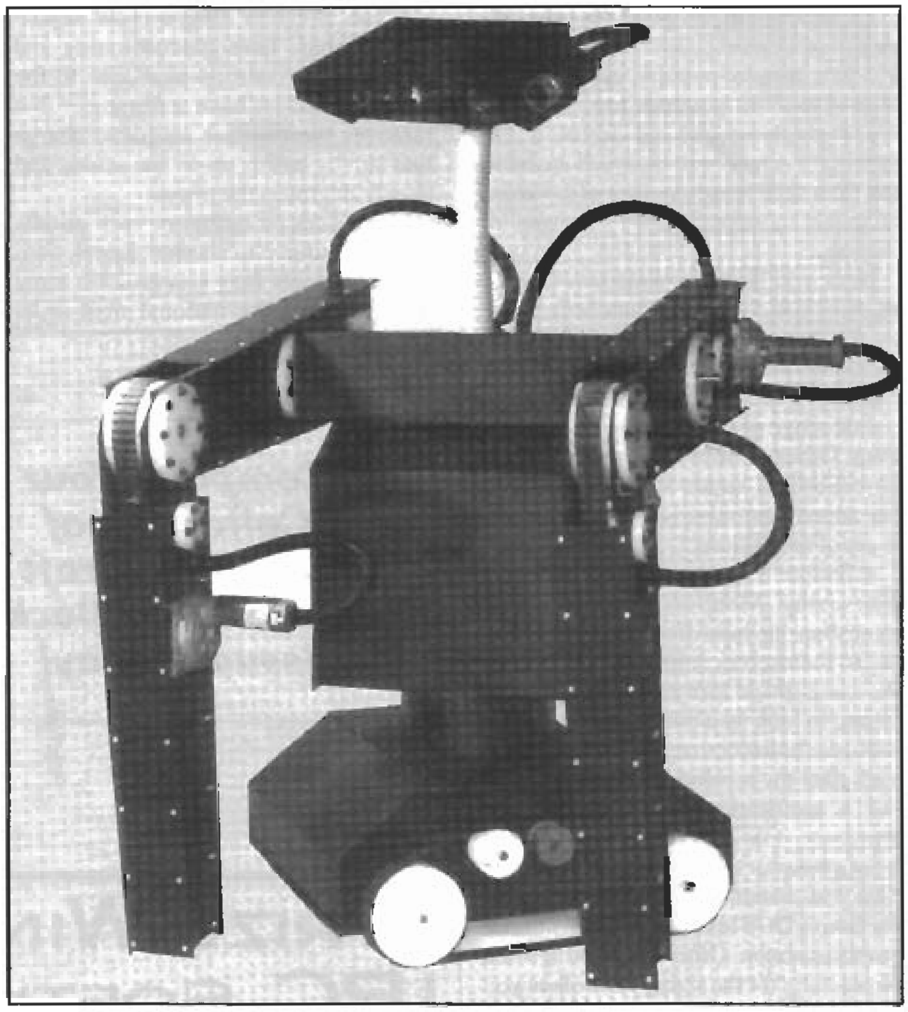
Build A Real-World Work Robot

Part 4

Adding the CYBER Hand to the basic robot assembly

If you've been following the development of the RONAR (Remotely Oriented Numerically Actuated Robot) project in the past three issues of *ComputerCraft*, you're probably anxious to add "hands" to your robot. Mechanical hands--or "grippers," as they're often called in the robotics industry—vary considerably with regard to design. Simple grippers often consist of nothing more than solenoid-actuated "tongs," while sophisticated fully articulated human-like hands can cost in the tens of thousands of dollars to fabricate and install. The CYBER Hand you'll be building this time out falls somewhere between these two extremes. Intentionally designed to be easy to build, this hand offers considerable flexibility at modest cost.



Hand and Motor Theory

You'll notice from the various photos and drawings throughout this article that the robot's hand assembly is composed of very simple metal and plastic components. As shown in Fig. 1, the hand is built around a wrist channel made up of a U-shaped aluminum bracket that supports extender channels and uses wrist pins to hold them in the proper position to permit the extender channels to rotate at the wrist. On the end of each extender channel, a foregrip channel is attached via two 4-40 X 1/4" screws and serves RONAR, much like our fingers serve us. Inside the wrist-channel bracket is a slide block assembly made from UHMW (ultra-high molecular weight) plastic material.

An Acme nut press-fitted into the slide block receives a threaded Acme shaft that's attached to a special drive motor. As this CY-Motor rotates, the Acme nut and slide-block assembly move along the shaft's axis. Clockwise rotation of the motor draws the slide block closer to the motor's faceplate. Counterclockwise rotation pushes the slide block away from the motor and toward the open end of the wrist-channel bracket.

Four 4-40 X 1/2" screws threaded into the corners of the slide-block assembly serve as guide screws that slide back and forth inside the extender-channel actuator and wrist-channel actuator slots. As the motor rotates in the clockwise direction and draws the slide block toward the motor, the extender channels also pull back, opening the hand. When the motor rotates in a counterclockwise direction, the hand closes its grip.

The hand can use several types of foregrips, or "finger-tips," depending upon the application you've chosen for your robot. I use a small piece of UHMW material as a foregrip because it provides good gripping characteristics but doesn't scratch or mar the object my robot is directed to pick up. You may find that foam rubber or urethane works better as a foregrip in your particular application.

I designed the hand to be as flexible a possible. By changing the foregrip channel slightly, you can adapt it to a variety of applications. For example, you may find that a wider foregrip is more useful in the type of work you're planning on doing with your robot. Perhaps individual spring-loaded "fingers" and an opposing "thumb" would better serve your needs. The hand's greatest strength is its ability to be easily changed and re-configured for your application.

tended capabilities. If you choose the latter, you'll probably be able to keep the same monitor when you update the adapter or even your entire computer.

Your second major decision is the size of monitor you want. Monitors, like television receivers, are measured by the diagonal size of the tube beneath the bezel. The exposed area of the tube will be slightly less, and the image itself will be even smaller. In the past, 13" and 14" monitors were standard. Today, 16" and 17" monitors are popular, especially for high-resolution graphics use. After all 1,024 pixels spread out across a 17" monitor's screen will be much easier to see than then same number of horizontal pixels squashed into a 13" or smaller display.

Next, you'll want to make sure that the monitor you choose can handle the same resolutions as your video adapter. Multi-scanning monitors (like those in NEC's MultiSync line) can adjust themselves to a wide range of video modes and resolutions. Other monitors, like many that are advertised as super-VGA-compatible, can adjust themselves to match a specific set of resolutions.

A feature related to multi-scanning is auto-sizing. Monitors that can accept more than one input frequency can either adjust themselves automatically to keep the same image size regardless of resolution, to look up a preset image size for each resolution or to require user settings each time the resolution changes. If you use a multitasking environment like *Windows*, OS/2 or *DesqView*, you'll want a monitor that can adjust itself each time you switch video modes, for example from a DOS text screen to a *Windows* graphics screen. Otherwise, you'll often be reaching for the sizing controls as you silently curse your monitor.

You'll also be concerned with the dot pitch of the monitors at which you look. Anything greater than 0.31 mm is probably not worth considering, even for a computer dedicated to games. Most high-quality monitors have a dot pitch of 0.28 mm or even less. If you tend to use high graphics resolutions you'll probably want the smallest dot pitch you can afford.

Finally, the locations and number of controls is an important consideration. Some monitors hide the controls on the back, forcing users to fumble for them and try to guess which knob is which. Other, more user-friendly monitors have all of the controls on the front. One new monitor, the Optiquest 4000DC, features on-screen programming of major adjustments. Your settings are stored in an internal microprocessor and its memory.

Some controls are essential and available on almost all monitors. For example, it would be difficult to accept a monitor without both brightness and contrast controls. Other common controls set horizontal and vertical image position and size.

Some monitors have a color adjustment. Others have pincushioning and convergence controls available to the user. Still others have a degausser that removes the residual magnetic charge that slowly builds up on the screen and slowly degrades the image.

The prices of monitors vary greatly from one source to another. Local, non-discount stores may charge 25% more than some of the national mail-order sources. If you're lucky enough to live near one of the large discount computer warehouses, you might want to buy a monitor there, so you can return it for repair or replacement if your particular monitor has poor convergence or another distortion.

Whether you spend $250 for a simple VGA or super-VGA monitor or $1,500 for a 17" multi-scan monitor with 0.25-mm dot pitch and 1,280 X 1,024 resolution capabilities, a new monitor will change the "feel" of any computer. Bright colors, a crisp image and a large display will make you feel like you've got one of the best computers in the world. On the other hand, if you spend your computer time looking at a blurry image and washed-out colors, you won't think much of even the most powerful personal computer available. ■

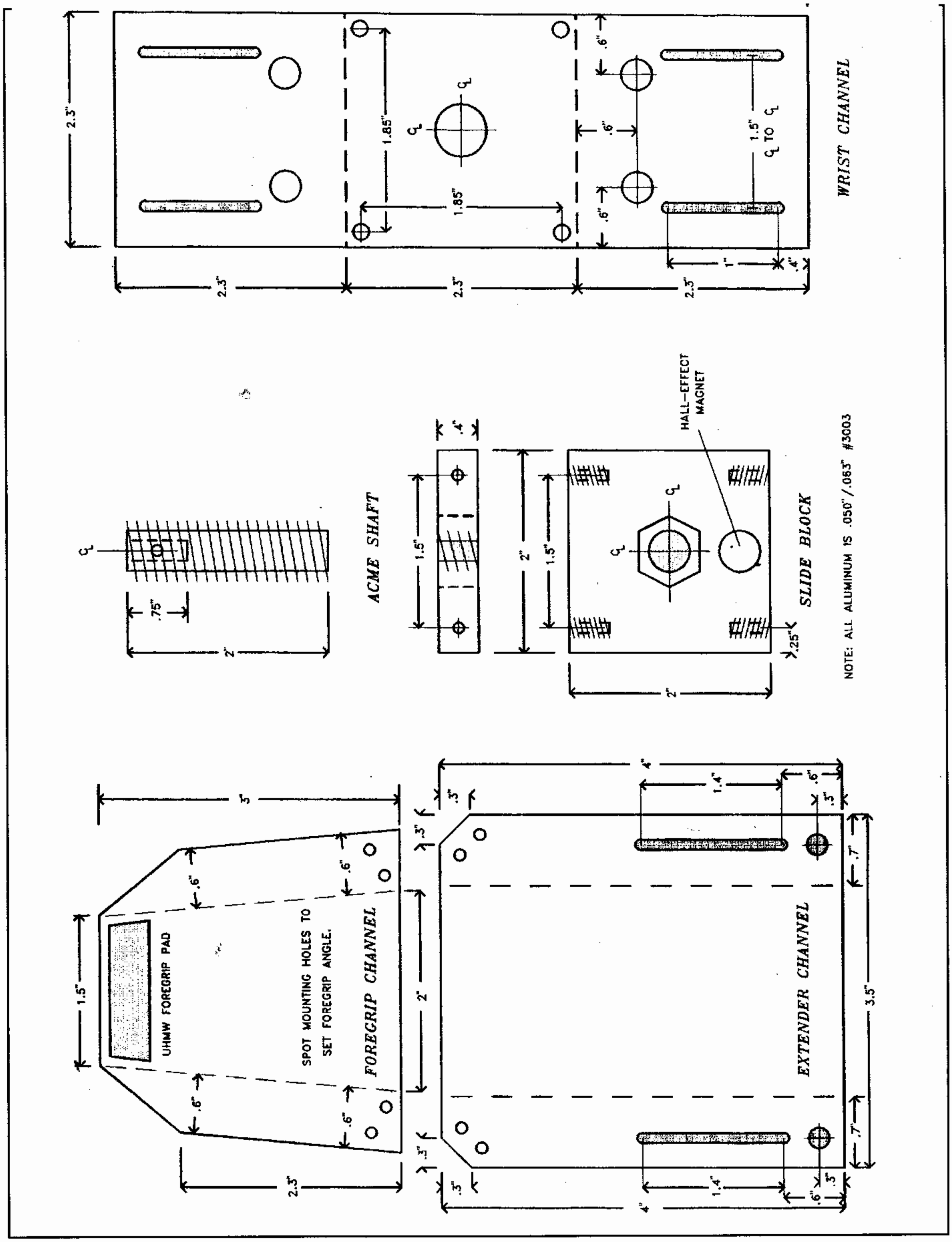


Fig. 1. Machining details for mechanical members of CYBER Hand assembly.

PARTS LIST

1—Wrist channel bracket
2—Extender channels
2—Foregrip channels
2—Foregrips
2—Wrist pins
4—1/4" Wrist Pin E-clips
8—4-40 X 1/4" button-head Allen screws
4—4-40 X 1/2" button-head Allen screws
4—#6 flat washers
4—4-40 X 3/8" Truss-head Phillips screws
12—4-40 Keps nuts
1—Hall-effect Sensor card with hardware
1—Slide-block assembly with Acme nut
1—2" Acme shaft
1—83 oz.-in., 12-volt dc CY-Motor (see text)
1—Hall-Effect 1/2" magnet
1—4-ohm 10-watt resistor
1—7812 voltage/current regulator IC

Note: The following items are available from U.S. Cyberlab, Inc., 14786 Slate Gap Rd., West Fork, AR 72774 (tel.: 501 839-8293 voice or 501 839-8221 fax): Kit of all prefabricated, plated and painted CYBER Hand metal parts, including slide-block assembly, Acme nut and shaft, $39.95; 83-oz.-in. digital CY-Motor and Hall-effect sensor card with Hall-effect magnet, $79.95; complete kit of all CYBER Hand components, including CY-Motor and Hall-effect components, $114.95. Add $7.95 insured UPS S&H. Arkansas residents, please add state sales tax. Check, COD or MasterCard/Visa welcomed.

The special CY-Motor that powers the hand is a new type of digital motor that makes motion control a snap. Essentially a four-phase precision stepper-motor, it has a micro-digital phase controller system built into it. Optically isolated and reverse-polarity protected, this motor operates directly from a 12-volt, 1-ampere power source.

As you can see in Fig. 2, the motor is controlled with only two lines. The brown STEP control line accepts a +5- to +12-volt pulse that causes the motor to rotate 1.8° (1/200 of a revolution). Rotation direction is controlled by the green DIR control line. With the DIR line high, the motor rotates in the clockwise direction. A low-level or open DIR line causes the motor to rotate in the counterclockwise direction.

Position sensing in the hand is facilitated by a Hall-effect device mounted behind the slide-block assembly. A small Hall-effect magnet forces low the output of the UGN-3119 Hall-effect sensor IC when the hand is in the full-open position. By counting and controlling the number of step pulses delivered to the motor, your control software can keep very accurate track of the position of the hand.

Built-in current limiting causes the motor to "slip" if the hand is directed to grip an object too tightly. This automatic-slip feature eliminates concern about damaging the hand's mechanical components in normal use.

Construction

Carefully following the details given in Fig. 1, fabricate the components for the hand assembly. If you don't have access to a sheet-metal shop, a complete kit of components is available from the source given in the Note at the end of the Parts List.

You can use 0.050" or 0.063" No. 3003 alloy aluminum to fabricate the various sheet-metal parts for the hand. When sheared and folded properly, the hand makes a very light weight and incredibly strong assembly. Follow the drawings carefully when measuring and marking the metal parts. A little extra time spent double-checking yourself at this point will save a lot of time and frustration later.

Be sure to use a good-quality zinc-oxide primer or conversion coating on the aluminum elements before painting them. Aluminum rapidly oxidizes when cleaned, making a nice slick surface to which paint doesn't like to adhere. Test-fit the various sheet-metal parts before proceeding, and make sure that everything is square and "true" before final assembly.

Using a lathe, turn a groove about 0.100" deep from the ends of the wrist pins, making it about 0.05" deep, to snugly accommodate E-clip retainers. If the E-clips snap off the wrist pins too easily, deepen the grooves a little more. While at the lathe, bore a 1/4" diameter by 3/4" deep hole in the end of the 2" Acme shaft. Finally, drill and tap the setscrew hole for a 4-40 thread, and test-fit the motor's shaft.

It will be difficult for you to cut the UHMW slide block material to size because this material is very difficult to cut using conventional techniques owing to its self-lubricating qualities. Be extremely careful when cutting the thin slide-block dimensions. Take your time and work slowly and carefully. A single slip could cause you to lose a finger. Likewise, always wear safety-glasses when working with metal and plastic.

Press-fit the Acme nut into the slide-block assembly, and drill and tap the 4-40 screw holes at each corner. Finish the slide-block assembly by gluing the Hall-effect magnet on the rear of the block. Double-check the orientation of the Hall-effect magnet using the Hall-effect sensor card you wired from an earlier installment of this series. The magnet will probably have to be rotated until you locate the appropriate spot that triggers the Hall-effect sensor output.

Begin putting together the hand assembly by attaching the foregrip material of your choice to the foregrip Channel. You can use 5-minute epoxy cement, cyanoacrylate (so-called "super glue") or even 4-40 screws for this operation. When the foregrip material has solidly bonded, attach the foregrip channel to the extender channel with four 4-40 X 1/4" button-head Allen screws and nuts, as shown in Fig. 3. By punching or drilling these four No. 27 mounting holes, you'll find that there's some play in the joint between the foregrip and extender channels. This play lets you perfectly align the two foregrips so that they match when the hand is closed.

With a Hall-effect sensor card, mount the device inside the wrist channel so that it will be aligned with the Hall-effect magnet mounted on the slide-block assembly. It's important that the Hall-effect magnet properly operate the sensor for the hand to sense its "home" position.

Next, using the wrist pins, attach the extender channels to the wrist channel. Slide the wrist pins through the wrist channel and secure each end with an E-clip. Wear safety glasses when snapping the E-clips into place to obviate any possibility of eye injury should the clips, under quite a bit of tension, snap off and become dangerous missiles.

Secure the Acme shaft on the motor shaft by tightening the Allen setscrew. Then, using four 4-40 X 1/2" truss-head Phillips screws and Keps nuts, mount the motor on the rear of the wrist-channel assembly. You'll have to move back the extender channels to make room for the 4-40 screws. The complete hand assembly is shown in Fig. 4.

With the motor attached to a controller circuit (or by pulsing the STEP line of the motor manually), rotate the Acme shaft clockwise while holding the slide-block assembly against the Acme shaft. The slide block's Acme nut should thread itself onto the Acme shaft and begin moving toward the faceplate of the motor. Carefully monitor the output of the

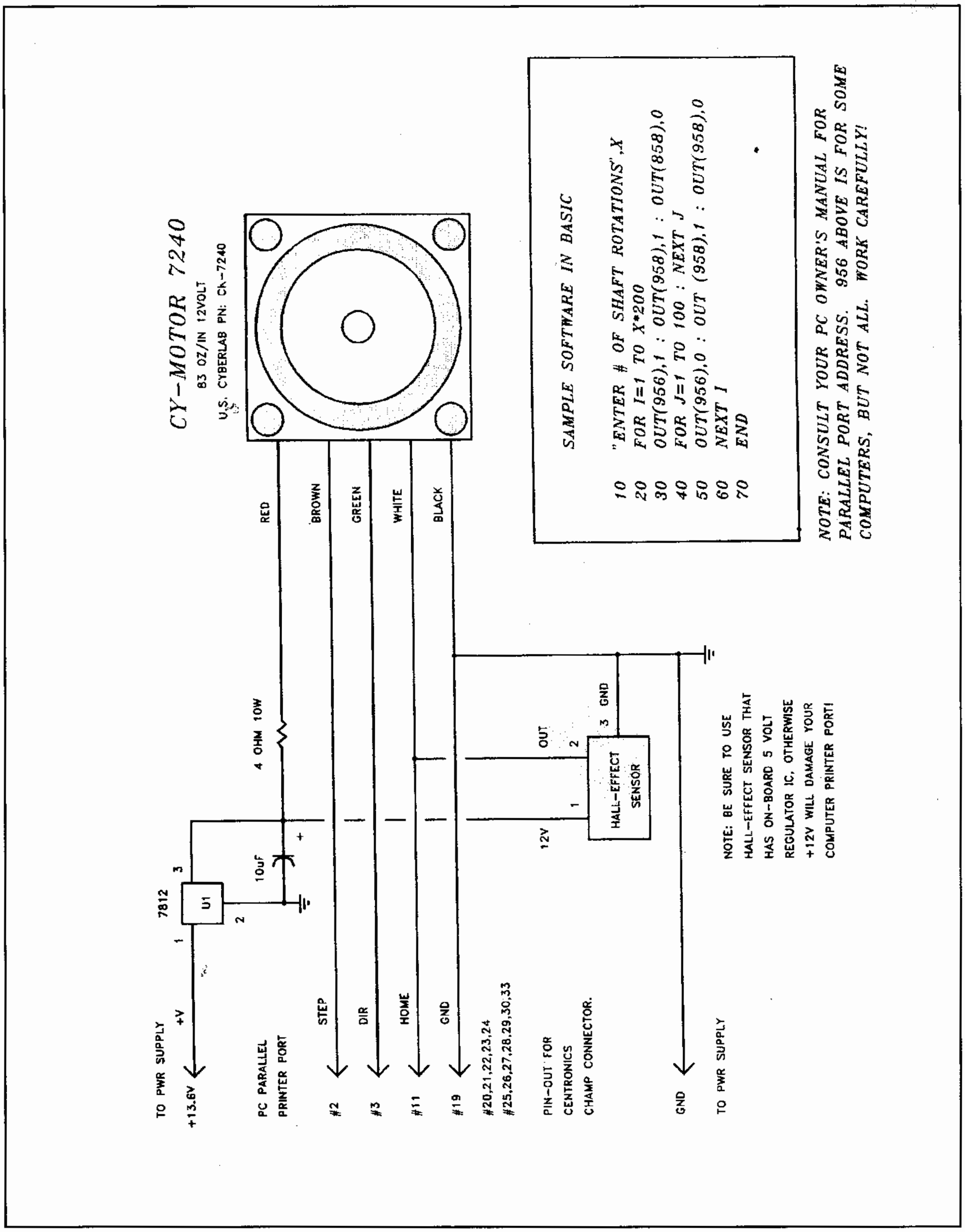


Fig. 2. Electrical motor connection details for hand.

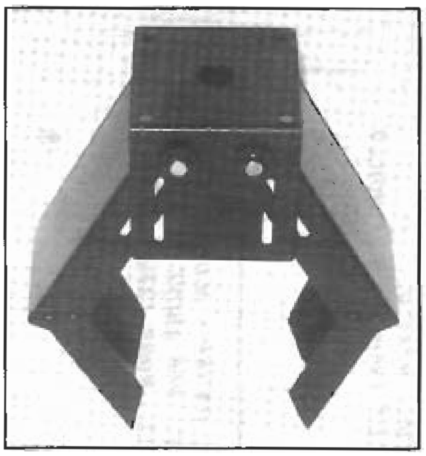


Fig. 3. Attach the foregrip channel to the extender channel with four 4-40 X 1/4" button-head Allen screws and nuts.

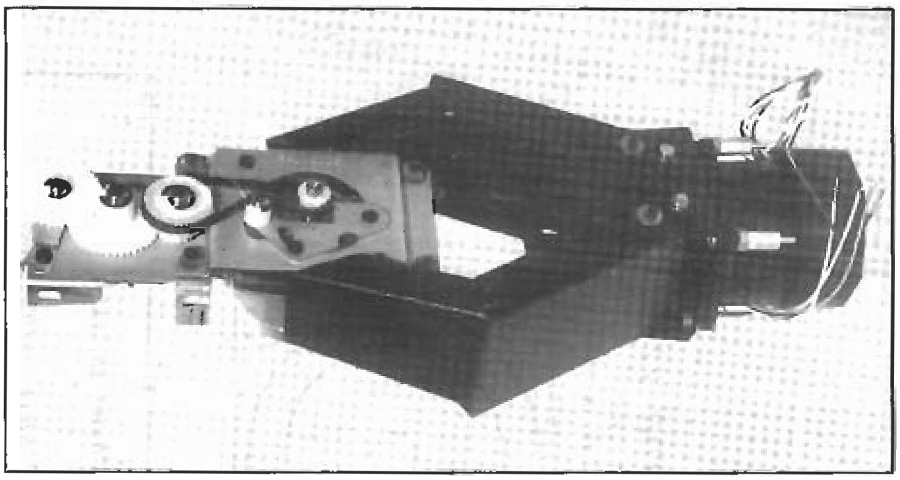


Fig. 4. Completed hand assembly.

Hall-effect sensor to make sure that it's able to override the motor to ensure against damaging the sensor IC might. When the slide block assembly is in its full-back position, use No. 6 washers and 4-40 X 1/2" button-head Allen screws to form the guide screws. Don't fully tighten these four screws. The four guide screws must be free to slide back and forth in the extender- and wrist-channel actuator slots.

Checkout & Use

If you don't have the CYBER Link controllers for your robot unit up and running yet, simply attach the hand to the parallel printer port of your PC/compatible computer. You can operate the motor directly from your PC's parallel port using a simple BASIC program. With one data bit used to control the DIR line and a second to control the STEP line, your program can open and close the hand assembly on command. If you want your program to be able to monitor the status of the Hall-effect sensor (hand fully-open), simply connect the sensor output line to the paper-out input of the parallel printer port. (Consult the computer operator's handbook for your PC to determine the pinout and port addresses for your particular machine.) Using the CY-Motor for power, a cog-belt or direct-drive arrangement would be a fairly straightforward proposition.

Feel free to experiment with the foregrip channel. Spring-loaded or fully-powered and articulated fingers are within your reach and could make for an exciting addition to your robot project. I'd start with the hand design presented and then, with some experience under your belt, move to a more-sophisticated design. Some people have suggested that tactile or "load-cell" sensors could be easily retro-fitted to the basic hand assembly. I'll leave these advanced applications to you.

To mount the hands on your robot's arms, you must notch the C channels to allow the motor to clear. Then, using the hand mounting bracket, secure the unit using four 6-32 X 3/8" screws. The CYBER Link controllers used throughout the robot can directly interface with the hand's motor. If you're up to the challenge, you can try your hand at developing, building and installing a rotary wrist for each of your robot's hands. ■

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