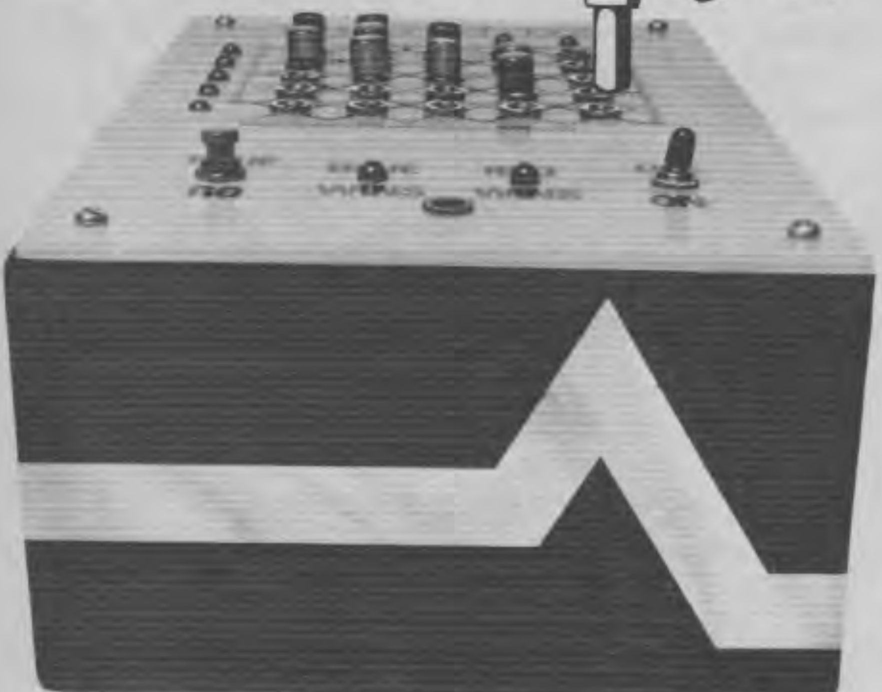
Dual Line Game

By A. Russell



RULES OF THE GAME

THE GAME of Dual Line is played by two contestants on a board marked out with a lattice of interwoven red and blue lines. One contestant (for example BLUE) has a supply of blue plugs, the other (RED) has red plugs. Each player takes turns to insert a plug into an unoccupied socket on the board (there are sockets at each point on the board where red and blue lines cross).

The object of the game, for the RED player, is to create an unbroken red line from top to bottom of the board. When a red plug is inserted into a socket, the red line through that point is assumed to be completed, and the blue line broken. A winning line may zigzag about all over the board so long as it connects the two opposite sides of the board with an unbroken line.

Similarly the BLUE player is trying to complete a blue line stretching between the left and right hand sides of the board. Unlike the game of noughts and crosses the game can never end in a draw because one player can only prevent his opponent from winning by winning himself.

RESISTOR ANALOGUE

The unit decides the moves for one of the players (in this case BLUE). It operates on the following principle. A resistor network (Fig.1) corresponds to the lines of play open to the BLUE player (lines of play for the RED player are shown on the same diagram as dotted lines). All resistors have the same value.

When BLUE inserts a plug into a jack socket, the resistor corresponding to that socket is short-circuited. When RED inserts a plug into a jack socket, the resistor corresponding to that socket is open-circuited. Thus when BLUE completes his line from left to right hand side of the board and wins, the entire network is short-circuited.

Similarly when RED completes a line from top to bottom of the board the network is open-circuited. These two conditions are detected by the win detecting circuit (Fig.3) and cause the RED WINS or BLUE WINS l.e.d.s to light.

MAKING A MOVE

When the circuit is called upon to decide its next move, a voltage source is applied across the network. The strategy of the machine consists of choosing the resistor across which the maximum voltage occurs. If two or more resistors show the same maximum voltage, one is selected at random.

The move is indicated to the human contestant by lighting two l.e.d.s which point to the row and column co-ordinates of the socket where the machine would like its move made. Of course this requires a measure of integrity on the part of the human contestant because the machine cannot tell when it is being cheated.

A simple machine may be made by using light bulbs, instead of resistors, in the network of Fig.1. The machine moves can then be determined by observing which bulb glows the brightest. It is often difficult to decide which of several bulbs is brightest and so a more sophisticated circuit was developed to automate this decision.

The difficulty here is how to detect the network resistor with the highest voltage across it, bearing in mind that there is no common point in the circuit to measure the voltage with respect to.

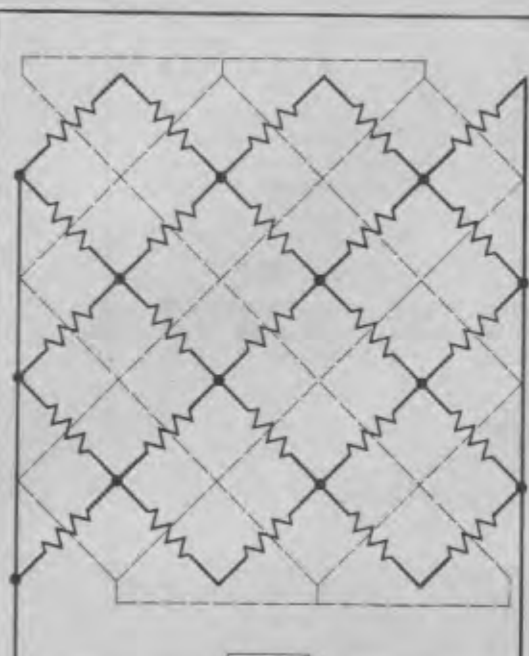


Fig.1. Resistor analogy network for the Dual Line Game.

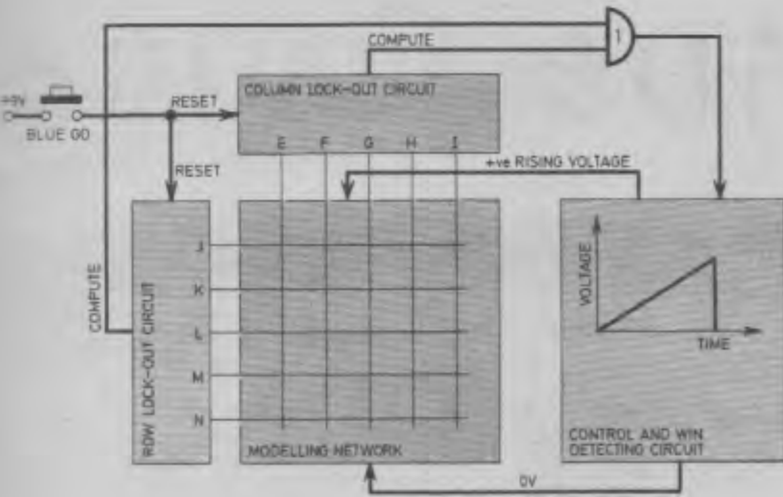


Fig.2. Block diagram showing all sections of the game.

The completed Dual Line Game.

In this circuit the emitter-base voltage of a silicon transistor (which is the same between transistors at the same temperature) is used as a reference. Each resistor in the *modelling network* has a transistor emitter-base junction across it. Those resistors where current could flow in either direction depending on the state of play have two transistors connected in opposite senses.

BLOCK DIAGRAM

The sequence of events, which takes place when the machine decides its next move, is best visualised by referring to the block diagram (Fig.2). When the BLUE GO button is pressed, row and column *lock-out circuits* (Fig.4) are reset which in turn send compute signals to the *control circuit* (Fig.3). Compute signals cause a variable voltage generator in the control circuit to apply an increasing voltage to the modelling network (Fig.5).

POTENTIAL DIFFERENCE

Voltage continues to rise until the potential difference across one resistor is enough to switch on its associated transistor. Sensing lines (*E, F, G, H, I* and *J, K, L, M, N*) from the row and column lock-out circuits (Fig.4) detect row and column co-ordinates of the switched on transistor, light the appropriate l.e.d.s and take away the compute signals which causes the output of the voltage generator to return to zero.

Lock-out circuits hold the row and column l.e.d.s on until BLUE GO is pressed again. If either BLUE or RED has won, no voltages will be developed across any resistor in the modelling network. The output of the control circuit will rise until the win detecting circuit comes into play and identifies the winner.

COMPONENTS

Resistors

R1	10kΩ	R18	10kΩ	R35	10kΩ
R2	47kΩ	R19	100kΩ	R36	100kΩ
R3	1kΩ	R20	2·2kΩ	R37	2·2kΩ
R4	220Ω	R21	2·2kΩ	R38	10kΩ
R5	10kΩ	R22	100kΩ	R39	100kΩ
R6	2·7kΩ	R23	2·2kΩ	R40	2·2kΩ
R7	27kΩ	R24	100kΩ	R41	100kΩ
R8	10kΩ	R25	2·2kΩ	R42	2·2kΩ
R9	10kΩ	R26	10kΩ	R43-67	2·2kΩ (25 off)
R10	100kΩ	R27	100kΩ		
R11	2·2kΩ	R28	2·2kΩ		
R12	10kΩ	R29	10kΩ		
R13	100kΩ	R30	100kΩ		
R14	2·2kΩ	R31	2·2kΩ		
R15	10kΩ	R32	10kΩ		
R16	100kΩ	R33	100kΩ		
R17	2·2kΩ	R34	2·2kΩ		

All ¼W carbon ±5%

COMPONENTS approximate cost £20

Capacitors

C1 50μF 15V elect.
C2 50μF 15V elect.

Semiconductors

TR1, 2, 3 BC108 *npn* silicon (3 off)
TR4-TR15 BC557 *pnp* silicon (12 off)
TR16-TR49 BC108 *npn* silicon (34 off)

D1-D4, D9-D14, D16-D21, D23-D28, D30-D35, D37-D48, D50-D55, D57-D62, D64-D69, D71-D76, D78-D139: IN 4148 or similar small signal silicon diode (126 off)

D5 BZX85 5·1V Zener diode

D6-8, D15, D22, D29, D36, D49, D56, D63, D70, D77: TIL 220 red light emitting diode (12 off)

See Shop Talk Page 323

Miscellaneous

SK1-SK25 3·5mm jack sockets with one normally closed switch (25 off)
S1 single-pole on/off toggle
S2 miniature push-to-make single-pole switch
B1 9V type PP3

Stripboard: 0·1 inch matrix, 36 strips × 51 holes (3 off); 6 metres of ten-way ribbon cable; PP3 battery connector; size 10 knitting needles, one set plastic one set metal, for pegs; 7mm diameter wood dowelling and red and blue enamel paint for pegs; materials for cabinet; three 4BA nuts and bolts with spacers for mounting circuit boards.

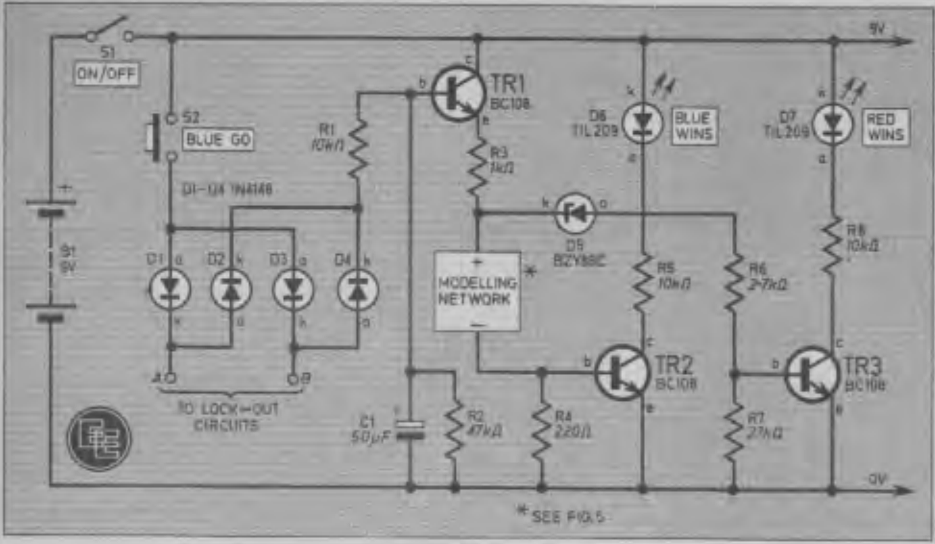


Fig.3. Complete diagram of the control and win detecting circuit. This is built on board A.

CONTROL CIRCUIT

The complete circuit of the control and win detecting circuit is shown in Fig.3.

When the BLUE GO button is pressed 9V is applied via diodes D1 and D2 to lines *A* and *B* of the row and column lock-out circuits. This resets the system and in turn applies 9V back to the control and win detecting circuit via the diode on gate D3 and D4.

Because of the *C-R* network (made up of R1 and C1), the voltage at the base of TR1 rises exponentially towards 9V. This rising waveform is buffered by the emitter follower stage formed by TR1 and fed into the modelling network (Fig.5).

If nobody has won yet, the voltage across the modelling network continues to rise until the voltage across one of the resistors in the network is sufficient to cause the associated BC108 transistor (TR16 to TR49) to conduct. Current is then fed from this transistor, through two isolating diodes, onto two sensing lines from the lock-out circuits.

WIN OR LOSE

If RED has won, the modelling network is open circuit and the emitter voltage of TR1 is free to rise toward 9V. When this voltage reaches 5·8V, D5 starts to conduct and feeds current into the base of TR3 which switches on and lights the RED WINS l.e.d. D7.

Similarly, if BLUE has won, the modelling network is short circuit and the current through TR1 rises until about 3mA is flowing at which time the voltage drop across R4 is about 0·7V; TR2 switches on and the BLUE WINS l.e.d. D6 is lit.

LOCK-OUT CIRCUITS

The modelling network is flanked by two lock-out circuits, one for the rows, one for the columns, and their function is to record and display the network element with the highest voltage across its terminals.

When the BLUE GO button is pressed, line *A* or *B* (depending on whether we are considering row or column lock-out circuits) is taken to +9V (see Fig.4). This energises TR9 (or TR15) which switches off TR4, 5, 6, 7 and 8 (or TR10, 11, 12, 13 and 14). At the same time compute signals are applied to the control and win detect circuit which in turn applies a rising voltage to the modelling network.

Assuming neither player has won, one of the elements in the modelling network switches on causing a volt-

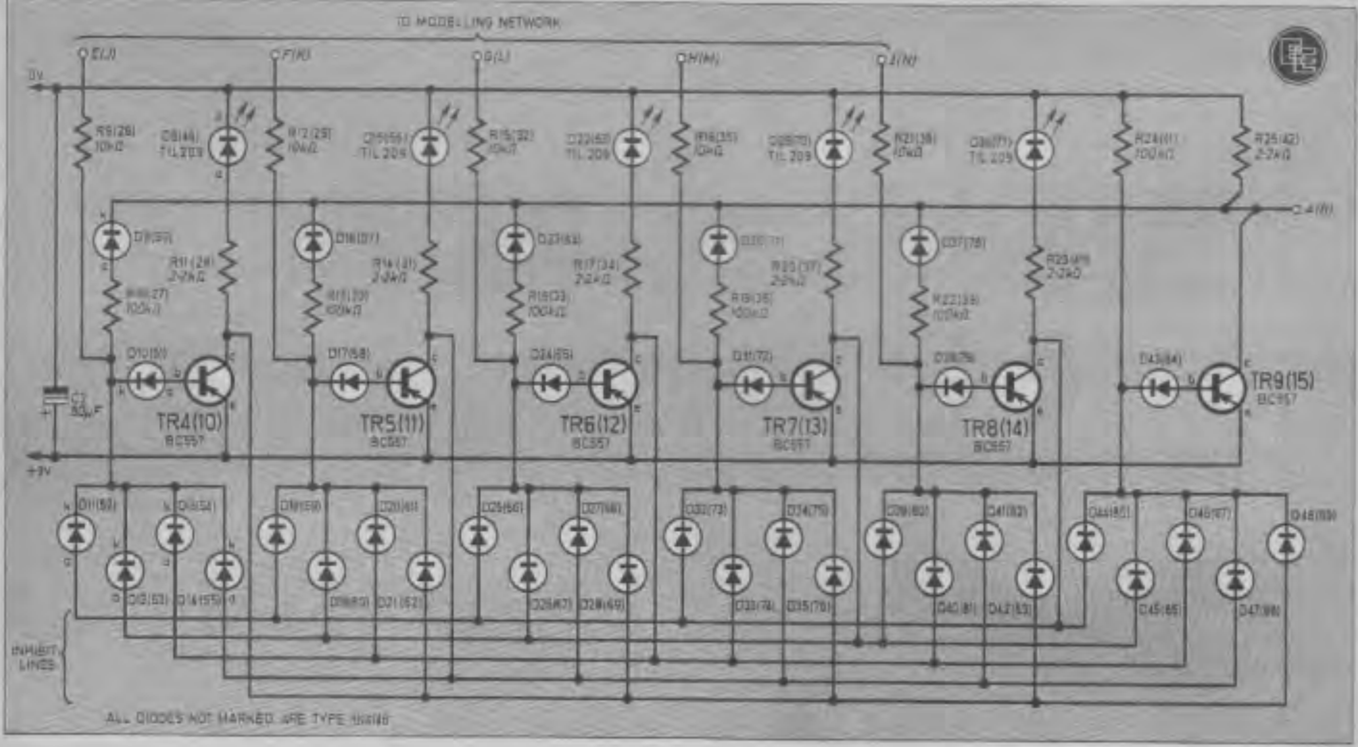
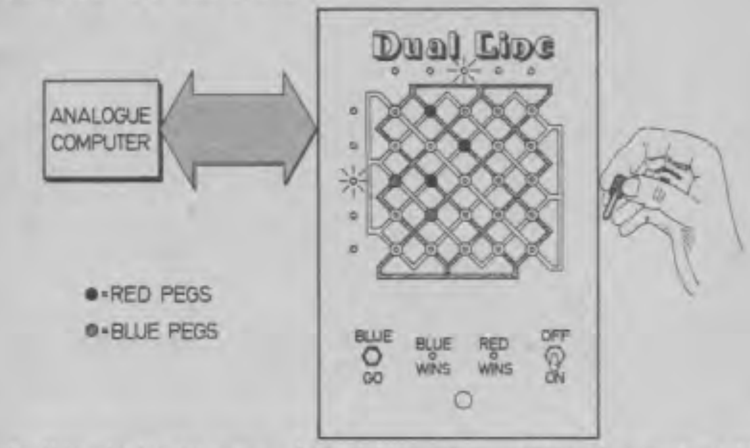


Fig.4. Complete diagram of the lockout circuits. Note that two of these are required, one for the rows and one for the columns. Bracketed component references are for the column lockout circuit and unbracketed ones for the row lockout circuit. These are both built on board B.

HOW IT WORKS



In this electronic game of Dual Line, the machine always uses blue pegs and the human contestant red pegs.

Assuming red moves first, the appropriate colour peg is taken and placed in the selected position. The BLUE GO button is then pressed. This causes the analogue computer within the unit to work out the best countermove and indicate its position by lighting up two l.e.d.s on the front panel.

The player then inserts a blue peg in the position given and the whole process is repeated again and again until there is a complete line of pegs—either blue or red.

When this happens, the machine works out who has won the game and lights up the correct WIN l.e.d.

age to appear on its respective sensing line. When this happens, the associated transistor in the lock-out circuit switches on illuminating the l.e.d. in its collector line.

To stop other transistors being activated at the same time, a set of inhibit lines are provided. These are initially all at 0V. When one transistor turns on it immediately clamps its associated inhibit line to +9V which turns off TR9 and prevents any of the other lock-out transistors from turning on.

MODELLING NETWORK

The complete circuit of the modelling network is shown in Fig.5. You will notice that there are two types of circuit elements. However, both essentially consist of a resistor connected across a semiconductor junction, the ends of which are connected into the matrix. There are also two sensing outputs *X* and *Y* each connected to the sensing lines from the lock-out circuits.

When the applied voltage across the network is sufficient to turn the transistor on in a particular element, these outputs go high energising their respective sensing lines. This causes the lock-out circuits to register this condition and indicate the next move.

CONSTRUCTION starts here

CIRCUIT BOARDS

Most of the components in the Dual Line Game are mounted on three circuit boards. These are all identical pieces of 0·1 inch matrix stripboard 36 strips by 51 holes and full details of component mounting and drilling are given in Figs. 6, 7 and 8.

Construction should start with the control and win detecting circuit board (Fig.6). It will be noticed

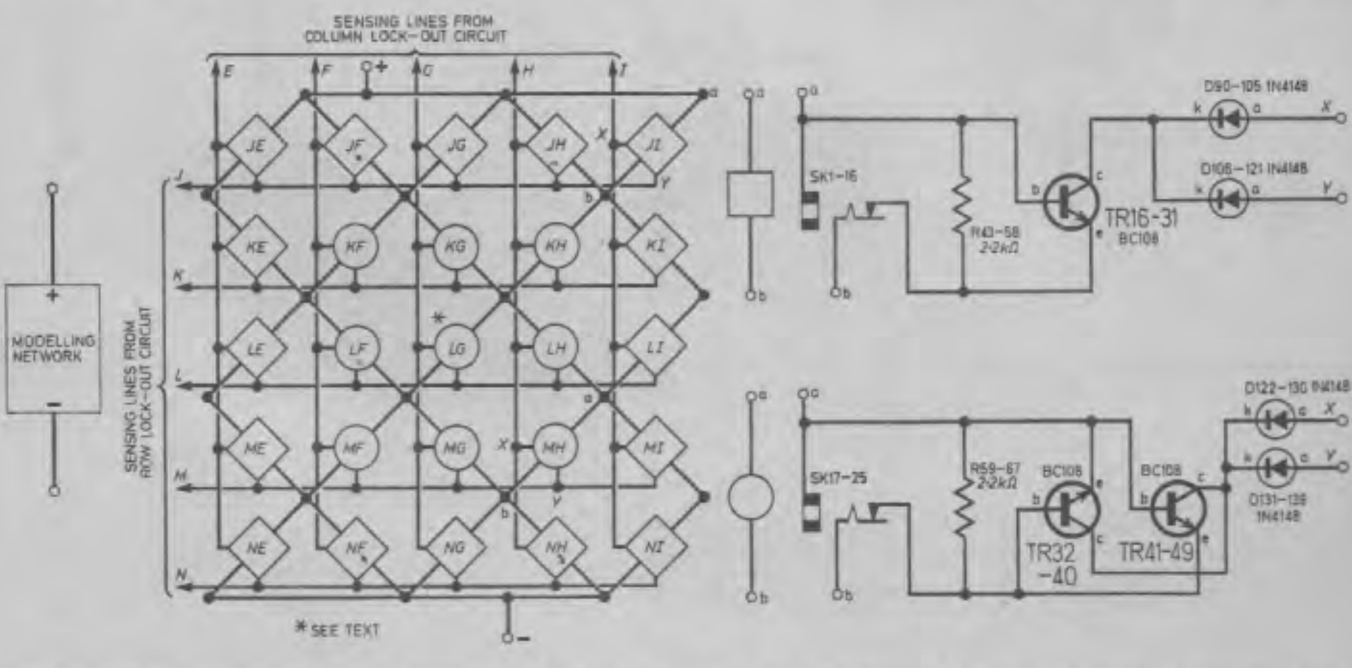
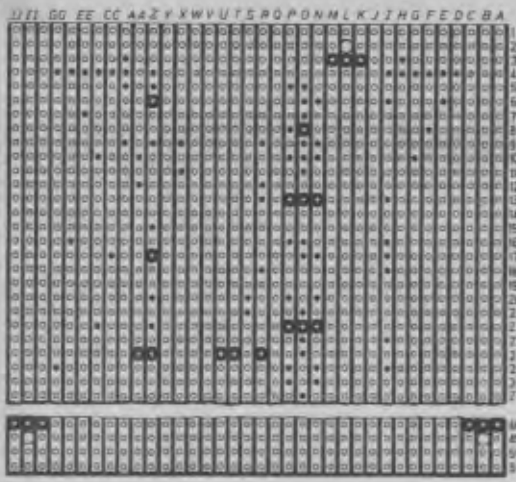


Fig.5. Circuit diagram of the modelling network. Note that this is made up of identical network elements, the circuit diagrams of which are shown on the right. This is built up on board C.



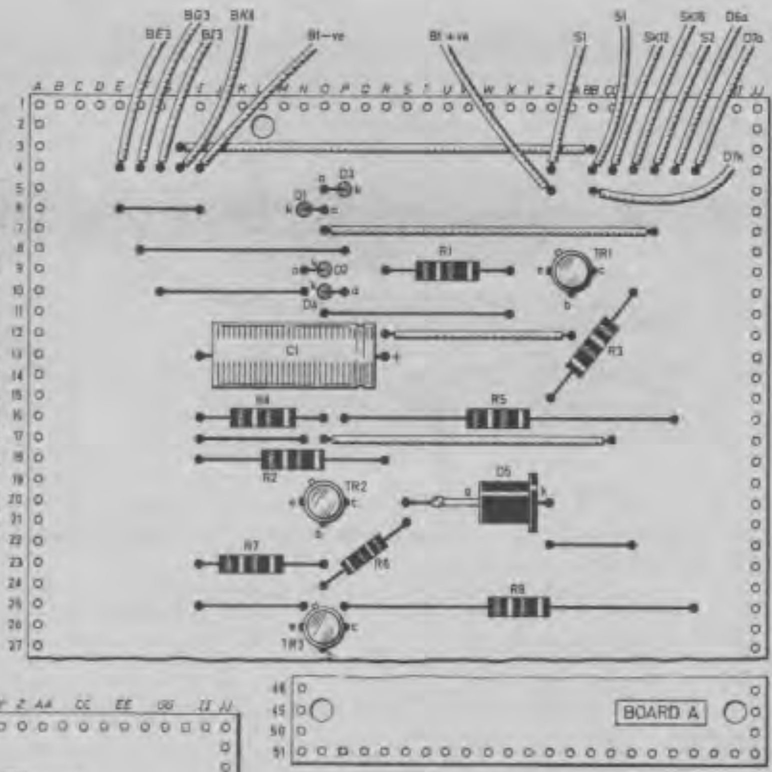
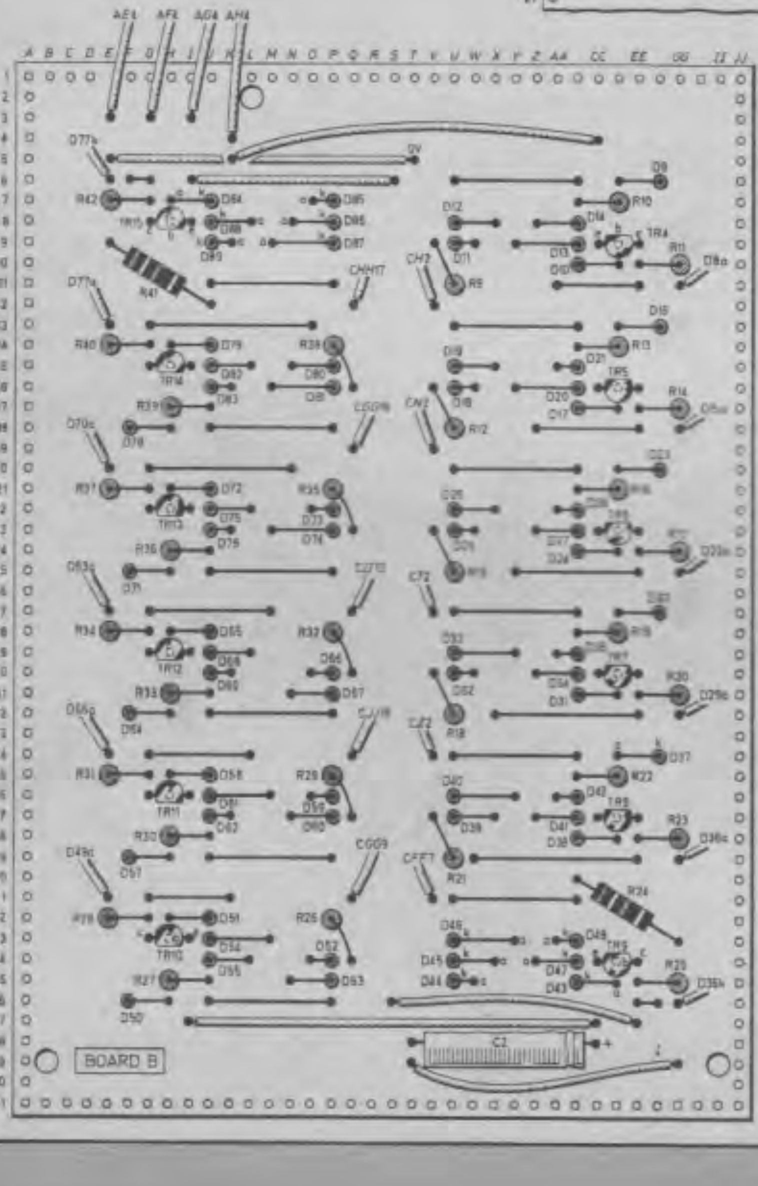
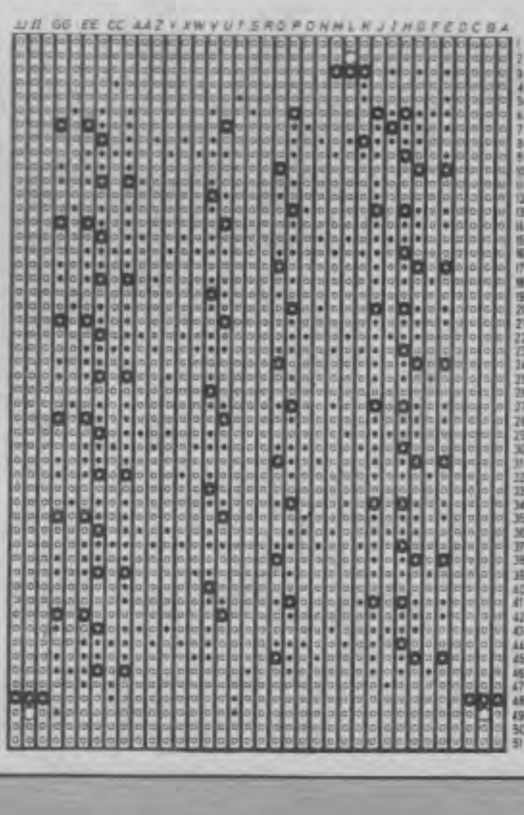
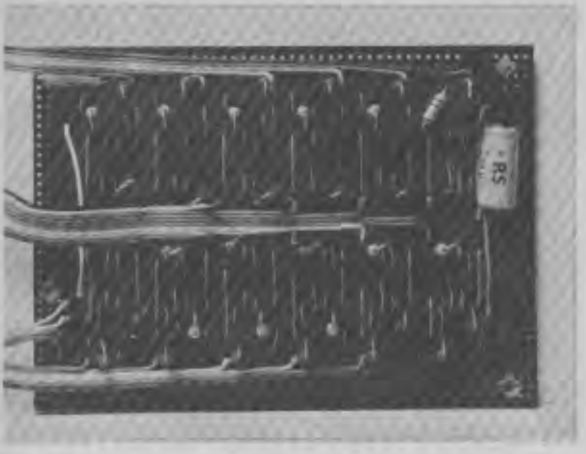


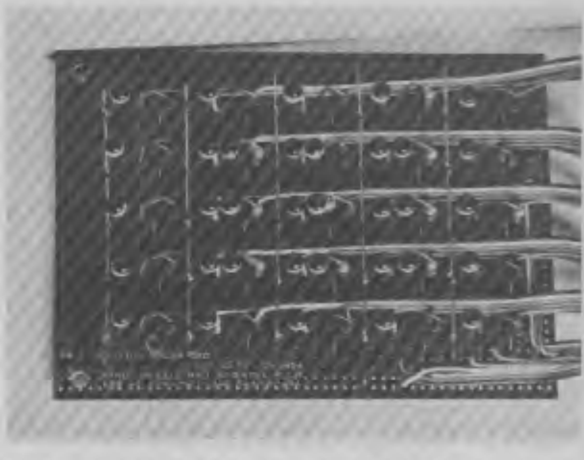
Fig.6. (above and left). Circuit board layout of the control and win detect circuit (Board A).

Fig.7. (below and left). Circuit board layout of the lockout board (Board B). See text for an explanation of the inter-board wiring references.









The left hand photograph shows a view of the top of the lockout board. Note the use of ribbon cable for off-board connections. The other photo shows a view of the modelling network board. Note the circular shaped plastic encapsulated BC108 transistors and copper bus wires.

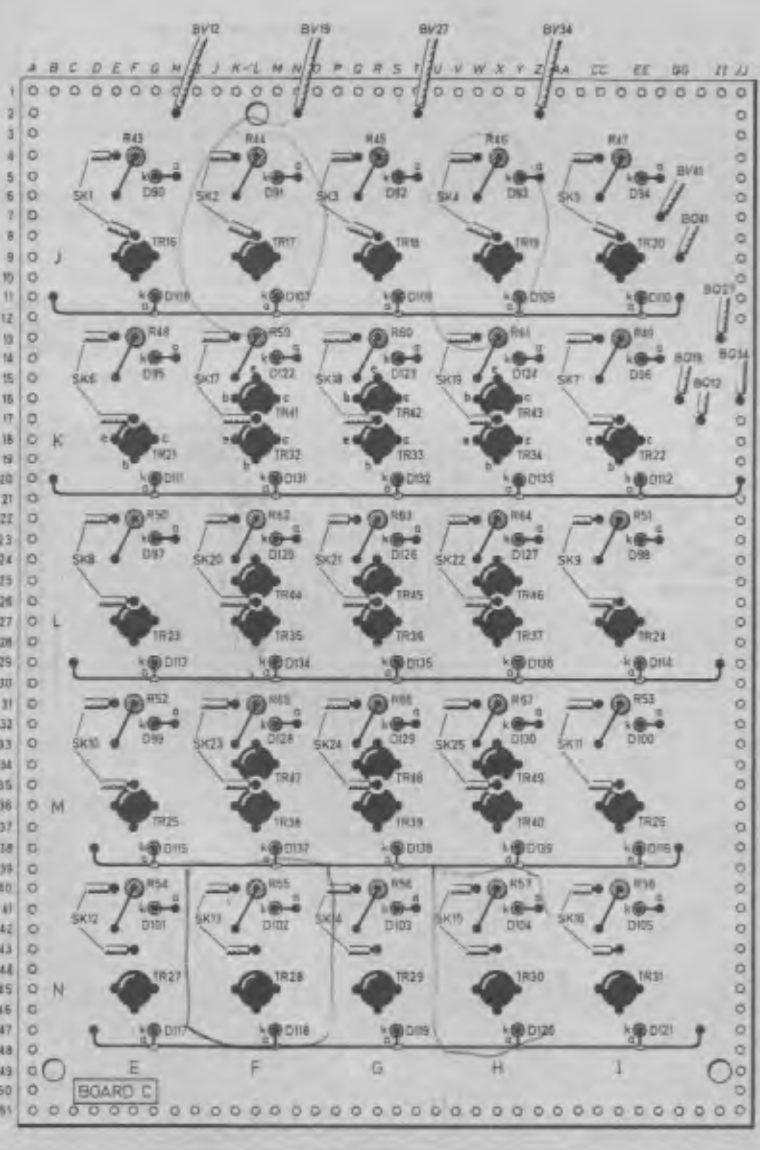
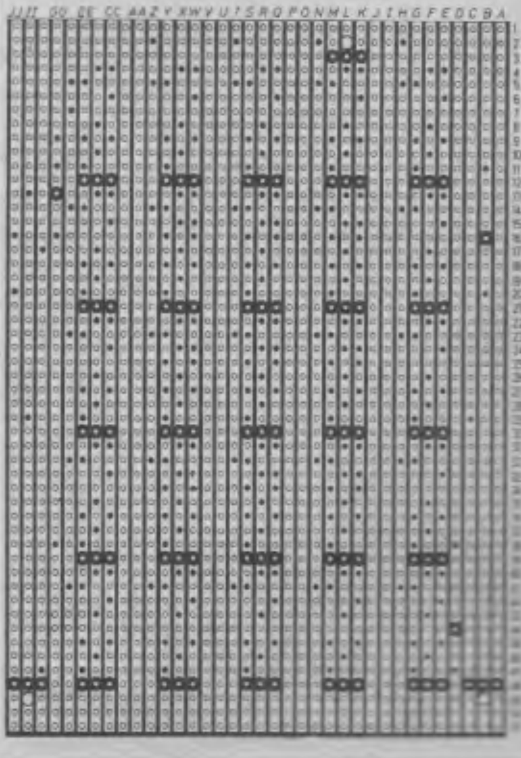


Fig.8. Circuit board layout for the modelling network board (Board C).



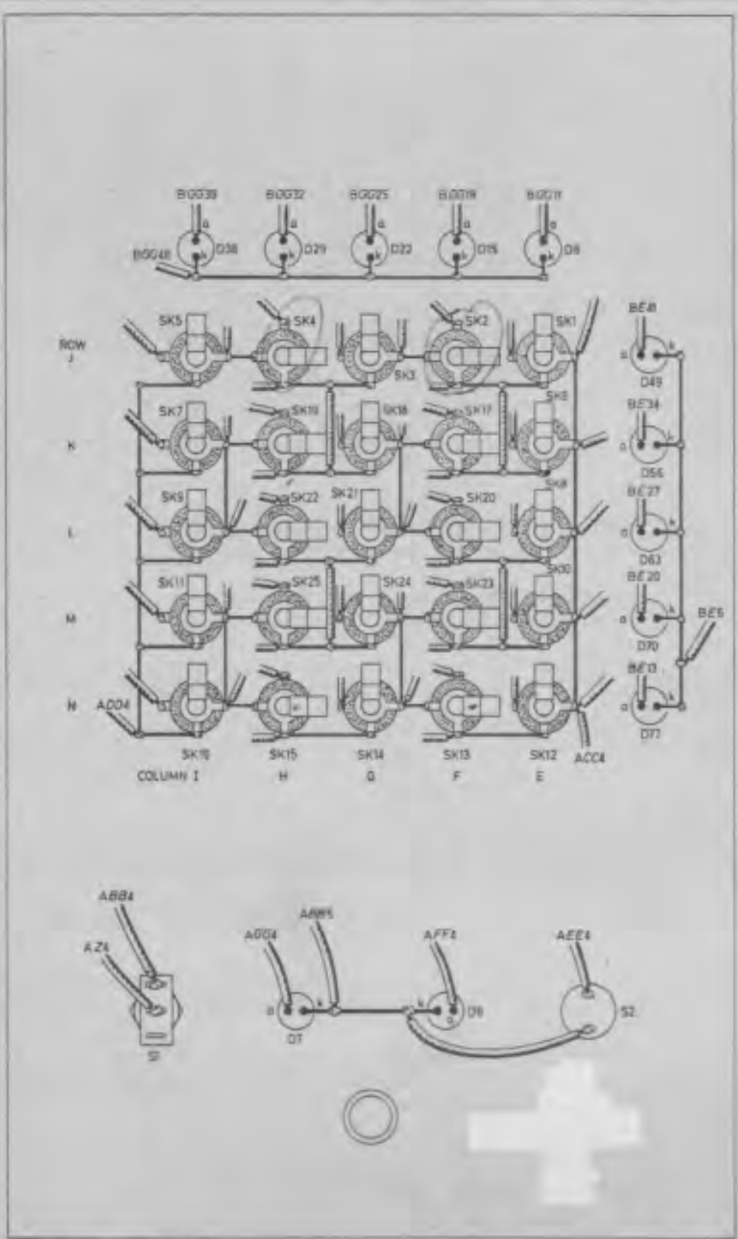


Fig.9. Wiring of the rear of the front panel.

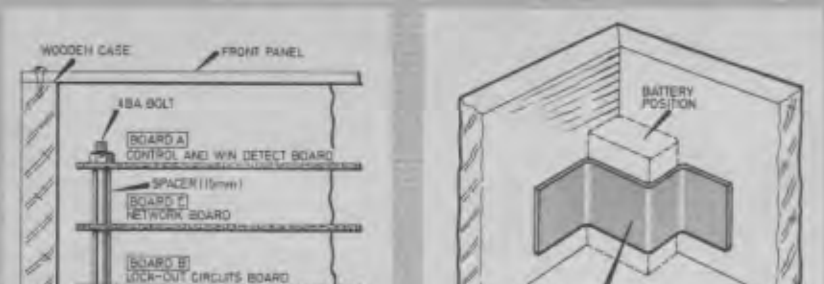


Fig.10. Interior views of the cabinet. The diagram left, shows the circuit board mounting arrangement and the one on the right shows the battery mounting clip.

immediately that only half the board area is used. However making all circuit boards the same size, means that mounting them in the cabinet is a lot simpler and this is what has happened here.

Multi-way ribbon cable is used for front panel connections both on this board and the others as this makes lead identification much easier and keeps the wiring reasonably neat.

To make it easier to keep track of interboard wiring, a simple system of board location identification has been adopted. The first letter refers to the board itself, and the rest of the letters and numbers refer to the strip/hole co-ordinates of a particular location in the usual way.

For example location C*AA*17 refers to location *AA*17 on board C (the modelling network board).

The lock-out circuit board (Fig.7) can be tackled next. Both row and column lock-out circuits are accommodated on the same piece of stripboard and apart from C2 are identical.

NETWORK BOARD

Finally the network board can be assembled. A quick glance at Fig. 8 will confirm that this consists of a large number of separate small circuits each with two wires going to a socket on the front panel and one each to the appropriate row and column lock-out circuit.

Bus wires made up of thick gauge copper wire are mounted about 7mm clear of the board from one side to the other to provide common returns for the lock-out circuit board input lines. This can be seen clearly in the layout diagram.

You will see that plastic encapsulated BC108 transistors have been used in the prototype. The more familiar TO-18 types can be used instead but take care that their cans do not short circuit to other parts of the circuit.

Component identification is made very simple by the fact that all transistors, all resistors and all diodes are of the same type and value. On the other hand, lead out wires from each section should be made easily identifiable so that they can be connected to the correct socket on the front panel. Care must also be taken to get the polarities of circuits round the edge of the board correct.

CABINET AND FRONT PANEL

In the prototype the cabinet (dimensions 200×130×70mm) was made up from 75×15mm (3×½ inch) softwood with a hardboard bottom.

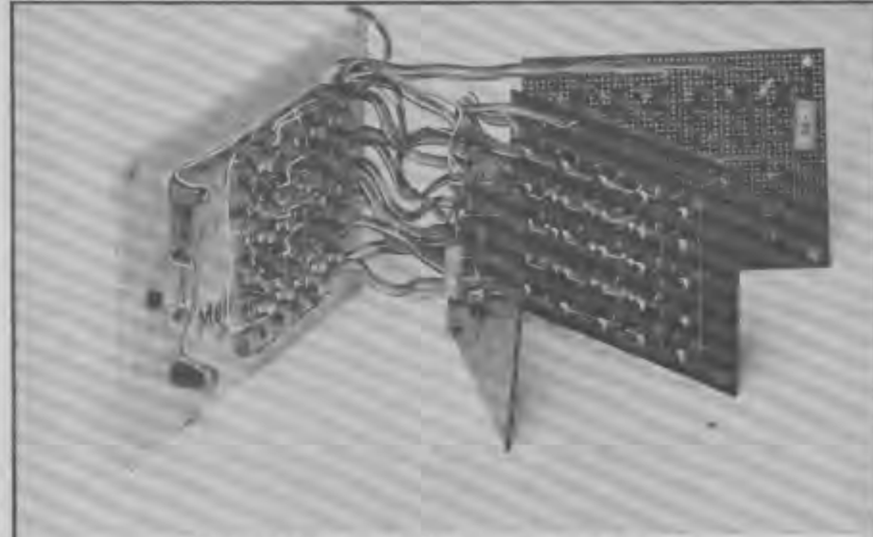
The front panel is made up from a piece of 3mm coloured Perspex. Great care is needed in drilling this material and a hand powered drill is best. Red and blue lines are made with coloured drafting tape and captions with rub on lettering protected by clear sticky tape.

The interior layout can be seen both in Fig. 9 and in the accompanying photographs. It is sensible to mark out and drill all the holes in the Perspex panel before mounting any components and it is also a good idea to check each jack socket. Some may need their contacts adjusting and this is easier to do before they are attached to the front panel.

A battery holder can also be made from a suitably shaped piece of plastic (or metal) and glued into position in one corner of the box (see Fig.10).

The completed circuit boards are mounted one above the other on three 4BA bolts which have been fixed with Araldite to the floor of the case. Spacers can be made up from old ball point pen cases.

Once interwiring between the boards is complete, they can be fixed in position using 4BA nuts, and wiring to the front panel completed. The unit is now ready for testing.



The completed unit before installation in its case.

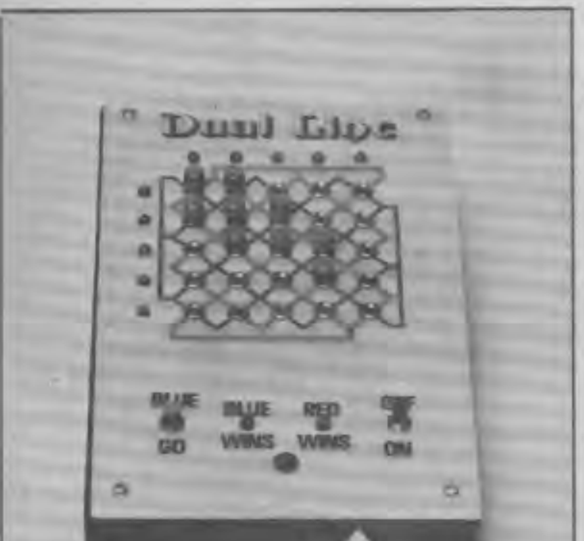
BLUE AND RED

To complete and test the Dual Line Game a set of plugs (or pegs) is required, 12 for RED and 12 for BLUE.

The red pegs are made up from size 10 plastic knitting needles. A 25mm section of needle is cut and Araldited to a 7mm long section of 7mm diameter wooden dowel. The pegs are finished off by giving the top a couple of coats of red enamel.

The blue pegs are made up in a similar way, the only difference being that metal knitting needles should be used, sanded down to ensure a good contact in the sockets.

Testing and setting-up the equipment can now proceed.



TESTING

When the circuit is first switched on it should draw about 10mA from a 9V battery and two l.e.d.s should be lit, one row and one column indicator. Pressing BLUE GO will cause the l.e.d.s to flash briefly, during which time current consumption will rise to about 25mA. A row and column l.e.d. will again be lit, probably different.

The 2·2 kilohm resistor on the modelling network board, board C, in circuit *LG* (R63) should now be increased in value (to about 3·3 kilohms) until every time BLUE GO is pressed D22 and D63 come on (no jack plugs should be in the board for this adjustment). This ensures that when the circuit is given the first go in a game it will choose the centre position which is the best first move.

Each position on the board can then be tested by forcing the machine to choose every position in turn. This is done by making a line of red pegs from top to bottom of the board, broken only at the point you wish the machine to choose.

Obviously, if the circuit is working correctly, it must choose to place its plug in the gap this being the only move which can prevent immediate defeat. Any fault shown by this test must be traced back from the front panel to modelling network board to lock-out circuit board until the error is found.

After passing this test the machine is ready to challenge you to a game. If you give it the first move you can expect to lose the game on most occasions. (Only one line of play has been found that can defeat it when it has first move.) When you take first move it has less chance of winning, but will if you make a bad mistake.

The advantage of the first player can be reduced if it is agreed that the first move may not be in the centre position. Under these rules the machine cannot calculate its first move, but it plays rather well if it is give position *MG* as its first move.

COMPONENTS

This circuit uses quite a large quantity of rather a small range of common components. For this reason it pays to shop around to find the best value. The advertisements in this magazine are a good place to start.

The semiconductors used in this circuit are not critical, any small signal silicon *npn* transistor will do instead of BC108 and any silicon *pnp* instead of BC557. The TIL220 and 1N4148 diodes may be replaced by any reasonable equivalent. It is not recommended that manufacturers "fall outs" be used in this circuit.

This article has described an analogue electrical resistance network which calculates moves for a simple game. There are similar resistance analogues for some other games. The processing power of these and more complex networks containing inductors, capacitors and other elements are overlooked in these days of digital computers. ⌑