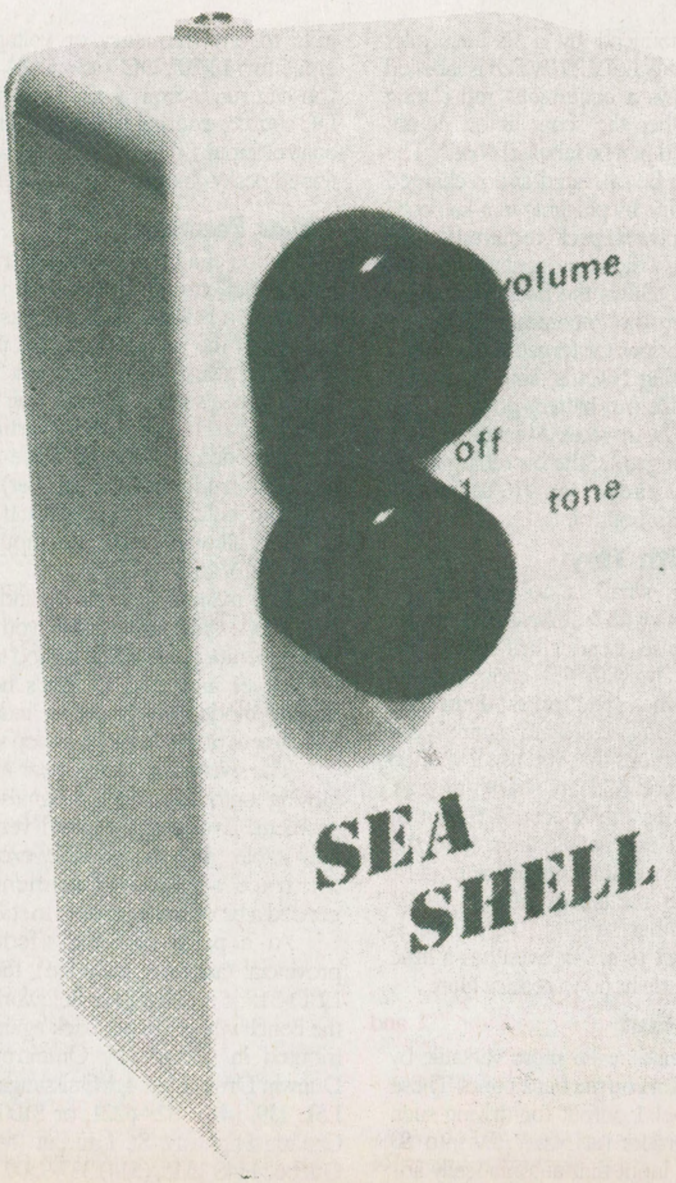
Wavesound Synthesizer

An exercise in the digital synthesizing of sound.

ANDY FLIND



This project will recreate the sound of the surf, either through headphones (try the effect during a stressful day at the office) or through a hifi, where judicious use of tone controls will simulate anything from actual presence on the beach to the muffled roar as heard from a distance. The realism is quite incredible; after a few minutes one tends to forget it's a simulation, the sound is unconsciously accepted as the real thing.

Design Objectives

The design objectives for this project were simple. The sound should be as realistic as possible, in stereo, with appropriate tone and volume changes plus apparently random variations.

There would be absolutely no compromise in sound quality. Also, if possible it was to be pocket-sized, portable and capable of driving Walkman-type headphones.

In practice this meant low-current operation for prolonged use from a single 9V battery. Unfortunately the first objective led to a fairly complex unit, which raised difficulties with the second, but eventually a successful design was arrived at.

Although the circuit is rather complex, all the components are fairly cheap so it is inexpensive to build. The complexity stems mainly from there being two of almost everything; if only one channel were needed it would be much simpler. However, the stereo sound produced is incredibly realistic; constructors will probably agree that the final result is well justified.

White Noise

The first problem was generation of suitable "white noise". Considering the effort sometimes needed to minimize electronic noise, it's amazing how difficult it is to find some when it's wanted.

Most recognized sources are not, in fact, very noisy; they only cause problems where high gain levels are used. The usual "noise generators" found in projects are Zeners and reverse-biased diode or transistor junctions.

Most Zeners and diodes produce less than a millivolt and, of transistors tried, fewer than one in five proved suitable. The quality of sound also varied widely between devices.

A prototype of this project used special "noise diodes" which were very effective, but subsequently these were withdrawn by the manufacturers and no suitable substitute could be found. Eventually, the circuit was redesigned with a digital noise source, based on IC4, IC5 and IC6 (see Fig. 2). The principle is shown in simplified form in Fig. 1, where a shift register has its output exclusive-OR'd with the output from a tap at stage *n* and returned to the input.

If the shift register is clocked at a suitable frequency, the output will be a pseudo-random series of 1's and 0's which will take a considerable time to repeat. Just how long depends on the number of stages and the tap position; choice of tap for the longest possible sequence requires involved calculation and is best left to the experts, but the arrangement used in this design has a 33-stage register with a tap at stage 14 and when clocked at 1MHz takes over two hours to repeat.

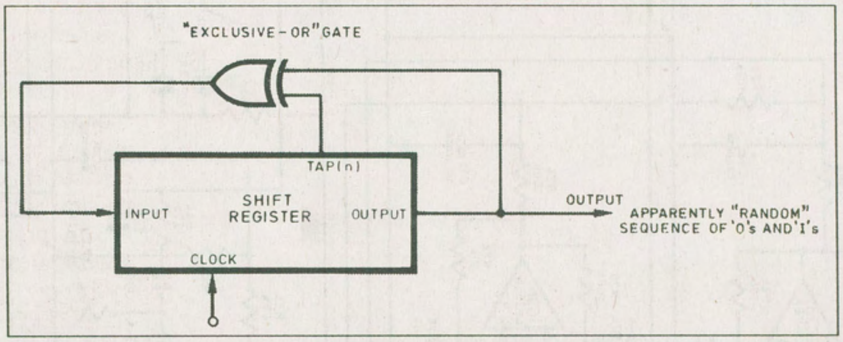


Fig. 1. A simplified digital noise generator using a shift register.

Circuit Description

In the full circuit diagram for the Seashell shown in Fig. 2, the clock consists of IC4a and IC4b, running at approximately 1MHz and driving a 33-stage register made up from IC5 and IC6. The register output, from IC6 pin 9, is EX-OR'd with the output from the tap, IC6 pin 13, by IC4c for return to the input, IC5 pin 1.

It is possible for the circuit to get into a state where all the circulating bits are "0's". This would result in an input of I, so the output would appear to be continuously low. This condition is avoided by the inclusion of capacitor C12 and resistor R27, which will rapidly inject a 1 to break the sequence should it occur.

Two apparently independent noise sources are required by this project. If a stereo amplifier is switched to mono and turned up until the background hiss is audible, the effect of switching to stereo will immediately be apparent. From being a mere irritant, the noise will acquire depth, suggestive of wind and wide open spaces, and this is the type of sound needed for processing into waves.

Instead of building two separate sources (with six chips.) the register input is EX-OR'd with another tapping point by the remaining gate IC4d to become a second output. A pair of two- stage low-pass filters convert signals, and attenuation by resistors R32 and R33 reduce them to a suitable level, about 35mV RMS, for the following stages. The two sources look sufficiently unrelated for the intended purpose on a scope, and they certainly sound right.

Volume and tone are controlled by diodes. Taking the channel following capacitor C17, the signal passes through diodes D5 and D7 to appear across resistor R40. The diodes act rather like variable resistors whose resistance falls as the DC current flowing through them is increased. The current needed is just a few microamps, supplied mainly from resistor R36. From here the signal passes through C21 and R44, which with capacitor C23 provides "top cut" tone control varying with the current, from resistor R42, passing through diode D9.

The full control network includes diode D3, resistors R8, R11, R38, and capacitors C19, and C25, and with the values given produces a realistic crashing-wave sound when supplied with a positive pulse lasting about two seconds. The tone change lags slightly behind the volume, so the wave crashes initially at high pitch, shifts rapidly to a deep roar, then as it dies away the pitch gradually rises again for a realistic backwash effect.

Volume control VR1a lets the user adjust the level before amplifier IC7a, which can produce an output of about 200mV RMS maximum. IC7 is a 1458, the dual version of the trusty old 741. Tests proved this to be capable of directly driving Walkman-type headphones for portable use.

Switch S1b offers two levels of overall tone control if required. The tone positions could well, in fact, be labelled "near", "far" and "furthest". The second channel, following capacitor C18, works in exactly the same way.

Sound Waves

The rest of the circuit is concerned with providing suitable pulses to control the sounds. IC1a and IC1b for a simple clock, cycling about once every ten seconds. The output is differentiated by capacitor C2 and resistor R3, so the coupled outputs of IC1c and IC1d are normally high, but go low for about one second with each clock cycle.

Each output pulse discharges capacitors C3 and C4 through resistors R4 and R5, taking about four seconds to reach half supply voltage where IC2c and IC2d each go high for about two seconds.

These positive (high) pulses are fed to the wave generators by D3, R11 and D4, R12. When the outputs go low again they provide the discharge paths for slow sound decay through resistors R8 and R9.

If the waves simply crashed regularly and in unison they would sound boring and unrealistic (though less control circuitry would be required.), so IC3 introduces a little randomizing. The two amplifiers in this chip are configured as very slow running astable oscillators, with slightly different rates set by resistors R19 and R20.

The signals found on capacitors C7 and C8 are very slow triangle waves (approximately), of which small proportions are fed to capacitors C3 and C4 by resistors R13 and R14 respectively. This alters the times taken by these capacitors to charge to half-supply, slightly varying the switching times of the following gates.

The apparent effect is that the waves occasionally crash initially a little to one side. A little crosstalk introduced by resistor R10 improves the realism. Two further signals taken from IC3 are fed directly into the amplitude controlling stages by resistors R34 and R35. The high value of these resistors keeps the effect small, but it results in the backwash effect after each wave varying in volume and apparently swinging around. Again a little crosstalk, this time through resistor R25, improves the effect.

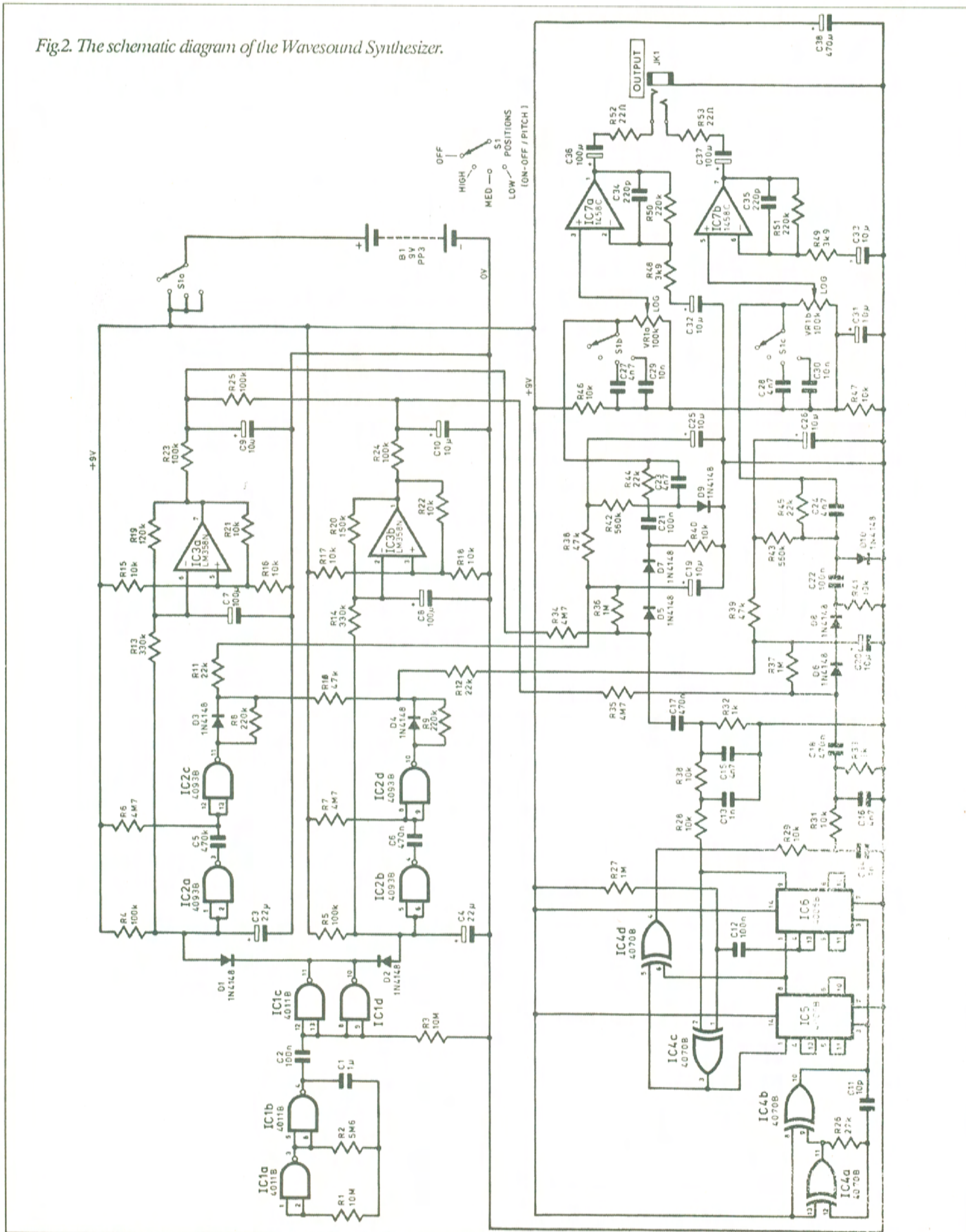
Construction

All components except the Volume control VR1, Tone (or Presence) switch S1 and the Headphone socket JK1 are accommodated on the printed circuit board. The component layout (assuming the board has not been cut) and copper foil master pattern is shown in Fig. 3.

There can be few projects where constructors are advised to begin by sawing the circuit board in half. This isn't necessary, of course, if it is to be housed in a case that will accept it in one piece. However, if pocket-size is required this is the first step.

The cutting line is marked by a dotted track, along the centre of the copper side of the board which should be carefully sawn

Fig.2. The schematic diagram of the Wavesound Synthesizer.



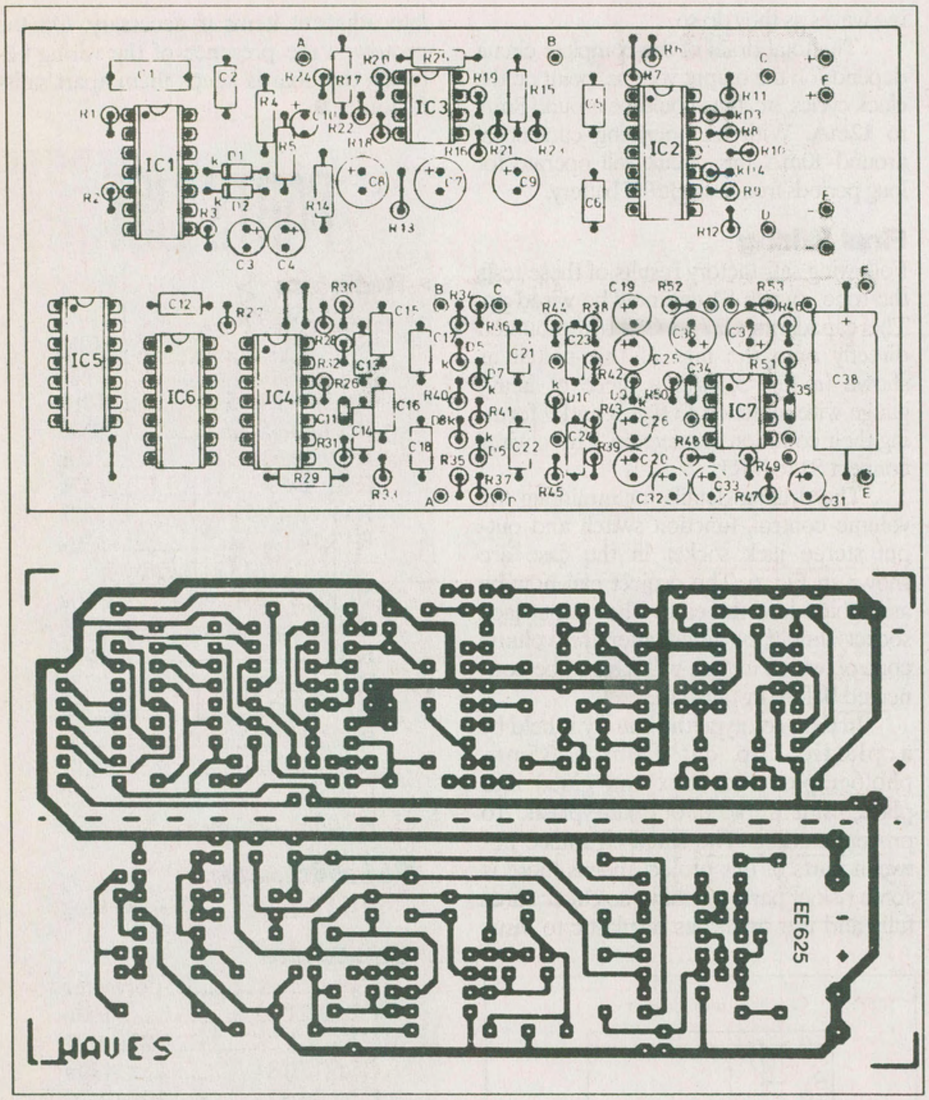


Fig. 3. The PCB and component layout. This board is cut in half if using the case specified.

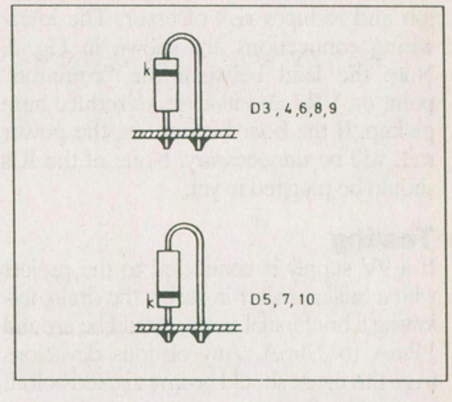


Fig. 4. Polarity guide for mounting the diodes on the PCB.

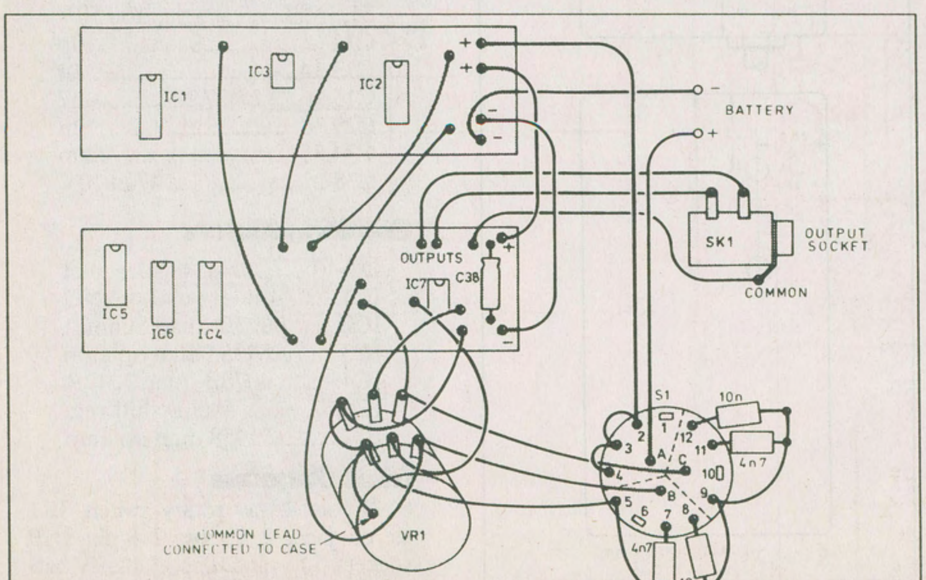


Fig. 5. Interwiring to the boards, VR1, JK1 and S1.

with a fine-toothed hacksaw. The two halves should then fit lengthwise into the moulded slots of the recommended case and the lid should fit; they can be trimmed with a file if necessary. Their edges can be smoothed with emery paper when cutting is complete.

As the components are quite densely packed together a fine-tipped iron is essential for construction. The components should be of the correct type, otherwise they may not fit. In particular, all the non-electrolytic capacitors, save C39 and C40, are miniature polyester layer types, not the larger polyester film variety.

All the electrolytics save capacitor C11 are the single-ended PCB mounting type. Their dimensions are 11mm (high) X 5mm (dia.) for 10uF and 22uF and 11mm X 6.3mm for 100uF. The height is important as space between the boards is limited.

The layout of all components is shown in the overlay drawing, Fig. 3. Care should be taken over the polarity of the diodes; Fig. 4 provides additional guidance for their installation. If they are bent and placed as shown their polarities will be correct.

The electrolytic capacitors normally have their negative leads identified with a broad stripe and all except capacitors C36 and C37 are fitted with positive sides uppermost. They must be fitted close against the board to minimize overall height. DIP sockets should be used for all the ICS, which should not be plugged in at this stage.

It is always preferable where possible to test a new project in stages, to minimize chances of catastrophic damage and simplify the location of any faults which may be present. Before starting to test this project, all connections between the boards and controls should be completed, temporarily if preferred, except those to the rotary switch S1 which should be added afterwards.

The use of coloured ribbon cable, though not essential, makes for a neater job and reduces risk of error. The interwiring connections are shown in Fig. 5. Note the lead between the "common" point on VR1 and its case, to reduce hum pickup. If the board is not cut, the power rails will be unnecessary. None of the ICs should be plugged in yet.

Testing

If a 9V supply is connected to the project with a milliammeter in series, the drain, following a brief initial surge, should be around 1.3mA to 1.4mA. Any obvious deviations from this figure should be investigated before progressing further.

If all seems well, IC7 can be fitted and power reapplied. This will raise the consumption to about 3.5mA. The voltage on pins 1 and 7 of this IC should be half the supply, or about 4.5V.

If the headphones are plugged in, a fair amount of hum will probably be heard, especially if the volume control VR1 is turned up. Touching the top ends of the volume control sections should produce loud hums on the corresponding headphone. Following this test, the volume should be turned right down.

The next stage is to fit IC4, IC5 and IC6. This will raise the drain to about 7mA. IC4 pin 4 and IC6 pin 9 should, if tested for DC voltage, show about half the supply. These are the outputs and if they are operating correctly this will be their average level. If there appears to be a problem, a check on IC4 pin 10 should show about half the supply voltage, indicating that the clock oscillator is running.

Fitting IC3 will increase the current to 7.7mA. IC3 pins 1 and 7 should be switching from 0.5V to 7.5V and back very slowly, about every 20 to 30 seconds. These provide a small amount of drive to the diode attenuator circuits, so if the volume is turned up a little the output sounds should be heard while they are positive.

If IC1 is now plugged in the current taken will start to vary slightly with the oscillator action. Pin 4 of IC1 should be clocking up and down at about 10 seconds per cycle, while pin 10 and pin 11 will be normally high, pulsing low about once every 10 seconds and pin 4 goes high.

IC1 on its own will not affect the audio output. Fitting IC2 should, however, result in the full "wave" sounds appearing.

If testing is needed here, pin 3 and pin 4 of IC2 should be normally low but go high for about three to five seconds in every 10 seconds, while pins 10 and 11 should also be normally low, going high for about two seconds in every 10 and triggering waves as they do so.

The total drain of the complete circuit depends on the output volume, point on the clock cycles, *etc*, but should be around 8mA to 12mA. With an operating current of around 10mA this circuit will operate for long periods from a single 9V battery.

Final Wiring

Following satisfactory results of these tests the tone switch S1 can now be wired up. The capacitors C27 to C30 are mounted directly onto the tags of this switch as shown in Fig. 5, with a piece of heavy gauge wire attached to tags 5 and 9 forming their common connection. Three wires connect S1 to VR1.

The drilling details for mounting the volume control, function switch and output stereo jack socket in the case are shown in Fig. 6. The project can now be assembled into the case. The output jack socket should be fitted after the volume control, which in turn will have to be connected before installation.

In the prototype the battery is held by a plastic clip cut from a 35mm photographic slide box and glued into place, with a piece of foam plastic to prevent rattling. The small clearance between parts of this project means there is some risk of parts touching, so check carefully and use small bits of plastic to insulate adjacent items if necessary. On the prototype the presence of the wiring between the boards keeps them apart satisfactorily. ■

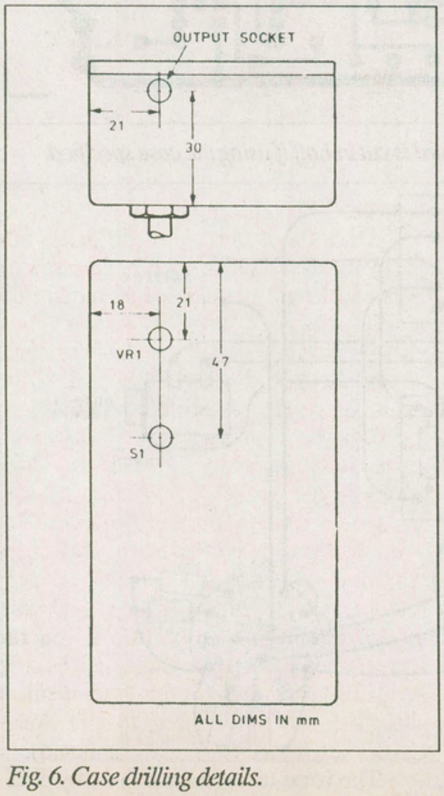


Fig. 6. Case drilling details.

PARTS LIST

Resistors

All .5W, 1%

R1,3	10M
R2	5M6
R4,5,23,24,25	100k
R6,7,34,35	4M7
R8,9,50,51	220k
R10,38,39	47k
R11,12,44,45	22k
R13,14	330k
R15,16,17,18,21,22,28 29,30,31,40,41,46,47	10k
R19	120k
R20	150k
R26	27k
R27,36,37	1M
R32,33	1K
R42,43	560K
R48,49	3k9
R52,53	22

Potentiometer

VR1	100k dual log

Capacitors

C1	1u polyester
C2,12,21,22	100n
C3,4	22u 16V
C5,6,17,18	470n
C7,8,36,37	100u 10V
C9,10,19,20,25,26 31,32,33	10u 50V
C11	10p
C13,14	1n
C15,16,23,24,27,28	4n7
C29,30	10n
C34,35	220p
C38	470u 10V

Semiconductors

D1-10	1N4148 sil. signal
IC1	4011B quad NAND
IC2	4093B quad Schmitt
IC3	LM358 dual op amp
IC4	4070B quad X-OR
IC5,6	4006B shift reg.
IC7	1458 dual op amp

Miscellaneous

S1 3-pole 4-way rotary switch, JK1 stereo jack, 2 knobs, 2 8-pin DIP sockets, 5 14-pin DIP sockets, 9V battery and connector.