PAVLOV'S BAGATELLE

BEAT THE TIMER & WIN A "SMARTIE"

NOTE: "SMARTIE" IS A TRADE NAME OF ROWNTREE HOADLEY LTD

Ideal for occupying the time of children (and young-at-heart adults) on cold wet days, "Pavlov's Bagatelle" is a game that involves skill, a steady hand, strong nerves and a certain amount of patience. To increase the excitement, a novel confectionery dispenser provides a reward for those who win the challenge against the clock.

by JOHN CLARKE

You are playing one of the latest electronic games. Perspiration drips from your forehead and, after a remarkable display of concentration, you win. What happens? Do you get a pat on the back, a ticker-tape parade or even a letter from the Queen? No! – absolutely nothing happens. It's all a complete anticlimax, so what was the point of winning? Don't you wish for something more?

Well now this situation has changed. Pavlov's Bagatelle (we'll explain the name later) is a game that takes advantage of one of psychology's finest principles – the reward system. At last we have a game that gives satisfaction to the winner!

Mechanical versions of Bagatelle invariably consist of a round flat container with a transparent top, inside which a small ball rolls around. The object of the game is to manoeuvre the ball into a hole at the centre of the container. However, because the ball is very light and both it and the surface over which it rolls are extremely smooth, it is difficult to control the direction of the ball. Even if one does manage to intercept the hole, the ball usually jumps back out again, since the hole is quite shallow!

Other versions of the game employ two or more balls, and these have a habit of jumping out of their respective holes just as the last ball is about to drop into place. Normally sane, placid human beings have turned into frothing Neanderthals from the frustration. What better than to produce an electronic version of such a fiendish contraption?

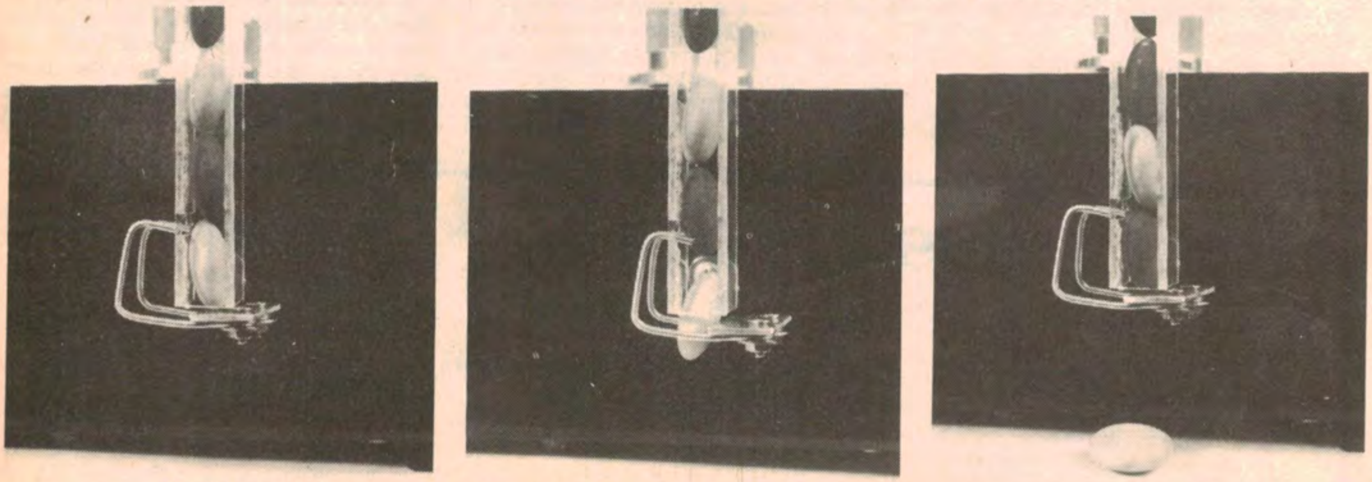
Our electronic version of the game uses LEDs to represent the ball. Four red LEDs – arranged north, south, east and west – are used to represent the rolling ball, while a single green LED represents the ball when it is in the hole. To add to the excitement, we have incorporated a timer so that the ball must be centred in the hole – ie the green LED lit – within a certain time in order to win.

But the ultimate feature providing the incentive to win is – wait for it – the "Smartie" dispenser. If after the extreme mental and physical effort involved, racing against the clock, you finally win, a sugar coated chocolate is dispensed to provide you with an enjoyable snack and to refresh you for the next onslaught.

It was this reward which prompted us to name the game after Pavlov, in memory of his famous experiment involving behavioural conditioning. After subjecting a dog to food and a ringing bell (conditioning), he found that the dog would salivate (conditioned response) as soon as it heard the bell ring, even though no food was offered.

Psychologists amongst our readers will probably point out that Pavlov was the pioneer of Classical conditioning whereas our game really is an example of Operant conditioning whereby a reward is used to partially reinforce behaviour. The pioneer of this work was B. F. Skinner but we couldn't very well call this project "Skinner's Bagatelle" could we? Everyone has heard of Pavlov and his dogs, so Pavlov's Bagatelle it is!

The general arrangement of the game controls can be seen in the photographs. First we have an on/off switch which is self explanatory. At the centre of the control panel is the "ball", depicted by the 5 LEDs and below this a joystick to control the "ball" position. To the right of the joystick is the Start Timer switch which initiates the timer, the clock against which you must race to place the ball in the hole.



The "Smartie" dispenser in action. It is designed to release only one "Smartie" for each operation.

All you have to do is light the green "hole" LED and beat the timer. Game can be made easy or difficult by adjustment of Handicap and Time controls.

PARTS LIST

1 printed circuit board, coded 81sm7, 102 × 69mm
1 Scotchcal front panel
1 plastic utility box, 196 x 113 x 60mm
1 SPST miniature toggle switch
1 momentary contact pushbutton switch
1 100kΩ joystick potentiometer
1 1MΩ linear potentiometer
1 1kΩ dual-ganged linear potentiometer
1 216 9V battery and battery clip
2 knobs (to suit)
1 6V solenoid (see text)
33 metres of 0.16mm (34 B&S) enamelled wire (see text)

SEMICONDUCTORS
1 4136 quad op amp IC
1 741 op amp IC
2 555 timer ICs
2 BC548 NPN transistors
1 BC338 NPN transistor
5 5mm red LEDs and bezels
1 5mm green LED and bezel
1 1N4002 rectifier diode
3 1N4148 small signal silicon diodes

CAPACITORS
1 2200µF 16VW axial electrolytic
1 100µF 16VW PC electrolytic
2 10µF 16VW PC electrolytics
1 4.7µF/16VW PC electrolytic
1 0.1µF metallised polyester
1 .01µF metallised polyester

RESISTORS (¼W, 5%)
1 x 1MΩ, 3 x 100kΩ, 4 x 47kΩ, 1 x 33kΩ, 6 x 10kΩ, 1 x 4.7kΩ, 9 x 1kΩ, 1 x 100Ω, 2 x 100Ω large vertical trimpots.

MISCELLANEOUS
Scrap aluminium, PC stakes, nuts, screws, washers, stiff wire, spacers, rubber feet, etc.

NOTE: Components specified are those used in the prototype. Capacitors and resistors with higher ratings may be used provided they are physically compatible.

Two potentiometer controls at the top of the panel adjust the game to the desired level of skill. The Time control gives adjustable clock times from virtually instantaneous to about 10 seconds, while the Handicap control adjusts the degree of difficulty of locating the ball in the hole. The game can either be simple to play, with easy location of the ball in the centre of the hole and a long time in which to do it, or the game can be virtually impossible if a short time is combined with a difficult handicap setting.

One time setting which has no external control but which is still important is the time required for the ball to be in the hole before a "Smartie" is dispensed. This time setting prevents a "Smartie" from being dispensed if the hole is found only momentarily.

Although various commercial dispensers are available, we have yet to see one suitable for "Smarties". Consequently, as part of this project, some mechanical construction is necessary to produce a hand-made "Smartie" dispenser. Producing this is not too difficult and sufficient details are given in the constructional section to enable you to fashion a reliable unit.

THE CIRCUIT

The circuit can be divided into two sections: the Bagatelle section itself, consisting of a 4136 quad op amp package, the five ball LEDs and a joystick; and a solenoid driver section. We shall look in detail at the Bagatelle circuit first.

The Bagatelle section consists of two "window" comparators formed by the IC1a/IC1d and IC1b/IC1c pairs. We shall only discuss the operation of the IC1a/IC1d pair as the two circuits are identical.

Both op amps are connected as comparators, so the output of each op amp is either high or low. When the voltage at the non-inverting input of the comparator is higher than that at the inverting input, the output is high. Alternatively, when the voltage at the non-inverting input is lower than the inverting input, the output is low.

As can be seen, the inverting input of IC1d is tied to the positive supply rail via a 47kΩ resistor, while the non-inverting input of IC1a is connected to the negative rail via another 47kΩ resistor. Between the two inputs is a 100Ω trimpot and the Handicap potentiometer. These components and the 47kΩ resistors form a voltage divider which sets the window voltage.

The window voltage can be varied simply by varying the Handicap potentiometer – ie the voltage between the non-inverting input of IC1a and the inverting input of IC1d is varied. Similarly, the two remaining inputs on IC1a and IC1d are wired to the wiper of the joystick control potentiometer, which forms a second voltage divider. This potentiometer is used to control the ball position.

The output of each op amp is used to drive the ball position LEDs via 1kΩ current limiting resistors. With regard to the north and south LEDs, there are three possible conditions: the north LED is on when the voltage at the non-inverting input of IC1d is higher than the voltage at the inverting input; the south LED is on when the inverting input of IC1a is lower than the non-inverting input; and neither LED is on when the voltage between the directly connected non-inverting input of IC1d and the inverting input of IC1a is between the voltage at the inverting input of IC1d and voltage at the non-inverting input of IC1a.

In other words, the red LEDs are off when we are within the "window" voltage.

There is one other possibility and that is that both LEDs can be on at the same time. Since the ball cannot be in two places at the same time, this possibility must be eliminated. The 100Ω trimpot achieves this by maintaining a minimum window voltage between the two op amps.

It can be seen that moving the N-S section of the joystick controls the vertical ball movement, while the other section of the joystick controls horizontal movement. The on/off state of the red LEDs tells us whether or not the ball has rolled to a given side of the hole. If all the red LEDs are off then the ball is in the hole.

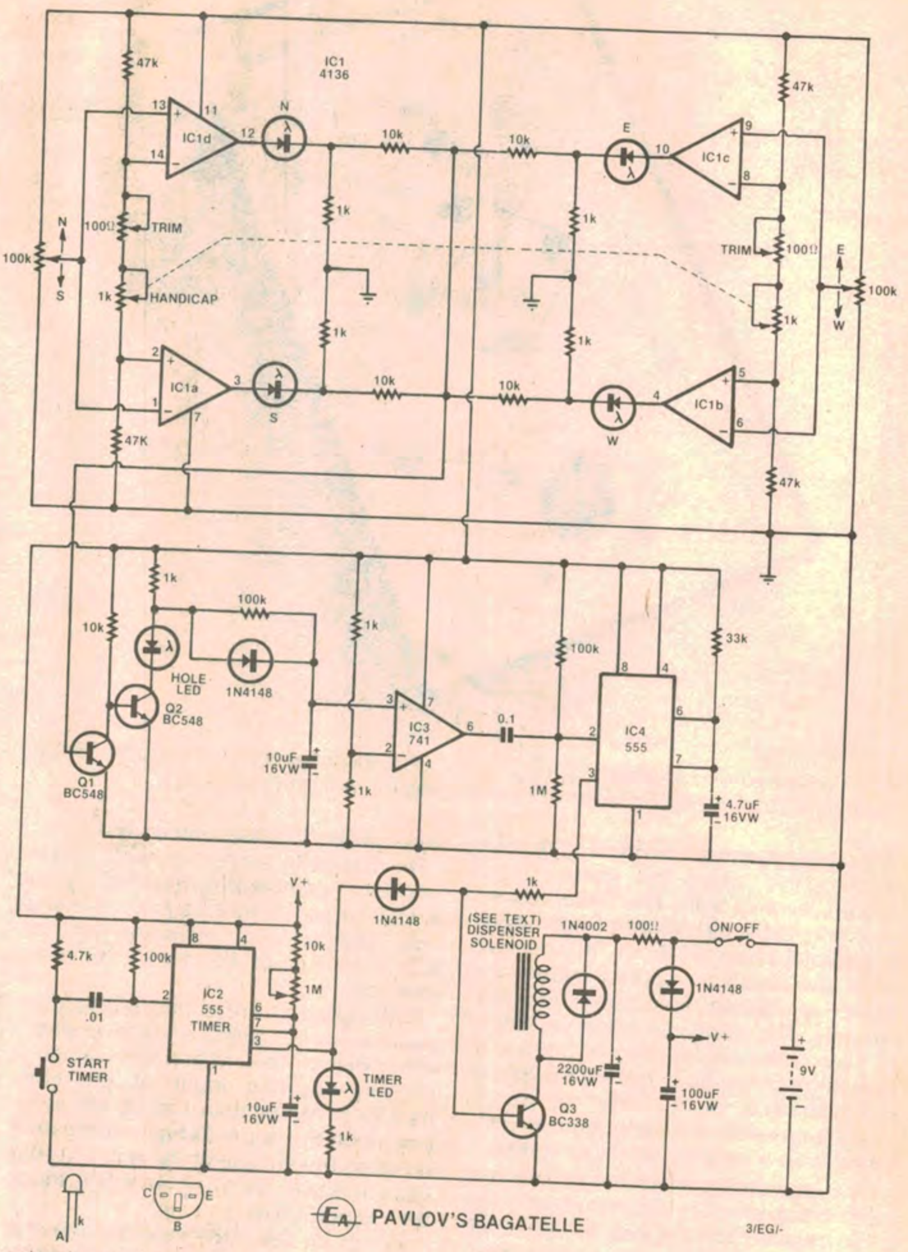
Increasing the resistance of the dual-ganged Handicap potentiometer increases the window voltage, giving greater joystick movement with the LEDs remaining off. In other words, a larger movement of the joystick is necessary to switch between opposing LEDs. This gives us control over the degree of difficulty of the game – the greater the window voltage the easier the game is to play.

When all four pointer LEDs are extinguished, the green centre LED comes on to indicate that the player has succeeded in manoeuvring the ball into the hole. The hole is detected as follows: a 10kΩ resistor is connected to the cathode of each of the four red LEDs, with the other side of each resistor connected to a common point. If a LED is on, the voltage at this point will go high, turning on Q1 and holding Q2 and the green "hole LED" off.

If, however, the red LEDs are subsequently extinguished, the base of Q1 is driven low and transistor Q2 turns on via its 10kΩ base resistor. This in turn drives the green LED to indicate that the ball is in the hole.

The second section of the circuit is relatively straightforward, and consists of three timers and the solenoid driver circuit. IC2 is a 555 monostable timer and is the clock you play against when the game is played. The timer is initiated with the Start Timer pushbutton which produces a negative going pulse at pin 2, the trigger input of IC2. Upon triggering the output, pin 3 goes high for a set period dependent upon the setting of the 1MΩ timer pot. This output drives the timer LED to indicate that timing has commenced.

IC3 is wired as a comparator, the input of which is connected to a time constant network consisting of a 10μF capacitor, 100kΩ resistor and a diode. Initially, when the hole LED is off, the voltage at the anode end of the diode is high and the 10μF capacitor charges quickly via the diode. When the hole LED comes on, the diode is reverse biased and the 10μF capacitor begins to discharge



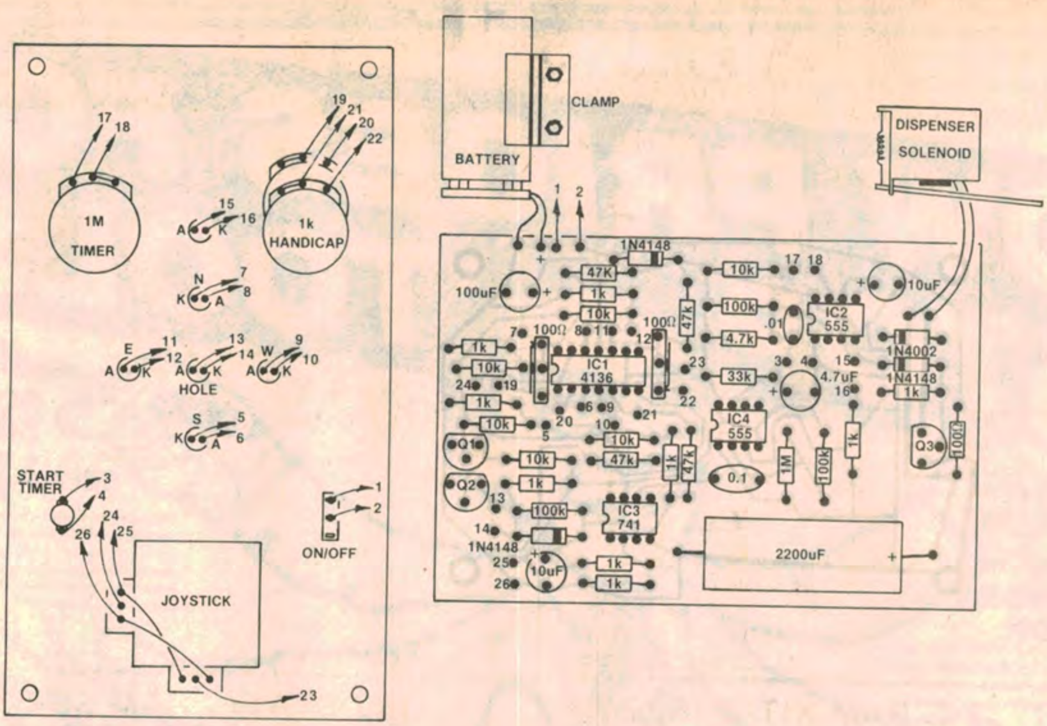
The circuit consists of two window comparators (IC1a/IC1d and IC1b/IC1c) for the Bagatelle section, together with three timers and a solenoid driver circuit.

through the 100kΩ resistor. When the voltage at the non-inverting input of IC3 goes below the voltage set by the 1kΩ/1kΩ resistor voltage divider, the output of the comparator goes low.

This time constant prevents the game from being too easy; the hole LED has to be on until the comparator changes to a low state before it is possible to win the game. If the hole is found for a time less than the time constant, then the capacitor will quickly charge again through the diode when the hole LED goes off.

When the output of IC3 goes low a pulse is sent to the trigger input of IC4, another 555 monostable timer, via a 0.1μF capacitor. This timer has a short time constant, about 150ms, and provides a short pulse to transistor Q3 to drive the solenoid. The duration of the pulse has been kept deliberately short to minimise battery consumption.

Note that for Q3 to turn on, there is an AND situation, whereby the outputs of both IC2 and IC4 must be high. If the output of IC2 is low, indicating that the time for the game has expired, the diode between it and the base of Q3 will hold off Q3 regardless of the output of IC4. Similarly, if pin 3 of IC2 is high but the output of IC4 is low, Q3 cannot turn on, because the diode will now be reverse biased. So Q3 will not come on unless



both the hole LED and timer are on.

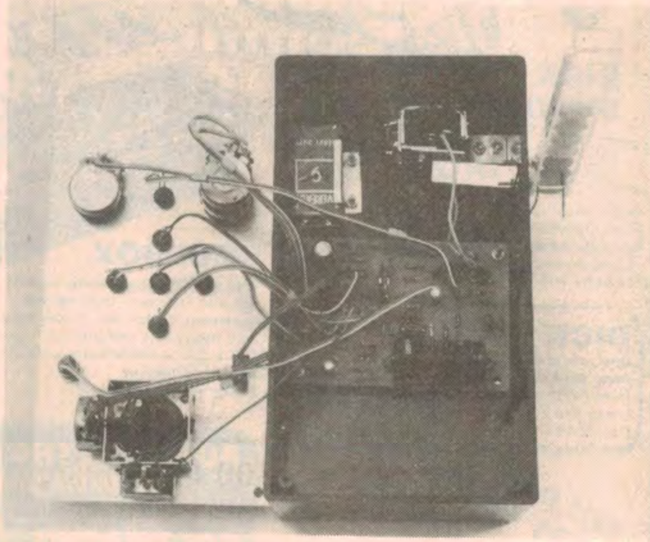
Current drive for the solenoid is supplied by a 2200μF electrolytic capacitor which is charged via a 100Ω resistor connected to the positive rail. This is necessary because the battery alone cannot supply the necessary peak current. Power for the remainder of the circuit is supplied via a 1N4148 series diode and filtered by a 100μF electrolytic capacitor. The arrangement is such that when the solenoid is activated, and the voltage at the anode end of the diode momentarily drops below the cathode voltage (ie diode reverse biased), the 100μF capacitor will keep the supply voltage intact for the rest of the circuit.

All that remains to discuss is the operation of the "Smartie" dispenser. Fig. 1 shows the basic principle. A square-section tube holds the "Smarties" in a stack end to end and they are prevented from falling out by a gating piece across the opening at the bottom of the tube. This gating piece is connected to the solenoid which, when activated, moves the gate away the tube opening to allow one of the "Smarties" to fall.

To prevent more than one "Smartie" from escaping at one time, an escapement is used to block the next "Smartie" in succession further up the tube.

When the solenoid is released, the gate again covers the exit of the dispenser tube and the escapement releases its hold on the next "Smartie". The "Smartie" then falls to the bottom of the tube, ready to be dispensed when the gate reopens.

Above and right: follow this wiring diagram and inside view when constructing the game.



CONSTRUCTION

Construction of the game is relatively straightforward, although a certain amount of patience is required to produce a reliable "Smartie" dispenser. Most of the components are mounted on a printed circuit board (PCB) coded 81sm7 and measuring 102 × 69mm. The board, along with the solenoid, LEDs and various other controls, is housed in a plastic utility case (196 × 113 × 60mm).

Start construction by soldering all the resistors and diodes in position on the PCB, followed by the trimpots and capacitors. The ICs should be mounted last of all, and each lead should be quickly soldered to prevent possible heat damage. Follow the overlay diagram carefully and pay particular attention to polarity-conscious components (ICs, transistors, electrolytic capacitors and diodes).

We recommend that you use PC stakes for all external connections to the board. Once the board is completed, it can be mounted in the case as shown in the internal photograph.

Holes for the LEDs, switches and potentiometers can now be drilled in the lid of the case using the front panel artwork as a drilling guide. This done, the front panel components can be mounted in their respective positions and the wiring to the PCB completed. We used pop rivets to hold the joystick to the lid, although screws and nuts could also be used.

The solenoid used in our prototype was obtained from Radio Despatch Service (869 George St, Sydney) and is a 6V type. At the time of writing, Radio Despatch Service has at least 50 of these in stock at a cost of around $1 each. Once stocks of these are depleted there are only 24V types available which,

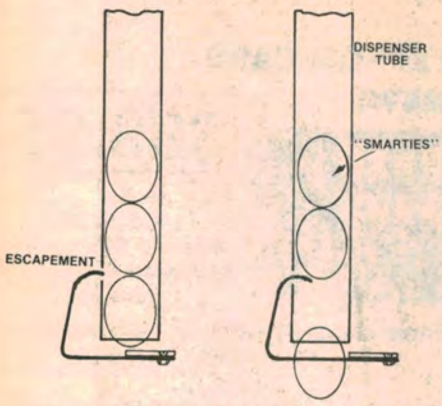


Fig. 1 DISPENSER IN OPERATION

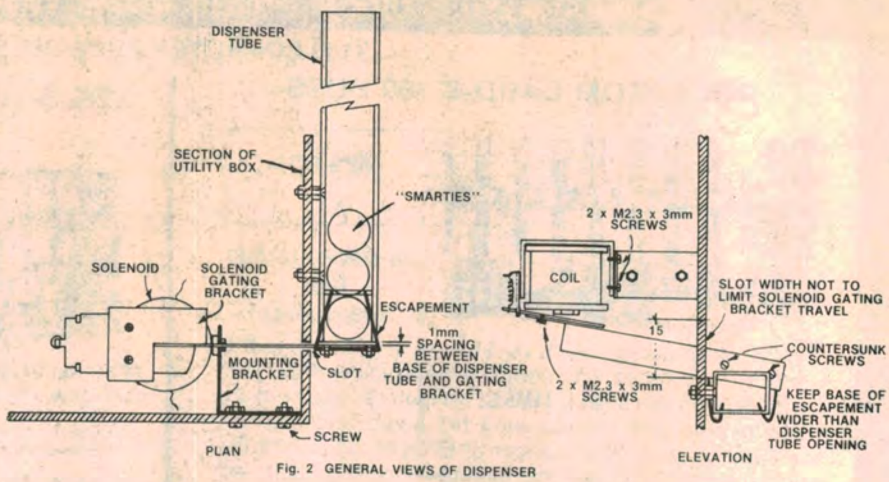


Fig. 2 GENERAL VIEWS OF DISPENSER

although unsuitable in their present form, have the same physical dimensions as the 6V type. These 24V solenoids have to be rewound for 6V operation.

First, remove the coil bobbin from the U-shaped metal bracket by drilling out the retaining rivet. The existing coil is then removed either by unwinding it by hand or, more conveniently, cutting through the coil with a sharp knife (the wire is very fine).

The bobbin is rewound with about 900 turns of 0.16mm (34 B&S) enamelled wire. This is best done using a hand drill, with the coil bobbin held in the chuck. Try to wind the coil as evenly as possible, keeping each winding adjacent to the previous one, in order to obtain maximum coil flux. Finish off the coil with a layer of insulation tape.

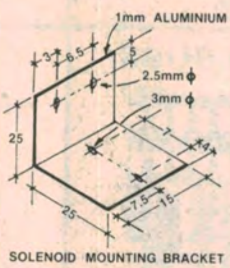
Fortunately, the bobbin has a 3mm tapped thread immediately behind the retaining rivet, so a 3mm machine screw and washer can be used to resecure it to the bracket. When replacing the striker plate, adjust the spring tension by bending the tabs inwards until there is just barely tension when the striker plate is open. This reduces the force required to close the solenoid.

While we have not tried it, it may be possible to modify other relays in a similar manner.

Constructional details for the "Smartie" dispenser are shown in Figs. 2 & 3. The dispenser tube can be made from various materials, such as aluminium, perspex or stiff cardboard. We used clear perspex for our prototype so that the "Smarties" could be seen inside the tube.

Each side of the dispenser tube was made by cutting a perspex sheet with a fine-bladed hacksaw and carefully filing each edge to a smooth finish. Two countersunk mounting screws are then secured to one of the pieces which are glued together using epoxy cement.

If you elect to make the tube out of



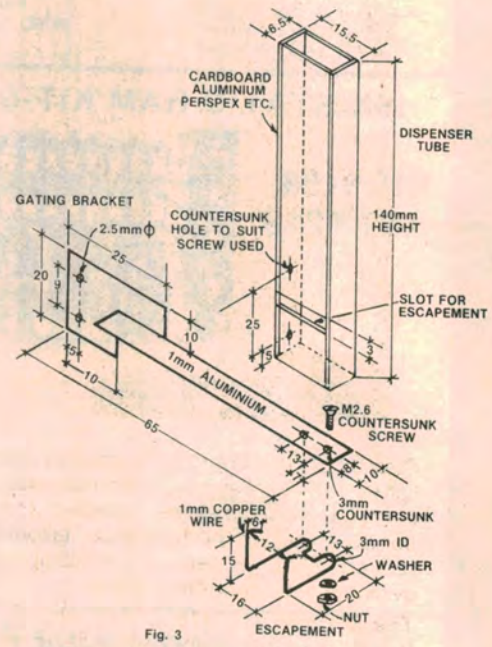
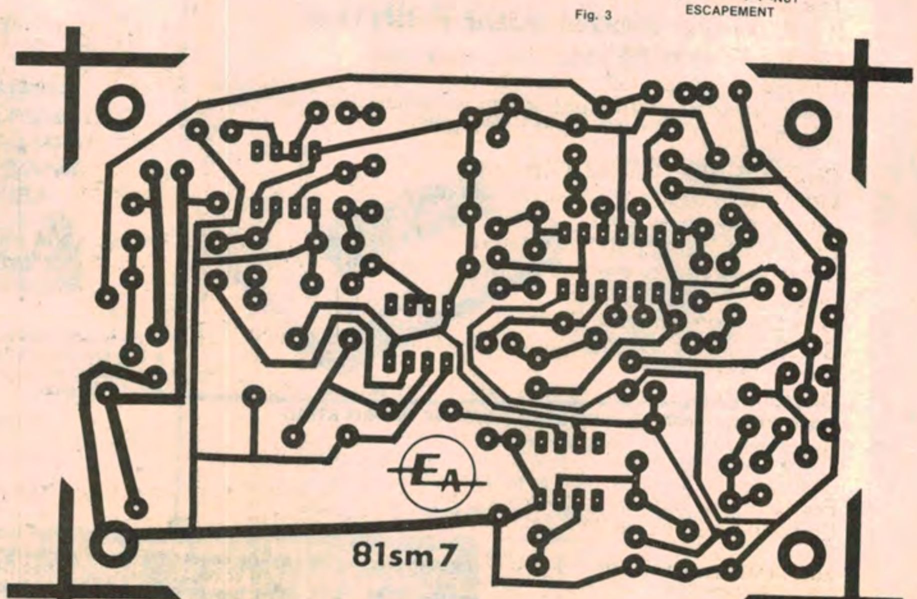


Fig. 3

Below is an actual size reproduction of the PCB artwork.



aluminium, the whole piece can be folded into shape, not forgetting to countersink and secure the two mounting screws before bending. To obtain a straight edge the aluminium can be scored to say one quarter of its thickness. The three bends can then be made by hand.

Fig. 3 also shows the dimensions of the escapement which is bent up from a short length of 1mm-diameter tinned copper wire. Some final touching up of the bends may be required after the project has been completed in order to achieve satisfactory dispenser operation. A small right-angle bracket is used to mount the solenoid.

As can be seen from the photographs, the dispenser and solenoid are mounted in the top right hand corner of the case. Attach the solenoid mounting bracket to the solenoid using two 2.3mm machine screws (the holes in the solenoid are already tapped), and then bolt the solenoid to the case. The position of the slot for the gating bracket can now be determined. Drill a few holes in line where the slot should be and then file the slot to shape.

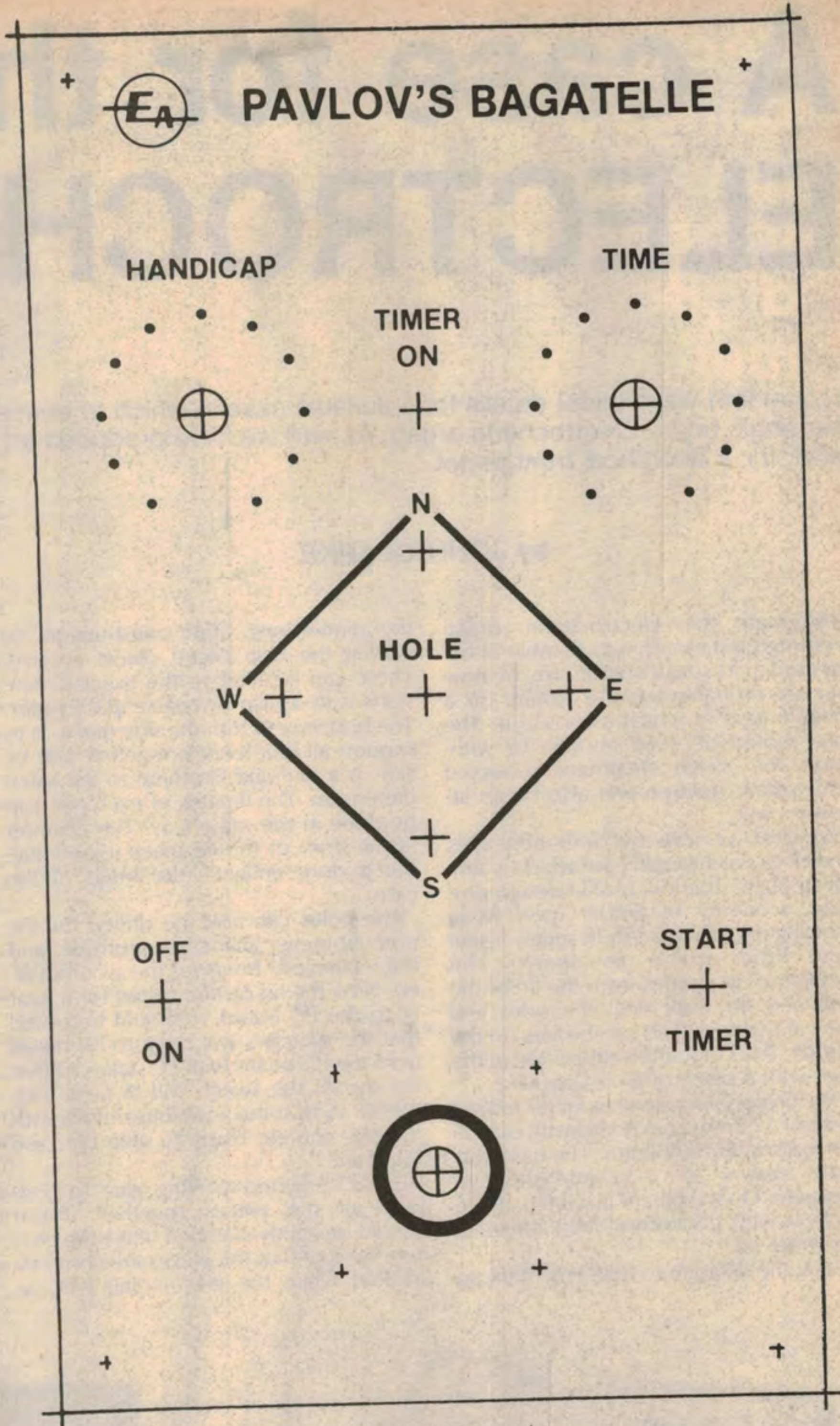
> We estimate that the current cost of parts for this project is
>
> **$27**
>
> This includes sales tax and the battery.

Another two 2.3mm screws are used to secure the gating bracket to the solenoid striker plate, again using pre-tapped holes. Once the solenoid and gating bracket are in position, the position for the dispenser tube can be determined and the appropriate mounting holes drilled. The base of the tube should be positioned 1mm above the gating bracket, such that the gating bracket just clears the tube opening when the solenoid is activated.

Note that the dispenser is stood off the edge of the case by about 4mm using nuts and washers to act as spacers.

With everything in place, the dispenser is ready to be tested. Operate the solenoid by hand at first, to make sure that the escapement does not foul when passing through the slot in the dispenser tube. Also, check that the escapement wires allow a complete opening at the base of the tube when the solenoid is closed.

You are now ready to try the dispenser out with some "Smarties" (you could call it "the 'Smartie' test"). The dispenser has been designed for a tight fit so that the stacked "Smarties" will not lay skewed in the tube and thus upset dispenser operation. Consequently, a few "out of tolerance" "Smarties" will be too large to fit in the dispenser tube and these can be discarded in any manner you see fit! It is here that the escapement may require some tweaking for satisfactory operation.



Actual size reproduction of the front panel artwork.

You are now ready to test the game for correct operation. Connect the solenoid leads to the PCB, install the battery and switch on. Check to see that all the ball LEDs light when the joystick control is manipulated and that the timer LED lights when the Start Timer button is pressed. Assuming that all is well, all that remains to do is to adjust the two trimpots associated with the Handicap control.

First, adjust the Handicap control fully clockwise. The N-S trimpot should now be adjusted so that the north LED goes out just as the south LED comes on (and vice versa). Ignore the E-W LEDs during this operation. Once this is done, the E-W trimpot should be adjusted in similar fashion.

Just one final point. Some readers may have realised that, in moments of desperation, it is possible to retrieve the "Smarties" simply by tipping the dispenser tube upside down. But that would be cheating and we're not going to let temptation get the better of us, are we?