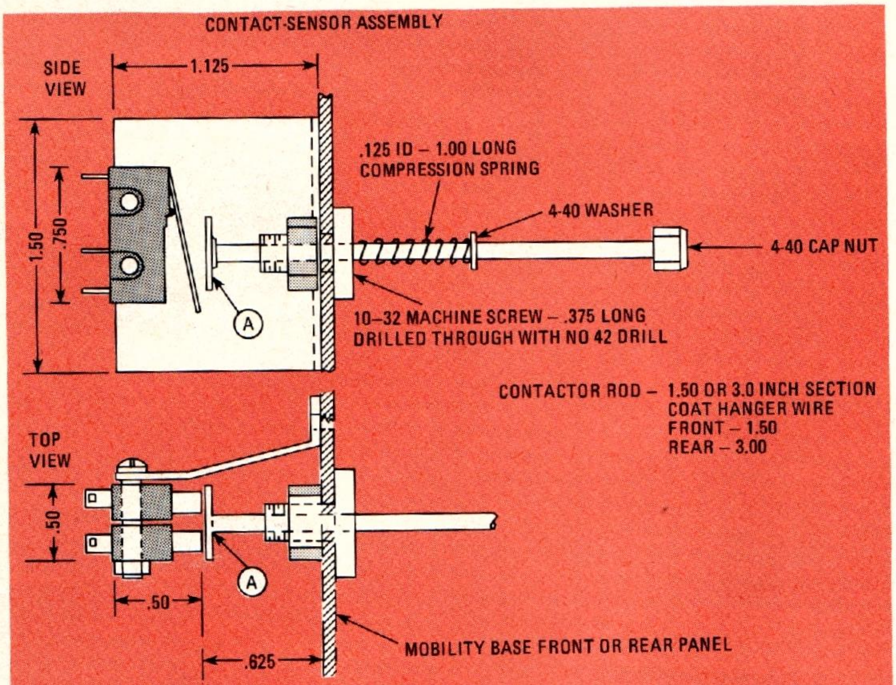
The end-nut (or bumper), spring and 4-40 spring-stop-washer should be attached to the rod first, and the unit inserted into the bushing. Then, using a wooden block to compress the assembly, and holding the brass washer with a pair of pliers, solder the washer to the end of the rod. Doing this will prevent your getting your fingers burned.

The brackets for the switches can be made from almost any material at hand—metal, plastic, or wood. They support the switches in the proper position and, if two switches are mounted side-by-side, allow the brass washer to contact both switch-levers at the same time.

The original Unicorn-1 used brackets made from scraps of 1½ × 1½ × .0625-inch aluminum, bent as shown in Fig. 86, and drilled to accept two 4-40 mounting screws. The section that fits flush with the mobility base need be no larger than ¼-inch if 4-40 hardware is used but should be at least ⅜-inch long for 6-32 hardware.

If the mounting holes in the switches are too small for 4-40 hardware, they can be enlarged with a No. 33 drill bit. Be sure to use a vise and to use either a hand drill or a *very slow* electric drill to prevent damage to the plastic switch case.

The completed front and rear contact-sensor assemblies are shown in Fig. 87. If larger switches are used, mounting brack-



ALL DIMENSIONS IN INCHES

Ⓐ .50 DIA. BRASS OR STEEL WASHER

MAKE SWITCH BRACKET FROM 0.0625 × 1.50 ALUMINUM SHEET

FIG. 86—CONTACT SENSOR tells the robot when it has bumped into something. Cap nut at end of rod should be provided with cushioning material (see text).

ets may not be necesary since the switches can be mounted directly on the bottom plate of the mobility base.

Connection of the switches will be discussed later.

Proximity sensor

While the contact-type sensor described above is extremely useful, there are times when it could prove embarassing (or worse) to have the robot collide with something. It would be better if it could sense the proximity (nearness) of an object and either stop or, if under computer control, take evasive action.

Figure 88 shows how an infrared-light-type proximity sensor would work. The transmitter, mounted on the robot's right side and angled slightly inward, projects a beam of infrared light that will be reflected by a nearby object to the infrared detector, mounted on the robot's left side and also angled toward the target.

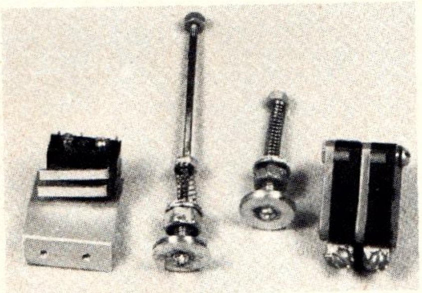
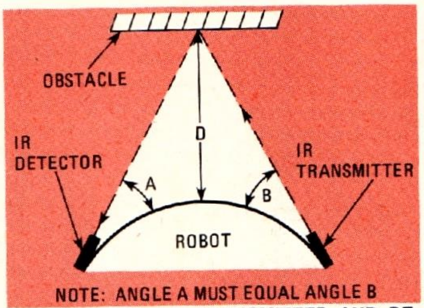


FIG. 87—COMPLETED CONTACT SENSORS used in original Unicorn-1. In this case, dual switch-assemblies were used.



NOTE: ANGLE A MUST EQUAL ANGLE B

FIG. 88—INFRARED TRANSMITTER AND DETECTOR are mounted on sides of robot's body or dome. Angle A must be equal to angle B.

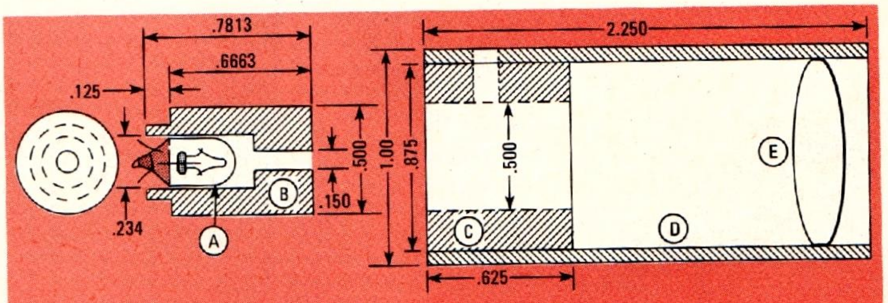
The distance between the transmitter and the detector, and the angle they form, will determine the distance, D, from the robot that the object can be sensed. The transmitter and detector must be aimed inward at equal angles for accuracy. (Remember that "the angle of reflection equals the angle of incidence;" and, the larger the angle, the farther away—up to about 20 inches in this case—an object can be detected.)

Using infrared light means that the system can be used under almost any lighting conditions since the infrared detector is not very sensitive to visible light. For that matter, the robot could even detect obstacles in the dark—it carries its own "flashlight."

Figure 89 shows the infrared-projector assembly used on Unicorn-1. When used with a lens, the 2174D infrared lamp generates a beam that is usable to a distance of about 20 inches.

The dimensions shown for the lens tube are only approximate, since there are so many variables (lens type, detection distance required, etc.) involved. The best way to find the dimensions you will need is to set up the lamp in its housing at one end of a ruler and to move the lens back and forth until you can see the beam focused into a spot on a screen or sheet of paper placed at distance D—your target distance. Don't forget that D is measured from the front of the robot, and not from the transmitter (or receiver).

Note the distance between the lens and the aperture of the transmitter assembly and make the lens tube that length. Critical adjustments can be made later by adjusting the position of the lamp housing slightly. The final assembly step, before mounting the projector on the robot, is to glue the lens in place in the tube using either epoxy or lens cement. Take care



NOTES:

Ⓐ IR LAMP TYPE 2174D OR EQUIV.

Ⓑ IR LAMP HOUSING – .500 DIA. ALUM. ROD

Ⓒ .875 DIA. ALUM. INSERT – I.D. .502 LENGTH .625

Ⓓ LENS TUBE – 1.00 DIA., .0625 WALL – ALUM. TUBE

Ⓔ LENS, DOUBLE CONVEX, FOCAL LENGTH 48mm TO 55mm, DIA. 18mm TO 22mm

Ⓕ ALL DIMENSIONS IN INCHES EXCEPT FOR LENS

FIG. 89—INFRARED LAMP HOUSING can be held in position in lens tube by set screw, once proper position has been determined.

PARTS LIST—CONTACT SENSORS

Item	Description or quantity	Source
Contact rod	1.5 inches	coat-hanger wire
″	3.0 inches	″
Mobility-base bushing	10—32 × ⅜ flat-head screw, (2)	hardware store
″	10-32 nut (2)	″
Cap nut	4-40 (2)	″
Compression spring	.125 I.D., 1 inch long (2)	ball point pen
Washer	4-40 steel (2)	hardware store
″	.5-inch brass (2)	″
Lever-type switch	2 or 4	**Radio Shack** (catalog No. 275-016) or equivalent
Switch bracket	1.5 × 1.5 × .0625 aluminum (2)	scrap or hardware store

PARTS LIST—PROXIMITY SENSOR

Item	Description or quantity	Source
TRANSMITTER:		
Infrared lamp	2174D, 12-volts	electronic-supply house
Lamp housing	.5-inch aluminum rod	hardware store
Lens tube	aluminum tubing, 1-inch O.D. × 2.25 inches long	″
Lens & lens cement	double-convex, 48-55mm focal length, diam. to fit lens tube	**Edmund Scientific** 101 E. Gloucester Pike Barrington, NJ 08007
RECEIVER:		
Sensor housing	5-inch aluminum rod & washer	hardware store
Lens tube	aluminum tubing, 1-inch O.D. × 2 inches long	″
Lens & lens cement	double-convex, 20-30mm focal length, diam. to fit lens tube	**Edmund Scientific**
PC board	1 ($2.50 + $1.50 S&H if total order less than $15.00)	**Hal-Tronix** P.O. Box 1101 Southgate, MI 48195
R1	68 ohms, ½-watt	
R2	22,000 ohms, ¼-watt	
R3	10,000 ohms, ¼-watt	
R4	4700 ohms, ¼-watt	
IC1	7404 hex inverter	
Q1	2N2222 or equivalent	
Q2	FPT-100 or equivalent (Radio Shack 276-130)	
D1	1N5227 3.6-volt Zener diode	
D2	1N5231 5.1-volt Zener diode	
D3	1N4001, 50PIV, 1-amp diode	
RY1	5-volt DPDT DIP relay (Radio Shack 275-215 or equivalent)	

not to get any of the adhesive on the lens. The completed transmitter assembly is shown in Fig. 90.

A diagram of the infrared-receiver assembly is shown in Fig. 91. As in the case with the transmitter, the dimensions are approximate. To determine the final dimensions, a method similar to the one outlined above is used.

First, cover the aperture of the detector housing with a translucent material, such as *Scotch* brand *Magic Tape*, to make a focusing screen. Attach the detector housing to a ruler and aim the ruler at a white or light gray surface placed at distance D. When making your final calculations, don't forget about the angles involved! Move the lens back and forth along the ruler until a sharply defined spot is seen on the focusing screen. The distance between the lens and the end of the detector housing will determine the length of the lens tube.

As in the case of the projector, cement the lens to the focusing tube and perform the critical focusing adjustment with the detector housing.

In performing these measurements, the projector and receiver assemblies should be placed in the positions they will occupy when mounted on the robot, and be angled accordingly. If this is not done, the results of the measurements will be invalid.

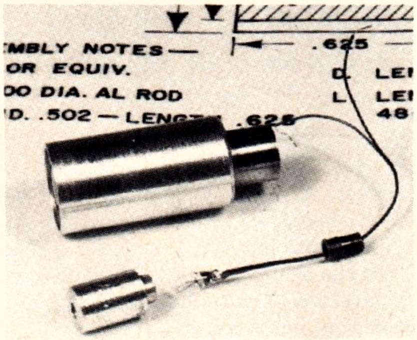


FIG. 90—UNICORN-1's infrared transmitter. Note insulating sleeve for lamp.

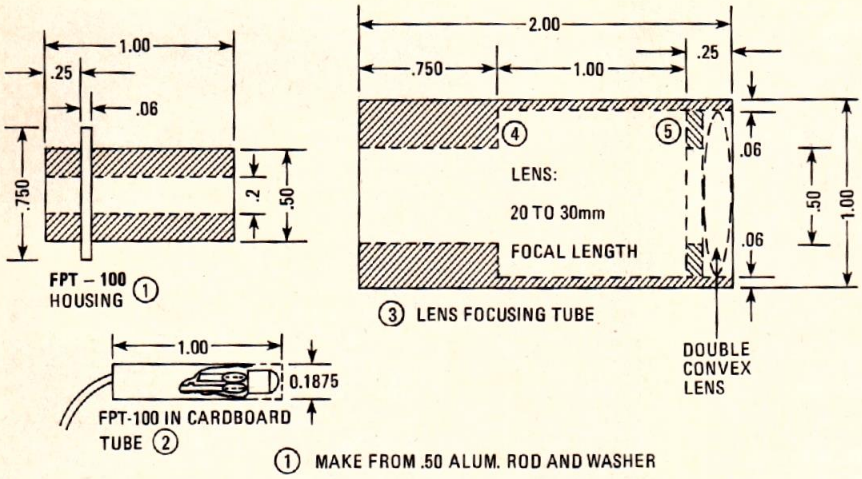
Receiver circuit

Both the transmitter and receiver can be operated from the robot's 12-volt power supply. A schematic for the receiver is shown in Fig. 92 (and the foil pattern and parts-placement diagram in Figs. 93 and 94, respectively).

The heart of the receiver is an FPT-100 infrared phototransistor (Radio Shack part No. 276-130 is an acceptable substitute). Its collector is connected to the 12-volt supply through a 10K load resistor, R3. The collector is also connected to pin 1 of IC1 through a 22K series resistor and through a 1N5227 3.6-volt Zener dioide (D1). That keeps pin 1 at a logic "high" when the detector is receiving no input.

The IC supply voltage of 5.1 volts is provided by D2, a 1N5231 Zener diode. This diode also provides the coil-voltage for RY1, a DIP relay of the same type used on the relay board described in Part 7 of this series. The circuit operates as follows:

When the infrared sensor, Q2, is at the optimum distance from a reflective obstacle, the reflected infrared light is at a maximum. The sensor is biased into a state of saturation and its collector voltage drops to zero. The 3.6-volts present at pin 1 of IC1 also drops to zero, causing the output at pin 2 to go from 3.6- to five volts (logic "high"). This biases transis-



① MAKE FROM .50 ALUM. ROD AND WASHER

② CUT FPT-100 LEADS TO .25", SOLDER 18" CONNECTING WIRES TO PC BOARD

③ MAKE FROM 1.00 O.D., .06 WALL, ALUM. TUBE

④ MAKE FROM .86 O.D. WOOD OR ALUM. ROD

⑤ MAKE FROM 1.00 O.D., .50 I.D., FIBER WASHER

⑥ ALL DIMENSIONS IN INCHES EXCEPT FOR LENS

FIG. 91—USE A CARDBOARD OR PLASTIC sleeve to prevent FPT-100 leads from shorting to metal housing.

We've been receiving a lot of correspondence from readers who are building—or contemplating building—their own versions of Unicorn-1. We'd like to see more, along with nice sharp photographs, so we can publish a segment showing off those robots and presenting some of the innovations that you've come up with. Write to **Radio-Electronics,** 200 Park Avenue South, New York, NY 10003 and mark your envelope "ROBOT UPDATE."

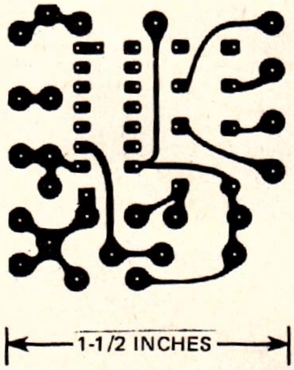


FIG. 93—YOU CAN ETCH detector board yourself from this pattern. Ready-made boards are also available (see parts list).

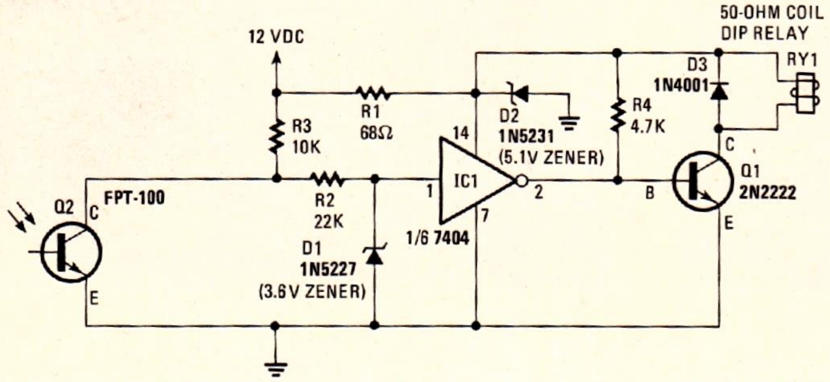


FIG. 92—INFRARED-DETECTOR circuit is simple enough to be built on perforated construction board.

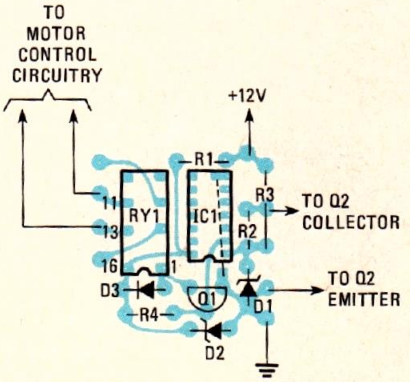


FIG. 94—DETECTOR BOARD is connected to FPT-100 sensor by 18-inch leads. See text for motor-control connections.

tor Q1, a 2N2222, into saturation, causing current to flow through the coil of the relay and opening the relay's normally-closed contacts, thereby cutting off power to the appropriate control circuitry.

Connection to robot

Depending on how advanced your own robot is, the signals provided by the sensor circuitry can be used in several ways.

If the robot is still operating at the end of a "tether," the contact-sensor switches and the proximity-sensor relay can simply be connected in series with the motor circuits (like the limit switches) and used to cut power to the motors when an obstacle is detected. This is why you might wish to use two switches each for the front and rear contact-sensors—one switch can control the right-hand wheel, and one the left-hand one. Unused switch or relay contacts can be used to actuate the robot's horn (or some other audible or visible signaling device) to alert you that it has run into difficulties. Without logic circuits, there's not much more that can be done at this stage.

If the robot is using radio- or computer-control, the output of the detectors can be connected to the appropriate "drop-dead" sections of the latch board (see Part 9) to achieve the same results.

Finally, if you are using a computer, a program can be written to make use of the "drop-dead" signal. For example, the computer could be programmed to respond to that signal and make the robot back up a bit, make a 45-degree turn, and check again for an obstacle. If none were present, it could continue its travel. And that just scratches the surface of the responses that could be programmed.

The rest is up to you, for this is the end of the Unicorn-1 series. We've shown you how to build a working robot, and how to enhance it with radio- and computer-control. As you continue to work with your robot you'll find its capabilities limited only by your imagination and resources.

Those of you who have built your own robots can take pleasure in knowing that you are advancing the science of robotics. In the near future, much of the hazardous and tedious work now performed by humans will be carried out by robots.

Even now we are seeing robots explore parts of the solar system that man will not visit in person for tens—or hundreds—of years. Enormous progress is being made in creating robots to serve in areas where man's help is either unnecessary or impossible to provide. What will be *your* contribution to the age of robotics? **R-E**

UNICORN-1 ROBOT

I was impressed by the very thorough series of articles, "Unicorn-1 Robot," that appeared in **Radio-Electronics,** August 1980 through June 1981. However, there appear to be a few errors that should be noted.

In the March 1981 issue (page 65), the relay driver circuit will not work as explained in the text. As shown, the 2N2222 transistor and relay will be turned *on* in absence of a command. That is opposite the condition that is desired. In other words, what is required at the transistor base is a logic-low to de-energize the relay in the stand-by mode.

There are a couple of modifications that can be made without altering the printed-circuit boards. The choices are:

Latch Board: take the output signal from the Q pins 6 and 8, or:

Relay Driver Board: drive the transistor directly from the decoder board or latch board by eliminating the octal inverter (2813A) and placing jumper wire between input and output pins of the IC socket.

The suggestion to use PNP transistors is not recommended because that places 5-volts across the base-emitter junction and the driver in series; that could damage the transistor.

In the April 1981 issue (page 68), Fig. 80, and (page 69), Fig. 82, the latch board input and output signals on pins 9 and 11 of the 7474 IC are reversed.

WALTER PALANKER,
Magnolia, NJ

PROGRAMMING FLAW

I am the proud owner of a new personal computer system, and because of that, your October 1981 issue of **Radio-Electronics** caught my eye. I got a lot out of that issue!

I did a lot of shopping around before I decided on the TRS-80, 16K, color outfit. Along with it, I purchased some software

continued on page 22