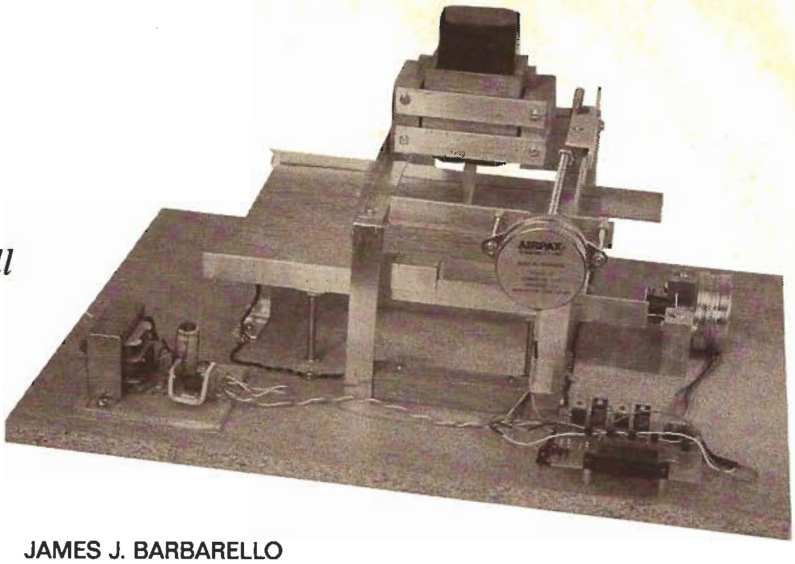
BUILD THE PCDrill

Build a machine that lets you drill PC board holes precisely, effortlessly, and inexpensively.



JAMES J. BARBARELLO

The printed circuit board is the foundation of many electronics projects, but creating PC boards in small quantities is always a problem. Several steps are involved in that process; those are:

1) Create the layout
2) Transfer it to the board
3) Etch the board
4) Drill the board

This project concerns Step 4.

Most people drill prototype PC-board holes manually. Typically, you use a very small, brittle drill bit that breaks easily—especially if you use a hand-held drill. Even if you use a drill stand, you must position the board for each hole. And you must prepare the board by marking each location with a center punch; otherwise you risk drill "wander" that can produce an off-center hole. In the age of 0.1-inch (and smaller) hole spacing, that can be disastrous! Further, stamping amounts to doubling the amount of work required per hole. Wouldn't it be nice to have a machine that lets you drill PC board holes precisely, effortlessly, and inexpensively?

Well, you can. For less than $100 (which includes a $30 mini-drill), you can build PCDrill, a computer controlled X-Y table that can locate any position on a 6-inch × 8-inch PC board with a resolution of 0.001-inch. Standard, easily available hardware is used throughout, and construction requires only hand tools, although some precise wood cutting is required for the drill caddy.

Any PC can drive PCDrill via a standard parallel port. The port controls two stepper motors, one for motion in each direction. In our design, the PC board table moves in the X direction, and the drill caddy moves in the Y direction. Also, the drill caddy is spring-loaded so that once the desired location is reached, a light downward force on the drill is all that's necessary to create a precisely located hole. The PC controls the stepper motors with a simple BASIC program that generates a series of X and Y coordinates based on input from a standard text file.

The project is straightforward to build, but there are many detailed steps. For that reason, we will go light on theory and heavy on hands-on construction details. For more detailed information on how stepper motors work, and how to control them, we refer you to the author's previous article, "Build an Automatic Parts Tray," which appeared in the November and December 1996 issues of **Electronics Now**.

The Motor and the Motion. This project uses a standard, off-the-shelf stepper motor that costs about $7 apiece. It is a bipolar device requiring a modest 5.75-volt DC power supply, and it has sufficient torque for this application. The motor moves 48 steps per revolution, or 7.5° per step. But how can we turn rotational motion into linear motion, and obtain 0.001-inch linear resolution in the bargain?

The secret is to couple the stepper motor's shaft to another, threaded shaft, and install a nut on that shaft, as shown in Fig. 1. If we prevent the nut from rotating while we turn the shaft, the nut will move back and forth across the shaft. Thus we convert rotational motion (R) into linear motion (L).

Let's assume that the threaded shaft has 20 threads per inch. In that case, one rotation of the shaft will move the nut 1⁄20 inch (0.05 inch). However, the stepper motor can break that single rotation down into 48 discrete steps, so each step rotates the shaft 0.05 inch/48, or 0.00104 inch. A 5⁄16-20 threaded rod, available at most hardware stores, contains 20 threads per inch. (Be careful not to get a 5⁄16-16 rod, which contains 16 threads per inch; that 5⁄16-inch rod type is even more common than the 5⁄16-20 type.)

But how do we get the stepper to move in the first place? In a nutshell, a stepper has two windings. By applying DC voltages to the windings in various sequences and polarities, we can cause the shaft to move in one direc-

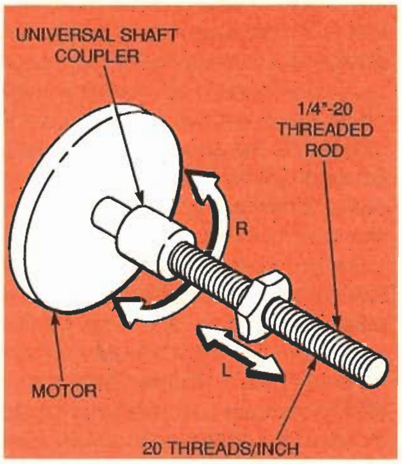


Fig. 1. The rotational motion of the threaded rod is converted to linear motion by the fixed nut.

TABLE 1—MOTION CONTROL SEQUENCE

Step	A(5)	B*(4)	B(3)	A*(2)	Decimal
1	1	0	1	0	10
2	0	0	1	1	3
3	0	1	0	1	5
4	1	1	0	0	12

tion or the other. Table 1 shows the motion-control sequence. By performing steps 1–4 sequentially, the tray rotates clockwise (CW). By performing the sequence backward (4–1), the tray rotates counterclockwise (CCW).

The Circuit. If you've seen the previous article mentioned earlier, the circuit shown in Fig. 2 should look familiar. Transistors Q1–Q12 and associated components are nearly identical to the circuits used in that project. The difference here appears in the bottom part of the figure, and involves Q13 and Q14, relay RY1, and their associated components. The purpose of the relay is simply to select one motor or the other. The remainder of the circuit serves to flip-flop the polarity of the voltage applied to the selected motor. The selected motor and polarities all depend on the states of the inputs at J1, which are of course driven by the PC's parallel port.

To give you an understanding of how the polarity-reversal mechanism works, let's examine the block consisting of Q1, Q3, Q5, R1, R2, R5, and R7. If pin 5 of J1 goes high, Q5 conducts, so its collector goes low. That low at the base of Q3 in turn forward-biases Q3, causing it to conduct, and bringing its emitter close to ground. Now look at the block consisting of Q8, Q10, Q12, R11, R12, R14, and R16. If pin 2 of J1 goes low, its collector goes high, causing Q8 to conduct and Q10 to remain off. At this point, we have a voltage difference between the emitters of Q3 and Q8, so if we connected the coil of a motor across them, the shaft would turn.

Each motor has four leads, denoted A, A*, B, and B*. Leads A and A* comprise one winding, and B and B* the other. Note that the A* ends of coil A in both stepper motors (MOT1 and MOT2) connect to the emitter of Q8. The A ends connect to the relay. Likewise, the B* motor leads connect to Q2, and the B ends to the relay. So depending on whether the relay is energized, one motor or the other will complete the current path from Q3 to Q8. Transistors Q13 and Q14 form a non-inverting buffer that provides enough current to drive the relay.

The remaining portion of the circuit consists of microswitches S1 and S2,

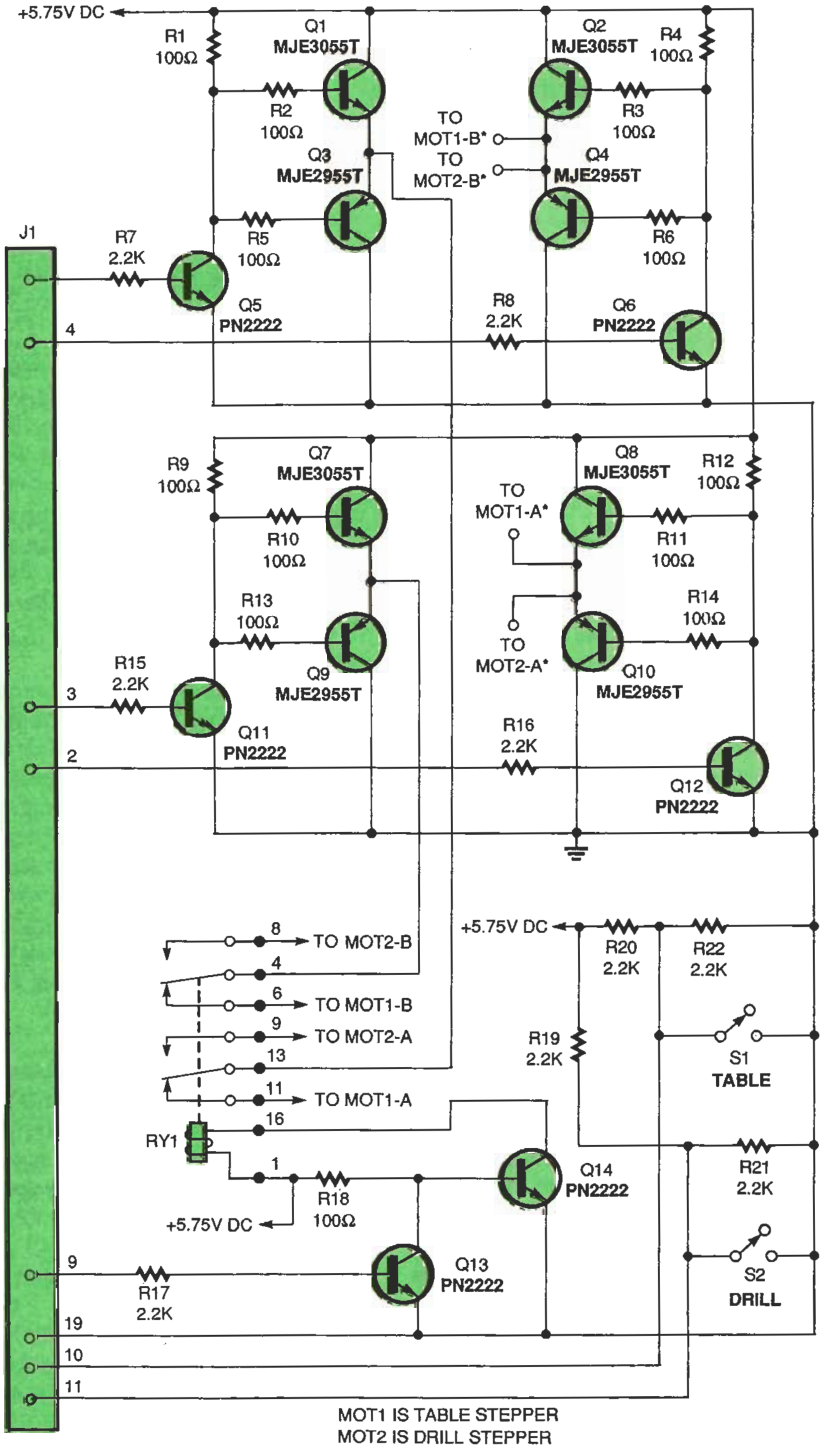


Fig. 2. The upper part of the circuit provides a digitally controllable way to swap the polarity of voltage applied to a motor. The lower portion allows one of two motors to be selected.

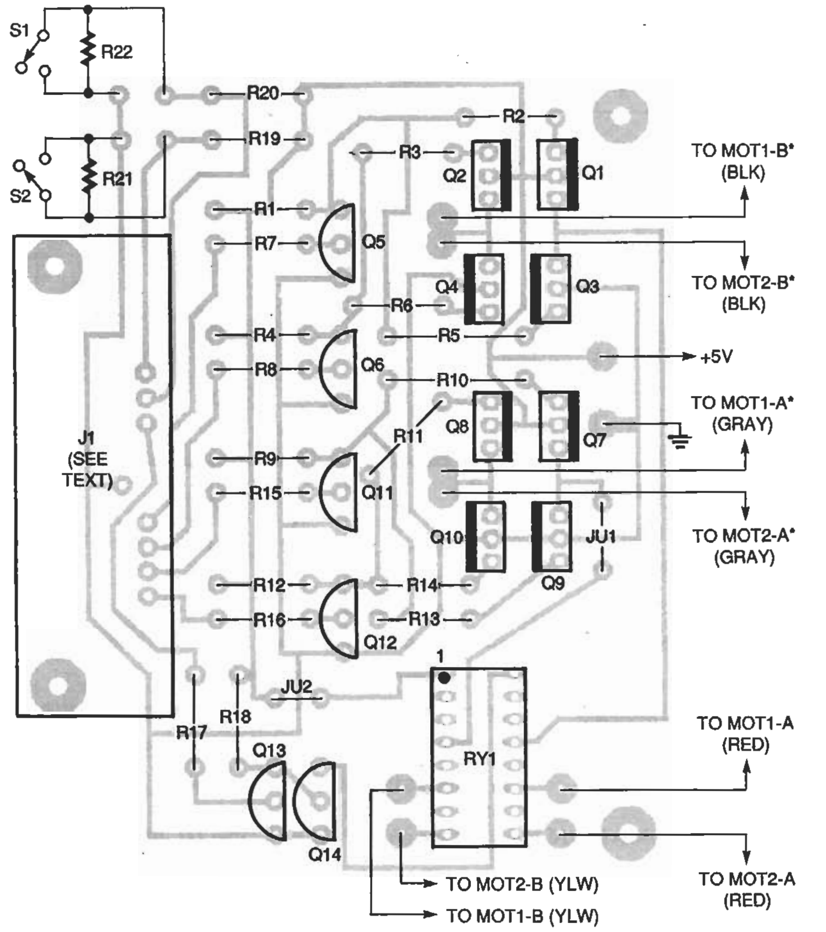
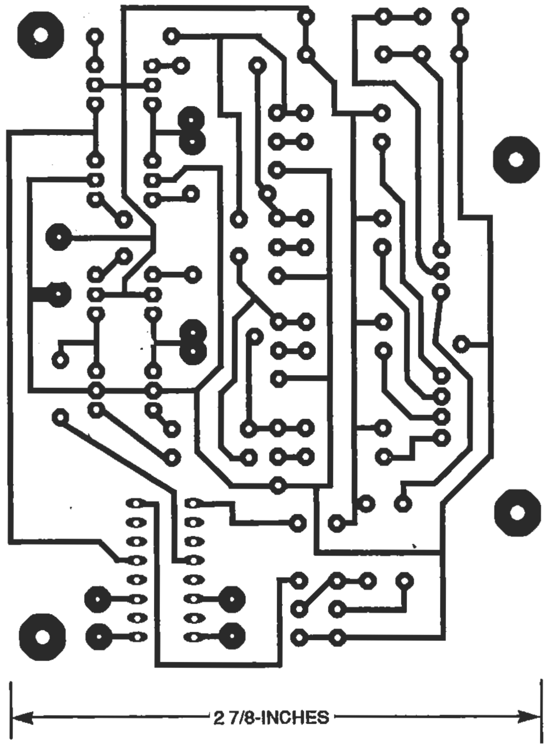


Fig. 3. Mount all components as shown here. Be careful with the orientation of all components, particularly the power transistors.



Here's the full-size PC pattern for the circuit board.

and the corresponding resistive voltage dividers. In operation, S1 and S2 function as limit switches that advise the software when the X or Y table has reached the end of travel. Both switches sit in the normally open state, providing a logic high (about 2.9-volts DC) to pins 10 and 11 of J1. When either switch closes, it grounds the associated pin on J1, indicating to the software that some action should be taken.

A note concerning current limiting: Many stepper-motor control circuits use current-limiting resistors to protect the motors against excessive current draw and consequent overheating. In our circuit, the relatively large current demand of the motor causes a measurable voltage drop across the power-providing transistors (in the example above, Q3 and Q8). Each will have a base-to-emitter drop approaching 1 volt. Therefore, the stepper motor coil sees only about 3.5-volts DC. With a coil resistance of 6.25 ohms, current is 3.5/6.25 = 560 mA. That's well within the motor's ability to dissipate the heat generated. Accordingly, no current limiting resistors are required.

MOTOR SPECIFICATIONS

Motor: Bipolar (2 Phase) AIRPAX Stepper Motor, P/N LB2773-M1
Mechanical: 2.25-inch D x 0.99-inch H. 0.61 lb.
Electrical: 5-volts DC, 800 mA, 6.25-ohms per coil
Resolution: 7.5°/step
Shaft: 0.25-inch D × 0.75- inch L
Mounting holes: 2 × 0.2 inch, 2.6-inches apart
Torque: 100 g-cm (detent), 1080 g-cm (holding)

Construction. There are seven major steps involved in building this project: 1) PC board, 2) base, 3) table tracks, 4) table, 5) drill-caddy support, 6) drill caddy, and 7) final assembly. We'll discuss them in order. Table 2 lists all required mechanical components.

Begin by fabricating the PC board using the foil pattern accompanying this article. Then install the resistors and transistors as shown in Fig. 3. We recommend use of a 16-pin DIP socket for RY1. Note the orientation of the

PARTS LIST FOR THE PCDRILL

SEMICONDUCTORS

Q1, Q2, Q7, Q8—MJE3055T NPN transistor, TO-220 case
Q3, Q4, Q9, Q10—MJE2955T PNP transistor, TO-220 case
Q5, Q6, Q11–Q14—PN2222 NPN transistor, TO-92 case

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1–R6, R9–R14, R18—100-ohm
R7, R8, R15–R17, R19–R22—2200-ohm

ADDITIONAL PARTS AND MATERIALS

MOT1, MOT2—5-volt DC, 6.25-ohm coil, bipolar stepper motor, Airpax LB82773-M1 (Jameco 117954 or equiv.)
RY1—DPDT relay, 5-volt coil (Jameco 115060 or equivalent)
J1—DB-25 connector, female, PC-mount
S1, S2—SPST microswitch (Jameco 98781 or equivalent)
5.75-VDC, 1 amp or greater power supply (Jameco 107326 or equivalent, see text); 22-gage stranded wire: mini drill (Jameco 26702 or equivalent); no. 64 (0.036-inch) PC drill bit (Jameco 16598 or equivalent); heat-shrink tubing; PC board; mechanical parts and materials (see Table 1); etc.

NOTE: The following are available from James J. Barbarello, 817 Tennent Road, Manalapan, NJ 07726: Enhanced software, executable on all PC platforms from XT through Pentium (CD-S, $12, specify disk size); PCDrill PC board (PCD-PC, $17); Drill caddy kit, consisting of spring, drill caddy sides, drill caddy slides, and drill holder (PCD-DC, $15). The author will answer any questions sent to the address above, if accompanied by a self-addressed stamped envelope.

relay, and be sure to align the transistors as indicated. Use two excess resistor leads to form jumpers JU1 and JU2.

Prior to installing J1, enlarge the two PCB mounting holes to a diameter of 5/32 inch. Also, clip off leads 1, 6–8, 12–18, and 20–25, leaving pins 2–5, 9–11, and 19 intact. Solder the leads into place, but do not mount J1 to the PC board at this time.

The stepper-motor leads are not

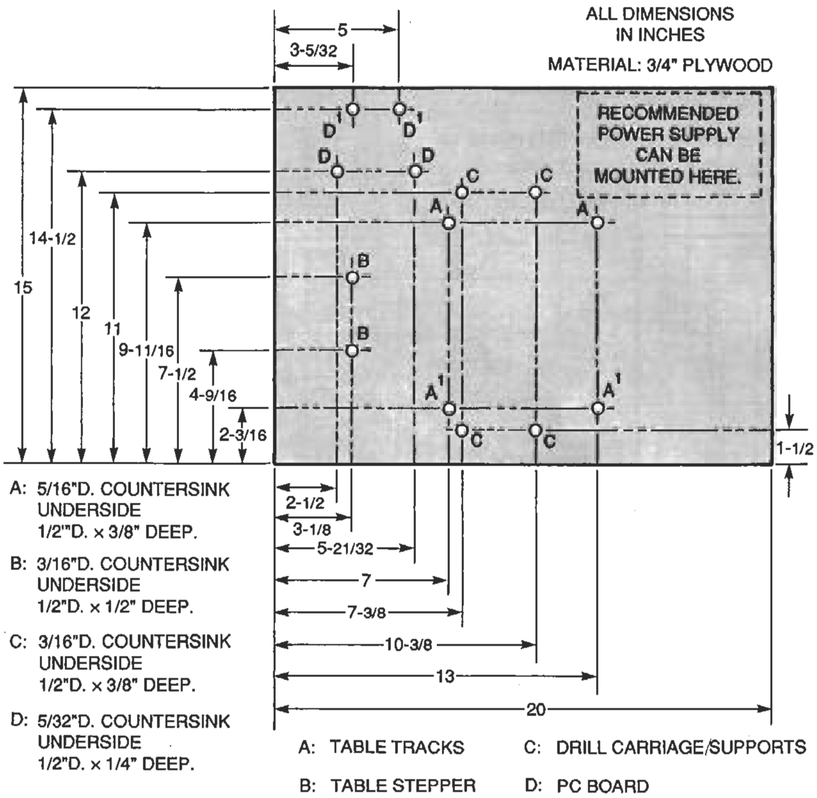


Fig. 4. The base plate has 14 holes in four groups (A, B, C, and D). Be sure to countersink all holes.

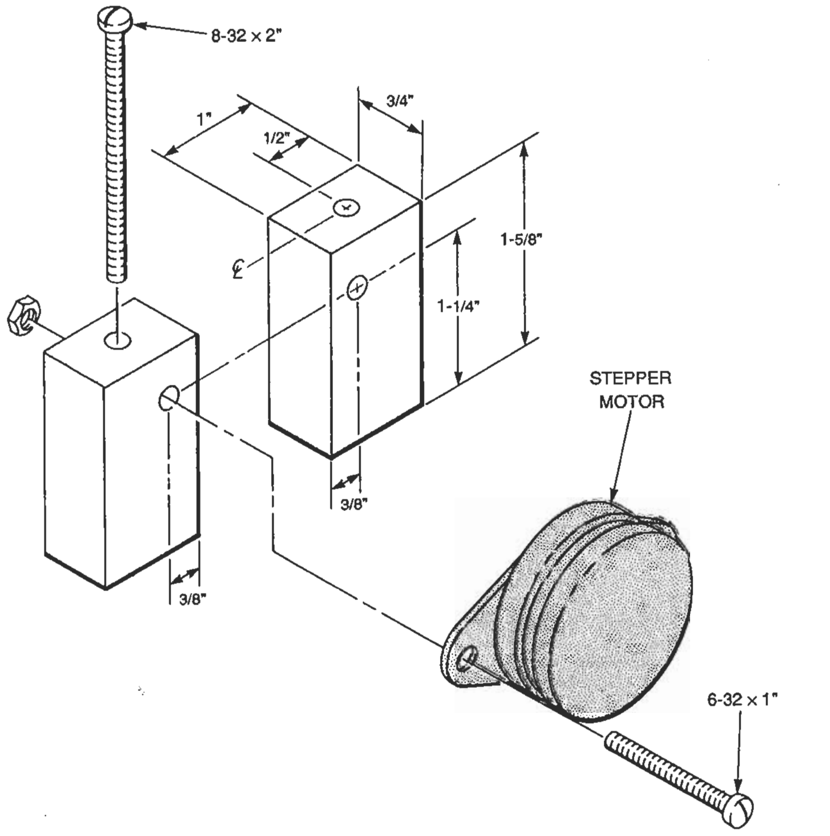


Fig. 5. The mounting blocks for the table stepper motor screw directly to the base plate.

long enough for our application, so remove the connectors on each motor. Obtain two sets of 22-gage yellow, gray, red, and black stranded wire (each about 4" long). Extend the motor leads to about 8 inches by splicing a sufficient length of like colored wire to each lead. Solder the splice and cover it with shrink sleeving or electrical tape. Mark one motor as MOT1, and the other as MOT2. Attach the leads to the appropriate points on the PC board.

Connect your power supply's leads to the PC board. If you use the supply cited in the Parts List, clip off the connector and attach the wires to the appropriate pads on the PC board. Adjust the PC-mounted potentiometer to obtain 5.75-volts DC.

The Base. As shown in Fig. 4, the base is a piece of plywood (or similar material) measuring 15 × 20 × ¾ inches. Drill 14 holes in the base, and countersink all 14 from the underside. That prevents mounting nuts from protruding from the bottom of the base.

Note in Fig. 4 that there are four groups of holes, denoted A, B, C, and D. Attach four threaded spacers to the D holes with 6-32 screws. Then attach the PC board to the spacers with 6-32 screws. Note that two of the screws will go through both J1 and the PC board. Also, mount the power supply in the indicated position at this time. For our prototype, we mounted the PC board and power transformer to a 4- × 3½- × ¼-inch scrap of plywood, and attached it to the base using #8 × ¾-inch sheet-metal screws.

Next, fabricate two table stepper mounts as shown in Fig. 5. Attach the mounts to the base with two 8-32 × 2-inch machine screws and nuts. Attach stepper motor MOT1 to the mounts as shown in Fig. 5. The motor's shaft should face the center of the base, and the leads should exit the top of the motor. We'll also need a support bracket for the table-zeroing switch, but we'll build it later, during the initial alignment.

Table and Tracks. Cut the table tracks from ¾- × ¾- × ⅛-inch aluminum angle stock. Cut two 12-inch lengths, then locate and drill four ¼-inch holes as shown in Fig. 6. Countersink the holes with a ½-inch drill bit so that the flat heads of the machine

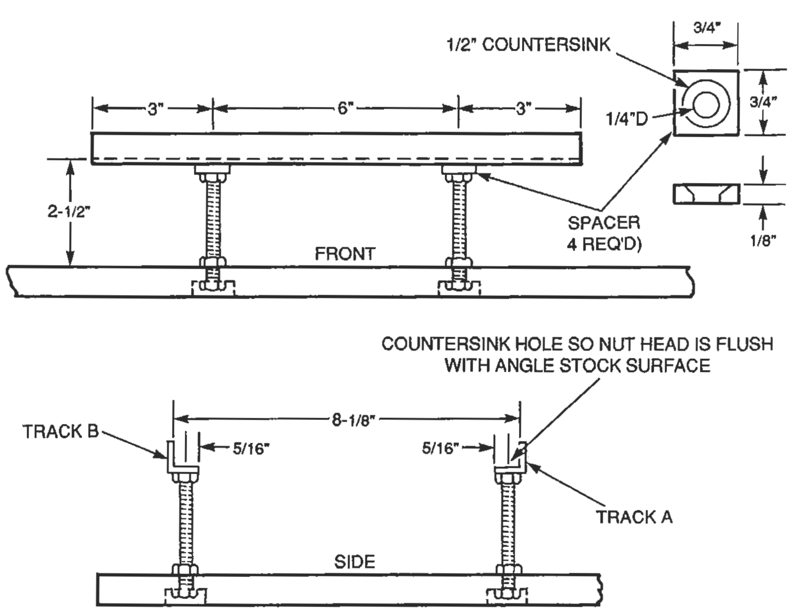


Fig. 6. Fabricate the table tracks from 12-inch lengths of ¾-inch aluminum angle stock.

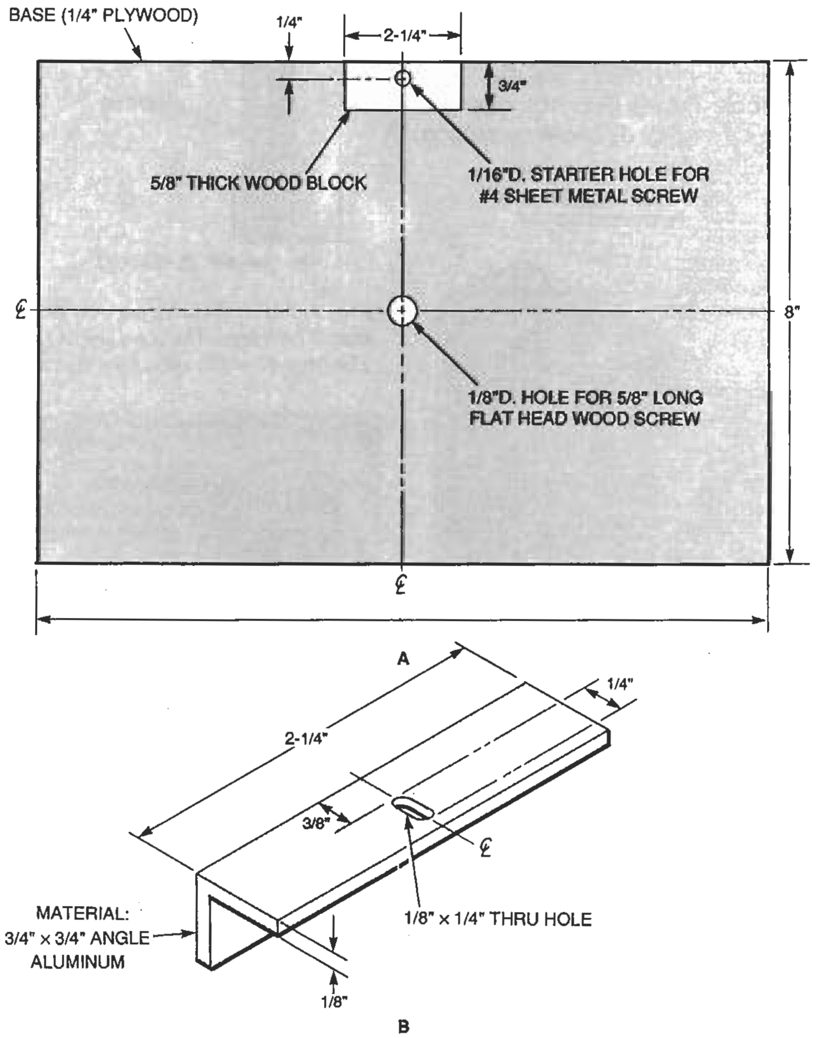


Fig. 7. As shown in A, the table base is fabricated from ¼-inch plywood. The small block is where the table guide (B) mounts. Make two table guides; the second is used in the support assembly.

screws sit flush with the surface.

Now form four spacers from ¾- × ⅛-inch flat aluminum stock, also as shown in Fig. 6. Pass a ¼-20 × 3-inch machine screw through each hole, place one spacer on each screw (countersunk side first), and then thread two ¼-inch nuts onto each screw. Tighten the first nut on each screw to secure the screw to the track, making sure each screw is perpendicular to the track. Thread the remaining nut on each screw about 1½-inch above the bottom of the screw.

Insert the screws into the A holes on the base (Fig. 4). Then, as shown in Fig. 6, thread another nut onto each screw and adjust the nut so that the inside horizontal surface of each track (on which the Table will rest) is exactly 2½-inch above the base. Secure the tracks to the base by tightening the top nuts. Adjust the tracks so that the inside vertical surfaces are 8⅛-inch apart.

The table comes next. The assembly consists of the table base (Fig. 7-a), two table guides (Fig. 7-b), and the table driver (Fig. 8). Begin by cutting

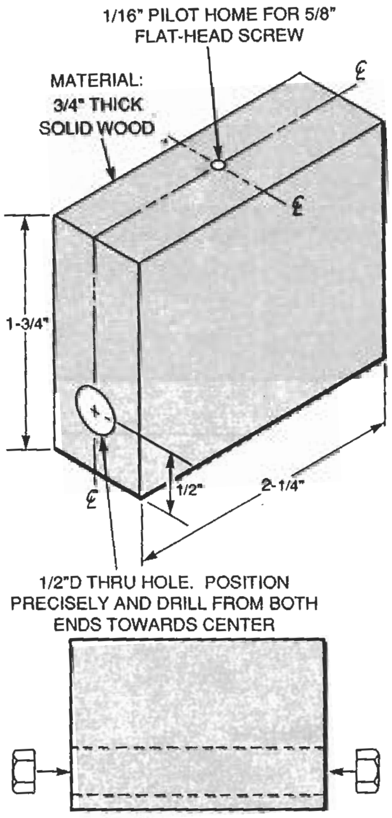


Fig. 8. The table driver has a precisely drilled ½-inch through-hole located ½-inch up from the bottom. Then press fit two 5/16-inch-20 nuts into the hole ends.

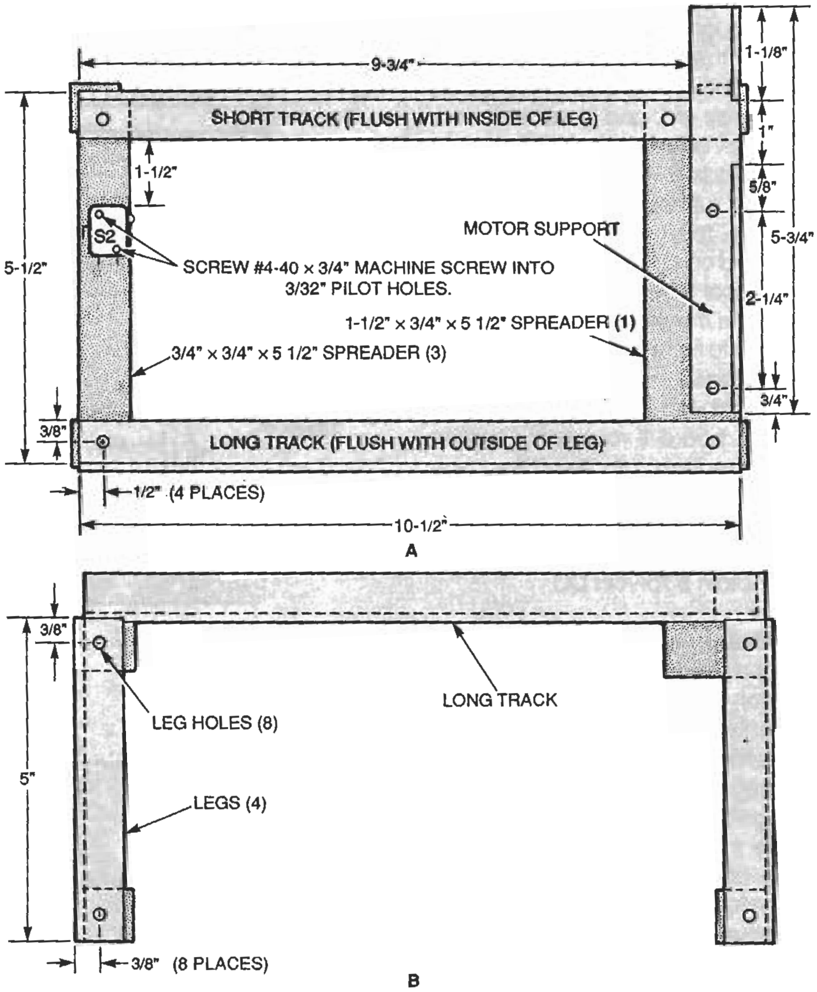


Fig. 9. The drill-caddy support framework supports the drill caddy above the table via four 5-inch legs. The top view (A) shows the short and long tracks, and the spreaders. The front view (B) shows the legs and the support track.

TABLE 2—MATERIALS LIST

QTY	DESCRIPTION	FOR
2	#4 × ½-inch sheet metal screw	table/drill guides
24	#8 × ¾-inch sheet metal screw	drill caddy support, drill caddy
1	#2 flat washer	spring holder
1	#2-56 × ½-inch machine screw and #2-56 nut	spring holder
4	#4-40 × ¾-inch machine screw	s1 & s2 mount
2	#4-40 nut	s1 mount
5	#6-32 × ⅜-inch machine screw	PC board/spacers and shaft couplers
4	#6-32 × ⅜-inch machine screw	spacers to base
2	#6-32 × 1-inch machine screw	table stepper mounting
2	#6-32 nut	—
4	#6-32 threaded spacer, ⅝-inch long (Jameco 77551)	spacers
2	#8-32 × 2-inch machine screw	table stepper mounts
4	#8-32 × 1¼-inch machine screw	drill caddy support to base
6	#8-32 nut	—
4	¼-20 × 3-inch flat head machine screw	table track supports
12	¼-20 nut	table track supports
2	5/16-inch × 12-inch long threaded rod	table & drill drive
4	5/16-inch nut	table/drill drivers
1	⅝-inch long flat head wood screw	table mount
1	¼-inch × 1-inch × .035-inch utility compression spring	drill caddy
1	8-inch × 12-inch × ¼-inch wood	table
2	2-inch × 2 21/64-inch × ¼-inch wood	drill holder sides
1	2-inch × 1 23/32-inch × ¼-inch wood	drill holder side
1	1¼-inch × 1 23/32-inch × ¼-inch plywood	drill holder side

the base from ¼-inch plywood and smoothing the ends with sandpaper. Next cut a small wood block as shown in Fig. 7-a, drill the 1/16-inch starter hole, and glue the block to the table with white (or carpenter's) glue. Next, fabricate a table guide per Fig. 7-b. To create the oblong hole, drill two ⅛-inch holes and file away the material between the holes.

After the glue dries, place the base on the table tracks with the block resting over Track A (see Fig. 6). Place the table guide on the block so it overlaps Track A. Push the block flush with the inside vertical surface of Track A. Place a piece of paper or a business card against Track A's outer surface and pull the guide flush to it. Secure the guide to the block with a #4 sheet-metal screw, and then remove the paper (or business card). Ensure that the table slides freely but does not wobble. Adjust as necessary.

The last part of the table, the table drive, is the most important. Referring to Fig. 8, cut a piece of wood to the dimensions shown. *Precisely* locate a point on each end that is ½-inch up from the bottom, and at the halfway point between the two sides. Starting with a small drill bit (1/16 or 3/32 inch), drill in from each side to create a pilot. Gradually increase the size of the hole using larger drill bits. You should eventually end up with a ½-inch through-hole. Now drill the 1/16-inch pilot hole on the top. Next, place a 5/16-inch hex nut over one end of the ½-inch through-hole, and temporarily secure it with some masking tape. Place the nut/block assembly in a vise and gently squeeze the nut into the hole until it is flush. Remove the tape and repeat the process with another nut in the other end.

Thread a 5/16-inch threaded rod through one of the nuts. As the rod approaches the other end, it will either thread through easily or begin to bind. If it binds, use another threaded rod from the outside and *gently* move the unthreaded nut slightly. Do this until the rod can be threaded through easily. Apply a light coating of oil to

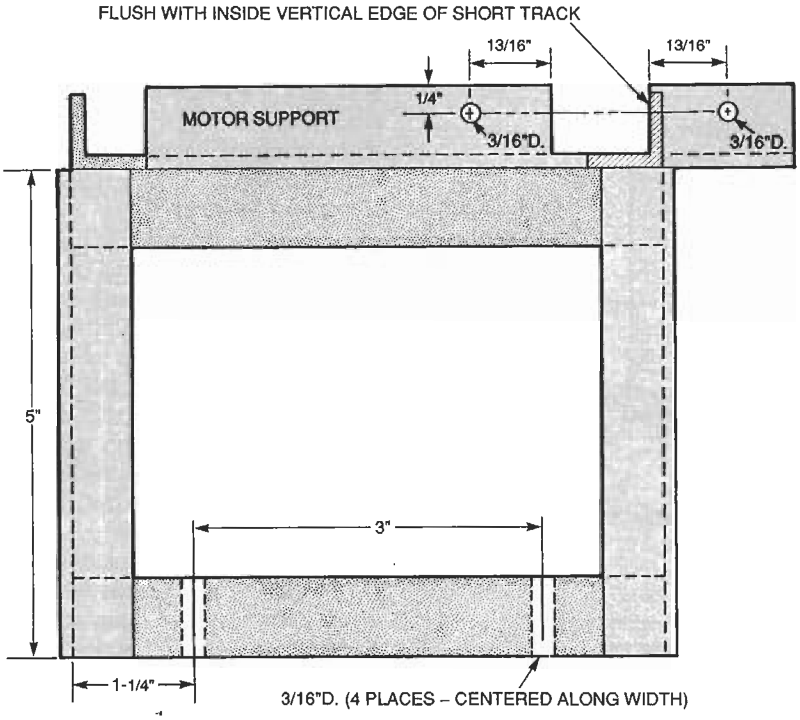


Fig. 10. This side view of the drill-caddy support details the holes where the motor mounts and the notch that provides clearance for the threaded rod.

1	15-inch × 20-inch × ¾-inch plywood or composition board	base
2	1/32-inch aluminum stock, ⅝-inch w × 2⅜-inch long	retaining clips
2	¾-inch × ¾-inch × ⅛-inch angle aluminum, 2¼-inch long	table/drill guide
4	¾-inch × ¾-inch × ⅛-inch angle aluminum, 5-inch long	drill caddy support legs
1	¾-inch × ¾-inch × ⅛-inch angle aluminum, 5¾-inch long	drill caddy motor support
1	¾-inch × ¾-inch × ⅛-inch angle aluminum, 9¾-inch long	short drill caddy track
1	¾-inch × ¾-inch × ⅛-inch angle aluminum, 10½-inch long	long drill caddy track
2	¾-inch × ¾-inch × ⅛-inch angle aluminum, 12-inch long	table tracks
4	¾-inch × ¾-inch × ⅛-inch flat aluminum stock, 4⅛-inch long	drill caddy side stretcher
1	¾-inch × ¾-inch × ⅛-inch flat aluminum stock, 4½-inch long	table zeroer support
2	5/16-inch × 21/64-inch × 2-inch wood	drill caddy slide
1	¾-inch × ⅝-inch × 2 ¼-inch wood	table base wood block
3	¾-inch × ¾-inch × 5½-inch wood	drill caddy spreader
1	¾-inch × 1-inch × 2¼-inch wood	drill driver
1	¾-inch× 1½-inch × 5½-inch wood	drill caddy spreader
1	¾-inch × 1¾-inch × 2¼-inch wood	table driver
2	¾-inch × 2-inch × 2¼-inch wood	drill caddy side
4	universal shaft coupler (Jameco 106606)	motor coupler
2	rubber coupler (Jameco 106622)	motor coupler

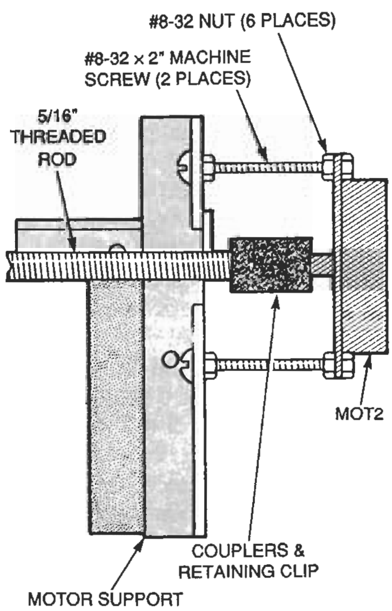


Fig. 11. As shown here, stepper motor MOT2 mounts against the motor support bracket.

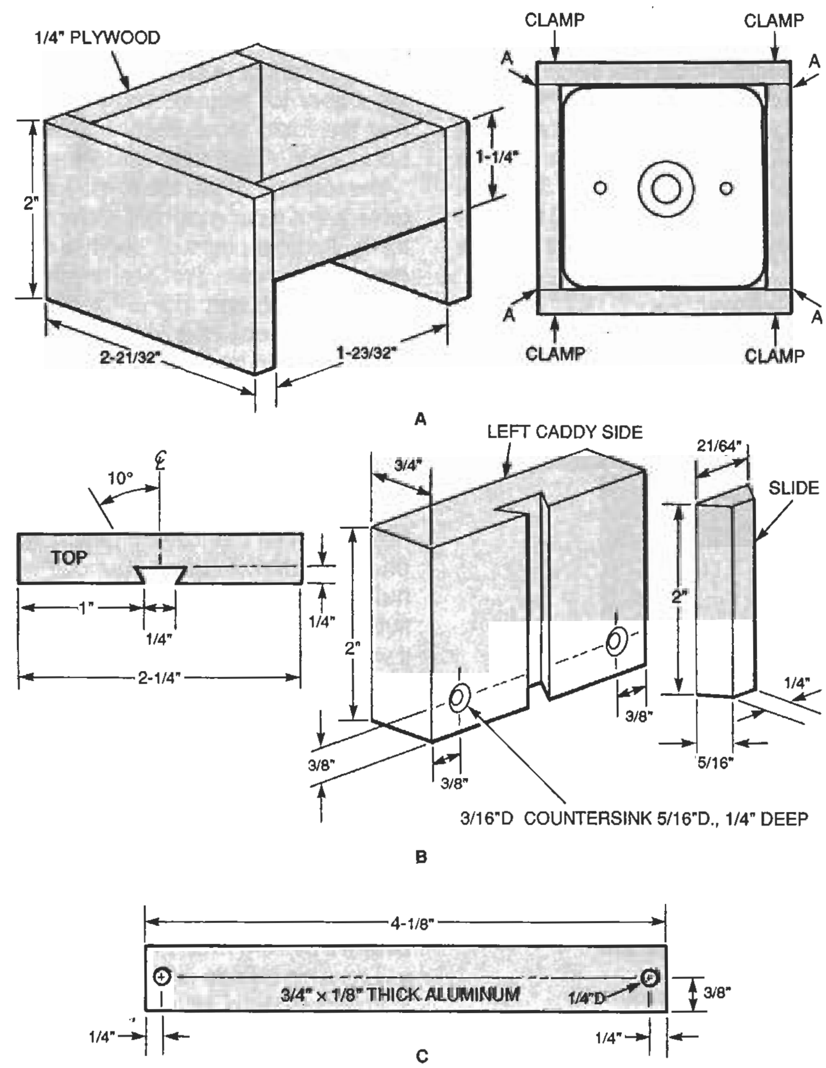


Fig. 12. The drill holder (A), the caddy sides and slide (B), and the side stretcher (C) are the drill-holder components shown here.

the rod and run the guide up and down the rod several times. You can do this quickly by chucking the rod into a variable-speed, reversible drill. The goal is for the rod to be able to move with no discernible resistance.

Place the guide on the underside of the table so both pilot holes align. Insert a ⅝-inch flat-head wood screw through the table into the guide. The screw's head should be flush with the table and the guide should be flush with the underside of the table, but the guide should be able to rotate without major resistance. That will allow the guide to move the table forward and back, but compensate for any minor misalignment of MOT1's threaded-rod drive after it is installed (during final assembly).

Drill Caddy and Support. Referring to Fig. 9-a, cut four legs and the short and long tracks from angle stock. Next, cut the four spreaders from ¾-inch wood stock. Drill and countersink two holes in each of the bottom spreaders as shown.

Drill two leg holes in each leg as shown in Fig. 9-b. Using #8 sheet-metal screws, connect the legs and stretchers to form two leg subassemblies, making sure they are square. Drill the track holes in each of the tracks and attach to the leg subassemblies. (Note that the short track is flush with the inside of the legs, but the long track is flush with the outside of the legs). Make sure the resulting top surface of the structure is square, and is of equal height on both ends.

Cut a 1-inch notch in the motor-support bracket and drill two spreader holes and two motor-mount holes. Secure the motor-support bracket with #8 sheet-metal screws. Make sure the notch aligns with and is perpendicular to the short track's inside vertical surface, as shown in Fig. 10. Secure the assembly to the base with four 8-32 × 1¼-inch machine screws in the base holes marked C. Mount microswitch S2 on the top spreader using two 4-40 × ¾-inch machine screws screwed into $\frac{3}{32}$-inch pilot holes. The edge of the microswitch with the plunger should be flush with the edge of the spreader. Finally, attach motor MOT2 to the motor support as shown in Fig. 11, using two 8-32 × 2-inch machine screws and six nuts.

The Drill Caddy. The last and most critical assembly is the drill caddy. It must hold the drill in a vertical position, allow it to travel up and down, and have no slop in any direction. The assembly consists of a pair of dovetail slides and a drill holder that is custom-fit to the drill to be used. The Parts List mentions one suitable drill, though many others could be used.

Refer to Fig. 12 as we proceed. Begin by cutting two pieces of ¼-inch wood stock to 2-inches high by $2\frac{5}{32}$-inches long. Cut another piece to 2-inches high by $1\frac{23}{32}$-inches long, and one more piece to 1¼-inches high by

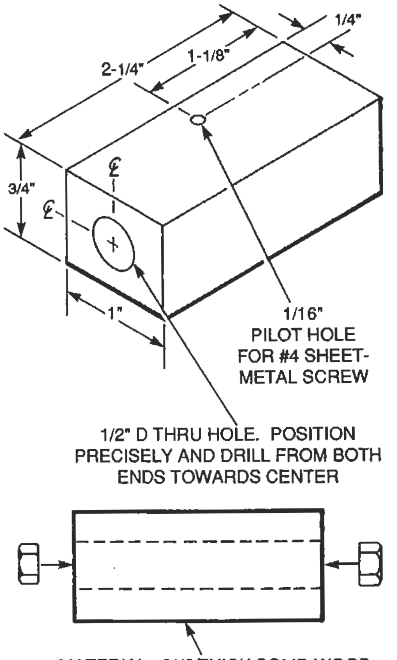


Fig. 13. The drill driver, like the table driver (Fig. 8), has a ½-inch through-hole.

LISTING 1—TEST PROGRAM

```
REM** PCDRL.BAS (c) 1995, JJ Barbarello, Manalapan, NJ 908-536-5499
REM** V951125
DEF SEG = 64: DEFINT A: add = 888: ON ERROR GOTO errortrap
DIM a(4), a$(5): a(1) = 5: a(2) = 3: a(3) = 10: a(4) = 12
OUT add, a(4): aseq = 4
a$(1) = "Table Towards Stepper": a$(2) = "Table Away From Stepper"
a$(3) = "Drill Towards Stepper": a$(4) = "Drill Away From Stepper"
a$(5) = "END"
start:
CLS : LOCATE 1, 25: PRINT "PC-DRILL CHECKOUT AND ALIGNMENT"
LOCATE 6, 5: PRINT "SELECT OPTION:"
FOR i = 1 TO 5
  LOCATE 8 + i, 10: PRINT USING "#. "; i;
  PRINT a$(i)
zNEXT i
getoption:
LOCATE 6, 20, 1: PRINT SPACE$(10); : LOCATE 6, 20
a$ = INPUT$(1): a = VAL(a$)
CLS
LOCATE 1, 25: PRINT "PC-DRILL CHECKOUT AND ALIGNMENT"
LOCATE 10, 16
SELECT CASE a
  CASE IS = 1
  steps = -1: which = 128: PRINT a$(1);
  CASE IS = 2
  steps = 1: which = 128: PRINT a$(2);
  CASE IS = 3
  steps = -1: which = 0: PRINT a$(3);
  CASE IS = 4
  steps = 1: which = 0: PRINT a$(4);
  CASE IS = 5
  CLS : OUT add, which: LOCATE 18, 1: END
  CASE ELSE
  BEEP: GOTO start
END SELECT
OUT add, a(4): aseq = 4
PRINT ". Press Enter to stop...";
motionloop:
  aseq = (aseq MOD 4) + steps
  IF aseq = 0 THEN aseq = 4
  IF aseq = -1 THEN aseq = 3
  OUT add, a(aseq) + which
start! = TIMER
WHILE (TIMER - start!) < .000001: WEND
  IF (INP(add + 1) AND 64) = 0 AND a = 2 AND which = 128 THEN GOTO start
  IF (INP(add + 1) AND 128) = 128 AND a = 4 AND which = 0 THEN GOTO start
  IF INKEY$ = "" THEN GOTO motionloop
OUT add, 0 + which
GOTO start
errortrap:
OUT add, 0 + which
RESUME start
```

1²³⁄₃₂-inches long. Using the selected drill as a mold, arrange those pieces around the drill to form a box, and temporarily clamp the sides as shown in Fig. 12-a. The drill should be held securely, only able to move if significant pressure is applied. If that is not the case, adjust the lengths of the shorter pieces as necessary. When done, remove the clamps, apply carpenter's glue on mating surfaces A, and re-clamp. **Note:** Make sure the box is square on all sides. Let the assembly sit for about an hour and then remove the drill, leaving the clamps in place. Let the assembly sit for another hour to ensure that the glue cures.

Cut two caddy sides from ¾-inch wood, as shown in Fig. 12-b. Form the dovetail slot centered in the 2¼-inch width of each piece. Cut two caddy slides and slide them into the dovetail slots. They should slide freely, but without any side-to-side or front-to-back wobble. If necessary, lightly sand the pieces until they fit properly. Drill two holes in the left caddy side.

Place the caddy slides in the caddy sides and position on each of the shorter sides of the drill box. Apply a thin line of glue along caddy-slide-surface G and clamp the complete assembly together, making sure the assembly is square on all sides. Let the glue cure for about one hour. Remove the clamp.

Cut four side stretchers from ¾- × ⅛-inch aluminum flat stock, as shown in Fig. 12-c. Screw the side stretchers onto the assembly after first drilling ³⁄₃₂-inch pilot holes. When done, the drill box should slide freely in the caddy without any side-to-side or front-to-back movement. If not, adjust the stretchers or lightly sand as necessary until free sliding occurs.

Referring to Fig. 13, fabricate a drill driver using the same methods as for the table driver. Remove screws from the side stretchers and left caddy side. Position the drill driver on the bottom outside of the left caddy side and temporarily clamp in place, making sure the bottoms of the caddy side and drill driver are flush. Drill two countersunk holes in the drill driver (Fig. 12-b) and secure with two #8 × ¾-inch sheet-metal screws. Ensure that the ends of the screws do not protrude into the cavity of the drill driver. If there is interference, remove the screws and file their ends down as necessary. Reassemble the drill caddy.

Remove screws from the side stretchers and right caddy side. Referring to Fig. 12-d, fabricate a ⅝ × ⁵⁄₁₆-inch square piece of wood to serve as the spring flange. After drilling the ⅛-inch hole, glue the flange to the caddy side as shown in Fig. 14. After the glue has cured, install a 1- × ¼-inch (diameter) spring by placing a flat washer in the end of the spring and inserting a 4-40 × ½-inch machine screw through the spring, washer, and flange. Secure in place with a 4-40 nut. Make sure the spring does not angle out into the path of the drill. Reassemble the drill caddy and thread a ⁵⁄₁₆-inch threaded rod about halfway into the drill driver.

Place the drill caddy assembly on

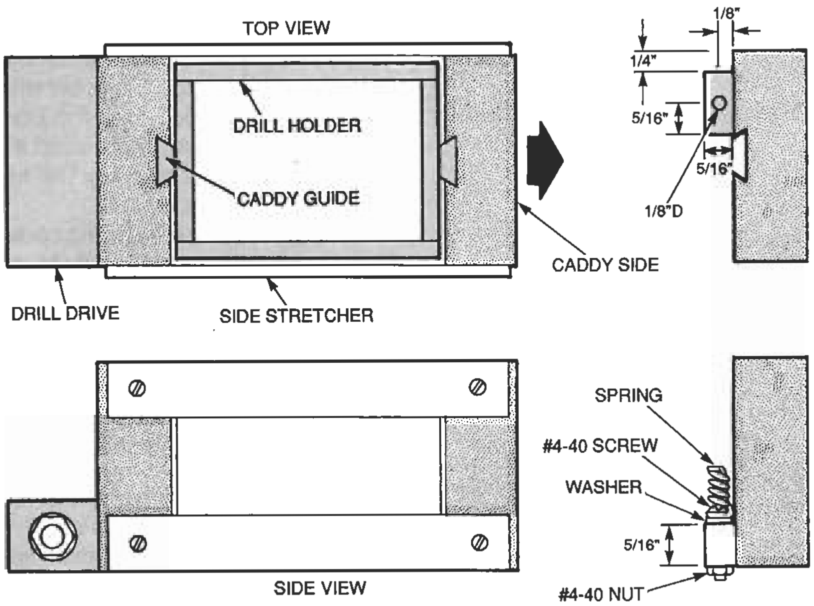


Fig. 14. The drill-caddy assembly contains all the components shown in Fig. 12 and Fig. 13.

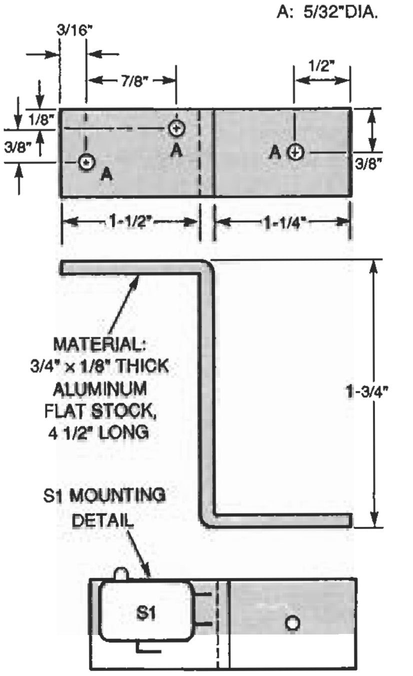


Fig. 17. The switch support bracket holds microswitch S1.

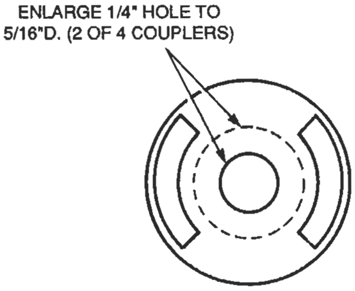


Fig. 15. You must modify the universal shaft coupler by enlarging the ¼-inch hole to 5⁄16-inch on half of each coupler. Optionally, replace the set screws with 6-32 screws.

the drill caddy support so the threaded rod protrudes through the 1-inch slot on the motor support. Form another guide as shown in Fig. 7-b, and position it on top of the drill driver. Fasten with a #4 sheet-metal screw, and adjust so the drill caddy moves freely with minimum wobble.

Final Assembly. We will couple the threaded rods to the motors using ¼-inch universal shaft couplers. First, however, we must modify the shaft couplers for our application, as shown in Fig. 15. When enlarging the ¼-inch hole, use progressively larger drill bits, and work slowly as the couplers are brittle. For safety, clamp the couplers in place when drilling. Enlarge only two couplers for the threaded rods; unmodified couplers fit the motors as-is. For convenience, you can optionally replace the set screws in the couplers with 6-32 × ⅜-inch machine screws.

Next, form two shaft coupler retaining clips from thin aluminum stock as shown in Fig. 16. If you cannot find thin aluminum anywhere else, the top of a used electronics hobby box works well.

Install a modified coupler on one end of each threaded rod, making sure the coupler is not cocked. If it is, loosen the set screw, rotate the rod slightly, and try again. Install an unmodified coupler on the shaft of each motor. Install one rubber coupler into each coupler on each motor.

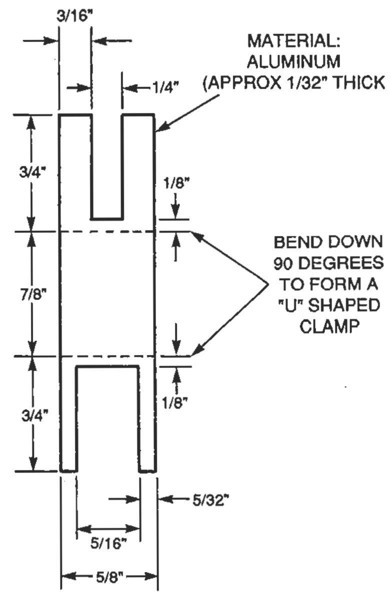


Fig. 16. The coupler retaining clip holds the universal-shaft-coupler components together. One clip is required for each motor/rod assembly.

Place the table on the table supports and slide toward motor MOT1. Align the rubber coupler and metal coupler on the threaded rod and push together. Snap the retaining clip over the couplers.

Slide the drill caddy assembly toward MOT2 and push onto the rubber coupler. Snap a retaining clip onto the couplers. Adjust MOT2 as necessary so it is in-line with the threaded rod. Carefully push the drill into the drill box until the bottom of the chuck is about ¾-inch above the table.

Fabricate a support bracket for switch S1 as shown in Fig. 17, and mount S1 using two 4-40 × ⅝-inch machine screws and nuts. Cut four 22-inch lengths of 22-gage stranded wire. Connect S1 and S2 to the PC board, routing the wires so as not to interfere with table or caddy movement. Mount R21 across S2's terminals and solder it in place. Mount R22 across S1's terminals and solder it in place.

Initial Checkout. Connect J1 to your PC's parallel port, and energize PCDrill's power supply. Next we'll run a test program. Either enter the QBasic program shown in Listing 1, or execute

(Continued on page 79)

BUILD THE PCDRILL

(Continued from page 46)

the compiled version. (Look for PCDRILL.ZIP on the Gernsback FTP site —ftp.gernsback.com/pub/EN).

Select each of the first four options in turn. The table and the drill should move in the selected direction. The test program moves the table and caddy in "slow motion," but real applications (like the one that will be presented next time) produce quicker and smoother movement. If either motor stalls and the table or drill does not move, the associated guide is probably jamming against the track. Adjust the guide and try again. Repeat the process until both table and caddy move smoothly throughout the entire range of travel.

Several tweaks can improve the performance of PCDrill. For instance, apply paste wax to all moving wooden surfaces, including the drill caddy sides and drill slides. All moving metal surfaces should get a thin coat of light oil. That includes the driver nuts, threaded rods, and aluminum angle tracks. Those lubrication efforts will decrease friction and make for smoother operation.

Next time we'll align PCDrill, and introduce the application program and all of its functions. We'll also look at the application's data file and explain each of its entries, including the Speed entry that maximizes speed of movement. We'll also provide details for building a 5.75-volt power supply from scratch, and use PCDrill to fabricate its own PC board. To round things out, we'll provide an AC wiring option that allows you to energize the drill only during actual drilling, as opposed to having the drill run continuously. See you then. Ω