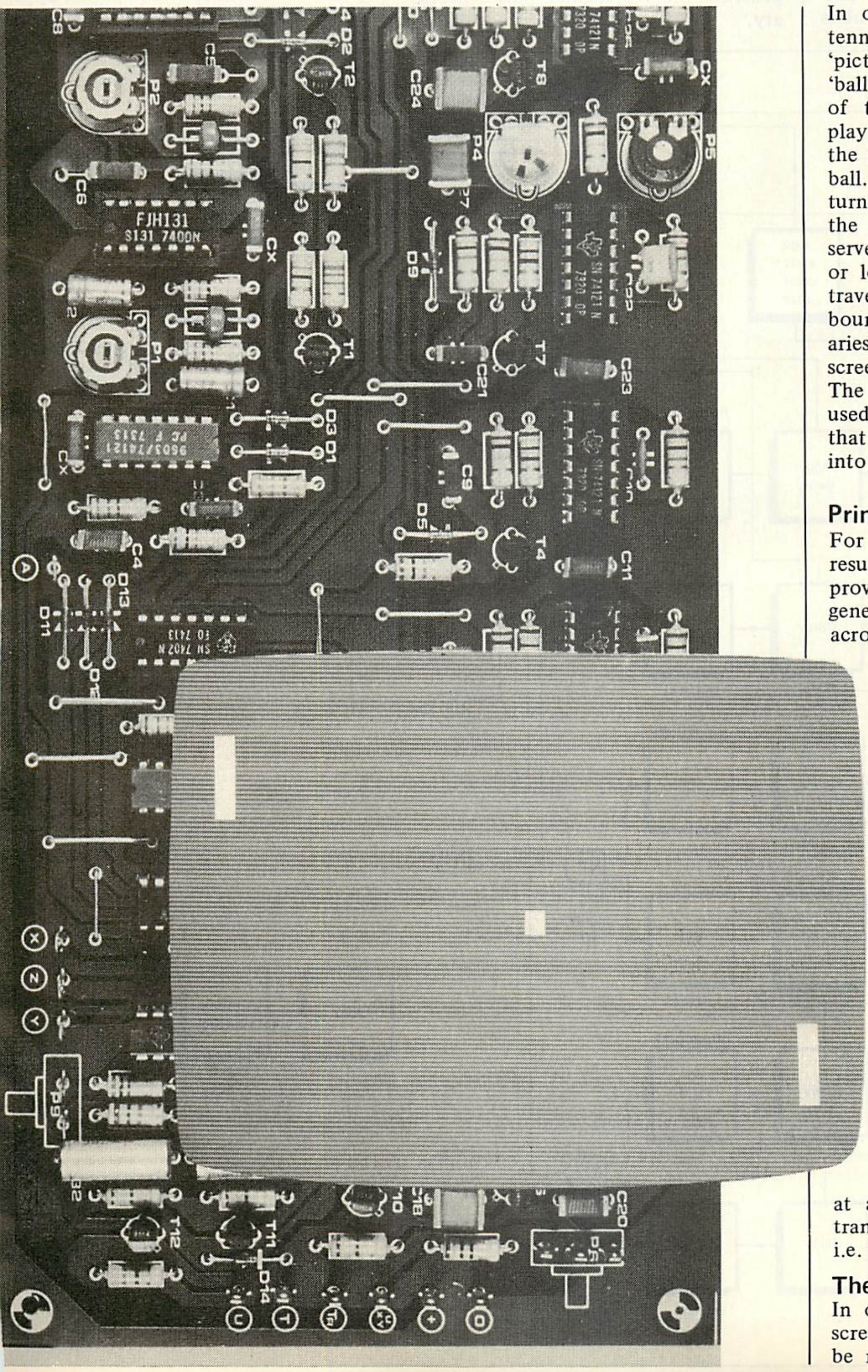
tv tennis

The popularity of television tennis games has prompted Elektor to produce a design that can easily be built by the home constructor for a modest cost. Although several designs have previously appeared on the market, it was felt that there was a need for a simple circuit using a minimum of components.



In order to keep costs down the TV tennis circuit generates the most basic 'picture' possible, i.e. two 'bats' and a 'ball'. The ball is 'served' from one side of the screen or the other and the players move their bats up and down the screen to intercept the path of the ball. If the ball strikes a bat it is returned, otherwise it leaves the side of the screen and a 'new ball' must be served. Should the ball reach the upper or lower edge of the screen during its traverse across the screen it will 'rebound'. The upper and lower boundaries are, however, not displayed on the screen.

The output of the TV tennis game is used to modulate a VHF oscillator so that the game may be plugged direct into the aerial socket of a television.

Principle of operation

For those not familiar with TV a brief resumé of the principles involved may prove helpful. A TV picture is, of course, generated by an electron beam scanning across the phosphor-coated face of a cathode-ray tube in a zig-zag fashion from top to bottom. At the end of each horizontal line the beam flies back to the left hand edge of the screen and starts the next line slightly lower down the screen. Each complete scan (frame) of the picture consists of either 405 or 625 lines, depending on the transmission standard. To reduce the bandwidth required to transmit the video information a complete frame is not transmitted in a single scanning of the picture, but is made up of two 'fields' containing half the number of lines in a frame. These two fields are interlaced with each other to make up a complete frame. Fields are transmitted at a 50 Hz rate, therefore frames are transmitted at half that rate, i.e. 25 frames per second.

The video waveform

In order to build up a picture on the screen the brightness of the trace must be modulated by varying the electron

beam current. This is controlled by the amplitude of the video waveform. So that the scanning of the electron beam in the TV set is in synchronism with the received signal in order to build up the picture correctly, field sync. pulses are transmitted (at the end of each field) and line sync. pulses are transmitted (at the end of each line).
To distinguish sync. pulses from video information, sync. pulses are negative-going and confined to a voltage below that required for zero beam current (black level). Video information occupies a range of voltages above black level up to the voltage required to saturate the TV tube phosphor (peak white level). Circuitry in the TV distinguishes between sync. pulses and video information. Field sync. pulses also have a longer duration to distinguish them from line sync. pulses.
From the foregoing some of the requirements for the circuit become apparent. Firstly, the circuit must contain oscillators capable of generating field and sync. pulses at the appropriate frequencies (50 Hz and 15625 Hz respectively). Secondly, circuitry for generating the bat and ball waveforms, and for controlling the movement of these, is required. Fortunately, since we are concerned only with white bats and ball on a black background the only modulation required is peak white level or black level, so analogue circuitry is not needed to produce these waveforms, and digital logic circuits can be used to generate the rectangular pulses necessary.

Block Diagram

The operation of the circuit is be understood with the aid of a bloc diagram (figure 1). Sync. pulses fro the field and line oscillators are mixe in the video mixer and then fed to th modulator. They are also used to co trol the timing of the other waveform

All the video waveforms are generate using monostable multivibrators and the generation of the 'bats' is simple this will be considered first. The lef hand player's horizontal bat generato IC5 is triggered continuously from th line sync oscillator. A presettable trigg delay is incorporated so that the puls appears a little time after the line syn pulse. This ensures that the bat appea some way in from the left hand edge o

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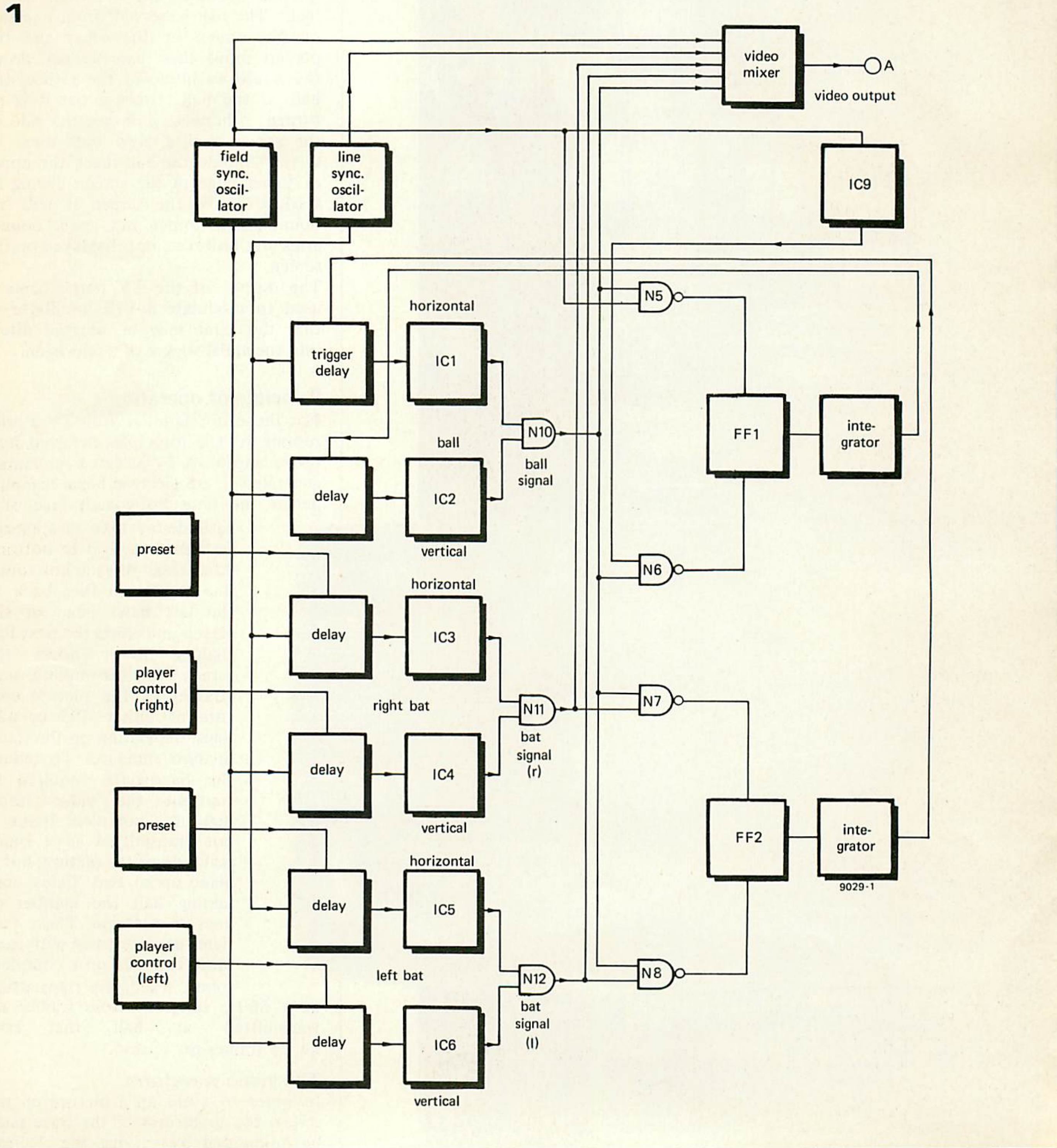
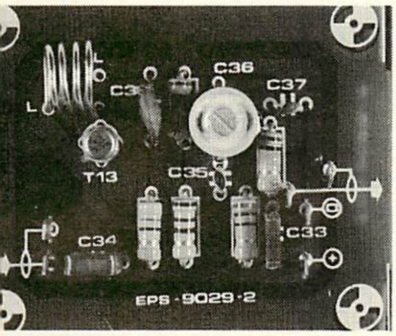


screen. The right-hand player's izontal generator IC3 incorporates a ger delay so that this bat appears r the right-hand edge of the screen. ce the triggering occurs after every sync pulse the result would be a ver- l band of white the full height of the een. This is where the vertical bat gen- or (IC6 left, IC4 right) comes in. s monostable is triggered from the d sync pulses via a delay which is tinuously variable by the player. s determines the vertical position of bat. The delayed pulse from the ver- l bat generator gates the pulses from horizontal oscillator so that they are y allowed through for the duration this pulse. The result is thus a verti- bar on the screen whose vertical ition can be varied by the player and

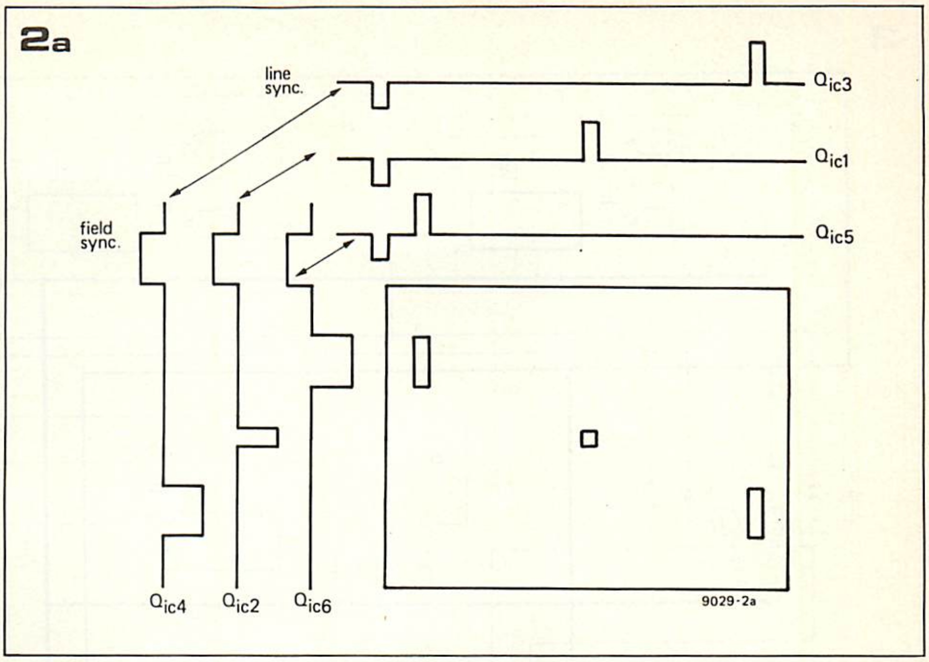


ose height (length of the bat) is ermined by the duration of the ver- l pulse. The same applies for both left- and right-hand bats.

ball is generated in a similar manner h two monostables (IC1 and IC2). wever, since the ball is continuously ving this in effect means that for vement to the right the horizontal ger delay is increasing all the time, for movement to the left it is de- asing.

downwards movement the vertical ger delay is increasing, while for up- ds movement it is decreasing. Of rse it is necessary to reverse the ction of ball travel when the ball kes a bat or the upper and lower ndaries. This part of the circuit rates as follows:

horizontal ball pulse generator l) is triggered via a delay by the line c pulses. The delay, and therefore horizontal position of the ball on screen, is controlled by the output an integrator, which is fed with a voltage and therefore generates a p which varies the trigger delay arly. The slope of the ramp (positive- negative-going) and hence the direc- n of ball travel is determined by state of flip-flop FF2. If FF2 is ially reset the ball will travel to the t. However, should the 'ball' out- and the right-hand 'bat' output h be high at the same time (i.e. the strikes the right hand bat) then the put of N7 goes low, resetting FF2 reversing the horizontal direction. en the ball strikes the left-hand bat n the output of N8 goes low, re- ting the flip-flop and causing the ball



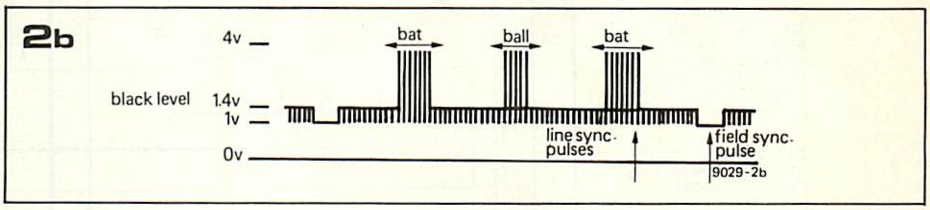


Figure 1. Block diagram of TV Tennis game (excluding modulator/oscillator).

Figure 2a. The horizontal and vertical waveforms are gated together as shown to produce the bat and ball display.

Figure 2b. The complete video waveform as seen on an oscilloscope.

to travel to the right. If the ball does not strike a bat it will leave the side of the screen and will not return until it is 'served', since the state of the flip-flop is not changed and the integrator output will eventually saturate in one direction or another. Service will be dealt with in the description of the full circuit.

Travel of the ball in the vertical direction is controlled in a similar fashion, but here the change of direction occurs at the upper and lower boundaries. The lower border of the picture corresponds with the leading (negative-going) edge of the field sync pulse, so change of direction at this boundary is accomplished by gating the ball signal with the field sync pulse in N5. To change ball direction at the top of the picture a monostable (IC9) is triggered by the trailing edge of the field sync pulse. The output pulse of the monostable is gated with the 'ball' signal to reset FF1. A timing diagram showing how the various pulses are gated together to produce the bat and ball outputs is given in figure 2, together with the general appearance of the complete waveform as seen on an oscilloscope.

Complete Circuit

The complete circuit is given in figure 3. Field sync pulses are produced by the circuitry in box A, which consists of an astable multivibrator driving a monostable to produce pulses of the correct length. Box B contains similar circuitry, but operating at a much higher frequency, to produce line sync pulses. The $\overline{Q}$ outputs of these monostables (to produce the negative-going sync pulses) are fed via D3 and D4

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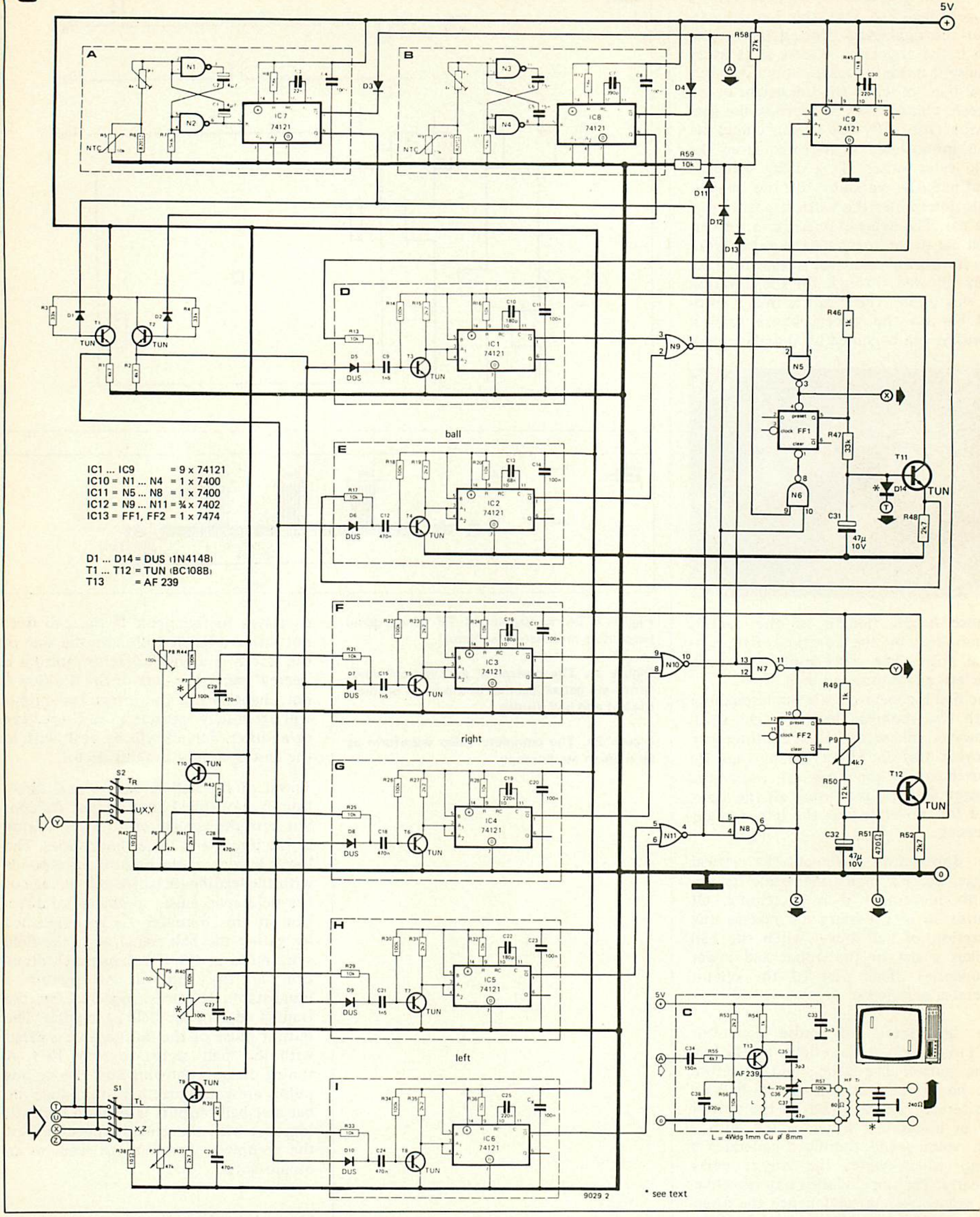
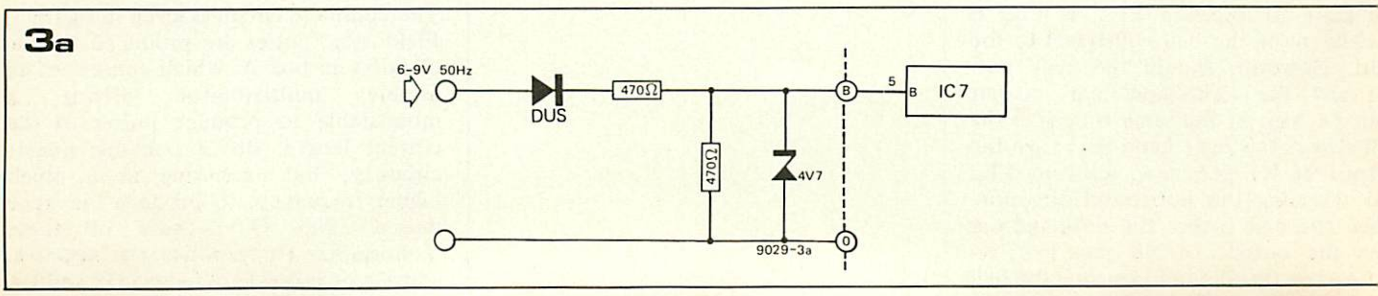

5V
IC1 ... IC9 = 9 x 74121
IC10 = N1 ... N4 = 1 x 7400
IC11 = N5 ... N8 = 1 x 7400
IC12 = N9 ... N11 = ¾ x 7402
IC13 = FF1, FF2 = 1 x 7474
D1 ... D14 = DUS (1N4148)
T1 ... T12 = TUN (BC108B)
T13 = AF 239
ball
right
left
L = 4Wdg 1mm Cu ⌀ 8mm
* see text
9029 2

3a


6-9V 50Hz
DUS
470Ω
470Ω
4V7
IC7
9029-3a

igure 3. The complete circuit of the TV nnis game. The modulator/oscillator rcuit is shown inset at the bottom right-and corner.

igure 3a. Suggested modification to derive eld sync pulses from the mains for mains nly versions of the game. This should give a ore stable picture than the free-running eld oscillator.

igure 4. Circuit of the mains power supply or TV Tennis.

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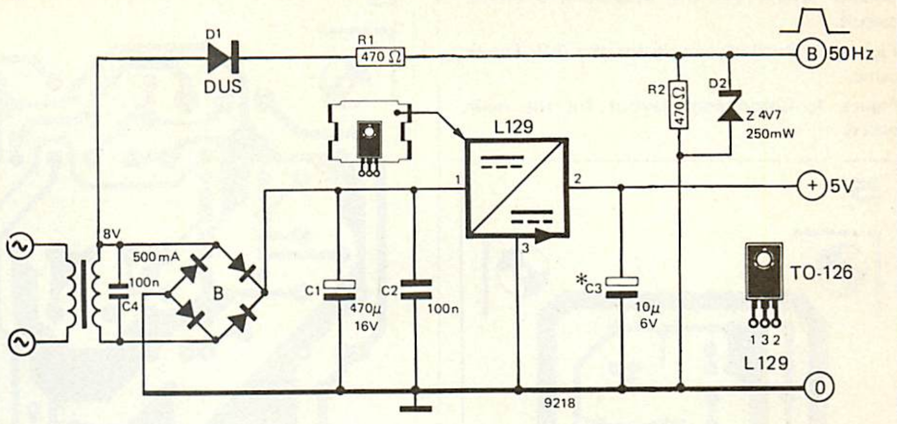


* see text

Parts list for figures 3, 5 and 7

Resistors:
R1,R2,R39,R43,R55 = 4k7
R3,R4,R47 = 33 k
R5,R9 = 10 k NTC
R6,R10 = 820 Ω
R7,R11 = 5k6
R8,R12 = 18 k
R13,R16,R17,R20,R21,R24,R25, R28,R29,R32,R33,R36,R56,R59 = 10 k
R14,R18,R22,R26,R30,R34,R40,R44, R57 = 100 k
R15,R19,R23,R27,R31,R35,R53 = 2k2
R37,R41,R48,R52 = 2k7
R38,R42 = 10 Ω
R45 = 1k8
R46,R49,R54 = 1 k
R50 = 12 k
R51 = 470 Ω
R58 = 27 k
P1,P2 = 4k7 lin. preset
P3,P6 = 47 k lin.
P4,P5,P7,P8 = 100 k lin. preset

Capacitors:
C1,C2 = 4µ7, 10 V
C3 = 22 n
C4,C8,C11,C14,C17,C20,C23 = 100 n
C5,C6 = 15 n
C7 = 390 p
C9,C15,C21 = 1n5
C10,C16,C22 = 180 p
C12,C18,C24,C26,C27,C28,C29 = 470 n
C13 = 68 n
C19,C25,C30 = 220 n
C31,C32 = 47 µ, 10 V
C33 = 3n3
C34 = 150 n
C35 = 3p3
C36 = 4 ... 20 p trimmer
C37 = 47 p

Semiconductors:
T1,T2,T3,T4,T5,T6,T7,T8,T9,T10,T11, T12 = BC547B
T13 = AF239
D1 ... D14 = 1N4148
IC1,IC2,IC3,IC4,IC5,IC6,IC7,IC8,IC9 = 74121
IC10,IC11 = 7400
IC12 = 7402
IC13 = 7474

Sundries:
L = 4 wdg, 1 mm ϕ Cu, ϕ 8 mm
HF Tr = 60 Ω → 240 Ω impedance converter (see text)

to the junction of R58 and R59. This portion of the circuitry fuctions as the video mixer. Black level occurs when the $\overline{Q}$ outputs of IC7 and IC8 are both high and the bat and ball inputs to D11, D12 and D13 are all low. The voltage at the junction of R58 and R59 is then solely determined by the value of these resistors and is about 1.35 V. When a sync pulse occurs then the junction of these two resistors is held down to about 1 V via D3 or D4. When bat or ball signals occur the inputs to D11, D12 or D13 go high, so the potential at the junction of R58 and R59 becomes about 4 V. If the unit is to be used for mains only operation the astable in box A can be dispensed with and field sync pulses may be derived from the 50 Hz mains by the modification shown in figure 3a. P1, R5, R6, C1 and C2 are omitted; the sync pulses are fed in at the original connection to the positive side of C1 on the board, and the track between this point and the output of N2 (pin 6 of IC10) must be broken.

The sync pulses are buffered by emitter followers T1 and T2 to avoid loading the monostables excessively. The buffered sync pulses are then fed via the trigger delays to the appropriate monostables which generate the horizontal and vertical components of the bat and ball waveforms. The trigger delay circuits are all identical in principle and merely vary in component values. The trigger delay for IC3 operates as follows: normally T5 is turned on by base current through R23. Its collector voltage (and hence the A inputs of IC3) is low. The cathode of D7 is held at a few volts positive by the voltage via R21 from P7 (max. 2.5 V), and since T2 is turned off the anode of D7 is at 0 V. C15 thus has a voltage across it equal to the voltage on the cathode of D7 minus the base-emitter voltage of T5. On the leading edge of the line sync pulse T2 turns on, forward biassing D7. C15 thus charges until the voltage across it is

$5\ V - V_{beT2} - V_{D7} - V_{beT5} = 3\ V$

approximately. On the trailing edge of the sync pulse T2 turns off. The voltage on the cathode of D7 therefore reverts to its initial value (the potential supplied via R21 from P7). However, since the voltage across C15 is still 3 V then the base of T5 must be negative. T5 therefore turns off. C15 now charges via R22 until the voltage on the base of T5 reaches about 0.7 V when T5 turns on and the collector voltage goes low, triggering the monostable.

It is evident that the trigger delay is dependent on the time taken to charge C15 after T5 has been turned off, which is in turn dependent upon the voltage applied to the cathode of D7 from P7. The trigger delay may thus be varied by a d.c. voltage, in the case of the bats derived from the various potentiometers, and in the case of the ball from the emitters of T11 and T12.

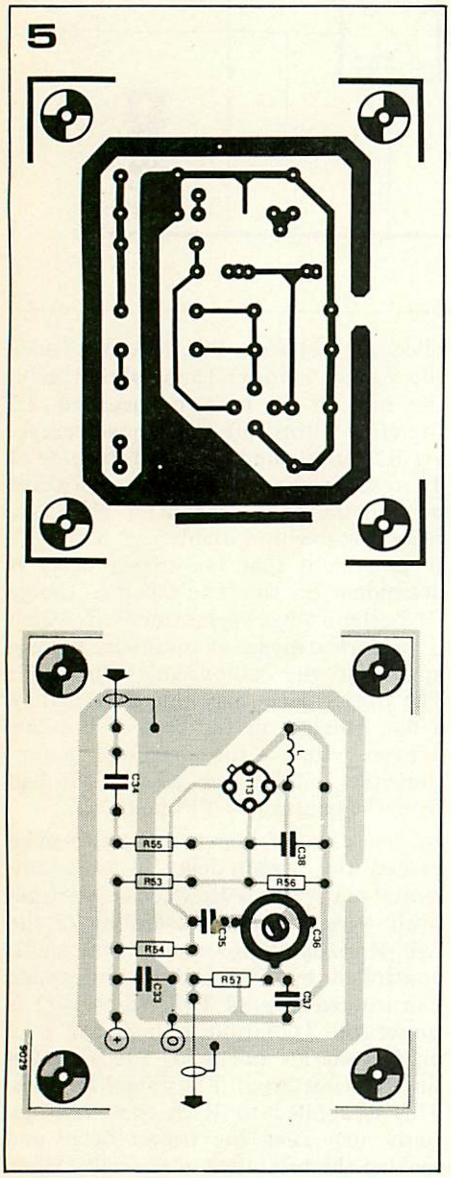
In the case of the ball, as explained earlier, the trigger delay in both horizontal and vertical directions is continuously varied to achieve motion of the ball. Horizontal movement of the ball is controlled by FF2 and the integrator constructed around T12. When FF2 is preset the Q output is high and C32 charges via P9 and R50. The potential on the emitter of T12 therefore rises. This is applied to R13, thus continuously increasing the trigger delay and making the ball move to the right. When FF2 is cleared (reset) then C32 discharges via P9 and R50. The voltage on the emitter of T12 falls, thus decreasing the trigger delay and making the ball move to the left. The rate of charge or discharge of C32, hence the speed of the ball, is determined by the setting of P9. Vertical ball movement is controlled in a similar manner by FF1 and T11. Note that in this circuit the AND-gates shown in the block diagram have been replaced by NOR-gates connected to the $\overline{Q}$ outputs of the monostables. This is of course exactly equivalent to AND-gates connected to the Q outputs (De Morgan's theorem).

The horizontal bat trigger delays are preset,by P7 for the right-hand player, and by P4 for the left-hand player. This allows the position of the bats to be adjusted to a few cm away from the sides of the screen. The vertical position of the bats is continuously adjustable, by P6 for the right-hand player and P3 for the left-hand player. P5 and P8 are presets used to adjust the bat position

Figure 5. Printed circuit board and component layout for the modulator/oscillator circuit.

Figure 6. Printed circuit for the TV Tennis game.

Figure 7. Component layout for the main board.

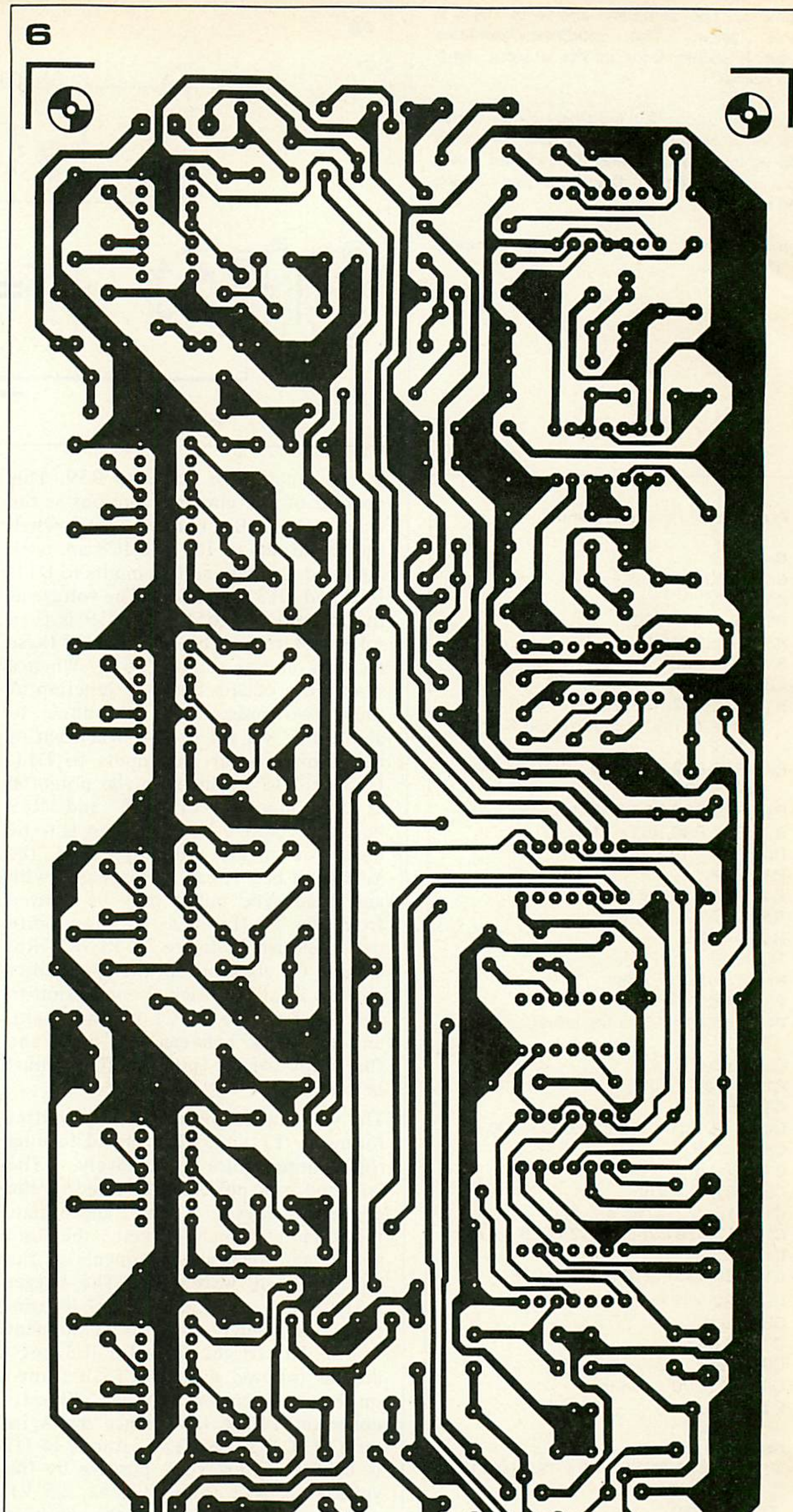


so that P6 and P3 are effective over the full height of the screen.

Service of the ball

It is evident that if the state of FF2 is not reversed by a coincidence between the ball and one of the bat signals then the voltage at the emitter of T12 will continue to rise or fall as C32 either charges or discharges, until it reaches either zero volts or supply minus the base-emitter voltage of T12. The ball will then disappear off one side of the screen or the other and will not return. For this reason (as well as for the rules of the game) it is necessary to 'serve' the ball when this has occurred.

Ideally the ball should emanate from the bat of the player who is serving. However, in practice this is difficult to achieve as it means that at the instant of service the vertical ball trigger delay must be matched to the vertical bat trigger delay. Since the delay circuits are independent component tolerances will make this unlikely. It is, however,



possible to make the ball service dependent upon the bat position at the time of service, though not coincident with it.

Service is accomplished as follows: for a service by the left-hand player the 4-pole switch S1 is closed. Thi produces several results. Firstly points X and Z are connected to ground via R38 This clears FF1 and presets FF2 so tha when the ball is served it will travel up wards and to the right.

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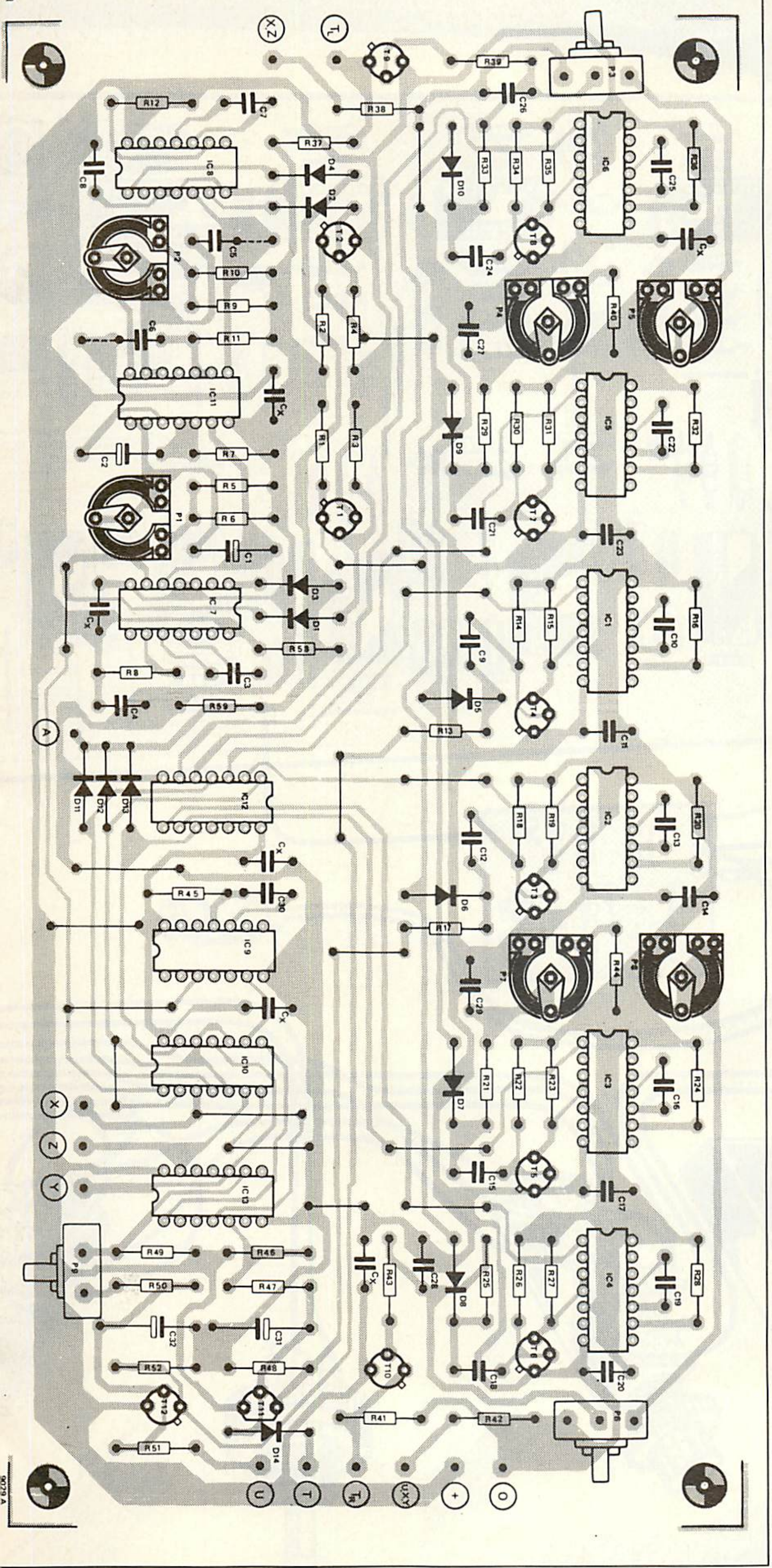

oint U (R51) is connected to positive upply, thus charging C32 rapidly and olding the ball off the left-hand side of he screen. Point T (cathode of D14) is connected to the emitter of T9, whose base is fed via R39 from P3 (left-hand bat control). The voltage on C31 is thus constrained to slightly above the emitter voltage of T9, thus determining the vertical position from which the ball will start. When the switch is released the constraints on C31 and C32 are released so the ball travels in a direction determined by the states of FF1 and FF2 (i.e. up and to the right).

Service by the right-hand player operates, so to speak the same way but backwards, i.e. pushing S2 grounds point X so that the ball still travels upwards. However, point Y is grounded so that the ball travels to the left, and point U is grounded to discharge C32 so that it starts from the right. The vertical starting position is determined by the emitter potential of T10.

Modulator and oscillator

The only part of the circuit which remains to be described is the modulator/oscillator which converts the video output at point A into a VHF signal suitable for feeding direct into a television aerial socket. This part of the circuit is shown inset in figure 3. An AF239 forms the basis of the oscillator circuit which is tuned to the required frequency by the coil L and C36/C37. The output may be fed direct into an unbalanced 50 - 75 Ω coaxial cable terminating in a normal TV coax plug, or if the TV has continental type 240 - 300 Ω twin feeder input then the output must be fed through an inverse balun transformer before feeding into the 300 Ω feeder.

Power Supply

A power supply which is absolutely free from mains ripple is absolutely essential for the TV Tennis game. The reason for this is fairly obvious. Any mains ripple will cause a variation in the input voltages to the trigger delay circuits, and hence in the trigger delays. This produces distortion of the picture as the trigger delay varies down the screen height. For portable operation a 6 V lantern battery or accumulator may be used, with a decoupling capacitor across the supply pins on the board (say 1000 μ), whilst for mains only operation the 5 V power supply shown in figure 4 is strongly recommended. It is based on an integrated circuit regulator the L129. This IC will provide a stabilised voltage of 5 V from inputs up to 20 V and will supply a maximum current of 600 mA. However, to minimise power dissipation within the IC it is recommended that a transformer with a 6.3 V RMS secondary voltage be used. This will give a D.C. input to the IC of about 9 V. The bridge rectifier is made up of 4 1-amp diodes such as 1N4001. Note that C3 should be a tantalum type to reduce output noise and any tendency to R.F. instability. Components D1, D2, R1 and R2 correspond with figure 3a.

Construction and adjustment

The p.c. board and component layout for the VHF oscillator are given in figure 5, for the main board in figures 6 and 7, and for the power supply in figure 8. A point-to-point wiring diagram is given in figure 9. Slider poten-

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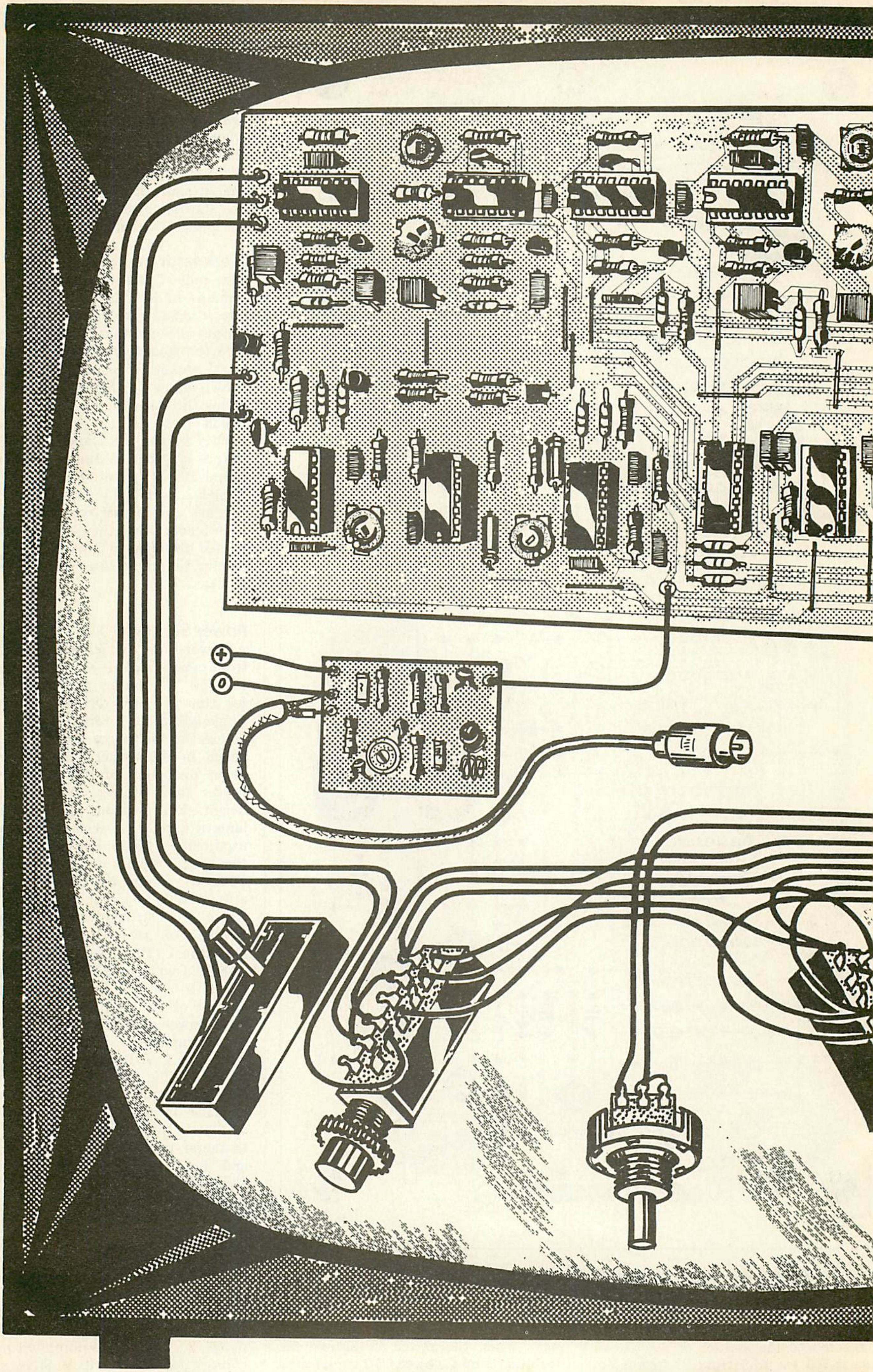

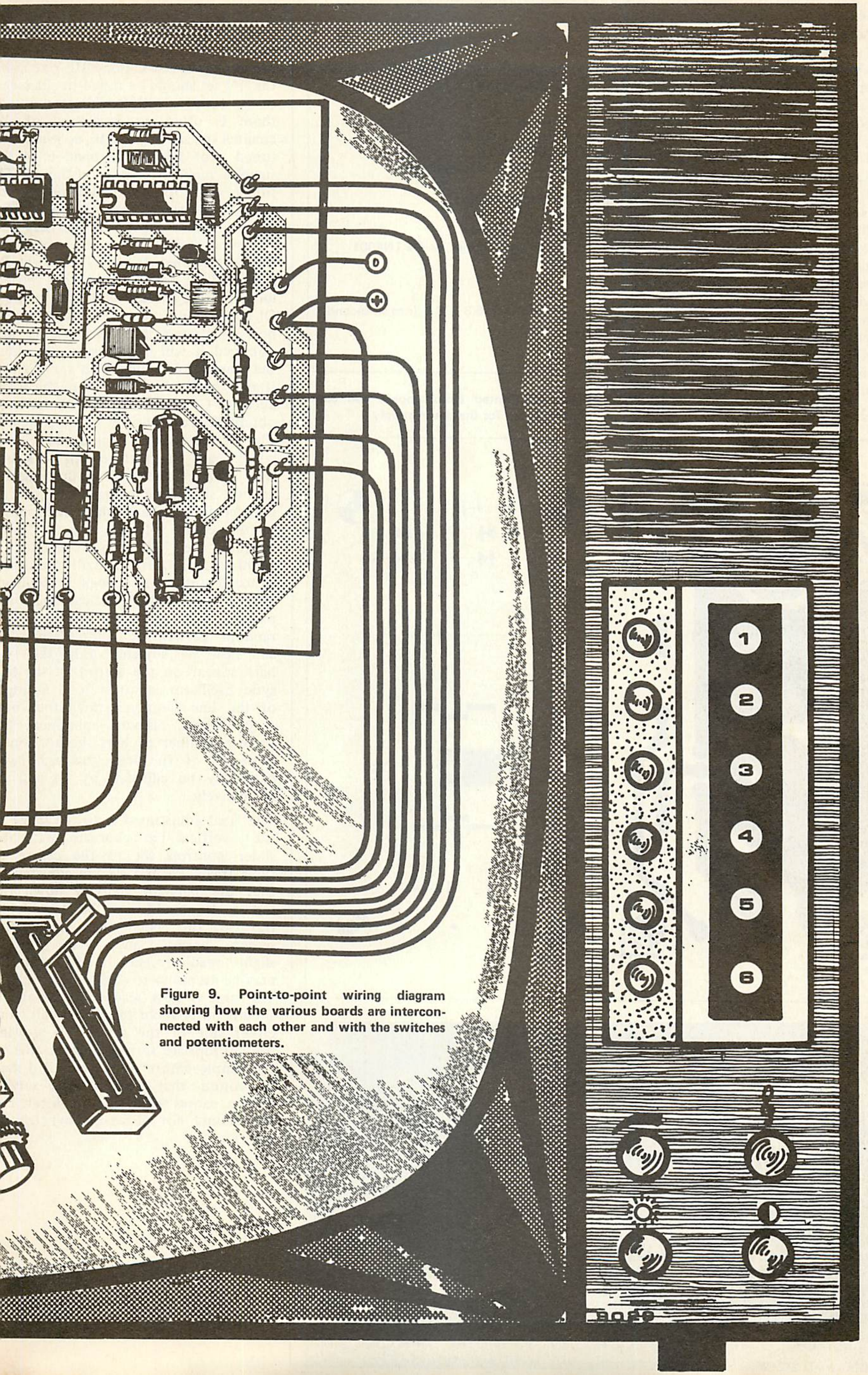

Figure 9. Point-to-point wiring diagram showing how the various boards are interconnected with each other and with the switches and potentiometers.

tiometers are used for the bat controls as these give easier control than rotary types and are sufficiently robust for domestic use. The oscillator is mounted on a separate board as it must be housed in a completely screened box to avoid radiated interference and to minimise pickup of other transmissions. A small diecast or pressed aluminium box with a lid is suitable. The main board housing should also be a metal box. Having checked that the circuit is correct and that the power supply is giving the correct voltage before connecting it to the unit, power can then be applied and the output of the VHF oscillator plugged into a TV set. Due to the harmonics generated extending into the hundreds of MHz the unit will function on both VHF and UHF although the line oscillator frequency is of course different for 405 and 625 line reception. Initially all the potentiometers should

Parts list for figures 4 and 8

Resistors:
R1,R2 = 470 Ω

Capacitors:
C1 = 470 µ/16 V
C2,C4 = 100 n
C3 = 10 µ/6 V (tantalum)

Semiconductors:
D1 = DUS
D2 = 4.7 V zener
B = Bridge rectifier, or 4 x 1N4001
IC1 = L129

Sundries:
Transformer, 6.3 ... 8 V (r.m.s.) secondary

Figure 8. Printed circuit board and component layout for the power supply.

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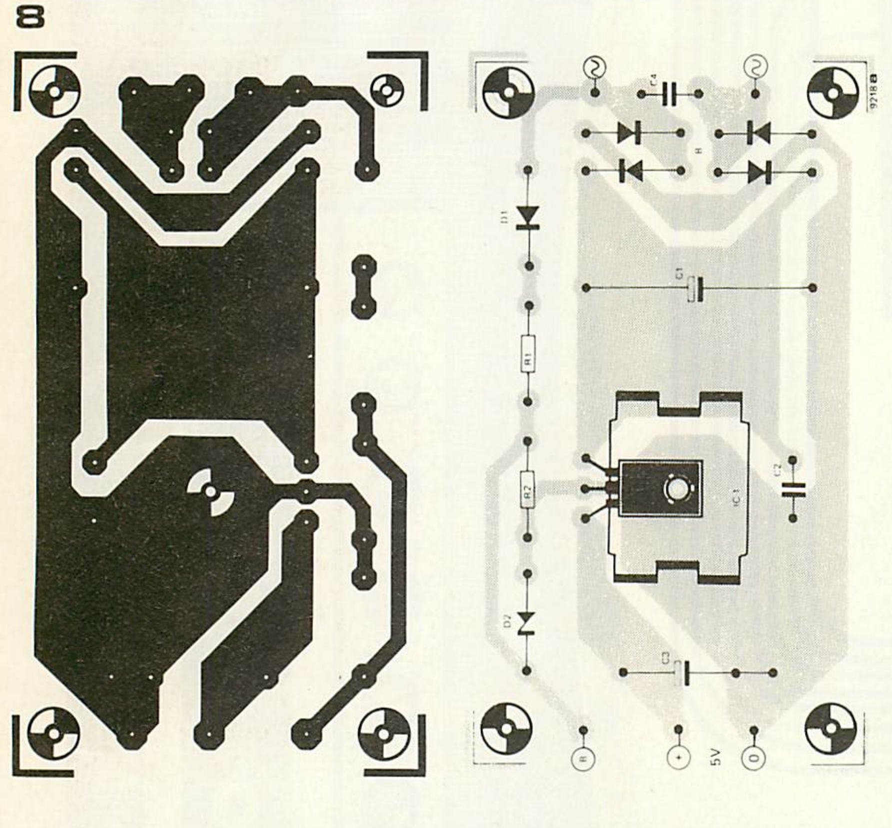

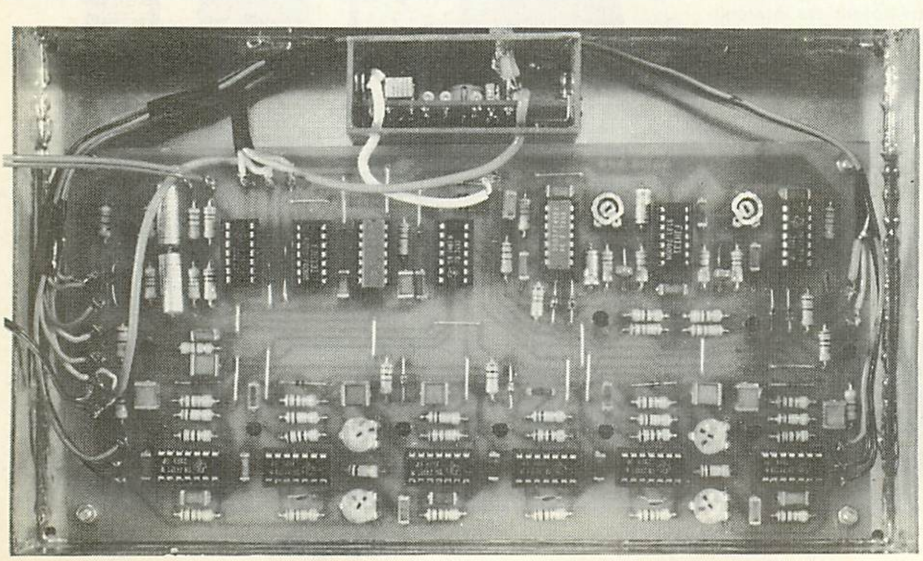

be set at the middle of their travel. If oscilloscope is available the waveform point A can be checked, if not, th proceed as follows. For VHF operati the TV set should be tuned to channel or 9, though with pushbutton tune there is often no indication of t channel the set is tuned to, so it must tuned over the entire band until t signal is picked up. By adjusting the T tuning and C36 it should be possible tune in the signal. At first the pictu will be rather chaotic as the field a line sync oscillators are not running the correct frequency. By adjusting it should be possible to obtain vertic lock, i.e. the picture will stop 'rollin Of course with mains field sync there no adjustment and if lock is n obtained it will be necessary to adju the frame hold control on the TV se It may be found that, due to the tole ances of C1 and C2 it is not possible obtain the correct field sync frequenc The oscillator may run at 25 Hz, which case the picture will lock b will jitter considerably. In this case C and C2 should be reduced to 2 µ 2. may be found that a black bar appea in the centre of the screen. This because the field sync oscillator running at 100 Hz, and P1 should adjusted until normal lock is obtaine Having obtained vertical lock t picture will probably consist of random pattern of white dashes. can now be adjusted until the tw bats appear on the screen. If the li sync oscillator is tuned to a multip of the line frequency then four ba may appear. Having obtained t correct number of bats the horizont positions of the left- and right-ha bats may be adjusted by P4 and respectively.

The final adjustment is to the range the vertical bat controls. With t slider controls set to the centre their travel P5 and P8 are adjusted that the bats are halfway down t screen. It should now be possible traverse the bats over the enti screen height, and some furth slight readjustment of P5 and may be necessary to achieve this.

The unit is now ready for use and should be possible to serve a ball fro either side of the screen by pressi the appropriate service button. Due the simple nature of the circuit it ma be found that pressing the servi button causes slight picture jitter, b this should not prove inconvenient practice.