Hours of fun for the whole family!

Build your own Video Ball Game

Do you find TV programs boring? If so, help is at hand. Our Video Ball Game will provide hours of fun, for all your family and friends. Using only thirteen CMOS ICs and a number of discrete components, the kit is easily assembled on a printed circuit board.

by DAVID EDWARDS

In recent months a large number of home video games have come onto the market. These usually cost in the vicinity of $100.00 or more, and are available either as fully assembled units or in kit form. Our Video Ball Game should cost you considerably less than this to construct—in fact it should cost you only about $40.

Used in conjunction with a standard VHF TV set, either colour or black and white, the unit produces a display similar in outline to that of a tennis court or ping-pong table. There is a central dotted vertical line, called the net, and upper and lower boundaries from which a small rectangular "ball" can be bounced.

Along the side boundaries may be moved small "bats", which can be controlled by two players using small hand-held units. The players move their bats up and down, hitting the ball to keep it in play. A player scores a point when his opponent misses the ball, and allows it to continue off the court.

The ball is brought back into play by pressing the appropriate serve button. Each player is provided with one of these buttons on his control unit.

The speed at which the ball moves, and hence the rate of play, is varied by a control on the front of the case.

Small slider switches are used to alter the display, allowing several types of games, by one or two players, to be played.

Turning now to the main circuit diagram, we can see how the display is produced, and how the design is implemented. 74C series CMOS logic has been used in the design, with gates functioning both in the normal digital manner and also as linear amplifiers. In addition to the CMOS gates, four discrete transistors have been used, as well as a number of diodes.

The box labelled "modulator" is a self-contained unit, which converts the video information generated by the remainder of the circuit into a form suitable for decoding by a standard VHF TV set. It is connected directly to the aerial terminals of the TV, and is described in detail later in the article.

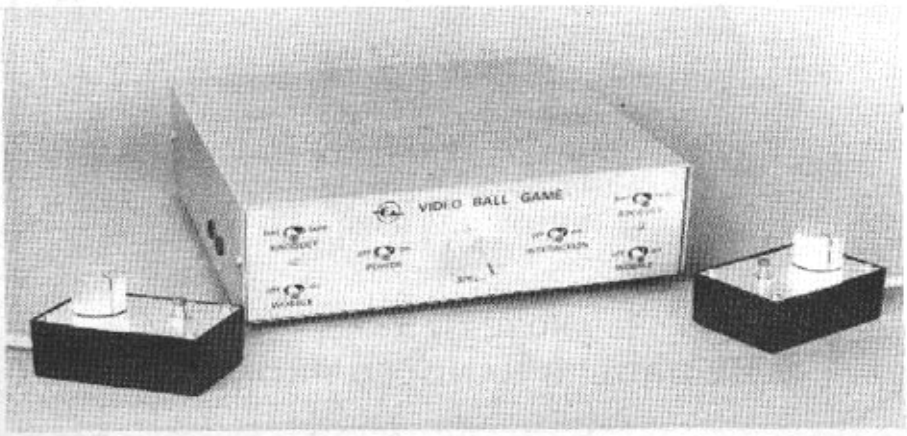
Before commencing with a detailed description of the circuit operation, we will digress for a short time, and explain the way in which the IC gates have been identified. Only two types of ICs have been used, the 74C00 type, which is a quad NAND gate, and the 74C02 type, which is a quad NOR gate. Each of the individual gates in each IC has been labelled "a", "b", "c" or "d", while the ICs themselves have been numbered consecutively. Thus gate 1a is the first gate in the first IC. The pin numbers of each gate are shown next to the respective terminations.

Five NAND gates, 1a, 1b, 1c, 1d and 3a are connected as a free running horizontal sweep oscillator. The horizontal hold control is used to set the operating frequency to about 15625Hz. In operation, a "low" pulse circulates through the gates, producing appropriate outputs at each gate. D1 ensures reliable starting and operation.

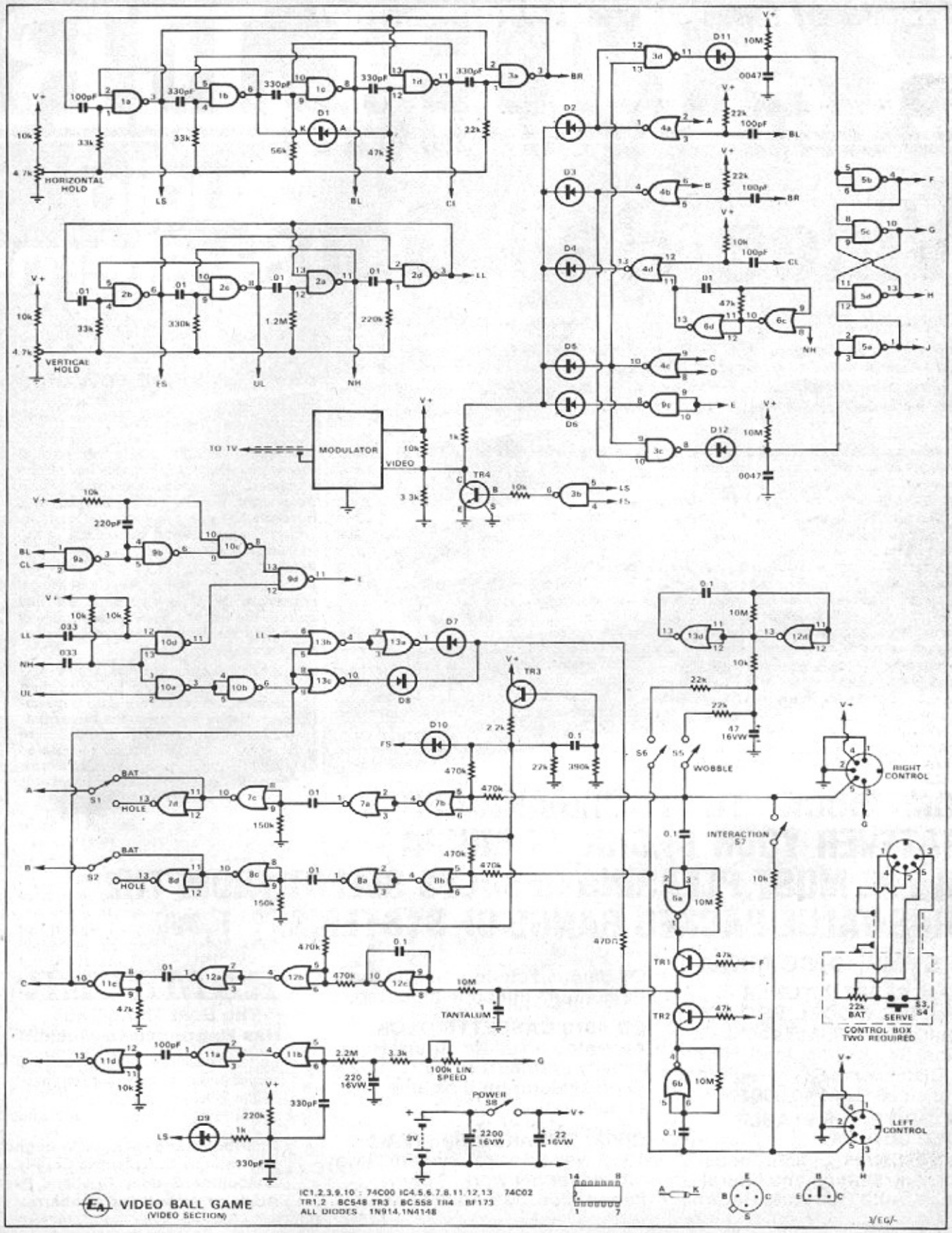
The line sync (LS), bat left (BL), centre line (CL) and bat right (BR) pulses produced by this oscillator determine the horizontal spacing of the display.

Four NAND gates, 2b, 2c, 2d and 2a are connected as another free running oscillator, this time with a frequency of about 50Hz. This oscillator produces the frame sync (FS), upper line (UL), net height (NH) and lower line (LL) pulses, which determine the vertical spacing of the display.

The LS and FS pulses are added together by gate 3b, to form a composite sync pulse, which is then injected into the video line by TR4. The LS and FS pulses



At left is a photograph of the completed Video Ball Game, showing the hand-held control units. On the facing page is the circuit diagram. Circuit details of the modulator are given later in the article.


HORIZONTAL HOLD
VERTICAL HOLD
MODULATOR
TO TV
VIDEO
WOBBLE
INTERACTION S7
RIGHT CONTROL
LEFT CONTROL
CONTROL BOX TWO REQUIRED
TANTALUM
100k LIN. SPEED
POWER S8
BAT
HOLE
SERVE
VIDEO BALL GAME
(VIDEO SECTION)
IC1,2,3,9,10 : 74C00 IC4,5,6,7,8,11,12,13 : 74C02
TR1,2 : BC548 TR3 : BC558 TR4 : BF173
ALL DIODES : 1N914,1N4148

are also used to generate line and frame ramps. The line ramp is produced by D9 and its associated components. The ramp is positive going, and is reset when the LS pulse discharges the 330pF capacitor through D9 and the 1k resistor.

The frame ramp is produced by TR3 and its associated components. A linear positive going ramp is produced as the 0.1uF capacitor discharges through TR3, connected as a Miller integrator. The capacitor is charged by the FS pulse, via D10.

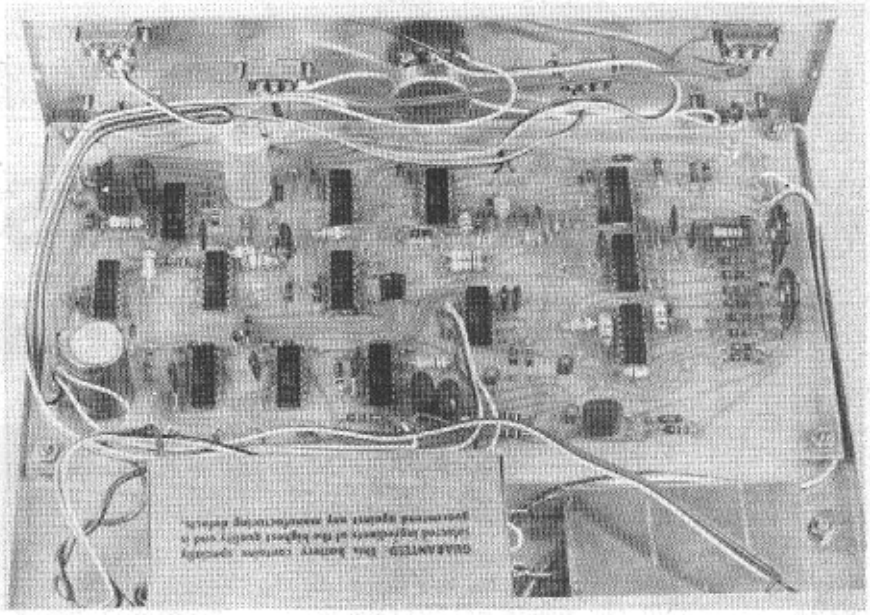
Gates 6c and 6d are connected as a free running oscillator, with a frequency of about 1000Hz. This oscillator is gated on and off by the NH pulse connected to pin 8. The oscillator output is combined in gate 4d with a differentiated CL pulse, and injected into the video line by D4. This forms the central dotted line called the net.

The two 22k bat controls are connected as potential dividers across the supply lines. The bat voltages are added to the frame ramp at the inputs to gates 7b and 8b. These gates act as comparators, and produce negative going transitions at their outputs whose positions with respect to the FS pulse vary directly with the positions of the bat controls.

These edges are squared up by gates 7a and 8a, and then differentiated. The differentiator time constants determine the vertical heights of the bats. The differentiated pulses are squared up by gates 7c and 8c, and then inverted by gates 7d and 8d. The bat pulses or their complements are selected by S1 and S2, and then passed to the inputs of gates 4a and 4b.

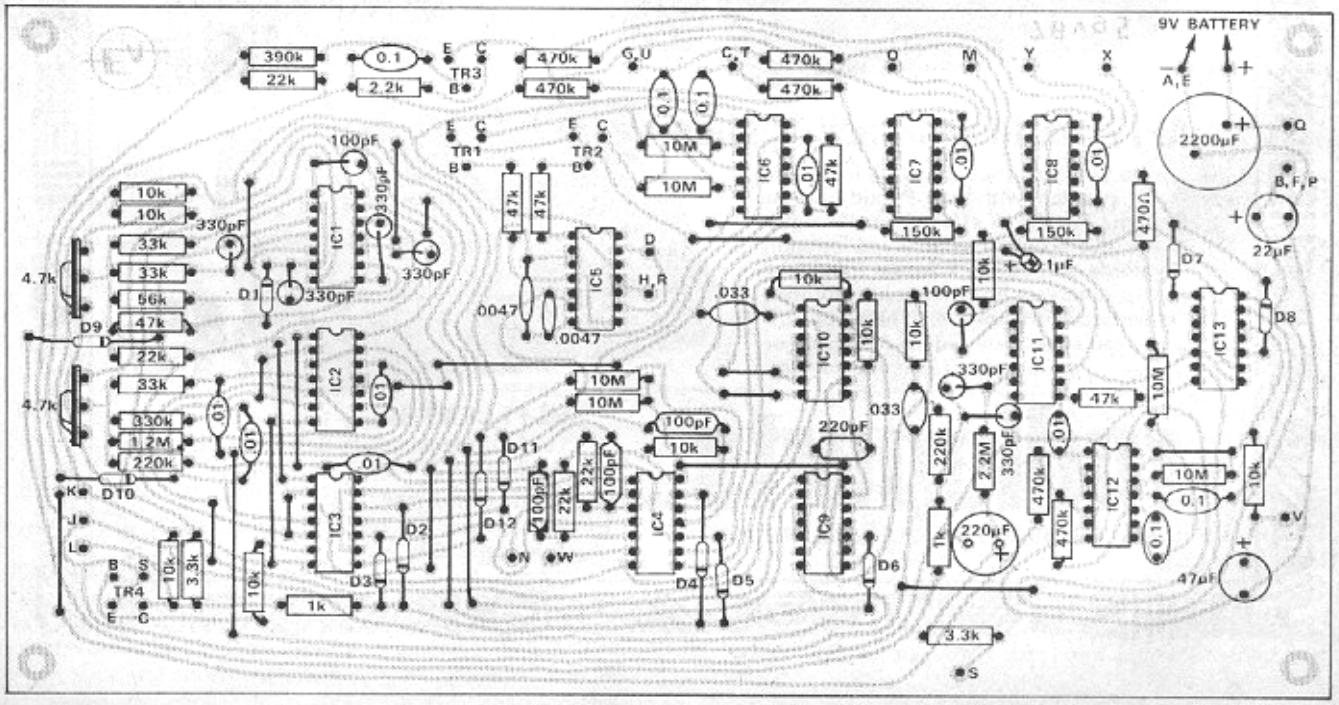
The BL and BR pulses are differentiated and fed to the remaining inputs of gates 4a and 4b. The width of these differentiated pulses determines the horizontal widths of the bats. The horizontal and vertical components of the bats are summed by gates 4a and 4b, and injected into the video line by D2 and D3.

As with the bats, the horizontal and vertical components of the ball are generated separately. The vertical velocity of the ball is represented by the voltage stored on the 1uF tantalum capacitor. This velocity is integrated by gate 12c, and the resultant voltage, which represents the vertical position of the ball, is added to the frame ramp at the input of gate 12b, to produce a negative going edge representing the vertical



This shot from the rear shows clearly the internal disposition of the component parts. The modulator assembly is shown in the lower right hand corner.

The printed circuit board component overlay is shown below. Pay particular attention to the polarity of diodes, electrolytic capacitors and integrated circuits.



position of the ball.

This edge is squared up by gate 12a, and then differentiated to produce a pulse proportional to the height of the ball. This pulse is squared up by gate 11c, and fed to one input of gate 4c, and to the inputs of gates 13b and 13c.

Consider first the case when the ball is descending. The 1uF capacitor will be charged to a higher voltage than the threshold of gate 12c, and its output will be falling. When the ball reaches the bottom of the "court", gate 13b will register coincidence between the ball pulse and the LL pulse. The resulting output pulse is inverted by gate 13a, and discharges the 1uF capacitor via D7 and the 470 ohm resistor.

The integrator output (gate 12c) will now commence to rise, and so the ball will "bounce" off the lower line, and commence to approach the upper line. When this occurs, a coincidence is registered between the ball pulse and the delayed UL pulse. (This pulse is delayed so that the ball will bounce off the bottom of the upper line.)

The positive pulse from gate 13c will now charge the 1uF capacitor again, via D8 and the 470 ohm resistor. Thus the ball is constrained to stay between the upper and lower lines on the court.

The voltage on the 220uF electrolytic capacitor represents the horizontal position of the ball. This voltage is added to the line ramp at the input of gate 11b, producing a negative going transition at the output corresponding to the horizontal position of the ball. This is squared up by gate 11a, differentiated, and then squared up again by gate 11d. The width of the ball is determined by the differentiator time constant.

The horizontal and vertical components of the ball are added together by gate 4c, and then injected into the video line by D5. Gates 3c and 3d detect coincidence between the ball and the left and right bats. These coincidence pulses are stretched by D11 and D12 and their associated circuitry, and then squared up by gates 5a and 5b.

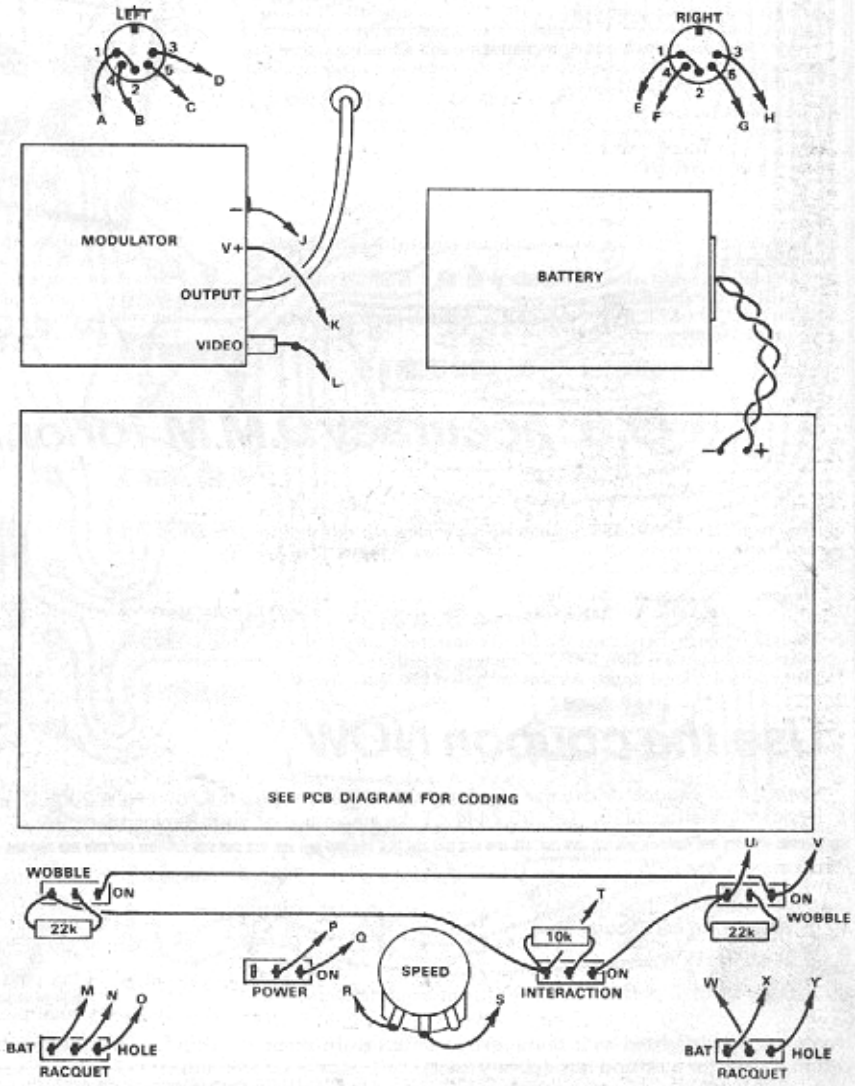
Gates 5c and 5d are connected as a flip-flop, and used to control the horizontal direction of the ball. If the ball is moving to the right, the output of gate 5c will be low, and the 220uF capacitor will be discharging via the 100k speed pot and limiting resistor. If the ball hits the right-hand bat, gate 3d will register coincidence, and gate 5b will toggle the flip-flop. The 220uF capacitor will now commence to charge up, and the ball will move to the left. When it hits the left bat, its direction is reversed in a similar manner.

The coincidence gates have a further function, not previously mentioned. Gates 6a and 6b are used to differentiate the outputs from the bat controls, giving voltages proportional to the bat velocities. The coincidence gates are used to switch these voltages onto the 1uF vertical speed capacitor at the moment of impact. Transistors TR1 and TR2 act as switches to perform this function, thus allowing the players to partially control the speed and direction of the ball.

If the ball misses one of the bats, the ball flip-flop is not toggled, and the ball continues past the bat and off the screen. Eventually the 220uF capacitor becomes fully charged or discharged, and a stable state is reached. The ball is returned into play by pressing the appropriate serve button, which simply toggles the flip-flop. The speed of play is regulated by the 100k pot which controls the rate of charge or discharge of the 220uF capacitor.

The upper and lower lines on the court are generated by gates 9a, 9b, 9d, 10c and 10d. These combine BL, CL, LL and NH pulses to produce the required video signal, which is injected into the video line by gate 9c. Gates 10a and 10b are used to delay the UL pulses, so that the ball bounces off the bottom of the upper line, rather than the top.

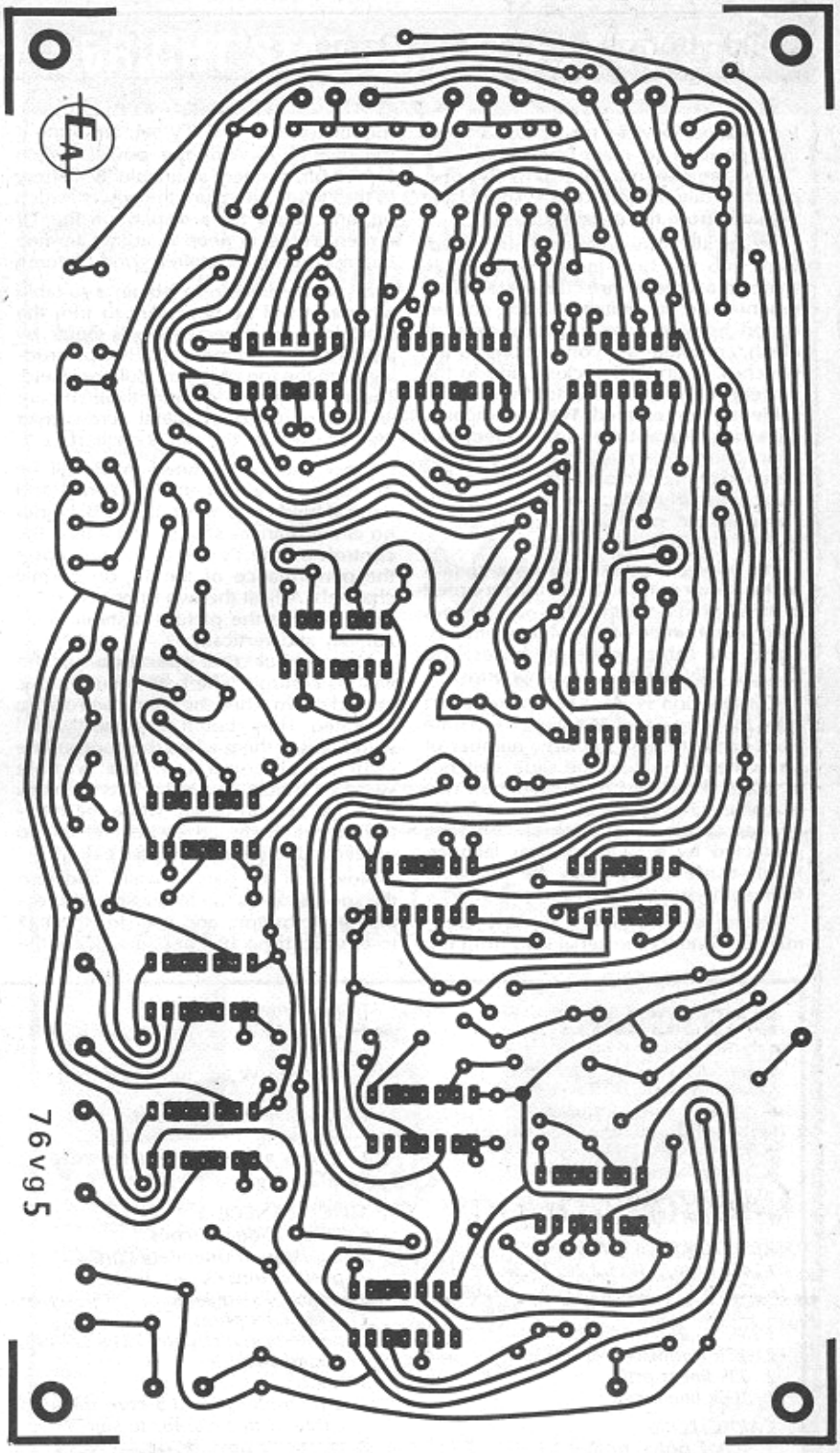
Gates 13d and 12d, which would otherwise be spare, are used to form a very low frequency oscillator. The output from gate 12d is filtered by an RC network, and used to wobble the bats up and down, under the control of switches S5 and S6. Switch S7 connects the wipers of the two bat controls together via a 10k.



This wiring diagram will aid in final assembly of the game. To facilitate later tracing of the circuit, use colour coded wire for all interconnections. Lace the wiring into a loom to achieve a neat finish.

Video Ball Game

Shown at right is a full size replica of the printed board pattern, which can be traced if required.



resistor, to provide interaction if this is required.

The power supply for the game is provided by a 9V battery. A 2500uF electrolytic capacitor is used to ensure a low supply impedance, and is connected permanently across the battery. Turn-on transients are eliminated by the 22uF electrolytic capacitor connected on the circuit side of the power switch, S8.

The composite video information, available at the collector of TR4, is fed to the modulator, along with suitable power supply voltages. This modulates the video information onto a carrier centred on 57.25MHz, for demodulation by a VHF TV set tuned to channel 1. The modulator is connected into the aerial socket of the set, so no modifications to the set are required.

Construction of the game is quite simple, as almost all components are mounted on a single printed circuit board. There is a separate board for the modulator. Do not remove the CMOS ICs from their protective packaging until they are to be inserted into the PCB. All other components should be fitted first.

There are 23 wire links to be fitted to the board, none of which need to be insulated. Use tinned copper wire for these (cut-off component leads are ideal).

Next mount all resistors and capacitors, making sure that the polarity conscious capacitors are fitted correctly.

We recommend that circuit board pins be fitted to the 19 external connection points, as this will make final assembly much easier. The twelve diodes and four transistors can be fitted next, taking care that they are inserted with the correct orientation.

The CMOS ICs can now be fitted. It is not necessary to use IC sockets, provided the following procedure is followed. First, ensure that the tip of your soldering iron is earthed, and also earth the PCB, at the – battery terminal. The easiest way to do this is to attach a flying lead to the body of your iron, so that it is in contact with the tip. Fit a crocodile clip to this lead, and simply clip it to the board. Remember to have the clip on for all soldering while you insert the ICs, and also for any soldering later.

The ICs can then be removed from their protective wrapping, and inserted into the board with the minimum of handling. If required, bend the leads by pressing against an earthed metal surface (not plastic) so that they are the required 7.5mm apart. After checking that the IC is in the correct place, and that its orientation is correct, solder first pin 7, and then pin 14. The remaining pins may be soldered in any order, applying a minimum of heat and solder.

When all soldering is finished, spend a few minutes checking the board for solder bridges and misplaced components. A little time spent at this stage may well save a lot of frustration later.

We can now turn our attention to the case and associated components. Metalwork dyelines are available from our

Information Services for $2.00, so those in a position to make metalwork can "brew their own". Alternatively, pre-punched aluminium boxes should be available from the usual sources.

Mount all the switches and other hardware into the box, including the PCB. Note that there are three resistors mounted on the switches. Using colour-coded hookup wire (rainbow cable is ideal), complete the connections to the switches, 5-pin DIN sockets, and to the battery, remembering to keep your soldering iron earthed. The accompanying wiring diagram shows all the required connections. The modulator assembly is fastened to the bottom of the case, at the rear, with the aerial lead to the TV clamped and passing through a grommetted hole in the rear of the case.

The wiring diagram also gives details of the hand controls. These are mounted in small plastic "zippy" boxes, with the controls mounted on the aluminium lids. Clamp the cables inside the boxes, and fit 5-pin DIN plugs to the other ends.

Construction is now complete, apart from the front panel. We used a separate front panel, to hide the large number of screw heads holding the slide switches in place. It is held in position by two machine screws, one at either end. We applied labels using stick-on lettering, protected by a layer of clear lacquer. Ready-made panels may be available from some suppliers, in due course.

Testing of the game can now commence. Connect the aerial lead from the modulator to a VHF TV set, and tune it to channel 1. With the power switch turned off, connect a suitable 9V battery to the circuit. Then turn the power switch on, and check for a display on the TV screen. You may need to adjust the fine tuning control to obtain a good picture.

If you are unable to obtain a suitable picture, it will be necessary to trim the modulator frequency. This is done by adjusting the trimmer capacitor protruding from the top of the modulator shield. The adjustment is quite critical, so care will be required. A metal screwdriver may be used, as the slot is earthed.

Once the set is tuned in, it will be necessary to adjust the horizontal and vertical hold controls on the PCB. Under no circumstances should you adjust the controls on the TV set, as this will upset the performance of the TV on normal channels. Adjust the two trimpots on the game so that the picture is stable horizontally and vertically.

Now check the operation of the various controls. The bats should move up and down when the hand controls are operated. They should turn into "walls" with holes in them when the appropriate switches are operated. The wobble switches should cause the bats or holes to move up and down, while the interaction switch should cause one bat to influence the other to a small extent.

Now turn the bats to walls, and turn the speed control up to maximum. Press one serve button, and wait for the ball to appear. If no ball appears, press the other serve button. If the ball still fails to appear, turn the power off, wait for a little while, and turn it back on again. Once you have found the ball, turn the speed down to a more manageable rate.

The ball should bounce from both walls, and also from the top and bottom lines. If the walls are moving when the ball hits them, some of the wall velocity should be imparted to the ball. The balls should pass through the holes in the walls. Once satisfied that all is correct, return the walls to bats, and commence to play.

To return the ball into play when it has been missed, press the serve button on the opposite side to the one the ball disappeared through. Thus if the ball goes off the left hand side of the screen, press the right hand serve button. The time taken for the ball to return depends on the speed setting and also on how long it has been left off the court.

Various types of game can be played, by appropriate manipulation of the switches. Tennis or ping-pong is played using the bats, while catch-ball requires the use of holes. Single players can have enjoyable games by setting up a wobbling hole in one wall, and trying to hit the ball through this with a bat. Skilful players can enjoy harder games by making their bats or holes wobble, while adding interaction adds to the difficulties yet again.

In fact, the number of different games which can be played is limited mainly by the imagination of the player or players. Be warned, however, that if you have children, you may need to purchase a second TV set, as otherwise you might be forced to miss your favourite program!

PARTS LIST

SEMICONDUCTORS
- 5 74C00 quad 2-input gates
- 8 74C02 quad 2-input gates
- 1 BF173 NPN transistor
- 2 BC548 NPN transistors
- 1 BC558 PNP transistor
- 12 1N4148 silicon diodes

RESISTORS (all ¼W):
- 1 470 ohm, 2 1k, 1 2.2k, 2 3.3k, 11 10k, 6 22k, 3 33k, 5 47k, 1 56k, 2 150k, 2 220k, 1 330k, 1 390k, 6 470k, 1 1.2M, 1 2.2M, 6 10M
- 2 4.7k trimpots
- 2 22k linear pots
- 1 100k linear pot

CAPACITORS
- 5 100pF polystyrene
- 1 220pF polystyrene
- 6 330pF polystyrene
- 2 0.047uF LV polystyrene
- 8 0.01uF LV polystyrene
- 2 0.033uF LV polystyrene
- 5 0.1uF LV polystyrene
- 1 1uF tantalum
- 1 22uF 16VW electrolytic, PCB mounting
- 1 47uF 16VW electrolytic, PCB mounting
- 1 220uF 16VW electrolytic, PCB mounting
- 1 2500uF 16VW electrolytic, PCB mounting

MISCELLANEOUS
- 6 DPDT slide switches
- 2 miniature momentary "on" pushbuttons
- 2 5-pin DIN sockets
- 2 5-pin DIN plugs
- 1 printed circuit board, 221 x 122mm, coded 76vg5
- 3 knobs
- 2 2-metre lengths of 5-core shielded cable, with 2 clamps to suit
- 2 plastic "zippy" boxes, 80 x 50 x 28mm
- 1 aluminium case, 230 x 205 x 68mm
- 1 modulator assembly (see text)
- 3 grommets
- 4 rubber feet
- 1 9V battery and clip

Hookup wire, solder, circuit board pins, machine screws, nuts, washers, self-tapping screws

RF Modulator

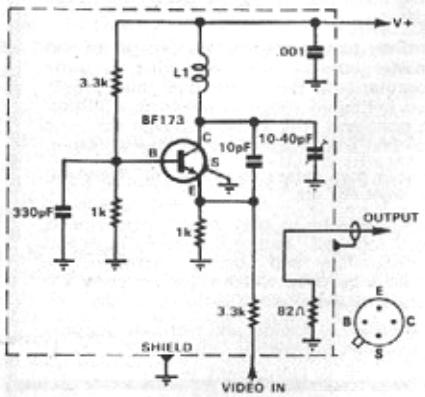
- 1 BF173 NPN transistor
- 1 10pF ceramic capacitor
- 1 10-40pF trimmer capacitor
- 1 330pF plastic capacitor
- 1 0.01uF ceramic capacitor
- 1 82 ohm, 2 1k, 2 3.3k resistors
- 1 printed circuit board 66 mm x 66 mm, coded 76m5
- 1 tinplate box, see text
  solder, machine screws, nuts, 75Ω co-axial cable, 22 B & S gauge enamelled copper wire

Note: Resistor wattage ratings and capacitor voltage ratings, where given, are those for our prototype. Components with higher ratings may generally be used providing they are physically compatible. Components with lower ratings may also be used in some cases, providing the ratings are not exceeded.

Finally, a word about troubleshooting the game, should this be necessary. First of all, check that the battery is okay, as strange things can happen with a flat battery. Next, check the symptoms against the description of operation given earlier, and try to isolate the faulty section. Thus if the ball goes through the left bat only, the trouble is likely to be around gate 3c. If various elements of the picture are scaled incorrectly, then the trouble may be due to incorrect RC networks.

The most likely cause of a complete lack of picture is failure of the horizontal or vertical oscillator. Remember that the circuit works in a logical manner, and you should be able to track down most faults by analysing the fault in conjunction with the circuit diagram.

THE RF MODULATOR



L1 : 10T, 22 B & S ENAMELLED COPPER WIRE, 3mm DIAMETER. SEE TEXT.

VIDEO MODULATOR

The circuit for the modulator assembly is shown above.

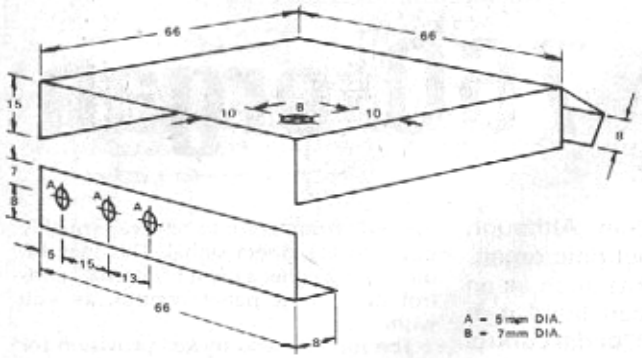
The RF modulator uses a single transistor, an NPN type coded BF173. It is enclosed in a small tinplate box, to minimise spurious radiation. The output has an impedance level of 75 ohms, and is coupled to the aerial terminals of the TV set by a shielded cable.

Operation of the modulator can be followed by referring to the circuit diagram. The transistor is connected as a Colpitts oscillator. Base bias is provided by the 3.3k and 1k resistors, connected as a voltage divider across the supply line. AC grounding of the base is provided by the 330pF capacitor.

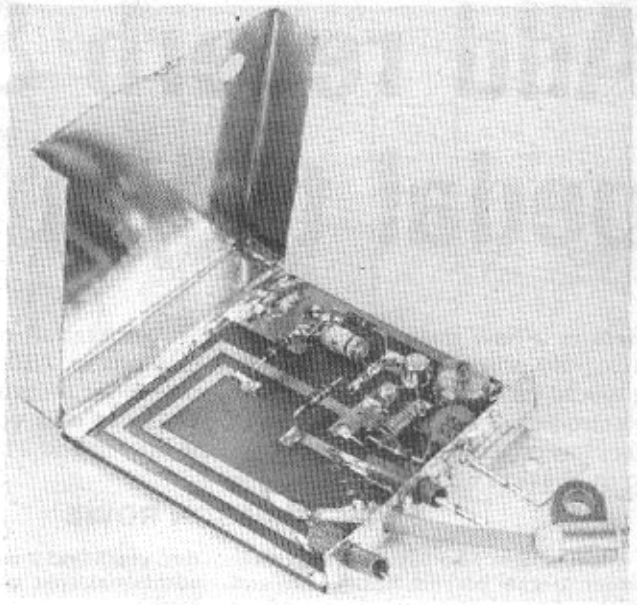
Frequency of operation is determined by the LC network formed by the inductor in series with the collector and the 10-40pF trimmer shunting the collector to ground. Feedback to maintain oscillation is provided by the 10pF capacitor between emitter and collector.

The input video signal is coupled into the emitter by a 3.3k resistor, and amplitude modulates the oscillator. The RF output signal is "sniffed" by a loop close

Video Ball Game



Above: This dimensioned drawing of the modulator shield, which is fashioned from tin-plate, will aid construction.



Right: A view of the completed modulator assembly, just prior to spot soldering the lid in position.

to the emitter lead. One end of this loop is terminated with an 82 ohm resistor (the closest preferred value to 75 ohms), while the other end is connected directly to the output cable.

Fine tuning of the oscillator frequency is provided by the trimmer capacitor, while coarse tuning is achieved by varying the number of turns in the inductor. Access to the trimmer capacitor is available from outside the shielding case.

The inductor is fashioned from ten turns of 22 B & S enamelled copper wire, wound with a diameter of 3 mm. In conjunction with the specified trimmer, this allows the modulator to be tuned to channel 1 or channel 2. Reducing the number of turns to 5 enabled us to tune all channels between 3 and 9. Thus if channel 1 or 2 is in use in your area, and you are suffering from interference effects, it is possible to tune the modulator to another, unused channel.

The modulator is constructed on a small printed circuit board, measuring 66 x 66 mm, and coded 76m5. A piece of double sided board is used, with a pattern etched on one side only. The other side acts as a ground plane. All components are mounted on the copper side of the board, so no holes are required in the board itself.

The shield is fashioned from tinplate, obtainable from jamtins, and is made in two pieces. An "L" shaped section with three holes in it forms the front section. The connections to the supply rail, the modulator input and the output are made through these holes.

The second section has a more complicated shape, and forms the lid and remaining sides of the case. It has a single hole in it, to provide access to the tuning capacitor. Dyeline drawings of the shield will be obtainable from our Information Service.

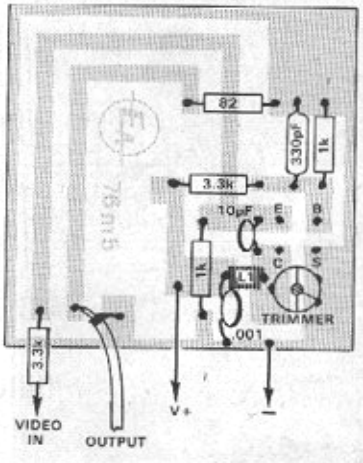
Before the components are mounted on the PCB, it is best to solder the shield to the PCB. The lid can then be hinged upwards, the components fitted, the lid pushed down again, and soldered at selected points. If you are making your own shield, make sure that you drill all the holes before you make the bends, as this makes it much easier.

Make suitable bends in the component leads, as required, remembering to keep all components close to the PCB. The coil is wound on a convenient former, such as a knitting needle or similar object, and the ends then cleaned and tinned. The trimmer capacitor must be mounted so that the adjusting screw is aligned with the hole, and so that the earthy side is connected to ground. This will enable a metal screwdriver to be used for adjustment, if desired.

The 3.3k video input coupling resistor is passed partway through the appropriate hole, and soldered to the pattern. The flying end is used as the terminal point for the lead from the video board. A piece of insulated hookup wire is placed similarly for the positive supply terminal. The earth connection is simply soldered to the shield.

The output co-axial lead is stripped for a short distance at one end, passed through the hole in the shield, and soldered in position. The lid can then be hinged down, and spot soldered in selected places. We fastened it down in position with two small angle brackets fashioned from tinplate.

Once the modulator has been connected to the video section, the TV is tuned to an appropriate channel, and the power switched on. The trimmer is then adjusted to obtain a suitable picture, with good contrast. No sound information is generated by the modulator, so the volume control can be turned right down to eliminate any spurious noise.



At left is the component overlay diagram, while on the right is a full sized copy of the PCB pattern. This should be etched onto one side of a piece of double-sided board, the unetched side acting as a shield.