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.

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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 to

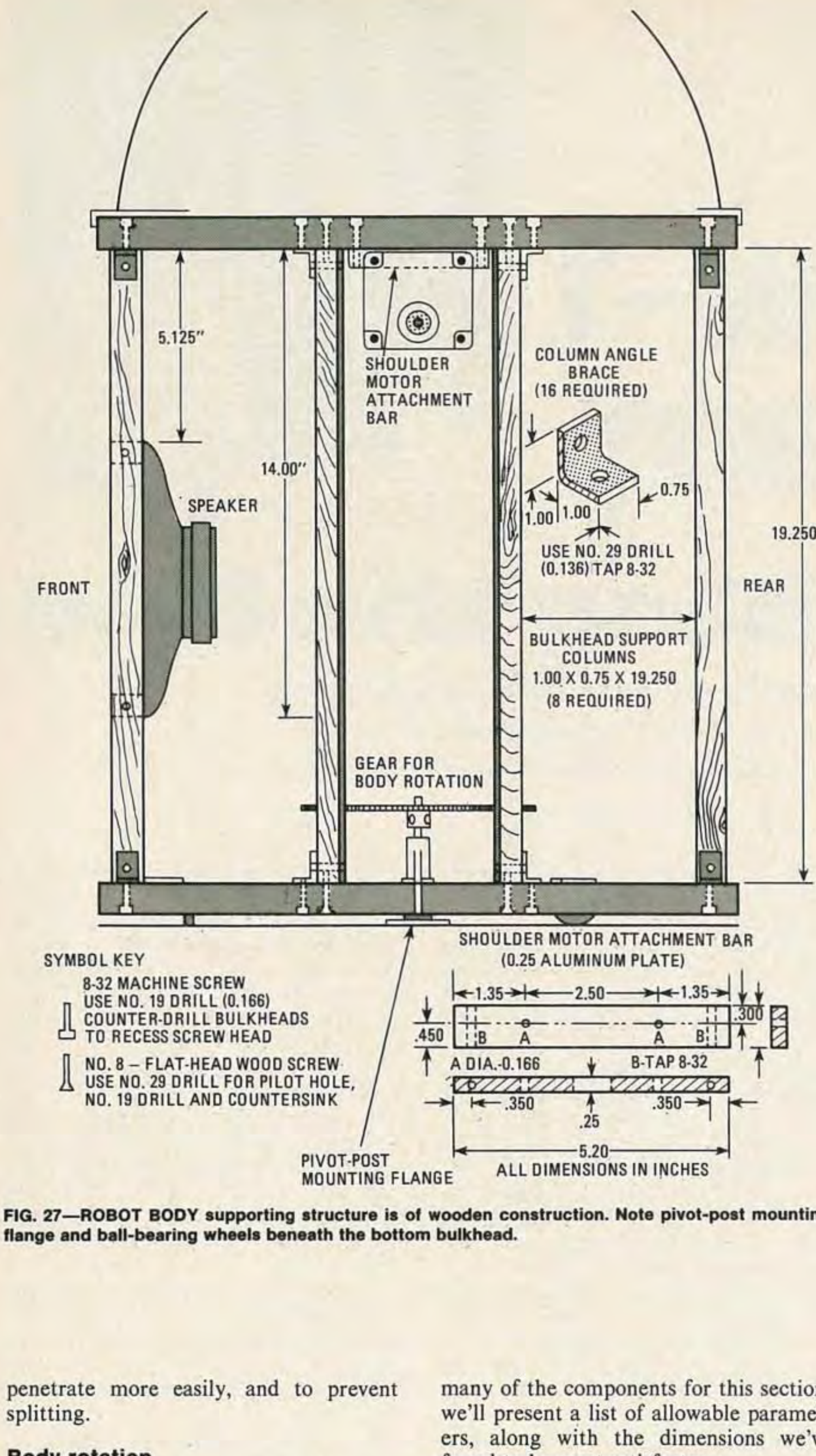
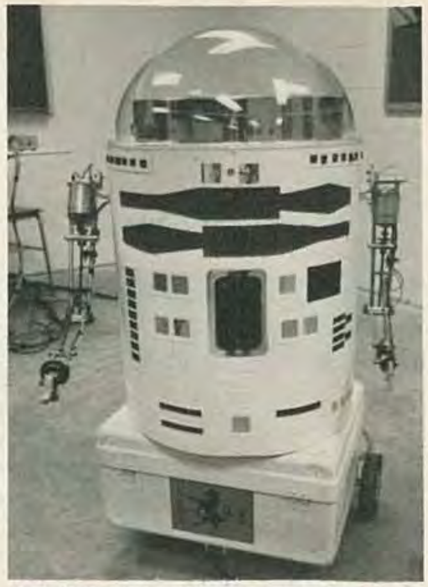


FIG. 27—ROBOT BODY supporting structure is of wooden construction. Note pivot-post mounting flange and ball-bearing wheels beneath the bottom bulkhead.



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.

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).
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

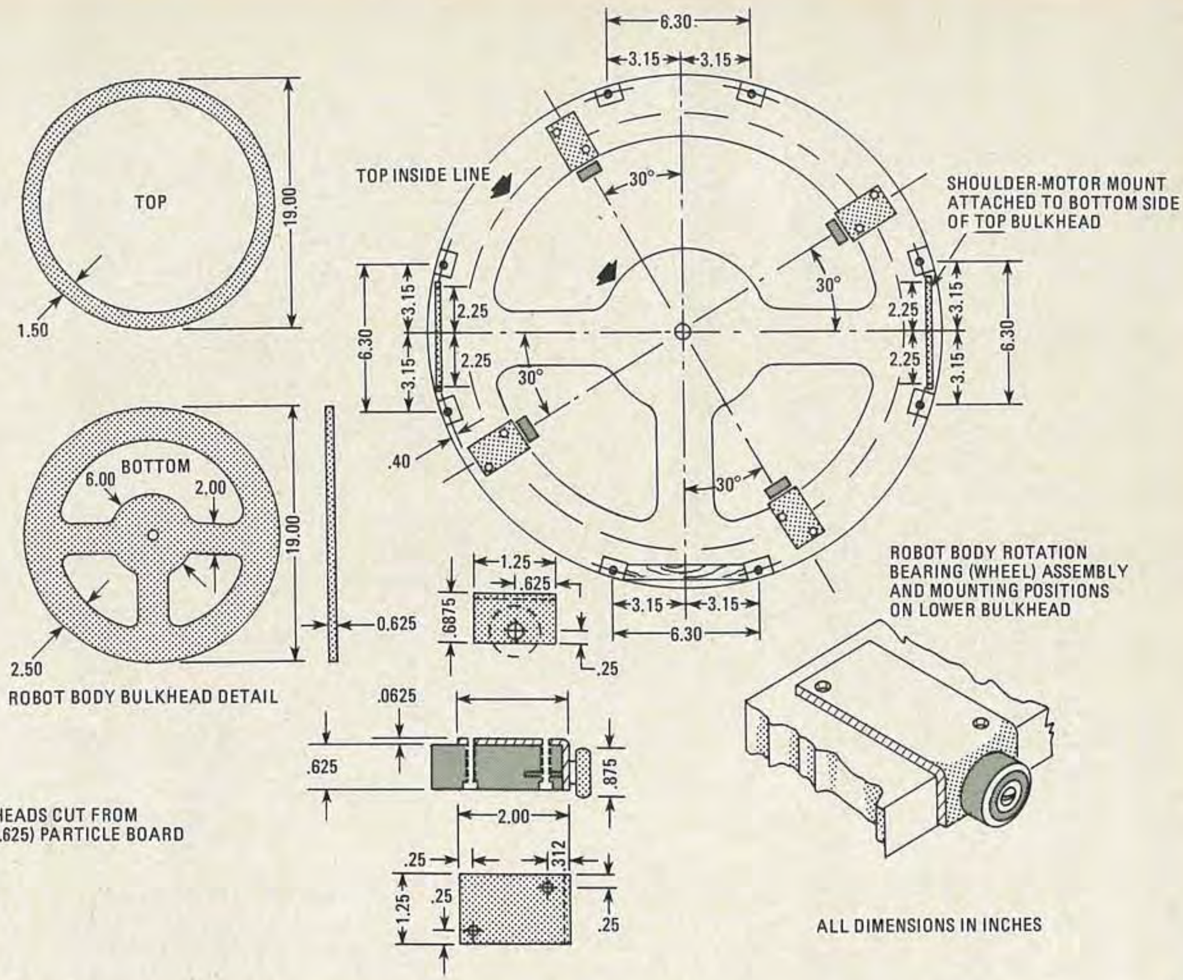


FIG. 28—TOP AND BOTTOM BULKHEADS are cut from particle board. Bottom bulkhead is sturdier to bear body weight. Bearing mounting brackets are made from 1/16-inch aluminum.

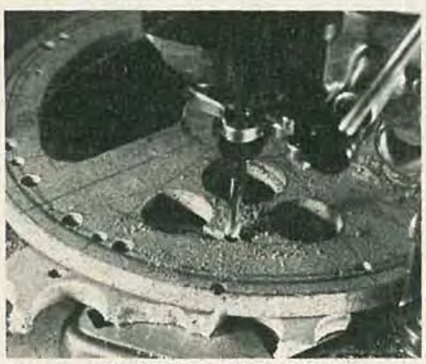


FIG. 29—A SERIES OF SMALL HOLES can be drilled to rough-cut bulkheads to shape.

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

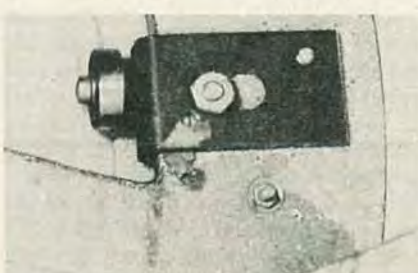


FIG. 31—BALL-BEARING WHEELS mounted on bottom bulkhead support body as it rotates.

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, 1/8-in. face, 1/4-in. bore	3	C48A18-023	Ⓐ,Ⓑ
	48 pitch, 120 teeth, 1/8-in. face, 1/4-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

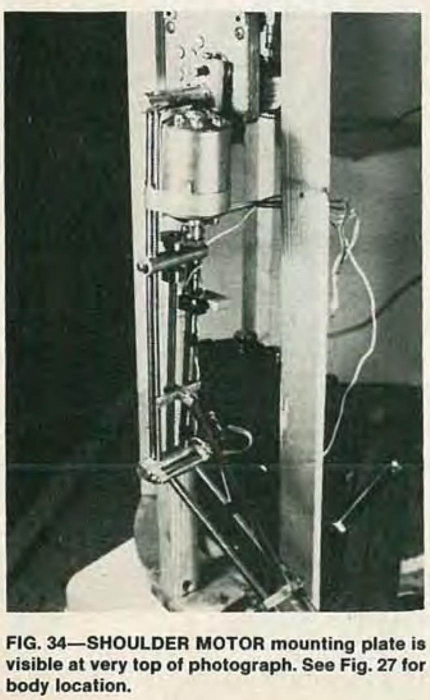


FIG. 34—SHOULDER MOTOR mounting plate is visible at very top of photograph. See Fig. 27 for body location.

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**