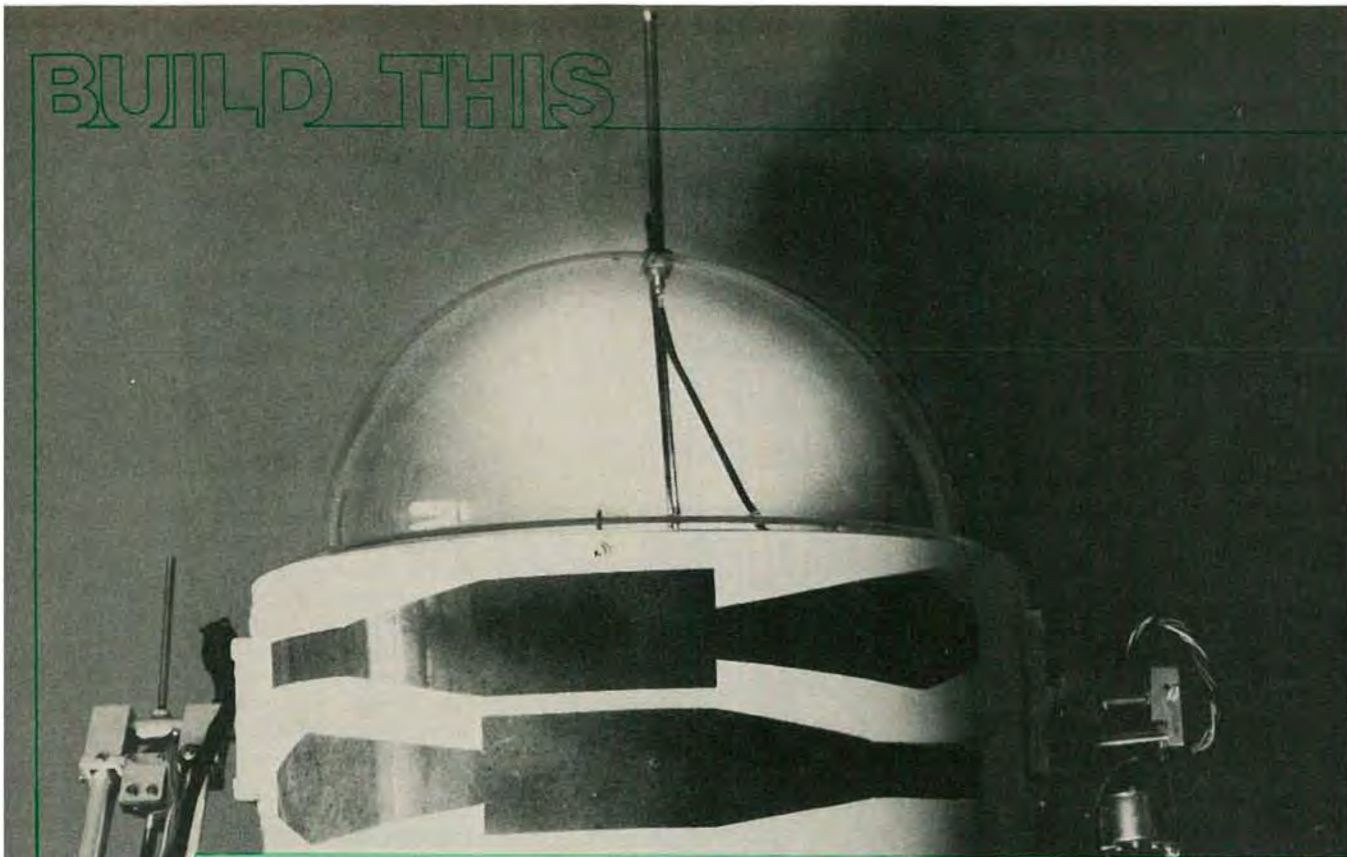


UNICORN-1 ROBOT

JAMES A. GUPTON, JR.

Adding Remote Control

Part 7—The first of several parts on adding remote control to Unicorn-1. The first step is a relay board to drive the 12-volt system from a five-volt source. Also, there's a uniquely robotic arm.

WHILE THE COMMAND CONSOLE AND UMBILICAL cable are fine for getting the feel of controlling the robot, there comes a time when you're ready to break loose and operate the robot from a distance—by radio control, for example. In this section we'll begin the changeover—whether it's for radio or computer control—by constructing a relay board to operate the robot's 12-volt motors and solenoids from 5-volt (logic-level) signals.

We'll also describe another type of manipulator arm for the robot that does away with the elbow-bending action and substitutes for it an *extendable* arm.

Relay board

Both the radio-control decoder circuitry and the computer-interface generate logic-level signals—where the voltages are either close to zero for a logic "0", or close to five volts for a logic "1". Since the motors and solenoids in the robot are designed to operate from a 12-volt supply, we must devise some way of switching 12 volts from a 5-volt control signal. That is the purpose of the relay board.

The board is a standard 22/44 finger (44 fingers, with 22 on each side), 4 × 5-inch perforated IC prototyping board that fits into a mating edge-connector and is available from a number of sources. One side has a foil pad at each of the perforations and two sets of traces for power distribution, but the other is bare, except for the fingers at the card-edge.

Figures 57 and 58 show the same relay board from the foil side with an X-ray view of the relays that are mounted on the bare side of the board. All wiring, with a few exceptions that will be pointed out later, is done on the foil side of the board. Two diagrams will show exactly how the wires are connected.

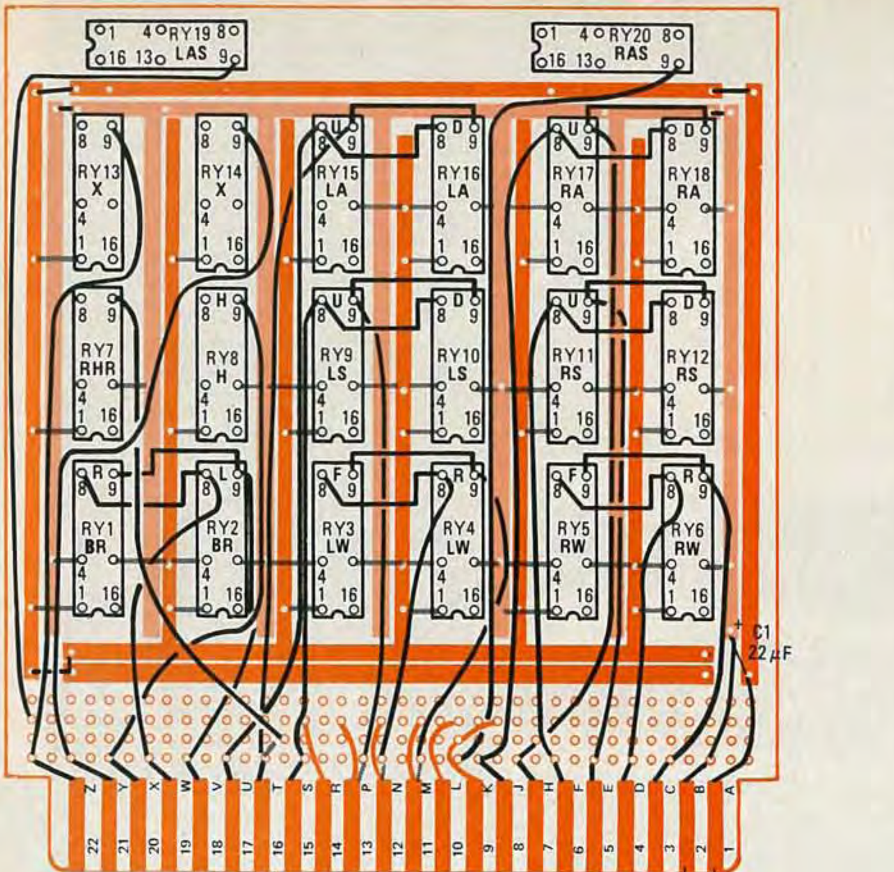


FIG. 57—RELAY COIL CONNECTION to card-edge fingers. Most of the wires go to the relay-side of the board (See Table 2 for specific pinouts).

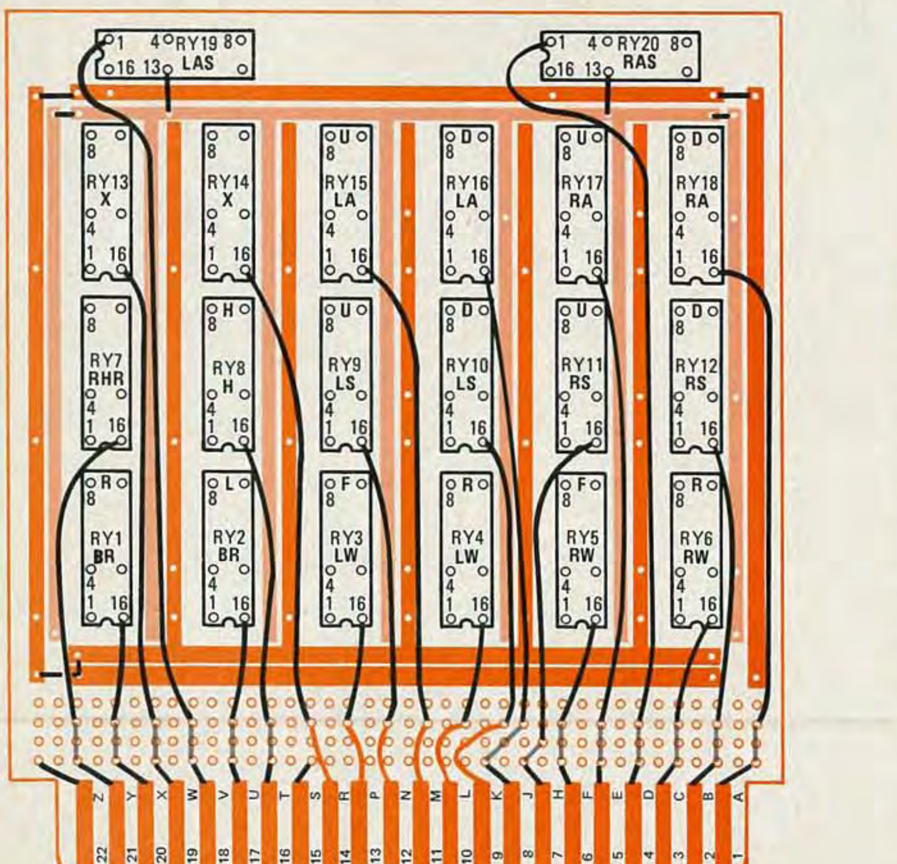


FIG. 58—MOST OF THE REMAINING connections are made on wiring-side of board. See Table 3 for details. Remember: Both diagrams show *foil-side* of board—relays will not be visible!

The DIP relays, capable of switching one amp, (see parts list) are mounted on the bare side of the board in 16-pin DIP sockets. Table 1 shows the function of each of those relays. The sockets can be secured to the board either by soldering their corner pins to the foil pads on the bottom of the board or by a bit of epoxy between the socket and the surface of the board. The first method is preferable. Sockets are used in case the relays have to be replaced.

All 20 relays are the same type, DPDT (see Fig. 59), even though, in some cases, only one section of a set of relay contacts may be used.

It is recommended that, whatever designations (if any) are given to the fingers on the prototyping board you use, you follow the ones given here, to reduce the possibility of confusion and miswiring.

Looking at the foil side and starting from the *right*, the fingers bear the letters "A" through "Z" (with four letters left out to give us 22). The fingers on the bare (relay) side of the board, but *still looking at the board from the foil side*, are numbered 1 through 22, from right to left. (Viewing the board from the bare side would show the numbers 1 through 22, but from *left to right*.) Finger "A" is opposite finger 1, finger "B" is opposite finger 2, etc.

Make sure you understand that system before you start wiring things up!

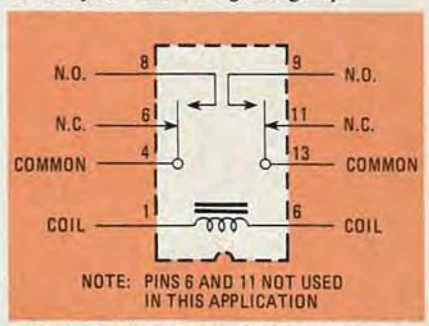


FIG. 59—PINOUT OF RELAYS used in this project by author. Relay contacts should be rated at one amp.

Wiring procedure

Refer frequently to Figs. 57 and 58, and to Figs. 60 and 61.

Begin by connecting pin 1—it feeds one end of the relay's coil—of each of the IC sockets to the ground rail of the board as shown in Fig. 58. The only exceptions to that are relays RY19 and RY20. In their case it is pin 16 that's connected to ground.

Use insulated wire throughout—there are going to be lots of wires, and the possibility of short circuits exists. You can use wire-wrap wire for connections to pins 1 and 16, but all the others will require at least 22-gauge wire to carry sufficient current for the motors and solenoids. Using a color-coding system will simplify signal tracing later.

Next, connect pin 16 (the other end of the coil) of each socket (pin 1 for RY19

TABLE 1 RELAY FUNCTIONS AND CALLOUTS		
Relay No.	**Function**	**Designation**
RY1	Body rotate, right	BR (R)
RY2	Body rotate, left	BR (L)
RY3	Left wheel, forward	LW (F)
RY4	Left wheel, reverse	LW (R)
RY5	Right wheel, forward	RW (F)
RY6	Right wheel, reverse	RW (R)
RY7	Right hand rotate	RHR
RY8	Horn	H
RY9	Left shoulder, up	LS (U)
RY10	Left shoulder, down	LS (D)
RY11	Right shoulder, up	RS (U)
RY12	Right shoulder, down	RS (D)
RY13	Unassigned	X
RY14	Unassigned	X
RY15	Left arm, up	LA (U)
RY16	Left arm, down	LA (D)
RY17	Right arm, up	RA (U)
RY18	Right arm, down	RA (D)
RY19	Left arm solenoid	LAS
RY20	Right arm solenoid	RAS

FIG. 60—BE VERY CAREFUL when wiring the relay board and check for shorts and solder bridges. Color coding wires helps.

FIG. 61—RELAY BOARD plugs into 22/44 pin edge connector that will be wired to relay-driver board and to 12-volt systems.

and RY20) to the appropriate finger at the card-edge, as shown in Fig. 57 and Table 2. That is part of the exception mentioned earlier—15 of those wires are connected to the fingers on the bare side of the board by passing them through convenient holes. Fig. 61 gives an idea of what that will look like.

You should note that the wires may not run straight down, as is suggested in Fig. 57, but may zig or zag to one side or the other to mate with the pad that connects to the appropriate finger.

A 22 μF tantalum capacitor is mounted on the relay-side of the board and soldered to the 12-volt and ground-supply rails. Make sure that the "+" side of the capacitor goes to the 12-volt line.

The 12-volt rail is connected to finger "B", and the ground rail to finger "A", on the foil side of the board.

Figure 58 shows the connections for the normally-open relay contacts (pins 8 and 9), and those connections are also listed in Table 3. Before making connections to the card-edge fingers, wire the pin 8-to-pin 8, and pin 9-to-pin 9 jumpers shown for some of the relays.

Finally, still referring to Fig. 58, connect pins 4 and 13 to either 12-volts or ground, as indicated.

Finishing up

Inspect the entire board for solder bridges and shorts, and make certain that every wire goes where it's supposed to. The wires should be held close to the board. They can be secured with a drop of one of those very-fast-setting glues, with epoxy, or with silicone sealant.

The operation of the relays can be checked by applying 5 volts and ground to pins 1 and 16 of the sockets or, better still, to the appropriate fingers at the card-edge. You should be able to hear the contacts of the relays click quietly as they close.

The long arm of the . . . robot

A telescoping (or extendable, if you prefer) manipulator was designed to give the robot added versatility as well as an additional unique feature. It replaces the flexing action of the elbow joint (a human attribute) with the ability to "stretch" the arm—something which is definitely not a characteristic of people, or of most other animals.

Refer to Fig. 62 as the construction of this new arm is described.

First, the manipulator with the claw-type end effector (that can even be the one with the rotatable wrist) is removed from the robot at the shoulder, and the entire upper section—from the elbow hinge to the shoulder-attachment section—is disassembled. Only the two side rods, the elbow-hinge cross-bar rod, the 1/4-20 threaded rod and limit switches are re-used. Hold onto the other parts, though—you may find a use for them later. (That's one of the prime rules of scrounging.)

The first step after that is to cut two 1/2-inch diameter aluminum rods six inches long, and to bore a 1/4-inch hole through the entire length of each. Those holes must be true, so work very carefully and slowly.

Next, the two 1/4-inch diameter side-rods that were removed from the original arm are cut to a length of six inches, as measured from the elbow-hinge end. (This end will be reattached to the shoulder motor later.) Each of those rods will then be mated to one of the 1/2-inch diameter rods by lapping the two until a smooth sliding action is achieved.

That lapping (which is the process of rubbing the two pieces together until all excess material has been worn away and they fit smoothly together—and, incidentally, is the way telescope mirrors are made and polished) is accomplished by applying a polishing compound to the inside of the bore hole in the aluminum rod and moving the 1/4-inch steel rod in and out of the hole while rotating it slow-

PARTS LIST—RELAY BOARD	
Item	**Quantity**
22/44-finger, 4 x 5-inch prototyping board (Radio Shack 276-154 or equivalent)	1
DIP relay, 5-volt coil, 1-amp contacts (Radio Shack 275-215 or equivalent)	20
16-pin DIP socket	20
22 μF tantalum capacitor	1
Miscellaneous: wire, solder, etc.	

TABLE 2
RELAY COIL WIRING

Relay	From pin no.	To finger no.
RY1	16	20
RY2	16	17
RY3	16	R
RY4	16	M
RY5	16	6
RY6	16	3
RY7	16	21
RY8	16	16
RY9	16	P
RY10	16	L
RY11	16	7
RY12	16	2
RY13	16	15
RY14	16	19
RY15	16	N
RY16	16	8
RY17	16	5
RY18	16	1
RY19	1	18
RY20	1	4
Ground trace	—	A
12-volt trace	—	B

TABLE 3
RELAY CONTACT WIRING

Relay	From pin no.	To finger no.
2	8	W
2	9	V
4	8	12
4	9	11
6	8	D
6	9	C
7	9	16
8	9	X
9	8	S
9	9	13
11	8	F
11	9	E
13	9	Z
14	9	Y
15	8	U
15	9	T
17	8	J
17	9	H
19	9	22

ly with an electric drill. (Ordinary automobile rubbing compound will work very nicely.)

A note of caution: The roughness left by boring the hole can, and probably will, grab the rotating steel rod and wrench the aluminum rod out of the clamp you are using to hold it. An indication that that is about to happen is an increase in the temperature of the aluminum rod that you can detect with your hand. Check for that frequently and, as soon as you notice it, either slow the speed of the drill or remove the steel rod and stop work until things cool down.

The job is finished when the steel rod slides smoothly within the aluminum one. **Stop at that point!** If you continue, the fit will become sloppy and the parts may jam when in motion.

Another note of caution: Each set of rods that is lapped must be kept together as a matched pair. A steel rod that has been lapped in one aluminum rod (now a tube) will not mate well with another!

The next step is to prepare two square posts (made from ¾-inch square extruded aluminum material with ⅛-inch walls) to attach the new arm to the shoulder motor cross-bar rod.

The length of each post is 1½ inches. One end of each post should be filed so that the walls, which were originally ⅛-inch thick, are reduced to a thickness of 1/16-inch. Fortunately, that only has to be done for the first quarter-inch of the post. Drill a ½-inch hole in the other, unfiled, end, so that its outer edge is ⅛-inch from the end of the post.

Four cross-pieces now have to be prepared. The first is the shoulder-hinge plate, shown at the upper-right of Fig. 62. It might be worthwhile to refer back to Parts 1 and 2 of this series (August and September 1980) to review the metal-working techniques presented there.

From a piece of ¼-inch aluminum plate cut a piece 2½ × ¾-inches. (Those are the final dimensions—remember to allow for wastage.) Mark two ¾-inch-square openings at the ends of the piece leaving ⅛-inch clearance from the edge (see Fig. 62).

You can cut out those openings by drilling a series of small holes along the inside of the lines you marked and then cutting or drilling through the "webs" between the holes to remove the center piece. Then, using a warding file, finish the opening, from time to time checking the size of the opening by fitting the *filed end* of the square post that will eventually go into that hole into it. The objective is a snug, push-in, fit with no play. Once the post is in the opening, it should not be able to be removed without some effort.

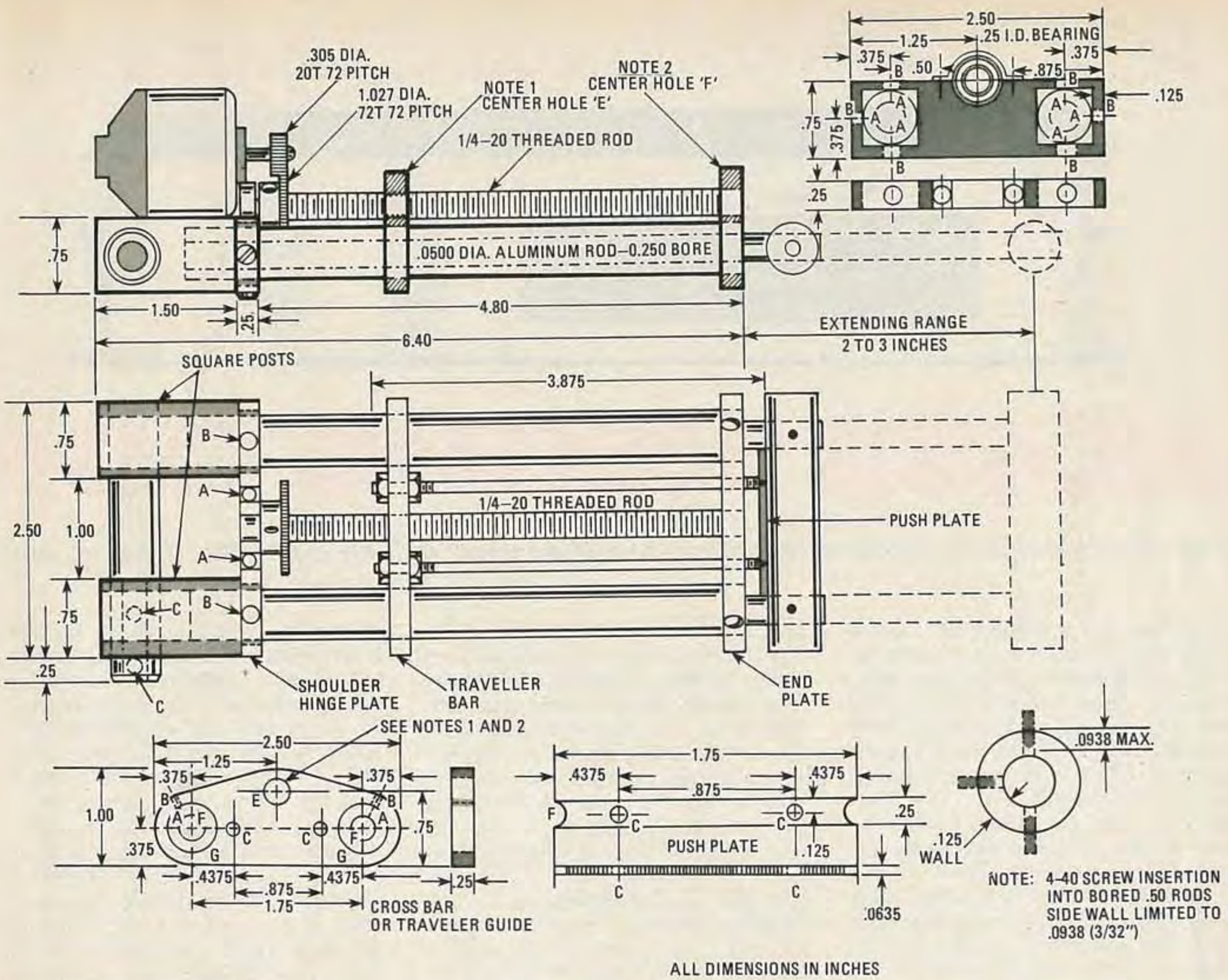
When both square holes are completed to your satisfaction, a recess must be made in the top of the piece to seat the bearing that will hold the end of the ¼-20 threaded rod.

That bearing can be one of two kinds. It can either have an inside diameter of ¼-inch that will accept the threaded rod as it is or, it can be smaller and the rod turned or filed down to fit it. The first approach will give more strength, and is recommended. After marking the position the bearing will occupy (the center of the bearing's opening even with the top of the bar, and the bearing in the middle of the bar), the semicircle can be cut using the drill-and-file technique described above or the metal can simply be filed away until the desired shape is obtained.

A ¼-inch-wide strap of aluminum or

PARTS LIST—EXTENDER ARM

Item	Size	Quantity	Supplier's part no.	Supplier
Aluminum side rod	½-in. diam. × 6-inch	2	AB-6	Ⓐ
¼-inch aluminum plate	1¼ × 2½-inches	2	APS-1	Ⓐ
Aluminum or brass plate	1/16 × ¼ × 2¼ inches	1		Ⓚ
	¾ × 2½-inches	1	APS-75	Ⓐ
Bearing	¼-in. I.D.,	1	B2-10	Ⓐ, Ⓑ
¾-in. square aluminum post	1½-long	2		Ⓚ
Push rod	4 in. ⅛-in. diam., long, threaded 8-32 both ends	2		Ⓚ
Gear	.305-in. diam., 20-T, 72 pitch	1	P72A-20	Ⓐ, Ⓑ
	1-in. diam., 72-T, 72 pitch	1	P72A-72	Ⓐ, Ⓑ



DRILL & TAP KEY			
A 43 DRILL–TAP 4-40	C 29 DRILL–TAP 8-32	E 7 DRILL–TAP 1/4-20	G 0.500 DRILL OR
B 33 DRILL (BODY DIA. 4-40)	D 19 DRILL (BODY DIA. 8-32)	F 0.250 DRILL (BODY DIA. 1/4-20; 0.2497)	DRILL 0.375, REAM TO 0.500

FIG. 62—USE THESE DIAGRAMS, together with instructions given in text, to build extender arm. Counterweight is not shown, but attaches to last cross-bar rod.

brass will be used to hold the bearing in place. With the bearing temporarily in position, bend the strap over it and mark a spot at each end of the strap for a mounting hole. Use a #33 drill bit to make these holes in the strap.

Then, mark *through* those holes to the edge of the plate, on either side of the semicircular cutout. Drill holes at those points using a #43 drill, and tap them to accept 4-40 screws. Do not mount the bearing yet—several more holes still have to be drilled in the plate.

Mark three drilling points in the edge of the aluminum plate for each square post so that the holes drilled will intersect each side of the square posts in the middle. Then insert the posts into the square holes, tapered-end first, and drill completely through the aluminum plate and the side walls of the posts using a #33 bit. You should wind up with six holes in all.

Now take a break and polish the two six-inch drilled-out aluminum rods to a high luster. That not only gives a good appearance, but also insures that the traveler bar (see below) will move freely.

Then insert one of the six-inch rods into the square opening of one of the posts (from the *unfiled* end) for a distance of 1/2-inch. Drill completely through the three holes previously drilled (through the plate and the square posts) into the aluminum rod with a #43 bit. Tap those holes for 4-40 screws. Do the same at the other square opening.

Attach the rods to the square posts using 4-40 machine screws *no longer than 9/32-inch*. The reason for limiting the length of those screws is to prevent their biting into the sliding steel rods and impeding their motion. Set the assembly aside for a while.

The next two cross-bar pieces, the end plate and the traveler bar, are both made from 1/4-inch aluminum plate, 2 1/2 × 1 1/4 inches, and filed to shape as shown in Fig. 62.

They are essentially the same, but have the following differences: The center hole in the end plate is simply made with a 1/4-inch bit. The center hole in the traveler-bar, however, must be tapped to 1/4-20 to accept the threaded steel rod. (Drill that one with a #7 bit before tapping.)

Another difference is that, while the 1/2-inch holes in the traveler-bar for the slide-rods must allow those rods to travel freely through them, their counterparts in the end-plate are cross-drilled, using a #43 bit, and tapped for 4-40 screws, to hold the plate in position on the rods.

Finally—and this holds true for both pieces—two holes are drilled in each, on the center line, and 7/16-inch from the center in each direction. Those holes are made with a #29 drill and are tapped to 8-32 to accept the two four-inch push rods, threaded on both ends.

The last piece to be fabricated is the push plate, which is made from 1/16-inch aluminum or brass plate, 2 1/4 × 1/4-inches in size. Mark a center line along the long dimension of the flat side of the plate. Then, measure 7/8-inch in from both ends along this center line, and drill 1/4-inch

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continued from page 63

holes at both points. Cut off the excess end-material to leave semicircular openings with a 1/4-inch diameter.

Drill two 1/8-inch holes, 7/16-inch from each edge of the plate for the push rods, and tap them for an 8-32 thread. Finally, drill another 1/8-inch hole at the exact center of the piece, and tap it to 8-32, as well. That hole will be used to attach the push plate to the forearm.

Position the push plate against the steel cross-bar rod that used to belong to the elbow and, using a center punch, mark the exact center of the hole that was just drilled in the push plate. Set the push plate aside and use a #19 drill bit to drill completely through the cross-bar rod. The push plate will be attached to the cross-bar rod using a 3/4 × 8-32 screw inserted, of course, through that rod into the threaded hole in the plate.

Final assembly

Cut the 1/4-20 threaded rod from the original arm to a length of five inches. That rod is pushed through the end plate and threaded into the traveler plate for approximately two inches. Install the two four-inch push rods and secure them to the traveler bar with 8-32 hardware.

Secure a shoulder-lock gear (1 inch, 72-T, 72-pitch) to the upper-end of the threaded rod and, having inserted the threaded rod into the bearing, clamp the assembly into place on the shoulder-hinge bar.

Replace the motor that originally drove the threaded rod with a small 12-volt DC miniature motor (see parts list) and attach a 0.305-inch, 20-T, 72-pitch gear to its shaft. Secure the motor to the outside square bar on the shoulder-hinge mount and attach the square bars (and the arm they're attached to) to the shoulder motor as shown in Fig. 63.

Limit switches can be installed on small aluminum plates attached to the end plate and mounted under the motor, which is fastened to the aluminum bar mounting-post. Those limit switches take the place of the ones that are used in the flexing-elbow assembly and are wired accordingly.

The additional weight of the manipulator may present too great a load for the shoulder motor to handle. If that is the case, a lead counterweight can be fabricated and attached to a rod inserted into the shoulder assembly and extending backwards from the joint as shown in Fig. 64. Move the counterweight back and forth until the motor operates without strain.

FIG. 63—COMPLETED EXTENDER ARM shows how new motor is attached and how it is connected to drive threaded rod.

FIG. 64—LEAD COUNTERWEIGHT (left) is used if weight of entire arm assembly puts too much strain on shoulder motor.

Coming up

The next two sections of this series will give instructions for building the relay-driver board that supplies 5-volt signals to the board described here; for building a *Touch Tone* encoder to generate signals for remote-control operation; for the companion decoder that supplies logic-level signals to the relay-driver board, and for an FM transmitter to get the signals from the encoder to the decoder.

And, for everyone waiting to let his computer do the work, the relay-driver board will also accept instructions from the computer's parallel port.

Just wait till you see what's coming up! **R-E**