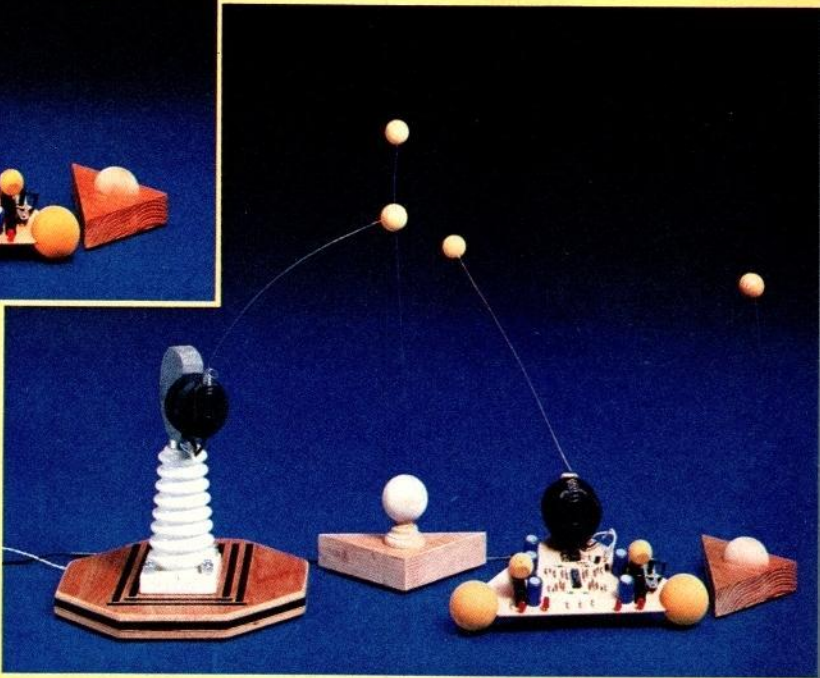
FIG. 1—WATCH THE DANCING BALL on the end of the spring. An erratically oscillating solenoid on the Bonker sends the ball into unpredictable gyrations captured with time exposure (left). The Bonker at rest (below). Spring-mounted balls on stationary bases add to the chaotic effect.



Build this fascinating device whose moving ball can hypnotize and captivate you with its random (chaotic) motion.

CREATING CHAOS

ROGER SONNTAG

DO YOU WANT RELIEF FROM THE MONOTONONY of routine activities that get you down—daily commuting, your job, or those pesky chores that you must do every day? What you need is a little chaos in your life—safe and controlled, of course—at desktop scale. How do you do this? Build the Bonker and go a little crazy watching its bouncing ball whirl and spin in random loops. Then you'll be ready to return to your dull routine.

Unlike a clock pendulum or that executive toy with all its little suspended bearings that clatter back and forth, Bonker's action is completely unpredictable. And you can turn it off when you've had enough chaos for the day. Chaos is defined as extreme confusion or disorder and the kind of formless matter and infinite space that is said to have existed before the universe was ordered. In short, it's the opposite of orderly and predictable.

Figure 1 shows one Bonker setup. Small wooden balls on the end of wire springs are sent into wild gyrations by oscillating solenoids whose motion is controlled by a four-stage pulse generator. It's a fascinating and eye-riveting gadget that will evoke a lot of comments when it's running on your desk.

How does it work?

Figure 2 is a simplified schematic showing only one of the four pulse oscillator circuits that drive the rotary solenoid. Each oscillator is formed from an operational amplifier and a network of external components. Three other circuits similar to that shown on the left side of the diagram all feed the same common bus. The summed output of all four oscillators provides a variable pulsed drive signal for the MOSFET gate.

The MOSFET is in series with the solenoid's coil. When the MOSFET conducts, current flowing in the coil causes the solenoid shaft to oscillate back and forth within a limited angular sweep. Solenoid oscillation is controlled by the summed output of the four oscillator stages.

The op-amp shown in Fig. 2 is IC1-a, one of four op-amp circuits in a quad LM324 shown in Fig. 3, the complete schematic. Each of the four op-amp-based oscillators is identical except for different values of their *charge* and *discharge* resistors. In Fig. 2, R2 in the feedback loop of the op-amp is the charge resistor, and R1 is the discharge resistor.

Diode D2 couples the output of the oscillator to the base of Q1 through resistor R23. Diodes D4, D6 and D8 perform the same functions for the other three oscillator stages formed from op-amps IC1-b, IC1-c, and IC1-d. When the output of any two oscillators is positive, Q1 conducts.

Resistors R4 and R5 divide the 12-volt power from a wall outlet adapter to obtain 6 volts. Positive feedback through resistor R3 cleanly switches the oscillator at each output state. Resistors with identical values in the other three oscillator circuits perform the identical functions.

Figure 3, the complete schematic, shows each of the four oscillator stages that include a LED. The first and fourth stages include a trimmer potentiometer to introduce additional variation in the pulse train.

The differences in the value of resistors R1, R6, R11 and R25 in parallel with grounded aluminum electrolytic capacitors C1, C2, C3 and C4 provide different time constants for each oscillator. The approximately ± 20 % variation in tolerances of those capacitors imparts additional randomness.

The differences in the values of the discharge resistors R1, R6, R11 and R25 (25 to 180 kilohms) determine the pulse duty cycle, and the 1-kilohm values of the charging resistors R2, R7, R12, and R24 determines pulse width.

Bonker action is initiated by closing switch S1. Light-emitting diodes LED1 to LED4 give visual indications of the output from each oscillator. Linear potentiometers R27 and R28 control the swinging of the ball. They can adjust the motion from a gentle swing to a wild, eccentric movement. Electrolytic capacitor C5 shunts any AC transients that might appear on the 12-volt source to ground. Table 1 summarizes the variations in pulse repetition rate that can be be set in each oscillator stage, as well as variations that can be introduced by the capacitor tolerance.

Circuit construction

A printed circuit board is available from the source given in the Parts List. However, a foil pattern is included in this article for those who want to make their own circuit boards. There is nothing critical about parts placement in this circuit, so it could made with point-to-point wiring techniques if the parts placement diagram is followed.

Refer to the parts placement diagram Fig. 4. Begin assembly

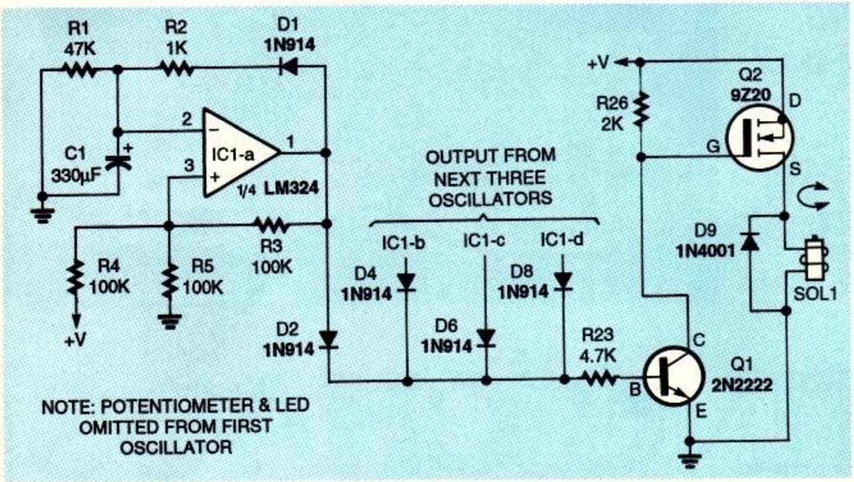


FIG. 2—A SIMPLIFIED SCHEMATIC to explain how the Bonker's solenoid drive circuit works.

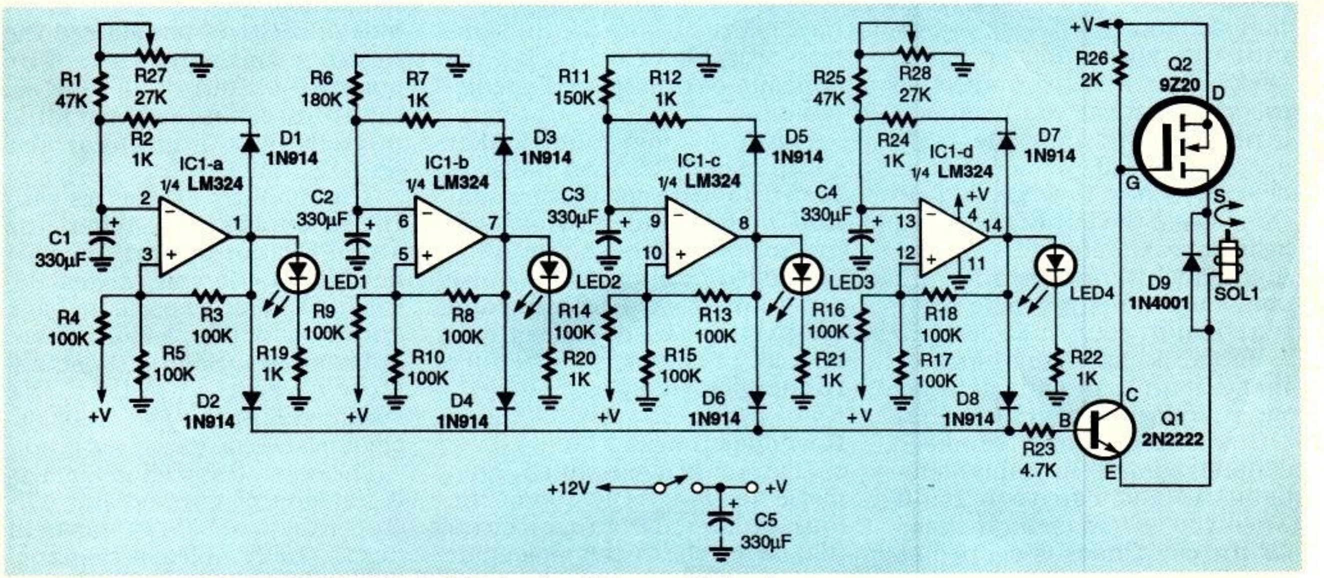


FIG. 3—SCHEMATIC FOR BONKER SOLENOID drive circuit. Four oscillator stages are formed from a quad LM324N op-amp IC. LEDs provide a visual indication of the pulse output of each stage.

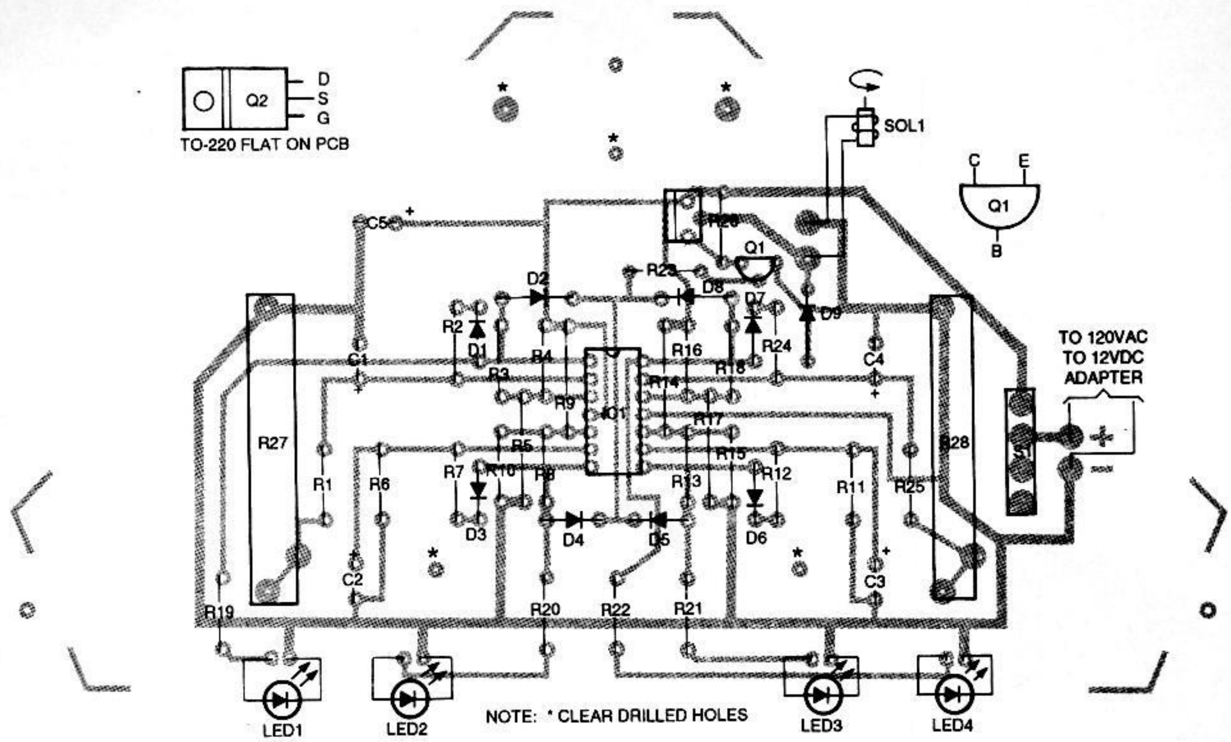
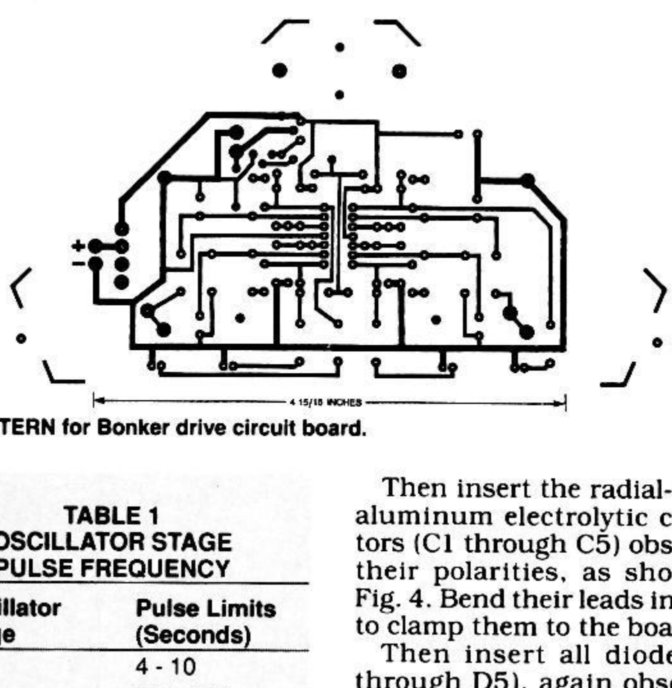


FIG. 4—PARTS PLACEMENT DIAGRAM for Bonker drive circuit. Bend the leads of MOSFET Q2 so it lies flat on circuit board.



FOIL PATTERN for Bonker drive circuit board.

TABLE 1
OSCILLATOR STAGE
PULSE FREQUENCY

Oscillator Stage	Pulse Limits (Seconds)
1	4 - 10
2	20 + 20%
3	26 + 20%
4	4 - 10

of the components to the circuit board by inserting all fixed resistors (R1 through R26) in the board as shown. Bend their leads together to clamp them in position close to the board.

Then insert the radial-leaded aluminum electrolytic capacitors (C1 through C5) observing their polarities, as shown in Fig. 4. Bend their leads inwards to clamp them to the board.

Then insert all diodes (D1 through D5), again observing the positions of their anodes, as shown on Fig. 4. Bend their leads to clamp them in position. Solder all of these components to the circuit board, but do not trim the leads at this time.

Next, insert transistor Q1 and bend its leads to clamp it temporarily. Bend the leads of power MOSFET Q2 at right angles so that the heat sink of its TO-220 package will lie flat on the board when the leads are inserted in the proper holes of the board.

Insert trimmer potentiometers R27 and R28 and the four light-emitting diodes (LED1 to LED4) as shown in Fig. 4, but do not twist their leads to clamp them. Now solder the leads of the second group of components inserted.

Carefully file or trim off about one-third of the width of each of the four flat terminals of slide switch S1 uniformly so that they can be press fit in the assigned holes in the circuit board. Insert the switch in the circuit board and solder it.

Identify the plus (+) and (−) wires of the DC output cable of a 120 VAC to 12-volt, 1 ampere, DC-regulated adapter, cut off the coaxial jack, and trim the insulation back on the two wires. Insert them from the component side of the board in the (+) and (−) positions (marked on the foil side of the board), and solder them in position. Trim all excess lead lengths close to the board.

Note: The circuit and solenoid can be run from a battery pack consisting of eight 1.5-volt C or

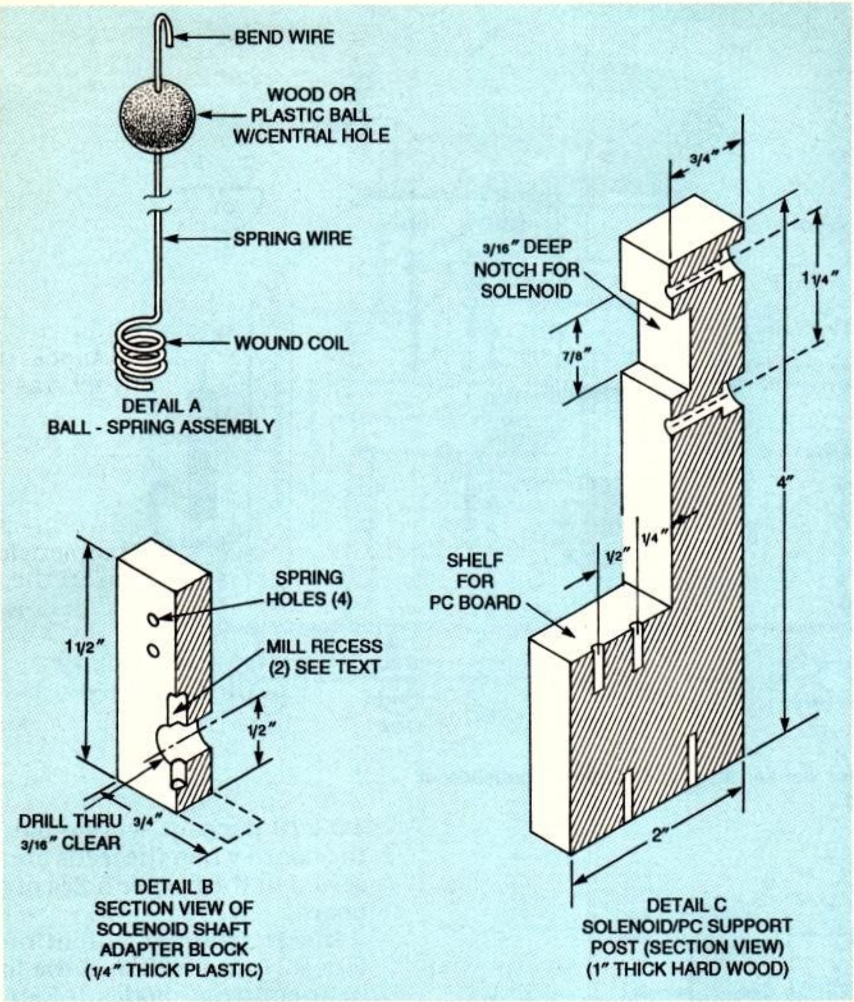


FIG. 5—DETAILS OF MECHANICAL PARTS: ball-spring assembly (Detail A); solenoid shaft adapter block (Detail B); solenoid/PCB support post (Detail C).

D alkaline cells, if you prefer not to run it from an adapter.

Turn on switch S1 to apply power. All of the LEDs should turn on and then go off. Then illumination patterns will be established: LEDs 1 and 4 will turn on every 4 to 10 seconds and continue to repeat that cycle, and LEDs 2 and 3 will turn on every 15 to 25 seconds and repeat that cycle. After you have verified this, turn off switch S1.

Place the rotary solenoid with its shaft side down and find the end of the spring that is coiled around the back end of the shaft within a slotted enclosure. With needle-nose pliers and a small screwdriver, pry up the end of the spring and re-insert it two places to the left (counterclockwise). Releasing the spring tension permits the solenoid to be operated from a 12-volt source.

Strip the insulation back from the ends of the two solenoid wires, insert them in the holes as shown on Fig. 4, and solder them temporarily in position to check the drive circuit's operation.

When S1 is switched back on, the shaft of the solenoid should oscillate back and forth over a limited angular sector. Check to see that a LED lights whenever the shaft oscillates. This response verifies that the circuit is operating properly.

Special mechanical parts

Refer to mechanical detail drawing Fig. 5, Detail A. Securely clamp the ¾-inch diameter wood ball in a vise and carefully drill a hole through its center with a No. 60 drill bit.

Clamp the end of an approximately 15-inch length of 0.028 steel piano wire in a vise and wrap the other end of the wire

PARTS LIST

All resistors are ¼-watt, 10 %
R1, R25—47,000 ohms
R2, R7, R12, R12, R19, R20, R21, R22, R24—1000 ohms
R3, R4, R5, R8, R9, R10. R13, R14, R15, R16, R17, R18—100,000 ohms
R6—180,000 ohms
R11—150,000 ohms
R23—4.700 ohms
R26—2000 ohms
R27, R28—25,000 potentiometer, slide, PC mount, Slide-Trol 112 or equiv.

Capacitors
C1–C5—330μF, 25 VDC, aluminum electrolytic, radial leaded

Semiconductors
D1–D8—1N914/4148 silicon switching diode, 75 PIV
LED1–LED4—light-emitting diode, red, T-1¾ package
Q1—2N2222 silicon transistor, Motorola or equiv.
Q2—IRF9Z20 power MOSFET, N-channel, TO-220 package, International Rectifier or equiv.
IC1—LM324N quad operational amplifier, 14-pin DIP, National Semiconductor or equiv.

Other components:
SOL1—rotary solenoid, Ledex 188687-001 or equivalent.
S1—slide switch, SPST, 5A, PC mount

Miscellaneous: Wood or plastic base (see text); wood ball, ¾ diameter; steel spring wire (0.018 in.), 15 inches long; solenoid/circuit board mounting bracket (see text); 120 VAC to 12 VDC, 1 A, regulated wall-outlet adapter; round or pan head wood screws; insulated hookup wire; solder.

Note: The following options are offered by General Science and Engineering, P.O. Box 447, Rochester, NY 145603, 716-338-7001

- **Printed circuit board—$7.50**
- **Bonker kit including printed circuit board, all electronic components, rotary solenoid, spring wire with coil, and wood sphere—$38**
- **Finished Bonker ready to operate—$89.00**
- **Alternative wood bases and solenoid mounting posts: pine—$9.50; veneer—$12.00; oak—$16.00; ceramic insulator and oak base—$16.00**

Money order, Visa, or Master Card accepted. Add $3.00 S&H. New York State residents add local county sales tax.

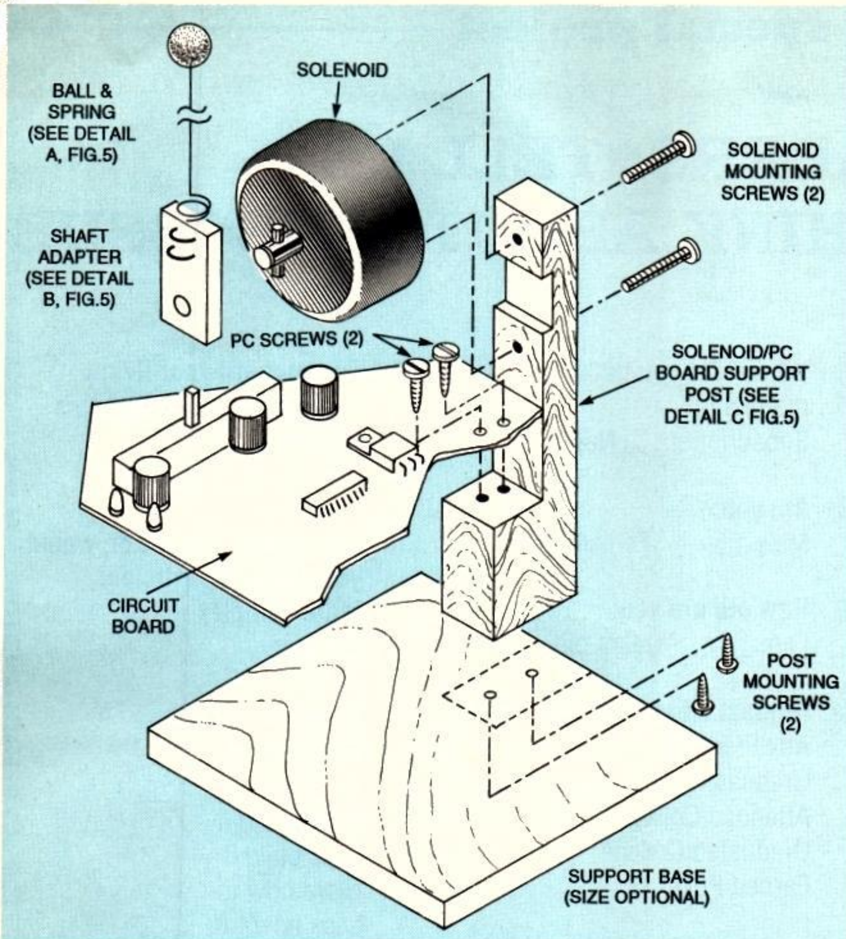


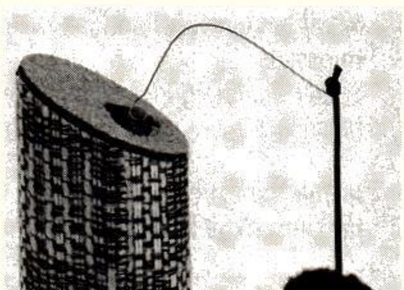
FIG. 6—ASSEMBLY DIAGRAM: The support base can be round or rectangular provided it is thick enough and has an area larger than about 30 square inches so it will be stable.

about eight times around a ⅛-inch dowel to form a coil spring with the aid of pliers. (Expect the diameter of the coil to expand after releasing tension on it.)

Insert the free end of the spring wire in the hole drilled through the ball, and then bend about ¼-inch of the end of the wire back on itself and push the bent end back into the drilled hole to assure a secure press fit.

Note: It is important that the ball be fastened securely to the wire so that it will not fly off when the solenoid is oscillating. If you want to paint or spray the ball with bright red or yellow enamel to make it more conspicuous, this a good time to do it.

Refer to Fig. 5, Detail B. Cut a rectangle measuring 1½ × ¾-inch from ¼-inch thick hard plastic and file the edges smooth. Drill a 3⁄16-inch hole through the block ½-inch in



THE BONKER CAN BE BUILT in many different configurations with a choice of base styles and materials. This one is designed to drive cats wild.

from one end (as shown) so that it can be press fit over the rotary solenoid shaft. Push the block onto the shaft and mark the ends of the cross-pin on the surface of the block.

Remove the block and cut or mill out short slots on both sides of the hole so that the cross pin and shaft will seat securely in the block. With a 1⁄16-inch diameter bit, drill four small holes in the block in a square pattern, and set it aside.

Refer to Fig. 5, Detail C. A supporting post that is fastened to a base board is suitable for mounting both the solenoid and the apex of the circuit board. The general dimensions for a post are shown in the detail. It is suggested that it be made of wood that is hard enough so that it will not split when drilling the holes in it and fastening the base and circuit board to it.

The general outline of the post can be changed to suit your taste, but it has some critical dimensions: the size and spacing of the drilled and countersunk holes for mounting the solenoid, the spacing between the drilled holes for mounting the circuit board to the shelf, and the width and depth of the notch for accepting the end of the solenoid. You might want to paint or varnish this post before assembling it to a base.

Bonker Assembly

Refer to the mechanical assembly drawing Fig. 6. The bonker must have a suitable, sturdy base. This can be cut from wood or plastic in a round square, or rectangular shape but should be large and heavy enough to provide a secure support for the solenoid and circuit board. (A minimum of 40 square inches of material that is at least ¾-inch thick is recommended.) Again, you might want to paint or varnish the base before proceeding.

Drill and countersink two holes near the edge of the base with the same spacing as the matching holes in the base of the support post (Detail C, Fig. 5). Fasten the post to the base

(Continued on page 60)

tolerance or "hardness." Ω

CREATING CHAOS

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with wood screws, making sure the assembly is securely fastened and rigid.

Mount the solenoid on the post with the two screws provided. Fasten the circuit board to the shelf of the post with two flathead wood screws. If the wire connections between the solenoid and circuit board are too long, this is the time to unsolder, trim, and resolder them.

Assemble the ball-spring and solenoid shaft adapter block (Details A and B of Fig. 5) by inserting the coiled end of the wire in the drilled holes of the block and threading it through the holes. Snap the completed assembly over the shaft of the solenoid. The Bonker is now ready to give you hours of relief from those monotonous routines of life. Ω