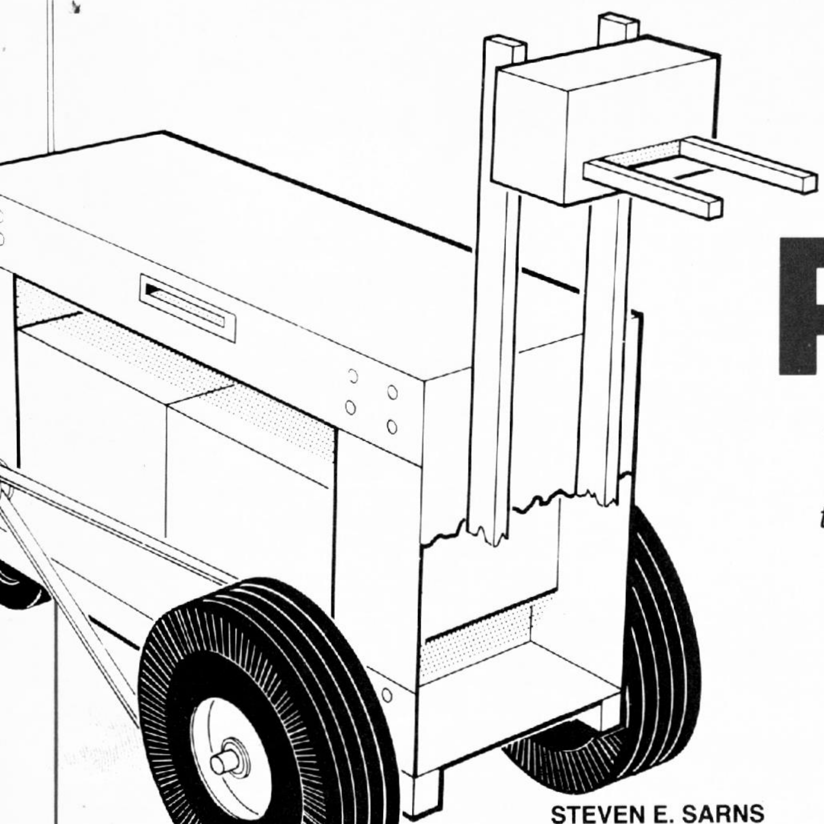

R-E ROBOT

This month, we show you how to build the robot's body. We'll also tell you about an updated drive system that will dramatically increase the robot's hauling power.

STEVEN E. SARNS

Part 4 ONCE THE DESIGN PROCESS is complete, it is time to begin building your robot. This month, we will start by showing you how to build the base unit that we designed. Remember that the procedures, dimensions, etc. will vary if you chose to use a different design.

Body construction

Our base-unit design is easy to manufacture and assemble. It consists of a "unitized-construction" body that is composed of four pieces of 0.090-inch 5051T-6 or 6065T-6 aluminium, plus two end caps (one of which is optional) formed from the same material. See Fig. 1. A chassis fabricated from 5051T-6 aluminum is available from Vesta Technology (see Sources Box); contact them directly for pricing and other details.

The upper and lower clamshells are formed from identical pieces of aluminum. See Fig. 2-*a*. Once the pieces are cut, they are bent as shown in Fig. 2-*b* to form a channel. Make the 90° bends using a 0.18-inch radius to prevent cracking the aluminum. Note that while Fig. 2-*b* shows right-hand bends, one of the pieces requires left-hand bends if the body clamshell is to fit together.

The two halves of the clamshell body are joined with the internal bulkheads. A cutting and bending guide for the bulkheads is shown in Fig. 3. Because of the thickness of the aluminum used, the notching shown at the four corners is required to allow the bulkheads to seat correctly inside the upper and lower clamshells. Form one bulkhead with left-hand bends; the other is formed with right-hand bends.

The bulkheads are the major strengthening component in the robot's chassis. When assembled, the resulting chassis is strong enough to carry a person without flexing, yet it weighs less than ten pounds. Further, the forward bulkhead serves as the mounting surface for the electronics package; the rear bulkhead holds the motors in their own compartment.

The four body components are fastened together with 6-32 × ⅜-inch machine screws. The holes are drilled in the outer shell, then each bulkhead is clamped in place and the bulkhead is drilled using the outside hole as a centering hole. Several precautions must be observed. First, securely clamp the bulkhead in place so that it cannot move during the drilling process. Second, ensure that the bottom of the bulkhead is in direct and flat contact with the bottom of the bottom clamshell. Third, use a carpenters square to ensure that the chassis is assembled squarely.

A cutting and bending guide for the end covers is shown in Fig. 4. As with the bulkheads, the corners must be notched as shown. The front end-cover will be used to mount the robotic arm assembly. The rear end-cover is optional and should *not* be used with the specified motors (more on those in a moment) unless plenty of ventilation holes are provided. The end covers are mounted to the body during the last step of assembly using sheet-metal screws.

Mounting the axle

The axle is an 18-inch long, ½-inch diameter steel rod. The rod is modified by drilling a small hole ¼-inch from each end. Once the wheel/axle assembly is complete, a cotter pin is placed through each hole to keep everything in place.

The axle is mounted to the lower clamshell with a 1–1½-inch U-bolt. See Fig. 5. A hardwood or a hard-rubber block is shaped to fit inside the U-bolt. A ½-inch hole then is drilled in the block to accept the axle. The centerline of that hole should be placed so that the robot's body sits level when the rear caster is attached. The dimension in our case was ¾-inch below the lower body. The U-bolt is placed around the block and inserted into two holes drilled into the lower clamshell just behind the forward bulkhead. To achieve maximum stability, it is important

Choosing a Tape

IF YOU OWN OR USE A VIDEOCASSETTE RE-corder, you are undoubtably aware of the variety of brands and formulations of videotape on the market. Basically, most manufacturers sell tapes in 3 or 4 grades. Each grade is suitable for almost any taping chore, although some grades are better for certain chores than others. For instance, it makes little sense to use an expensive professional-grade tape for time shifting soap operas. On the other hand, you would not want to entrust a copy of a movie or TV classic to a standard- or economy-grade tape.

When it comes to tapes for camcorders, if you use a unit that accepts standard VHS or beta tapes, the same tapes you use in your home deck are used in those units. Now, however, different grades of tape are becoming available in the smaller VHS-C format.

For users of VHS-C camcorders, there are basically three grades of tape available. It is perhaps most convenient to think of them in terms of good, better, and best. Let's look at the tape grades offered by one manufacturer, JVC, and see how each is best used.

HG Super is JVC's "good" tape. It is designed for general use and is most effective when you're shooting in the SP or 20-minute mode.

As with home decks, the quality of the image recorded by a camcorder degrades as tape speed decreases. Therefore, if you are extending recording time by shooting in the EP or 60-minute mode, a higher tape grade is required for best results. JVC's grade of better tape is called *Super HG*

Premium- or "professional"-grade videotape, such as JVC's *Super Pro* is used when top recording quality is essential. For instance, you would use premium-grade tape when the original recording is to be dubbed to a second tape; a top-quality original is necessary to minimize the picture degradation that always occurs during dubbing. Premium tape used at SP speeds yields the closest thing to professional results available to the consumer.

Currently, manufacturers are offering just one tape grade for 8mm users. However, because 8mm standard requires tapes that have either a metal-particle or evaporated-metal formulation (currently only metal-particle formulations are available), all 8mm tapes are outstanding performers. But quality is not cheap; prices for 8mm blank tape vary between about $17 and $24, depending on tape length. By contrast, VHS-C blank tape costs between $7 and $10 per cassette. **R-E**

TDK 8mm VIDEOTAPE

significant of those is the camcorder's pickup.

Initially, consumer video cameras all used vacuum-tube pickups. Those devices, which go under tradenames such as Newvicon and Saticon, generally perform well in low-light conditions. On the other hand, if a vacuum-tube video camera were panned past a relatively bright light source, streaking or "comet-tailing" would occur. If such a video camera were pointed at a bright light for any length of time, the unit would be damaged.

Many newer camcorders and video cameras use solid-state CCD (*C*harge *C*oupled *D*evice) or MOS (*M*etal *O*xide *S*emiconductor) pickups. Those pickups are less susceptible to streaking and to damage from bright lights. They also produce a sharper image than that produced by a vacuum-tube pickup. But they require higher light levels than vacuum-tube pickups for satisfactory performance.

The camcorder's lens is the window through which it sees the world. Therefore, lens quality and features play a large role in determining which images eventually wind up on tape.

All camcorders are supplied with lenses of solid, though not spectacular quality. Most are of the zoom variety, with focal lengths variable between 9mm and 54mm (a 6:1 zoom ratio). Some manufacturers, such as Panasonic (One Panasonic Way, Secaucus, NJ 07094), Quasar (9401 W. Grand Ave, Franklin Park, IL 60131), and General Electric (Portsmouth, VA 23705), offer units with 8:1 zoom ratios.

When comparing lenses, two features to watch for are *macro* and *maximum aperture*. A macro setting allows the lens to be used to tape items at extremely close range (as close as 1 inch). Maximum aperture (which is sometimes referred to as lens *speed*) tells you the maximum width of the lens aperture or opening. The larger the diameter of the lens opening, the more light will be admitted.

Some models have removable lenses. Those most often use C-mounts and allow you to use wide-angle, telephoto, or any lens that accepts that mount.

NIKON *VN-800*

If you are purchasing a VHS or VHS-C unit, you may want to look for one with HQ (*H*igh *Q*uality) circuitry. Beta has always enjoyed a technical edge over VHS in the area of horizontal resolution. To the viewer, that means that a Beta picture will usually appear somewhat sharper than a VHS one. JVC, the originator of VHS and VHS-C, developed the HQ system to combat that superiority. HQ actually consists of three separate circuits, but many units call themselves HQ while using only one or two. The most commonly found HQ circuit is white-clip extension. That circuit reduces the amount of white clip by about 20%, resulting in crisper outlines between light and dark areas of a scene. Another circuit boosts high-frequency signals (which contain the picture details) during recording. The third circuit boosts high-frequency picture details during playback. Note that the three circuits are completely independent and that any combination of them may be found in a particular model. Also, HQ and non-HQ tapes and equipment are completely compatible.

Most camcorders are completely automatic, offering such bells and whistles as automatic aperture setting, automatic white balance (the white balance setting is used to adjust for proper color fidelity), and autofocus. If you like more control over your recording, be sure that the model you select allows you to override those automatic features. On the other hand, bear in mind that a camcorder that lacks one or more of those features can be more difficult to use.

Camcorders are designed to be light and comfortable, but eyeglass wearers may have to look harder to find a comfortable viewfinder. Likewise, left-handed people will find that most models have admittedly been designed for right-handed users.

As you can see, there are many things to consider when choosing a camcorder. To make the job a little easier, we've compiled a list of models available at press time; it is found in Table 1. Bear in mind that the table is only a guide; specifications, list prices, etc., are always subject to change. Also, new models are introduced from time to time, and old ones are discontinued. **R-E**

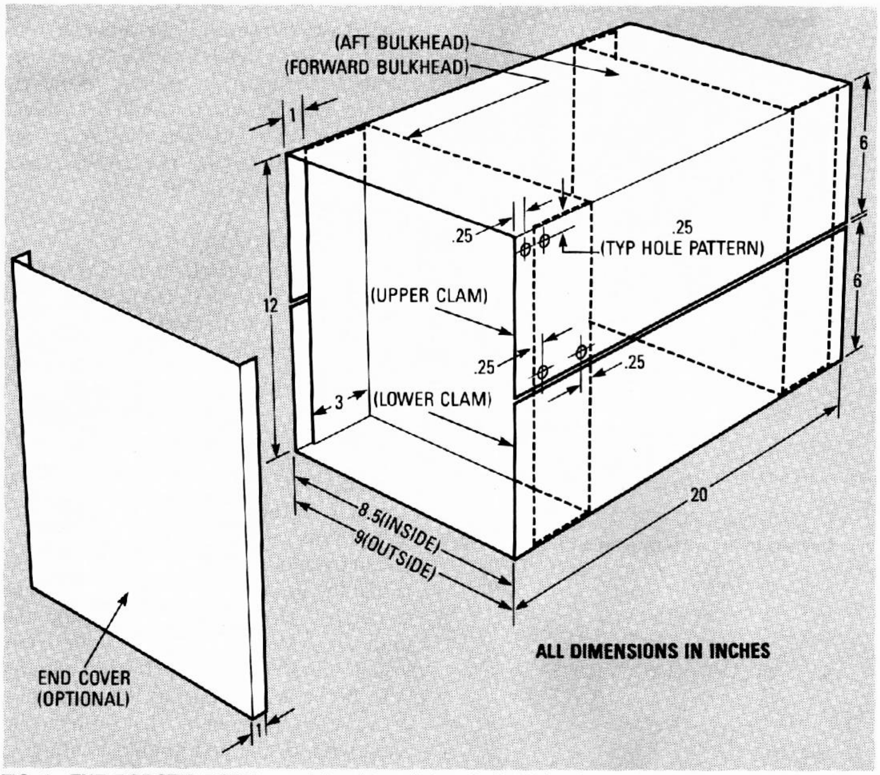

FIG. 1—THE ROBOT'S BODY consists of two "clamshells" joined together by two bulkheads. The bulkheads are the major strengthening component of the assembly.

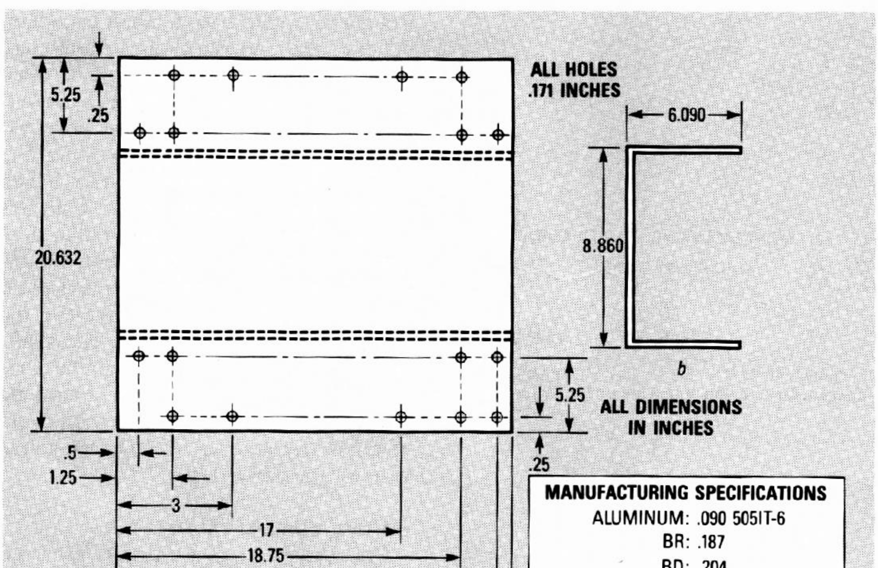

FIG. 2—USE THIS GUIDE to cut, drill and bend the clamshells. Cutting and drilling information is provided in *a*; bending dimensions are shown in *b*.

to keep the forward axle as far forward as possible without interfering with the electronics compartment.

The U-bolt approach is only one possible solution to the problem of fastening the axle to the chassis. Another approach is to use a piece of angle material at least 1.5-inches long, drilled to accept the 0.5-inch axle.

Wheel assembly

A diagram of our wheel assembly is shown in Fig. 6. The tires are 10.5- × 4-inch go-kart tires with ½-inch ball bearings. Those tires allow the robot to navigate rough terrain, like shag carpets. They are available from Spadel Tire and Wheel (2440 S. Tejon St., Englewood, CO 80110, phone: 303-935-1972); ask for part number 51354. Contact the company directly for cost, shipping charges, or other information.

The tires are assembled with 4 bolts holding the two wheel halves together. That provides us with a convenient means of mounting the pulleys. Replace two of the bolts with 5⁄16- × 1½-inch machine bolts. Be sure that the bolts protrude through the side opposite the tire's air valve. Re-establish the force on the wheel by installing a nut and lockwasher as shown in Fig. 6. Then using the wheel/machine-bolt assembly as a guide, drill 5⁄16-inch holes in two spokes of the pulley. If the center hubs of the wheel and the pulley are aligned properly, those holes should be 1.41 inches from the pulley's center hub. To ensure proper alignment, use the axle as a guide. Install the pulley on the wheel using nuts. Do not over tighten the nuts or you may crack the pulley spokes. Once the pulley is installed, recheck the alignment of the center hubs to be sure that there will be no friction on the

Sources

Can you imagine what a robot we could build with a staff of 250,000 (the entire readership of **Radio-Electronics**)? One key to the success of the **R-E** Robot is the collective development capability of that readership. In an effort to encourage the exchange of software, sources of parts, hardware enhancements, and any other items of general interest, **Radio-Electronics** will open a special section of its new remote bulletin-board system (RE-BBS) to builders of the **R-E** Robot. You can reach the bulletin board by calling 516-293-2283.

To help simplify the mechanical aspects of building the robot, Vesta Technology (7100 W. 44th Avenue, Suite 101, Wheatridge, CO 80033, 303-422-8088) will offer an aluminum chassis similar to the one discussed in these articles. Vesta also will offer the RPC, its PC board, and the source code for testing the robot and implementing the RCL. For pricing and availability information, contact Vesta Technology directly. Complete construction details for the RPC, including schematics and PC board patterns, will be presented in a future installment of this series.

A complete description of a modified drive-train system for the robot is shown this month. For those that have difficulty finding appropriate drive-train components for the robot, a good source is Stock Drive Products (55 S. Denton Ave, New Hyde Park, NY 11040, 516-328-0200). Contact them directly for pricing and availability information.

Additional sources for various sub-systems and parts for the robot will be provided as appropriate in future installments of this article. **R-E**

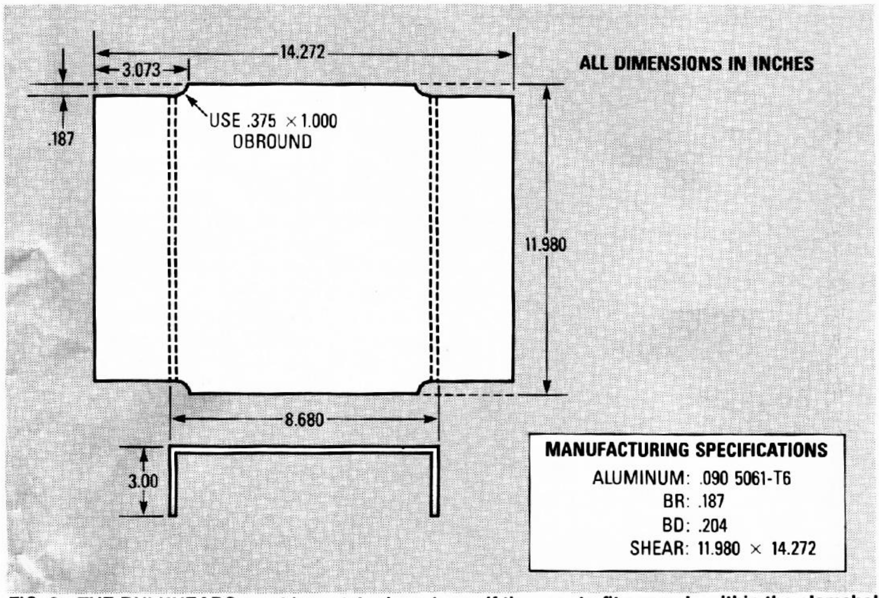

FIG. 3—THE BULKHEADS must be notched as shown if they are to fit squarely within the clamshell body.

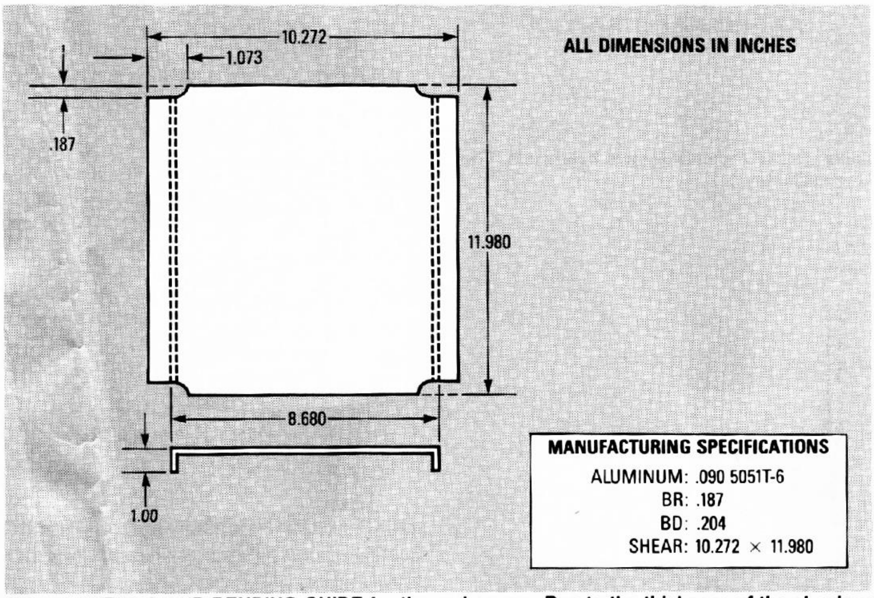

FIG. 4—CUTTING AND BENDING GUIDE for the end covers. Due to the thickness of the aluminum used, the covers must also be notched for proper fit.

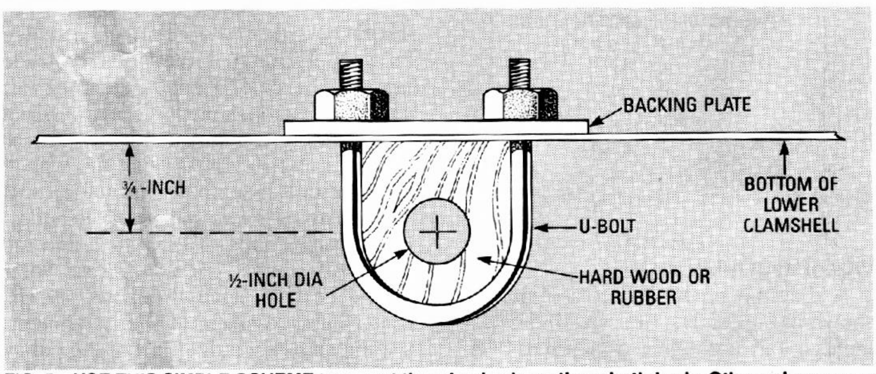

FIG. 5—USE THIS SIMPLE SCHEME to mount the wheel axle on the robot's body. Other schemes can also be used with satisfactory results.

axle when the wheel turns. A photograph of the assembly is shown in Fig. 7.

The rear caster is a 5-inch diameter hard-rubber unit on a ball-bearing swivel. The single rear caster is located on the centerline of the robot, as close to the rear edge as possible to obtain the longest wheelbase. However, if the robot is going to carry heavy loads, such as a person, another scheme must be used to prevent flexing. One alternative would be to locate the caster under the rear bulkhead; another would be to use two casters, each located at one edge of the body.

Finish

The outer clamshells can be anodized for a hard, insulating finish in the color of your choice. Anodizing the robot's body should cost about $50, provided that you can find someone willing to do such a small job.

Alternately, if you carefully degrease the aluminum with turpentine or another solvent, paint will produce an excellent finish. Careful spray painting will produce a finish that's as smooth that as produced by anodizing. An added advantage is that the finish can easily be touched up as needed. However, don't paint the unit until all systems have been completely tested. Otherwise the finish will undoubtedly be scratched during the assembly/disassembly procedures that go hand-in-hand with testing and troubleshooting.

Wiring channels

The wires that interconnect the electronics package, motors, shaft encoders, batteries, etc., are run along the bottom of the chassis. To prevent coupling between the motor-drive lines and the shaft encoder lines, those wires must be physically separated as much as possible.

To facilitate that separation, a 1-inch diameter hole or cutout is made in the left and right lower corners of both bulkheads. Later, when you wire the robot, motor-control, battery, and common lines should be bundled and passed through either the left or the right set of holes. The shaft-encoder lines (and any other signal lines your design might call for) should be bundled and passed through the other set of holes. Be sure to select heavy-gauge wire for the power leads.

Battery compartment

The battery compartment is accessed by removing the upper clamshell. To make installation and replacement of the two 12-volt utility batteries easier, a battery holder similar to the one shown in Fig. 8 should be built. The battery holder is a wooden platform that is cut so that it fits snugly within the battery compartment. The end pieces are then attached securely using nails or glue. Those end pieces hold the batteries in place by friction. To make installing and removing the platform easier, handles should be made by drilling holes in the end pieces through which short lengths of nylon cord are looped. Cushion the batteries and plat-

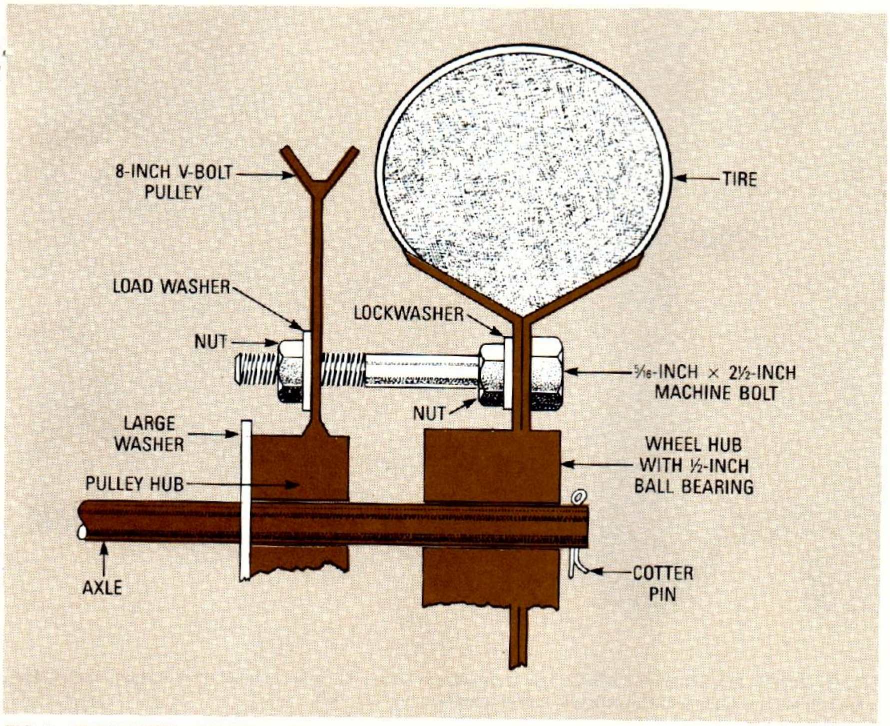

FIG. 6—THE WHEEL AND PULLEY are bolted together and mounted on the wheel axle. The assembly is held in place with a cotter pin.

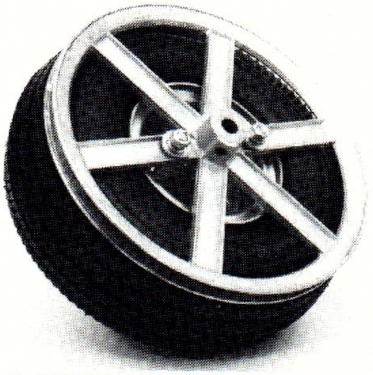

FIG. 7—IF BOLTED TOGETHER PROPERLY, the wheel and pulley assembly will resemble the one shown here.

form by placing about two inches of packing material in the bottom of the battery compartment.

Electronics compartment

We'll deal with the robot's electronics (control board, RPC, etc.) in depth in future installments. Full details, including schematics, foil patterns, construction details, and more will be presented then. However, in designing and building your robot's body, it would be useful to have some idea of how the boards are mounted. Here, we'll see how the control board and RPC are installed in our version of the robot.

The electronics are located within the forward compartment and are mounted on the forward bulkhead, as shown in Fig. 9. We mounted the control board on the bulkhead using ¾-inch by 6-32 standoffs (the height is not critical, however). The RPC is stacked on top of the control board using 1-inch hinged standoffs. We located the hinge at the top edge rather than the bottom edge of the board. Although that requires a considerable amount of slack in the connecting wires, hinging the board makes testing and troubleshooting much easier.

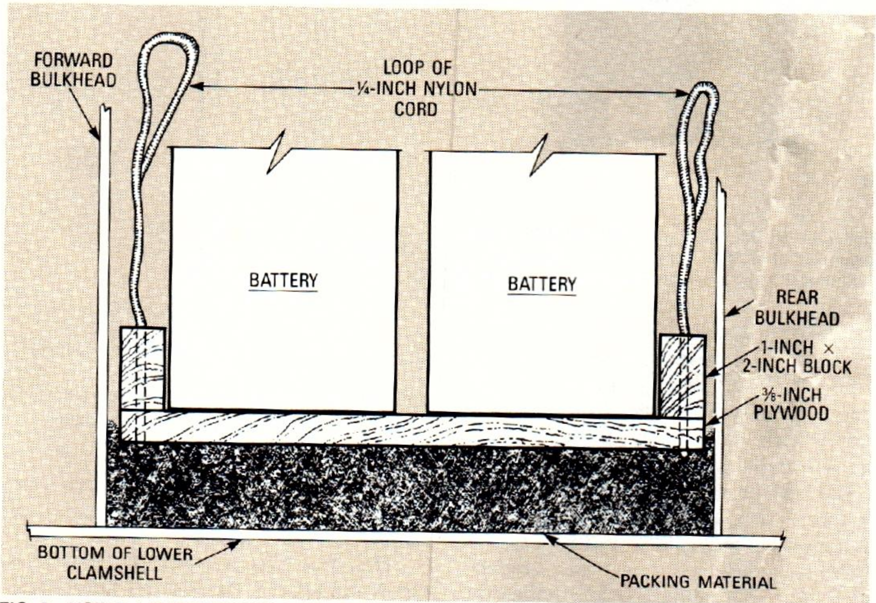

FIG. 8—USING A BATTERY HOLDER will make installing and removing the batteries easier.

The control board's foil pattern (which, once again, will be presented in a future installment) contains provisions for mounting two power transistors used to control drive-motor operation. However, the heatsinking on the board is minimal. If you plan on having the unit carry particularly heavy loads, or to be in motion for extended periods of time, we suggest that those transistors be mounted on the bulkhead instead, using TO-3 sockets and insulators. Drill two TO-3 footprints near the top edge of the bulkhead. Mount the sockets under the control board so that they are in the electronics compartment, and the transistors, when installed, are in the battery compartment. The sockets are then wired to the appropriate points on the control board.

Motors

When we started the design of the drive train, our expected power requirements were calculated at 1/20 HP. It soon became evident, however, that there were many useful tasks that the robot could not perform without more power. Consequently, we had a special motor designed for our robot.

Our aim, as always, was to obtain maximum utility at minimum cost. That aim was achieved. The motors deliver ¼ HP with a stall torque of 2.5 foot-pounds. With such a motor, the robot is capable of carrying a 150-pound load, while towing another 150-pound load! The cost was a relatively modest $65 each, plus shipping. To aid readers, Vesta Technology (see Sources box for address) will collect orders (prepaid only) and have the motors made. When they're ready, the motors will be shipped and shipping charges will be invoiced.

The two motors are mounted in the lower half of the rear compartment as shown in Fig. 10. Mounting them there allows the upper clamshell to be removed without also removing the motors. Due to the length of the motors, they are offset, with one motor mounted higher than the other, as shown in the figure. The mounting and drive-shaft holes must be drilled through both the rear bulkhead and the clamshell. The drive-shaft diameter is 5/16-inch. Use a piece of scrap aluminum or PC-board material to create a drilling template for the motor-mounting holes. The template is used to mark the positions for the holes on the robot's body.

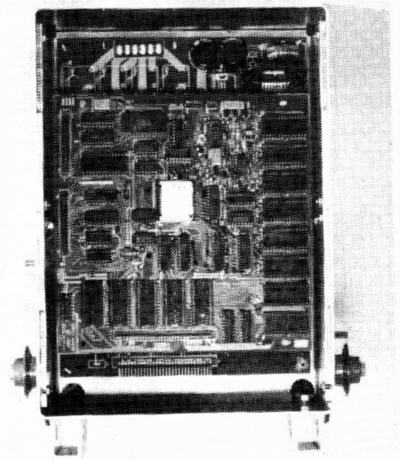

FIG. 9—THE CONTROLLER BOARD and the RPC are stacked and mounted on the forward bulkhead.

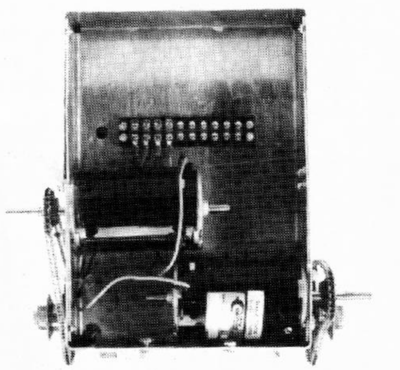

FIG. 10—THE MOTORS ARE MOUNTED in the lower half of the rear compartment. Because of their length, they must be staggered as shown.

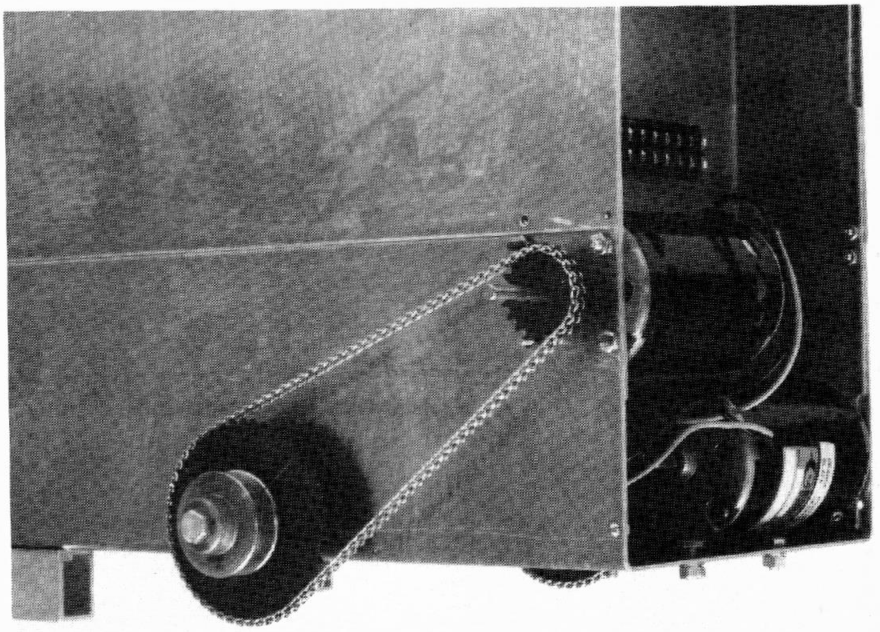

FIG. 11—UPDATED DRIVE SYSTEM. The motors are linked to a jackshaft via a ladder chain. The jackshaft will be linked to the wheels, when installed, via a V-belt.

Drive-train update

The original drive train used a 1/2-inch V-belt pulley to link the motor and the wheels directly. That arrangement did not provide sufficient pulling force. Ideally, the 4:1 reduction of that arrangement would have provided about 8 foot-pounds of torque at the wheel. Of course, the actual torque provided would be less.

We have designed a new speed-reducing system that provides a 12:1 reduction ratio. That results in a calculated torque at the wheel of 24 foot-pounds. (Of course, once again, the acutal torque delivered will be somewhat less.) Our test system achieved a top speed of four miles per hour when connected to a single 12-volt battery. With a 150-pound payload, the system reached a speed of about two miles per hour over a deep carpet. When connected to 24 volts, speed increases of about 50% are expected.

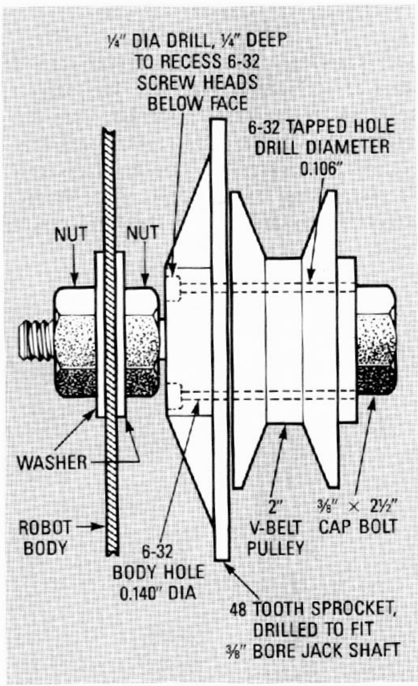

FIG. 12—JACKSHAFT DETAILS. Be sure that the unit is assembled so that the chain and the pulley are as close as possible.

The modified reduction system is shown in Fig. 11. An 18-tooth sprocket is mounted on each motor. The sprocket bore must be drilled out to match the motor's 5/16-inch drive shaft.

The motor sprocket is linked to a jackshaft assembly via a chain drive. The details of the jackshaft are shown in Fig. 12. A 2-inch V-belt pulley is drilled to accommodate two 6-32 screws. A 48-tooth sprocket is drilled for a 3/8-inch bore. Temporarily mount the 48-tooth sprocket and the 2-inch pulley on a 3/8-inch bolt and drill the sprocket to match the hole pattern on the pulley. Tap the pulley holes and bolt the pulley and the sprocket together so that when the jackshaft is assembled there will be a minimum distance between the sprocket and the V belt.

A 3/8 × 2.5-inch cap bolt is used as the jackshaft axle. The pulley/sprocket assembly slides onto the bolt in such a way that when the jackshaft is mounted on the robot, the pulley will be on the outside and the sprocket will be on the inside. Using a 37-inch V belt to link the jackshaft to the robot's wheels, determine the proper mounting point on the robot's body by observing the tension on the belt. Drill the robot's body and mount the jackshaft using nuts and washers as shown. Link the sprocket on the jackshaft with the sprocket on the motor using an appropriate length of 1/4-inch ladder chain. Finish up by removing the set screws from the pulley and sprocket hubs (typically, those are supplied with such screws installed) and place a few drops of oil on each jackshaft for lubrication.

Before we finish up, let's pass along a word of caution. Although we have not reached the point in our series of articles where the motor controllers are driving our robot, the robot is now at a stage where it could be energized. **Do not do so!** Even at four miles-per-hour, a runaway robot could cause considerable damage. Do not energize the robot until the motor-controller board is built, tested, and installed. We will cover the controller board in depth, including schematics, PC patterns, etc. **R-E**