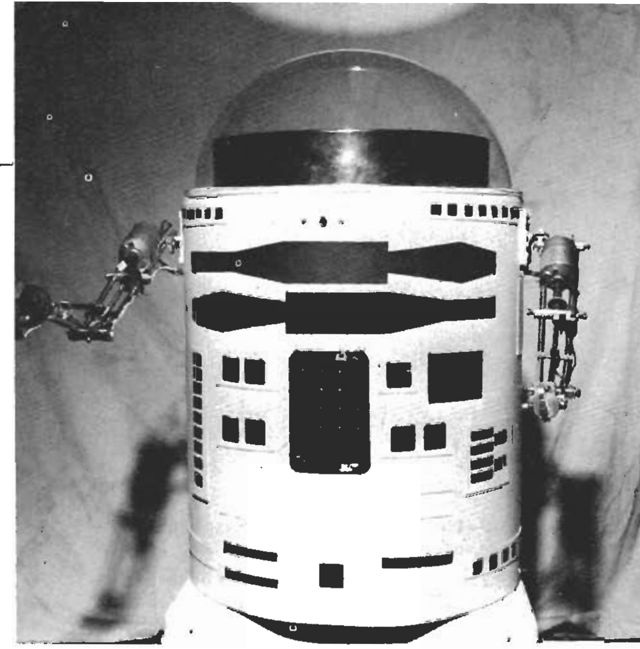
BUILD THIS

# UNICORN-1 ROBOT



*Part II—By the end of this section, your robot's arm will be operational. Here are instructions for completing the arm, and for building several types of hands.*

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UNICORN-ONE IS A ROBOT THAT YOU CAN build for between two- and-four hundred dollars, depending on your ingenuity and scrounging abilities. It is fully mobile and has the ability to use its arms and hands. It can be controlled by a cable link to a console, by radio control from a console, or in conjunction with a computer.

The first part of this series described some of the components used in the robot's construction, and covered most of the assembly of its *manipulator(s)* (arms).

In this installment we will complete Unicorn-One's manipulators and build its *end-effectors* (hands). From time to time we will present you with certain options that you may or may not want to include in your version of the robot.

Remember that one of this project's objectives is to build a working robot, but at a reasonable cost. When you start adding frills—which *you* may consider necessities—that cost is going to go up. It might be wisest to start with the essentials, to prove that what you have set out to do *can* be done, and to add the extras later. Unicorn-One was designed with that plan in mind and all the options described—as well as most extras that you'll think of yourself—can be added afterward, with no major alterations to the robot already constructed.

## Completion of manipulator

The last part of the manipulator to be fabricated is the *contractor-bar* (we saved the easiest for last). That is simply a bar of aluminum $\frac{1}{4} \times \frac{1}{2} \times$ approximately 6 inches long. The actual length will depend on how far you want the elbow to bend, but we've found that 6 inches is a good size to work with. Use a No. 33 bit to drill a hole close to each end of the rod so it may be connected to the rest of the arm with No. 4-40 screws at the two contractor-bar pivot pieces. See Fig. 9 and Fig. 6 (part 1, last month) for details.

At this point you are probably anxious to see how (and whether) the elbow action of the manipulator works. Before you power it up, though, there is one more step that must be taken. If you were to turn on the mechanism now there is a very good chance that you would unintentionally allow the threaded rod to travel too far . . . and jam. That could prove extremely embarrassing.

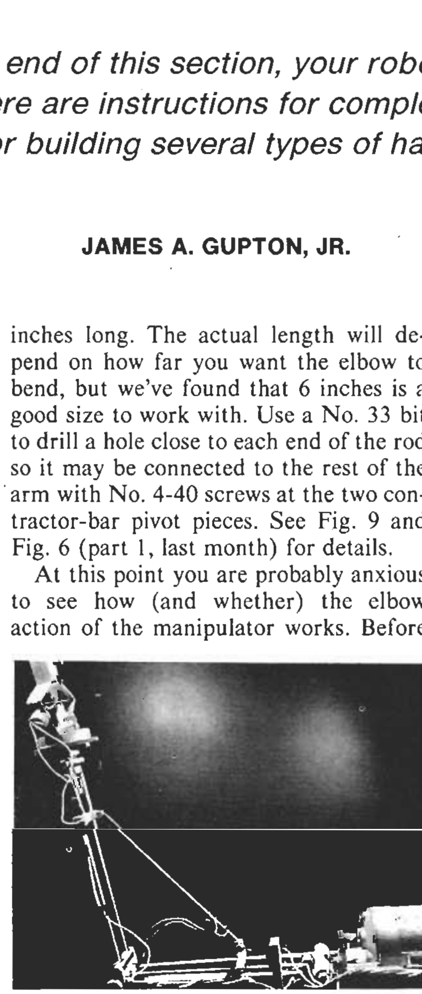

**FIG. 9—MANIPULATOR, showing contractor-bar and its attachment to the two pivot-pieces.**

To prevent jamming from taking place, we have to install *limit switches*. Those are lever-type snap-action switches that are placed so that power to the elbow motor will be cut when the part in motion reaches the desired limit of its travel.

Both upper- and lower-limit switches are used to protect the mechanism during motion in either direction. If power is applied to the elbow motor through one of the limit switches, the threaded rod will turn and cause the forearm to move up or down. When it has gone as far as it can, it will contact the limit switch and stop the motor.

Since we are using DC motors, reversing the current flow in the windings (connecting the power source "backwards") will make them turn in the opposite direction. Therefore, to make the arm move the other way, the other limit switch supplies the motor with current of the opposite polarity.

Almost any size lever-type, N.C. (*N*ormally-*C*losed) snap-action switch may be used, as long as there is room to mount it. There is no firm rule as to where the limit switches must be located—the objective is to place them so that they will be turned on by some moving part of the arm in time to stop its motion before damage occurs.

Figure 10 shows one possibility for the placement of the upper- and lower-limit switches. Here, the upper-limit switch is attached to the side rod so that its contacts are opened when it is contacted by the upper pivot hinge. The lower is placed so it will contact the side rod when the arm is lowered and the side rod and contactor-bar are nearly parallel. There are other ways of achieving the same results, of course.

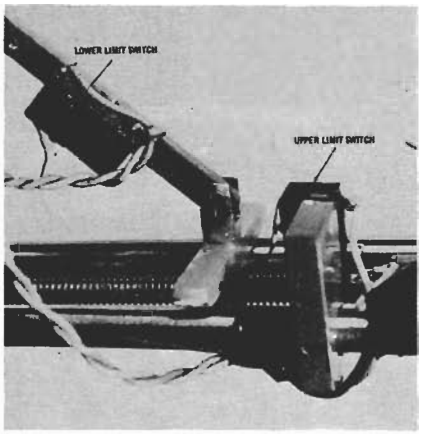

**FIG. 10—LIMIT SWITCHES attached to contractor-bar and aluminum block on side rod.**

There are two things to bear in mind when placing the limit switches. First, make sure that positive contact will always be made and that there is no possibility that the switch can be turned on accidentally. Second, when taping the switches' wires (and those of the other electrical parts, such as the motors) in place, take care that the tape and wires do not impede the action of any of the moving parts.

The wiring of the limit switches, end-effectors and motors will be covered in some more detail toward the end of this section.

## End-effectors

An arm is of little use without a hand at the end of it, so we will present two elementary, but serviceable, types of end-effectors for you to choose from and give you the option of constructing a more complex (and expensive) one, should you so desire.

The two basic hand types we'll describe are the *finger* and the *claw*. Your robot, being ambidextrous, can actually have one of each, using one for one purpose, and one for another.

The grasping action of both types of hand is provided by solenoids—electromagnetic coils with rods through their centers. When a current is passed through the coils, the rod is either pulled into them or pushed out of them. If that rod is connected to part of the hand, the hand will close (in our case) when power is applied to the solenoid. When power is cut, the hand opens by means of a spring which is either part of the solenoid or part of the hand mechanism itself.

Selection of the solenoids is not critical. There are three conditions which must be satisfied: voltage, size, and degree of travel.

The solenoids should be rated to turn on with 12 volts since the robot will almost certainly be using a self-contained 12-volt storage battery when it is operating under its own power. The size of the solenoids will determine the strength of its grip. You may want to use a stronger solenoid in one hand than in the other to allow the robot to perform tasks requiring

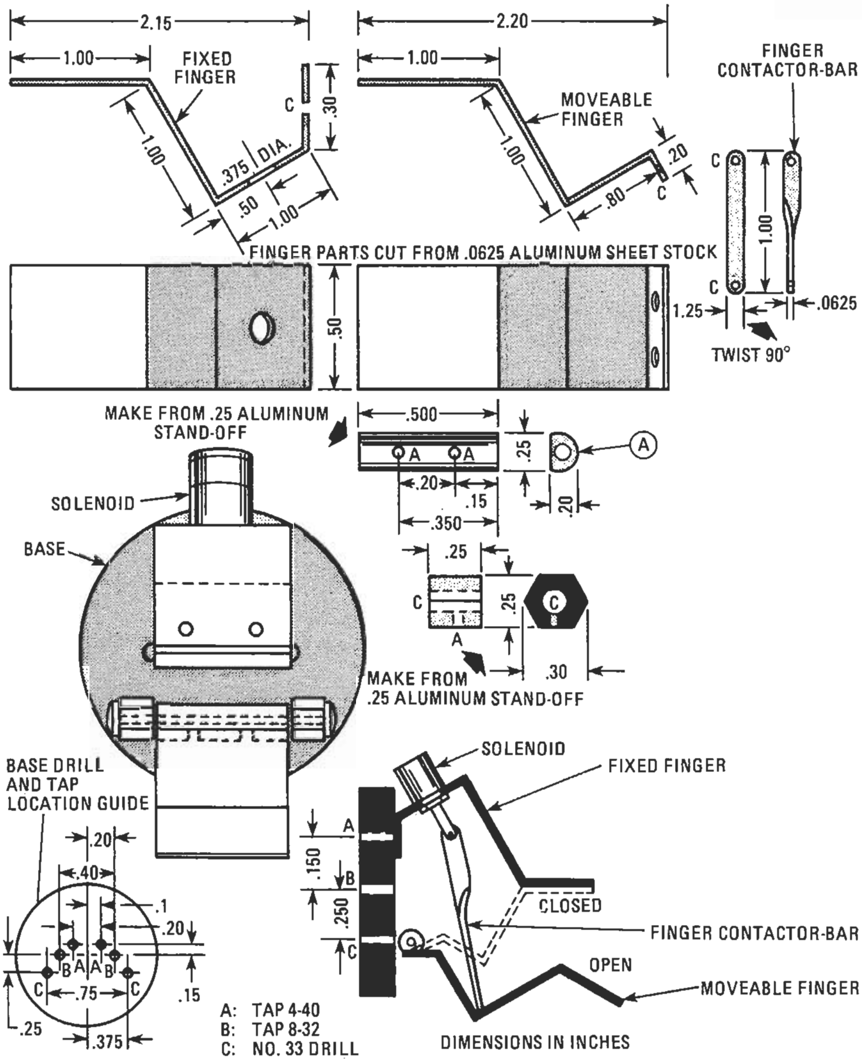


**FIG. 11—FINGER-TYPE end-effector assembly drawing. Hinge construction is described in text.**

different degrees of delicacy. As for the degree of travel (the distance of the solenoid's rod can move) we've found that a ½- to-¾-inch rod allows the hand to open far enough for most applications.

## Finger-type

Dimensions of the finger-type end-effector are shown in Fig. 11 and one of the completed units in Fig. 12. The material used for that part is $1/16 \times 1/2$-inch sheet aluminum. The fixed (upper) finger is made from a piece 3.3 inches long and the movable (lower) finger, from a 3-inch one. The angles should be formed by placing the metal in a vise and bending as evenly as possible. Use a hammer to give uniformity to the surface.

The *finger contractor-bar* is made of $1/16 \times 1/4$-inch aluminum, drilled at both ends. The length depends on the solenoid's travel. As shown in Fig. 11, a half-twist is put into that bar. One end of the bar is attached to the solenoid, which is mounted on the outside of the fixed finger, and the other is inserted through a slot sawed in the outside edge of the movable finger and secured with a cotter pin or similar device.

The movable finger is attached to the hinge (refer to Fig. 13) by two No. 4-40 screws. The hinge itself is supported at

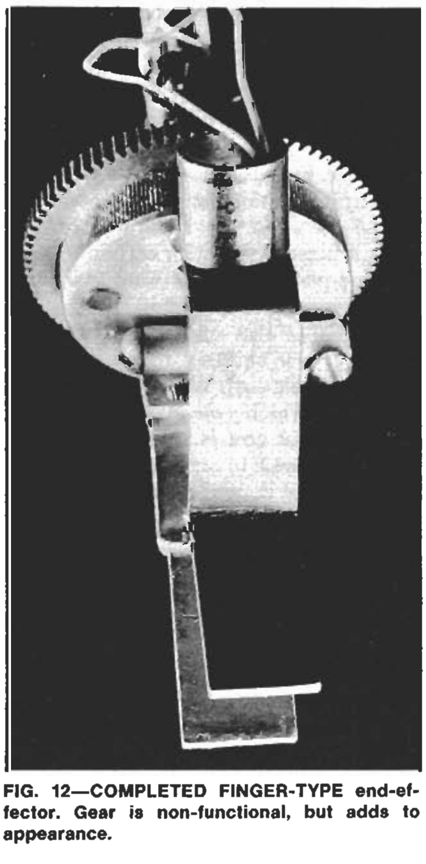

**FIG. 12—COMPLETED FINGER-TYPE end-effector. Gear is non-functional, but adds to appearance.**

one end by a ½-inch diameter piece made from a section of an aluminum stand-off with a long No. 4-40 screw acting as the hinge pin. The finger/hinge assembly is

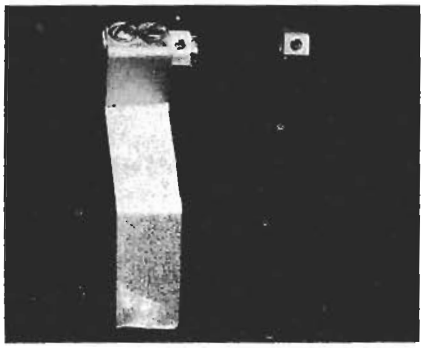

**FIG. 13—DETAILS OF HINGE used in finger-type end-effector assembly.**

fastened to an end-plate one inch or more in diameter and ½ inch thick using No. 8-32 screws and that, in turn, is mounted to the last cross-rod of the manipulator's forearm. The original Unicorn-One used a non-functional gear to build up the end plate and to give the robot a touch of class.

The finished end-effector may be fixed horizontally, vertically, or at any angle in between. Its position depends on the use to which the member will be put.

## Claw-type

For heavier-duty applications, you might want to use a claw-type end-effector; that type of hand is shown in Figs. 14 and 15. On ¼-inch aluminum plate, use a scribe to mark the outline of the two sections. Rough-cut the pieces, taking care to keep to the outside of the outline to allow a margin for error.

Using a hacksaw on the inside angles of the claw may prove to be difficult or even impossible. Instead, try drilling a closely-spaced series of small holes along the *outside* of the part. Then, using a cold chisel, knock it out and file it to shape, along with the rest of the claw.

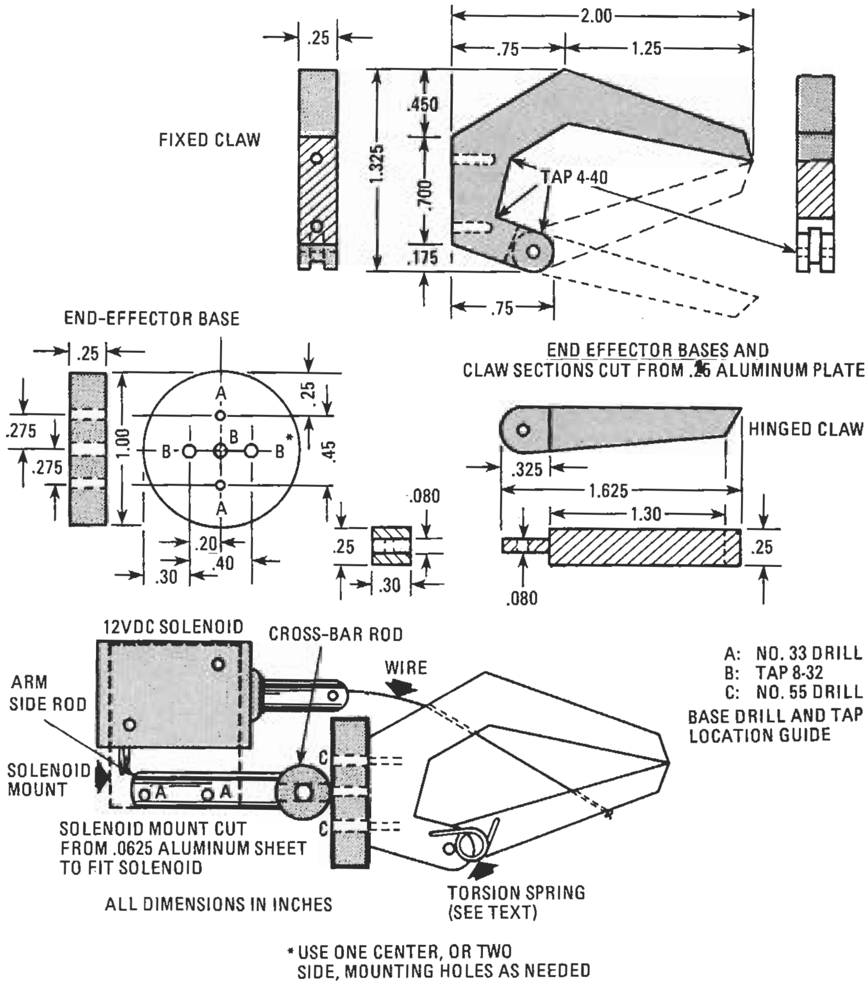


**FIG. 14—CLAW-TYPE end-effector assembly drawing. This is a heavier-duty mechanism than the finger-type and you may want one of each.**

Drill two small holes through the two claw sections, in the plane of movement (parallel to the flat sides of the claws), to pass the cable from the solenoid, which can be anchored by a screw to the lower

**PARTS LIST**

| Item | Size | Quantity | Supplier's part no. | Supplier |
|---|---|---|---|---|
| Sheet aluminum | .0625 in. thick | 1 X 7.5 in.* | SA625 | A |
| Sheet aluminum | .250 in. thick | 1.5 X 6 in.* | SA250-9 | A |
| Sheet aluminum | .250 in. thick | 0.5 X 6 in. | SA250-3 | A |
| Solenoid† | Size 50, ½ X 1 in. 12 VDC | 1 | 176801-085 | F |
| Solenoid† | Size 75, ¾ X 1½ in. 12 VDC | 1 | 174610-031 | F |
| Solenoid† | ½-in. stroke, 12 VDC | 1 | 26 | G |
| Solenoid† | ½-in. stroke, 12 VDC | 1 | L26 | H |
| Solenoid† | "D"-frame, 12 VDC | 1 | 290001-033 | F |
| Snap-action switch | Subminiature roller-lever-type, 5-amp | 4 | 275-017 | I |
| Snap-action switch | Subminiature lever-type, 5-amp | 4 | 275-016 | I |
| Machine screws | 2-56 X ⅜ | 8 | | |
| Machine screws | 4-40 X ½ | 11 | | |

**SUPPLIERS**

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

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

**F Ledex, Inc.**
Box 427
Vandalia, OH 45377

**G Guardian Electric Mfg. Co.**
Advertising Dept.
1550 W. Carroll Ave.
Chicago, IL 60607
(Write for list of local distributors.)

**H Liberty Controls, Inc.**
500 Brookforest Avenue
Shorewood, IL 60431

**I Radio Shack**
Consult your local telephone directory.

NOTES: Items marked with "*" were already specified in the parts list for Part One of this series. Items marked with "†" are to be selected according to the builder's requirements. Components may also be available from suppliers other than those indicated. Some suppliers have minimum order requirements. Inquire before placing order.

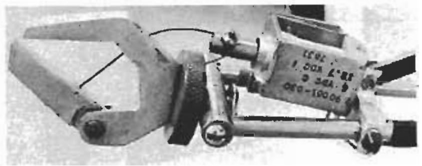

**FIG. 15—ASSEMBLED CLAW-TYPE end-effector. Piano wire may be used to connect solenoid and lower portion of claw.**

claw. A small hole should also be drilled into the *flat* side of each claw into which the ends of the spring which will keep the hand open when the solenoid is not turned on.

Robot manipulator-claw springs are not an off-the-shelf item in most places, so you'll probably have to make your own. Figure 16 will give you an idea of what you'll need. If you haven't taken apart any clocks recently, you might try using a section of the type of spring used to close

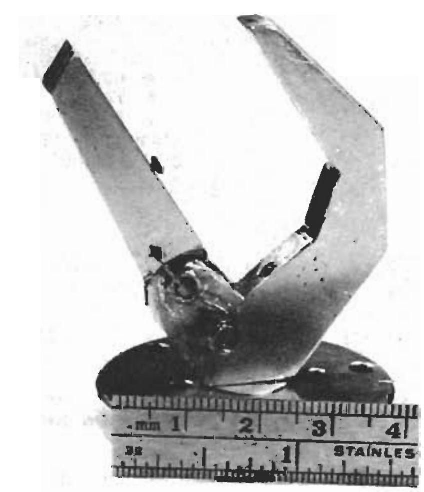

**FIG. 16—CLAW-TYPE end-effector showing homemade torsion spring. Text gives details.**

screen doors in the summer. Material 1/32-in. in diameter seems to work out well.

The tension of the spring will affect the claw's actions. If it's too strong, the claw will not close properly and the robot's grip will suffer, and if it's too weak, there can be problems with keeping it open. If that sounds confusing, bear in mind that the purpose of this particular spring is to hold the claw *open*, not closed.

Attachment to the manipulator is similar to that for the finger-type end-effector, but you may decide to mount the solenoid (which will probably be larger than the one used for the other) directly on the forearm and feed the cable through to the claw.

You might want to line this hand—or possibly both—with foam rubber or a similar material to give it a better grasp on slippery objects.

A more elaborate type of end-effector is shown in Fig. 17. It also uses the claw-type mechanism but has an additional *degree of freedom*—a term referring to the different ways a joint can move. (Your own arm, for example, has three degrees of freedom: It can twist, move up and down, and move from side-to-side.)

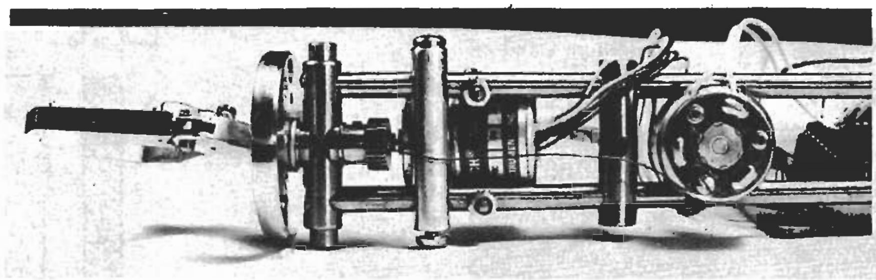

**FIG. 17—ROTATABLE end-effector mentioned in text. Stepper motor supplies wrist action.**

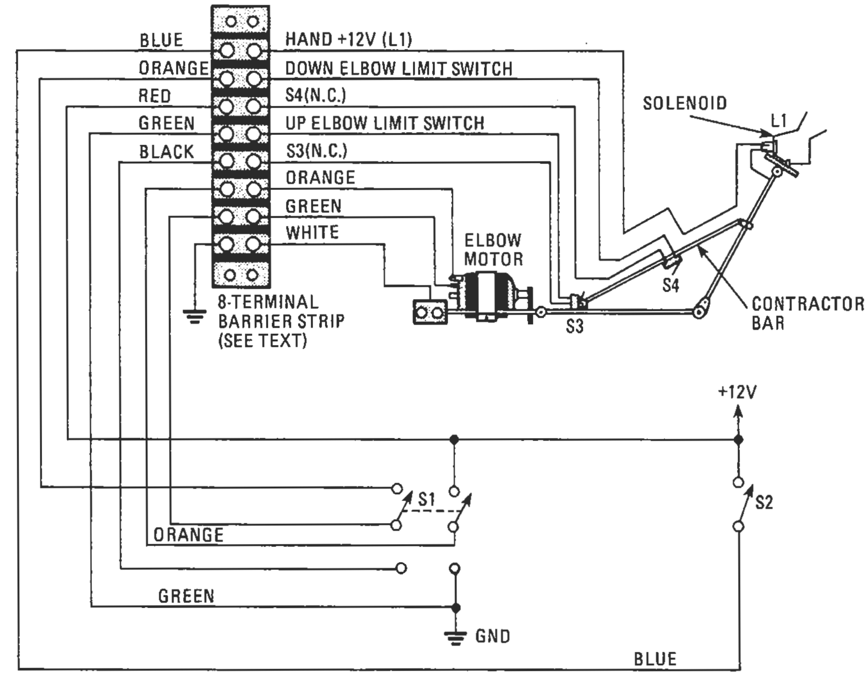


**FIG. 18—WIRING DIAGRAM for manipulator and end-effector. Color-code wires in order to avoid confusion.**

The added mobility is gained by placing a stepper motor between the arm and the hand. The stepper motor's shaft turns through a small portion of an arc each time a short electrical pulse is applied to it. The result, if enough pulses are applied, is a twist of the wrist—and an added degree of freedom!

Because those pulses are best generated by a digital electronic circuit—which we have not yet discussed—we'll postpone a description of the construction of this type of hand until we start putting together Unicorn-One's electronics. For certain applications, though, it can be indispensible.

## Wiring and testing

A wiring diagram for the motor, solenoids, and microswitches, with their associated controls, is shown in Fig. 18. The eight-position terminal strip illustrated is actually part of a 32-position strip, which will terminate all motor and switch connections. Since 32-position terminal blocks are difficult to locate, do the best you can with smaller ones—but allow for at least 32 positions. That will give you several extra positions which you can later use for your own options.

Color-code the wiring to simplify circuit tracing and make sure that everything goes to the right place and that you have electrical continuity.

*Now*, with the limit switches installed, you can check out the actual operation of the manipulators and end-effectors. In fact, this is the best time to do so. (If you were to wait any longer, and the arm were attached to the body, you might have to do quite a bit of tearing-apart to get to, and correct, any problem that showed up.)

The parts list shows sources of supply used by the author. There are certain to be others, though, possibly more accessible to you. In fact, many of the materials specified can probably be found, in a form close enough to work with, at your local hardware or building-supplies store. Even closer—and more economical—may be your basement or a nearby junkyard.

The next part of the Unicorn-One series will concern itself with design considerations and construction of the robot's mobility base—the section that gets it from place to place. Also included will be details of the main 32-position terminal strip, which will be the heart of the robot's electrical distribution and control system. The design of that section will permit easy changeover, when you're ready, from manual control by cable-connected console to radio control and, later, to control by microcomputer. **R-E**