number of teeth decides the *step angle* and the number of steps per revolution. In the absence of any electrical input, the rotor will lock to the stator by seeking out paths of minimum magnetic reluctance.

There are normally two groups of windings provided. The "A" winding is active one-third of the distance between teeth, while the "B" winding is active two-thirds of the distance between the teeth.

In typical use, a four-step process is used to advance to the next tooth position. The A winding first gets activated, attracting the toothed rotor one-third of the distance to the next tooth. Then the B winding is activated, attracting to the two-thirds point. Next, the A winding has its current reversed to further repel towards that two thirds point. In the final step, that current in the B winding gets reversed, repelling the rotor to its new and final position.

The speed gets determined by the number of steps applied per second. The direction is set by changing the roles of the A and B windings.

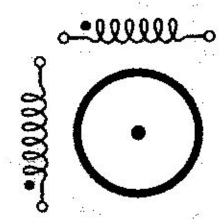


FIG. 1—IN A BIPOLAR (OR UNIFILAR) stepper motor, there is only a single grinding for each phase. Although the stepper itself is powerful and low-cost, the driver circuitry gets extra complicated, since a full-bridge circuit is needed—one that is able to send current in either direction. Bipolar stepper's often have four leads.

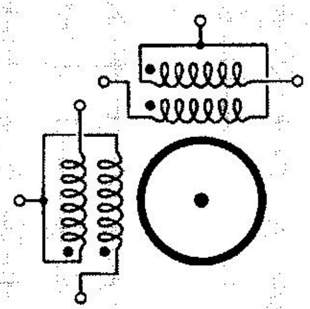
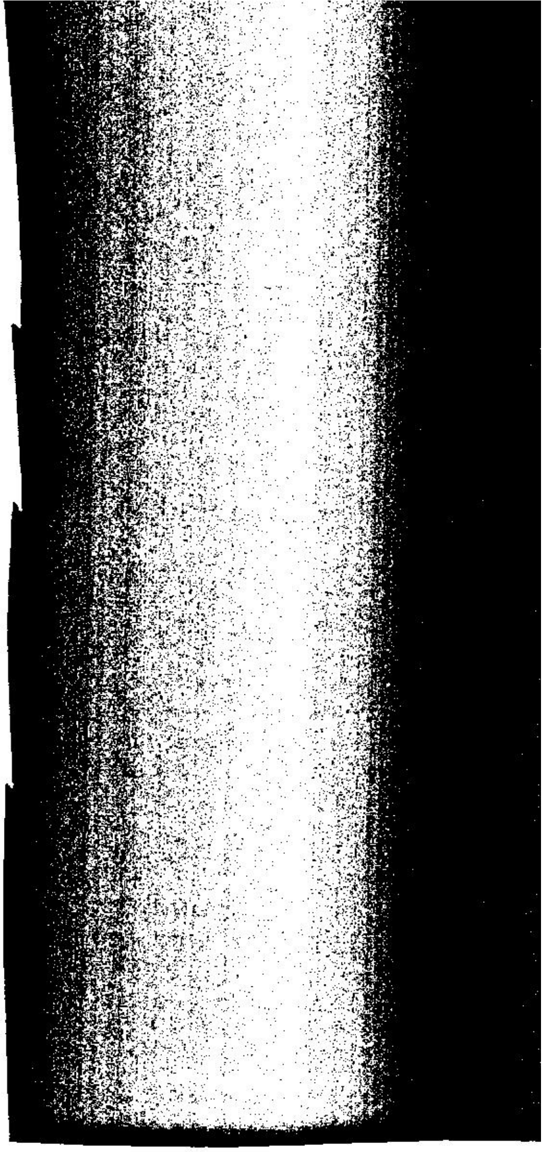


FIG. 2—IN A UNIPOLAR (OR BIFILAR) stepper motor, you will find a pair of windings for each phase. While that raises the cost and also reduces the available stepper power, your driver circuitry is far simpler and very much cheaper, since only a current sink is needed for each winding. A unipolar stepper often has six leads.



Other patterns of activating the A and B windings might give you various speed and torque options, as well as actually *microstepping*, the moving to a precise position *between* the rotor teeth.

As Figs. 1 and 2 show us, there are two different methods with which stepper motors are commonly wound. In a *bipolar* stepper there is only a single A winding and only a single B winding. That is cheaper and has more power, but requires you to electronically *reverse* the high current through both windings. Thus, what you gain in stepper economy, you lose in driver complexity.

In a *unipolar* or a *bifilar* stepper, there are two distinct A windings and two separate B windings. Each of the windings go in the opposite sense of the other, so a current in one winding will attract the rotor, while the same current in the other winding will instead repel the rotor. The unipolar windings are much easier to drive, but they cost more and offer less power.

You can usually tell which type of stepper you have by the number of leads. Assuming that all the leads are brought out separately, a bipolar stepper will have four wires, while a unipolar one will have six. For most hacker uses, the unipolar and bifilar windings are the best choice, since they are easier and cheaper to drive.

Good data sheets and ap-notes on steppers are available from *Airpax, Hayden, Superior Electric*, and most of the other suppliers. Bunches of technical articles and supplier ads for steppers appear in the *PCIM* and *Motion* trade journals, as well as the usual electronics insider magazines.

While new steppers are usually rather pricey, you can find lots of surplus ones in assorted sizes and voltages for as little as $2 through all the usual **Radio-Electronics** ads and similar surplus sources.

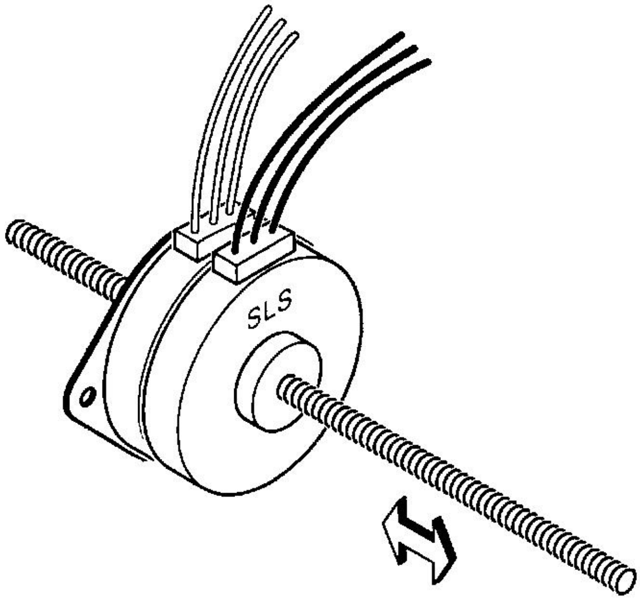


FIG. 3—THE HURST SLS LINEAR ACTUATOR is a real "sleeper" for hardware hacking. This easy-to-drive 12-volt, 12-watt unit offers 24 pounds of force in 2-mil (0.002) increments. What can you do with it that's new and really different?

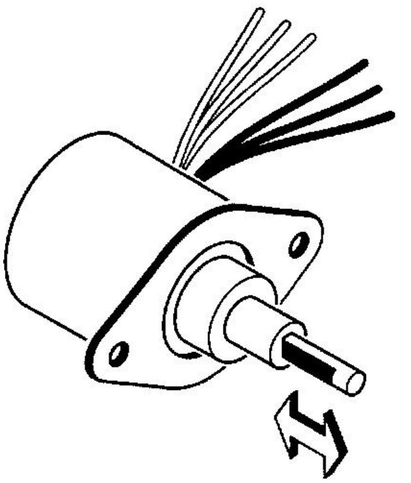


FIG. 4—THE AIRPAX 92100 is a smaller linear stepper motor having a ½-inch stroke. Similar units may be available at a junkyard as throttle idle controllers.

about cotton picking, what we have here is an easy and precise way to eliminate a most tedious and time-consuming job. If the teeth are too close, you destroy the machine. If they are too far away, your yield and your grade goes down.

A third source of linear actuators is *Eastern Air Devices*, but their military look and their refusal to include pricing in their mailings does not bode well for hackers.

Stepper drivers

Most of the stepper manufacturers have available driver circuitry for their devices, but those tend to be older hybrids that seem overpriced. Instead, there are several suppliers of single- and double-chip stepper-motor drivers. They include *Sprague, SGS*, and *Motorola*.

Figure 5 shows you a circuit for the *Sprague* UCN-4204B single-chip stepper driver. While I haven't yet been able to check the chip out (stay tuned), it looks like a typical modern circuit with 1.5 amps of drive capability and internal protection for both overheating and overcurrent. They are well under $4 in singles.

To use the circuit, you provide two inputs. The first is the direction input which decides whether your stepper will spin forward or backward. The second is a train of square-wave pulses that sets the speed in the chosen direction.

It is usually best to computer control your stepper driver. As we've seen, an otherwise unused Commodore 64 is ideal for that sort of thing, and their going rate is around $30 at a yard sale.

One microcontroller chip that I really like which includes dual low-level stepper drivers on-chip (among lots of other goodies) is the great M50734 by *Mitsubishi*. That dude cross-assembles beautifully on an Apple IIe or IIgs.

Three contests

Let's have three contests this month. There will be the usual *Incredible Secret Money Machine* prizes for the best dozen entries, with an all-expense paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best of all.

For the easy contest, just tell me something you would like to do with a linear stepping motor or a linear actuator. Or two or even three. Especially if they have twenty pounds of force in 2-mil increments.

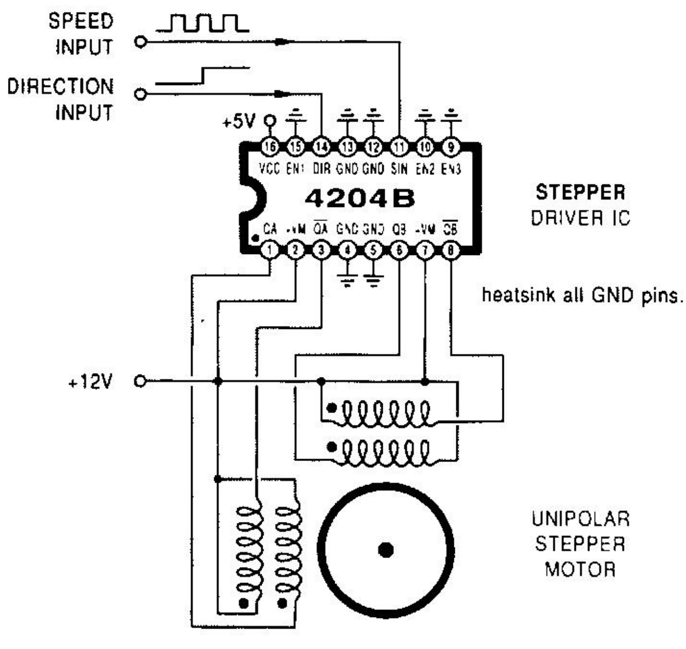


FIG. 5—LOW-COST SINGLE-CHIP stepper-motor drivers are readily available from Motorola, SGS, and Sprague, among others. Here's a popular Sprague driver.

Edmund Scientific
101 E. Glouchester Pike
Barrington, NJ 08007
(609) 573-6250
Evergreen Scale Models
12808 NE 125th Way
Kirkland, WA 98034
(206) 823-0458
Fastex
195 Algonquin Road
Des Plaines, IL 60016
(312) 299-2222
Fine Scale Modeling
21027 Crossroads Circle
Waukesha, WI 53187
(414) 796-8776
Fomeboards
2211 N. Elston Avenue
Chicago, IL 60614
(312) 278-9200
W.W. Granger
5959 West Howard St.
Chicago, IL 60648
(312) 647-8900
Herbach & Rademan
401 East Erie Avenue
Philadelphia, PA 19134
(215) 426-1700
Hygenic Manufacturing
1245 Home Avenue
Akron, OH 44310
(216) 633-8460
Jerryco
601 Linden Place
Evanston, IL 60202
(312) 475-8440
K & S Engineering
6917 West 59th St.
Chicágo, IL 60638
(312) 586-8503
Lindsay Publications
PO Box 12
Bradley, IL 60915
(815) 468-3668
Machine Design
1100 Superior Avenue
Cleveland, OH 44144
(216) 696-7000
McMaster-Carr
Box 54960
Los Angeles, CA 90054
(213) 692-5911
Milled Shapes
1701 North 33rd Ave.
Melrose Park, IL 60160
(312) 344-1220
Model Railroader
21027 Crossroads Circle
Waukesha, WI 53187
(414) 796-8776
New Equipment Digest
1100 Superior Avenue
Cleveland, OH 44114
(216) 696-7000
Northeastern Scale Models
PO Box 727
Methuen, MA 01844
(508) 688-6019
Nuts and Volts
Box 1111
Placentia, CA 92670
(714) 632-7721
Plastiglide
2701 West El Segundo Blvd.
Hawthorne, CA 90250
(213) 777-8108
Signcraft
1938 Hill Ave. PO Box 06031
Fort Meyers, FL 33906
(813) 939-4644
Sinclair & Rush
10315 Page Industrial Blvd.
St. Louis, MO 63132
(314) 426-4487
Small Parts
6891 NE Third Ave.
Miami, FL 33238
(305) 751-0856
Special Shapes
PO Box 487
Romeoville, IL 60441
No listing
Stock Drive Products
55 South Denton Ave.
New Hyde Park, NY 11040
(516) 328-0200
Synergetics
Box 809
Thatcher, AZ 85552
(602) 428-4073
US Plastics
1390 Neubrecht Road
Lima, OH 45801
(419) 228-2242
oodworker's Store
21801 Industrial Blvd.
Rogers, MN 55374
(612) 428-2899

Two linear steppers

Take an ordinary stepper motor, but make it hollow at its center. Then add a threaded shaft through the middle, which gets driven from a nutplate on the stepper armature. As the stepper is stepped, the nutplate turns, which in turn advances or retards the threaded shaft.

All of which gives you a way to push or pull things in tiny and very accurate increments under computer control. With lots of force over fairly long strokes.

Uses? Animation tables, printed-circuit drills, a numeric-controlled milling machine, plotters, robotics, valve actuators, electronic engine controls, research projects, point-of-purchase displays, plus dozens of uses previously unthunk of.

Figure 3 shows you the *Hurst* model SLS linear actuator. It's a 12-watt unit that gives you 25 pounds of force in 2-mil (0.002 inch) increments, over an 8-inch actuating length.

While under $20 in quantity, single evaluation units cost around $55, unless you can locate a surplus one. That seems rather high, until you take that "Uh, compared to what?" factor into account.

On custom order, lead screws up to several feet long can be obtained. Note that there is no theoretical limit to the stroke you could get out of one of those, so long as a lead screw that length is available. Maintaining the precision and avoiding any binding would, of course, get far worse with increasing length.

Figure 4 shows you a smaller *Airpax* series 92100 unit. They are much smaller and give you a half-inch maximum stroke, in 2- or 4-mil steps, having a force slightly over one pound.

The price is around $25 each, but you might be able to find one nearly free at your local junkyard, as some automobiles use them for computerized carburetor idle adjustments. Unfortunately, I don't know which specific models to send you after. There are also some plain old throttle solenoids that look just about the same, so make sure you are getting a "real" stepper when you make your visit.

You can step them up to 400 steps per second, which means you can travel the half-inch stop-to-stop distance in something like 0.6 seconds. But you do lose force at the higher stepping rates.

We're using that one locally to adjust the teeth on a cotton picking machine. The stepper acts as sort of a micrometer, advancing until it touches each tooth. The number of steps needed then tells the mechanic how much shim to add.

If you don't know anything

For our intermediate contest, just tell me which makes and models of automobiles use linear stepping actuators as their idle controls.

For the hard contest, nobody talks very much about the electrical and mechanical *eficiency* of a stepping motor. *Why?* Could a very large and extremely efficient linear stepping motor be built?

That would dramatically improve solar water-pump design, as the pump stroke and speed could be exactly and continuously matched to both the available input solar power and the well characteristics. Which might enormously simplify and cheapen both the electronic and mechanical designs. Especially for remote and third-world applications.

Modelmaking resources

In any large electronics company, the model shop is that secret lair where all of the mockups, mechanical prototypes, breadboards, concept pieces, and one-of-a-kinds come from. As a hacker, you are your own model shop, so it is super important to know where to go to get all of the non-electronic bits and pieces you'll need to make hacking more hackable. Our new Modelmaking Resources sidebar shows you a few places to go for model info and supplies.

Naturally, you will want to check out your own local resources first. Those should include a good hardware store, a large junkyard, a real hobby shop, and a few electronic surplus houses that do not have a catalog and do not advertise in any national magazines. One regional example around here is the *Apache Reclamation and Salvage.* Ask any ham radio operator for a complete neighborhood list.

I've also found a local horse-trailer factory to be useful, es-

NAMES AND NUMBERS

Airpax
150 Knotter Drive
Cheshire, CT 06410
(203) 271-6000

Brookfield
240 Cushing St.
Stoughton, MA 02072
(617) 344-4310

Burr-Brown
6730 S. Tucson Blvd.
Tucson, AZ 85706
(602) 746-1111

Computer Shopper
5211 South Washington
Titusville, FL 32780
(407) 269-3211

Hayden Switch & Instrument
1500 Meridan Rd. PO Box 3329
Waterbury, CT 06705
(203) 756-7441

Heath Buyers Club
PO box 217
Benton Harbor, MI 49022
(616) 982-3789

Hurst Manufacturing
Box 326
Princeton, NJ 47670
(812) 385-2564

Linear Technology
1630 Mc Carthy Blvd.
Milpitas, CA 95035
(408) 432-1900

Mitsubishi
1050 East Arques Avenue
Sunnyvale, CA 94086
(408) 730-5900

Motion Magazine
Box 6430
Orange, CA 92613
(714) 974-0200

Motorola
5005 E. McDowell Rd.
Phoenix, AZ 85008
(602) 244-6900

PCIM
2472 Eastman Ave. B33
Ventura, CA 93003
(805) 658-0933

Precision Monolithics
1500 Space Park Dr.
Santa Clara, CA 95052
(408) 727-9222

Rohm Corporation
8 Whatney
Irvine, CA 92718
(714) 855-0819

SGS
100 East Bell Rd.
Phoenix, AZ 85022
(602) 867-6959

Sprague
363 Platinum
Worcester, MA 01605
(508) 795-1300

Superior Electric
383 Middle St.
Bristol, CT 06010
(203) 582-9561

Tektronix
Box 4600
Beaverton, OR 97076
(800) 426-2200