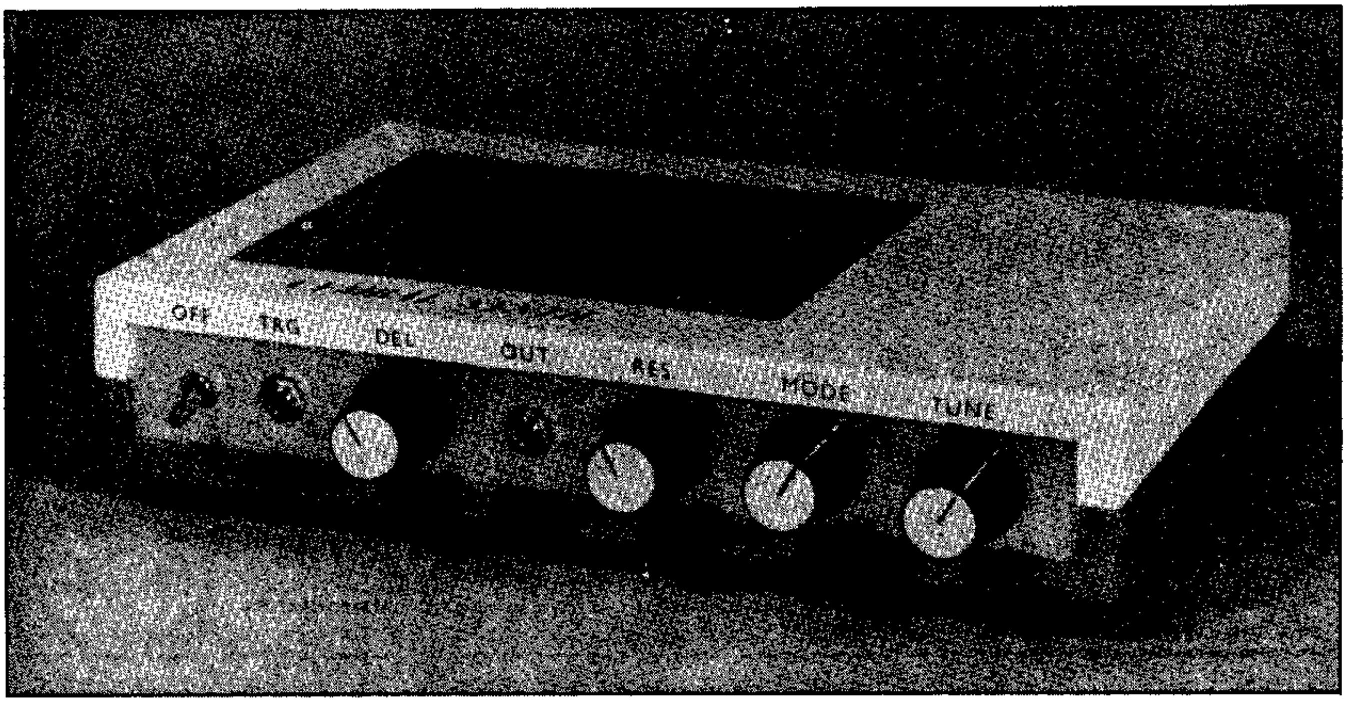


Cymbal Synthesiser

Using a series of ring modulation circuits, we bring you a synthesizer which gives a good cymbal effect for a reasonable price, and can be driven by hand or by a micro.

By R.A. Penfold

THE CYMBAL synthesiser described here has been produced after trying a number of different design types, and the result is a unit that has a reasonable low parts count and cost, but gives a creditable level of performance. It can be triggered either by hitting the case, or by a trigger pulse from a computer or sequencer. The nature of the sound can be varied by means of four controls, one of which is a decay control that enables decay times from less than a tenth of a second up to about six seconds to be achieved. The other three controls are part of a state-variable filter, and they control mode (highpass, bandpass, and lowpass), frequency, and resonance.

The circuit is powered from a built-in 9 volt battery, and the output is a few volts peak to peak from a low impedance source. The unit can therefore drive practically any amplifier, tape recorder, etc.

Cymbal Synthesis

A cymbal produces what is basically a noise signal, and the obvious way of synthesising a cymbal sound is to start with a white noise signal, and then use filtering and envelope shaping to give a suitable effect. In practice the use of white noise plus bandpass filtering and suitable envelope shaping does give a cymbal type sound, but one that has a definite lack of realism. The problem is that a cymbal is metal plate, and has the characteristic metal sound embedded in the noise sound it generates. White noise, even after filtering to give a more resonant sound, lacks this metallic content.

Metallic (gong and bell) type sounds can be generated by ring modulating two tones. Ring modulation gives heterodyning of the two signals so that sum and difference signals are produced. For example, tones at 100Hz and 250Hz would generate a sum frequency of 350Hz (100Hz + 250Hz) and a difference frequency of 150Hz (250Hz − 100Hz). This gives frequencies that are not harmonically related to the input frequencies, and it is this non-harmonically related frequency content that distinguishes bell and gong sounds from string, pipe, and most other musical sounds.

The original intention was to use two or three ring modulated tone generators plus a white noise source to provide the basic signal. The idea of this was simply to have the white noise provide the main signal with a small amount of ring modulated tone signal to add the missing metallic content. In practice this did not seem to work very well, with the two separate sound sources always sounding as such, and never mixing properly to produce the desired effect.

No White Noise

After some considerable experimentation the rather different approach outlined in the block diagram of **Figure 1** was arrived at. At a first glance this may look rather involved, but in essence the system used here is quite straightforward.

In the final version the white noise source has been eliminated from the design altogether. On the other hand, the ring modulation section has been substantially expanded. Oscillator 1 is modulated with oscillator 2, and oscillators 3 and 4 are processed in the same way. The two modulated ouputs are then processed by a third ring modulator. The oscillators all operate at fairly low audio frequencies, and have squarewave outputs that are rich in harmonics. The result of this is that a vast range of new frequencies are generated by the ring modulation, giving a signal that has a definite metallic sound to it, but is a form of noise signal due to the vast number of output frequency components.

This gives the type of signal required for this application, but just four oscillators produce a signal that has a bias to the metallic sound, rather than the noise-bias that we require for cymbal synthesis. In order to overcome this problem two more oscillators and ring modulators are used to process the signal, giving a final output that is even more rich in frequency components. In fact the output from the final ring modulator sounds almost like white noise with very little metallic content, but after filtering a suitably balanced sound is obtained.

The filter is a state variable type, and for the best cymbal sound it is used at a fairly high cutoff frequency, with a moderate amount of resonance, and in the highpass mode. However, by using different filter settings some interesting non-cymbal sounds can be obtained, and it is well worthwhile having the other two filter modes available.

The output of the filter is taken to the output socket via a voltage controlled amplifier (VCA) and a buffer stage which gives the unit a low output impedance. The VCA is controlled by a simple attack-decay type envelope shaper which has a fixed and short attack time, plus a much longer and variable decay time. An amplifier at the input of the envelope shaper enables it to be triggered by means of an input pulse or the signal from a pick-up. A buffer stage interfaces the high output impedance of the envelope shaper to the low input impedance at the control input of the VCA.

The Circuit

The circuit diagram of the oscillator, ring modulator, and filter sections of the unit is shown in **Figure 2**, while **Figure 3** gives the circuit diagram of the envelope shaper and VCA sections.

Taking the oscillator and ring modulator circuit first, all six oscillators are of basically the same type, and use two CMOS inverters in the standard astable configuration. A resistor is used to bias each pair of inverters into linear operation, and a capacitor is used to provide positive feedback that produces oscillation. The operating frequency depends on the time constant of the bias resistor and feedback capacitor. In some cases the oscillators are based on true CMOS inverters, in other cases either NAND or exclusive NOR gates wired as inverters are used. The oscillators all have slightly different resistor values so that they operate at different frequencies.

The ring modulation is provided by exclusive OR (IC2) and exclusive NOR (IC4) gates. These provide what is only a very crude form of ring modulation, but as we are only dealing with squarewave signals in this case the use of proper balanced mixer type ring modulators is unnecessary. For those who are unfamiliar with exclusive OR gates, which are admittedly not one of the most common forms of logic gate, they give a high output if either input 1 or input 2 is high. However, unlike an ordinary OR gate, a high output is not obtained if both the inputs are high. In other words, the output is high if just one of the inputs is high. An exclusive NOR gate gives the same action, but its output is inverted. In either case a good mixing action is obtained, but the same is not true if AND, NAND, OR, or NOR gates are used to provide the mixing. These tend to give an output that is predominantly in the high or low state (depending on the type of gate used), and they give a rather spikey and "rough" sounding output that is not suitable for our present purposes.

The filter is a conventional state variable type having bandpass, lowpass, and highpass outputs. S1 connects the desired output through to the VCA. With the addition of another operational amplifier a notch output could be provided as well, but this type of filtering is of little value in this application, and this feature has therefore been omitted. RV2 is the resonance control, and in the bandpass mode it enables the bandwidth of the filter to be controlled. In the highpass and lowpass modes it can be used to provide a peak in the response at the cutoff frequency. RV1 enables the cutoff frequency to be adjusted from less than 1kHZ to over 10kHZ.

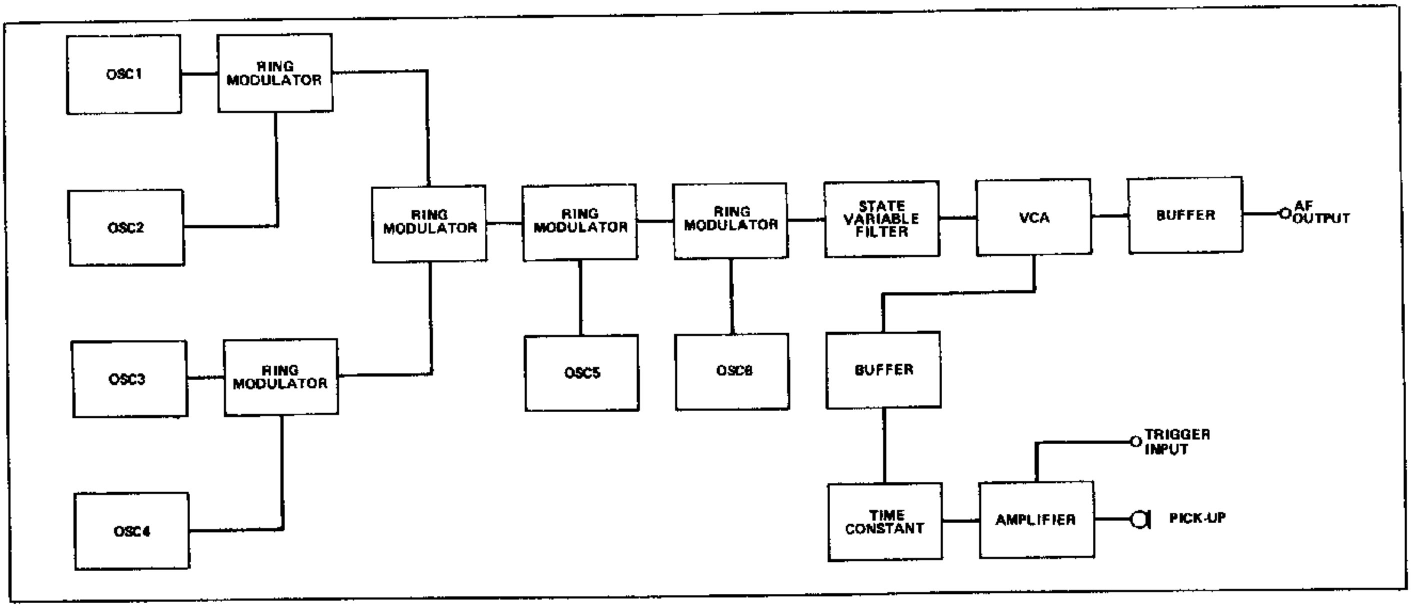


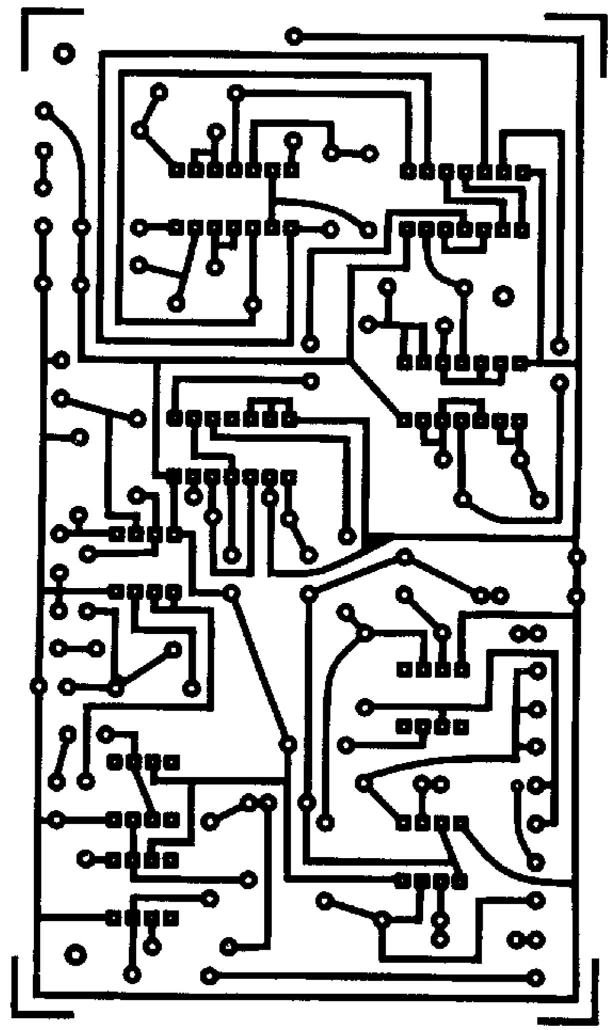
Figure 1. The block diagram is large but essentially simple, with a long chain of oscillators and ring modulators.

The VCA is based on a CA3080E transconductance operational amplifier (IC7). The voltage gain of the amplifier is controlled by the bias current fed to the amplifier bias input at pin 5. R20 has been added in series with this input so that the bias current is roughly proportional to the applied voltage, and voltage rather than current controller operation is obtained. IC8 acts as the output buffer stage and IC9a provides buffering at the control input of the VCA.

Under stand-by conditions IC9b is biased with its output at 0 volts. This gives zero control voltage to the VCA, and the signal is blocked from reaching the output. If a positive pulse is applied to the trigger input at SK2 the output of IC9b goes fully positive, almost instantly charging C12 and providing a strong control voltage to the VCA. This gives a strong output, but the output level decays as C12 discharges through R21 and RV3, causing the output signal to steadily fall back to zero. RV3 controls the decay time, with maximum value corresponding to maximum decay time D1 ensures the C12 can not discharge through the output stage of IC9b after the input pulse has ended and the output of IC9b has returned to the low state.

The unit can also be triggered by hitting the case, so that Mic 1 produces a short series of output pulses. Mic 1 is an inexpensive crystal microphone insert, and the negative output pulses from this componet take the output of IC9b high and give the required charging of C12.

The current consumption of the entire circuit is only about 7 milliamps, and this gives a reasonably long operating life from a 9 volt battery.



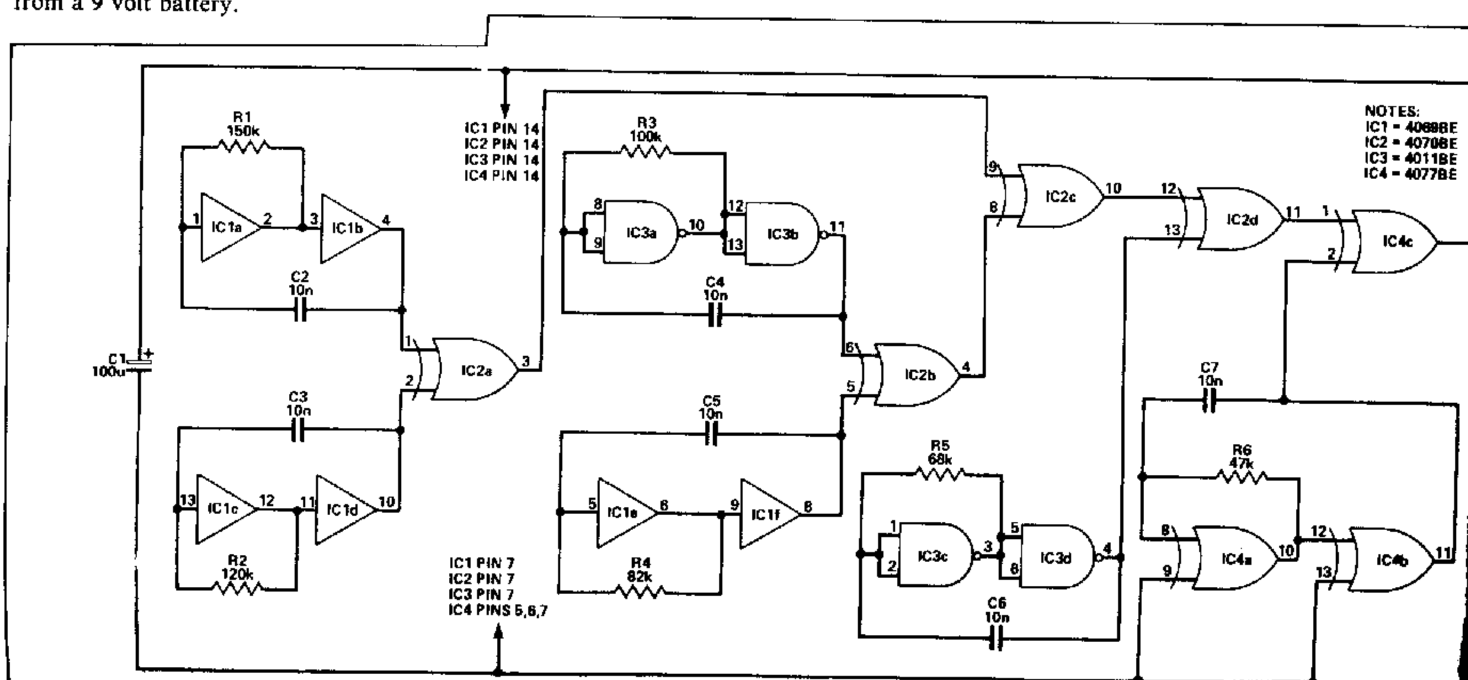


Figure 2. The circuit of the oscillator, ring modulator and filter sections of the Cymbal Synthesiser.

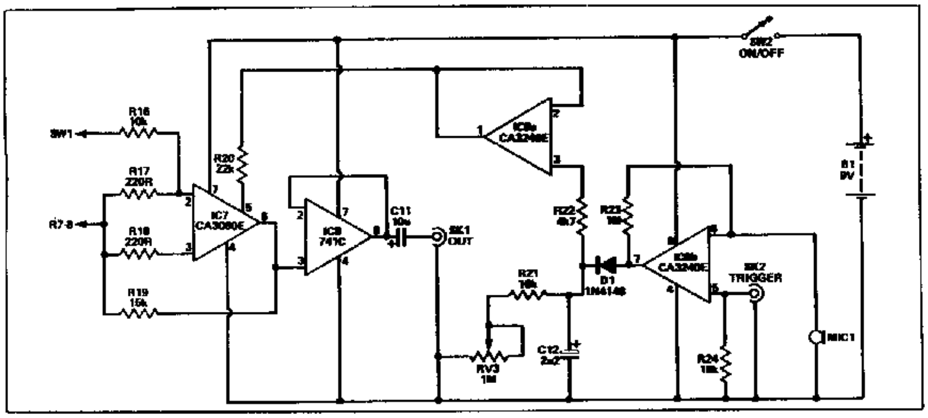


Figure 3. The circuit of the envelope shaper and VCA sections of the device.

Construction

Refer to **Figure 4** for details of the printed circuit board and wiring.

The first point to note about the board is that several of the integrated circuits (ICs 1,2,3,4 and 9) are MOS types and therefore require the normal MOS antistatic handling precautions. These devices should be fitted in IC sockets, and should not be plugged into place until the board and all the wiring are in other respects complete. Until this time they should be left in the antistatic packing, and they should be handled as little as possible when they are fitted in place. Note that IC7 to IC9 have the opposite orientation to the other integrated circuits.

There are a few link wires, and these are made from about 22 SWG tinned copper wire. Veropins are used to facilitate easy connection of the board to the controls and sockets. It is advisable to use the specified types of capacitors as these components should then fit easily and neatly onto the board.

A case having approximate outside dimensions of 205 by 140 by 40 milimetres makes a tough but attractive housing for this project. The controls and sockets are mounted on the front panel and the exact layout used is not important, but try to group them sensibly. The printed circuit board is mounted on the base panel, towards the right hand side of the unit. The use of short spacers to keep the connections on the underside of the board away from the case is strongly recommended. Otherwise there is a risk that the board will become distorted and damaged when it is bolted into place. The crystal microphone insert is glued in place on the base panel, towards the left hand side of the unit, using any good quality general purpose adhesive. Some microphone inserts have flying leads, but these are likely to be too short to reach the board. It is then advisable to cut these leads short and use two insulated leads to make the connections to the board.

To complete the unit the point-to-point style wiring is added, using ordinary PVC insulated multistrand connecting wire. Finally, a veneer of some kind can be added to the top of the case to provide protection over the area where it will be touch triggered. A piece of foam material can be used to trap the battery firmly in place when the lid of the case is screwed in place. It is important **not** to simply leave the battery to rattle around as this could easily lead to unwanted triggering of the unit.

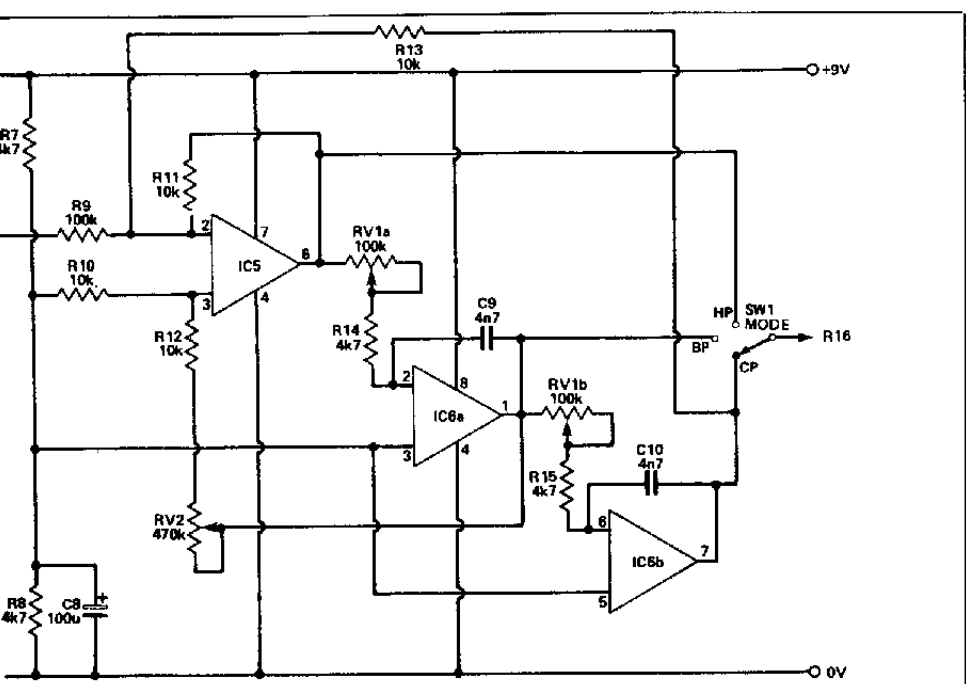
In Use

With the output of the unit connected to an amplifier and loudspeaker, or to a pair or medium or high impedance head-phones, tapping the unit should generate an output. Initially select the highpass mode, set the decay control at a roughly midway setting, and adjust the resonance control to somewhat less than half maximum. With the frequency control set at a fairly high pitch a reasonably good cymbal sound should be obtained. The precise pitch selected, the degree of resonance used, and so on, is obviously a matter of personal taste, and is also dependent on the exact type of cymbal sound you are trying to produce. By varying the controls around these settings a variety of cymbal type sounds can be obtained.

It is worthwhile experimenting with the controls over a wide range of settings since some interesting but non-cymbal type sounds can be obtained. For example, the use of lowpass filtering with a high level of resonance and a low effects.

The sensitivity of the unit when touch triggered depends on the value of R23. If necessary a higher value can be used to give increased sensitivity, or a lower value will give reduced sensitivity. However, satisfactory results will probably be obtained with the specified value, with the output level varying according to how hard the unit is struck.

If trigger pulses applied to SK2 are used to activate the unit these should be 5 volt positive pulses of between about 1 and 5 milliseconds in duration. Longer pulses will trigger the unit, but may significantly extend the decay time set using RV3, while shorter pulses may fail to trigger the unit properly. Ideally the pulses should be provided by a MOS or CMOS device which will give practically zero volts when the output is in the low state. Good results are obtained with most TTL outputs, but in some cases it might be necessary to add a DC blocking capacitor of about 100nF in series with the input in order to obtain satisfactory results.



PARTS LIST

Resistors
(All 1/4W 5% carbon)

R1	150k
R2	120k
R3, 9	100k
R4	82k
R5	68k
R6	47k
R7, 8, 14, 15, 22	4k7
R10, 11, 12, 13, 16, 21, 24	10k
R17, 18	22OR
R19	15k
R20	22k
R23	1M

Potentiometers

RV1	100k linear dual gang
RV2	470k lin
RV3	1M lin

Capacitors

C1	100uF 10V elect
C2, 3, 4, 5, 6, 7	10nF polyester
C8	100uF 10V axial elect
C9, 10	4n7 carbonate
C11	10uF 25V elect
C12	2u2 63V elect

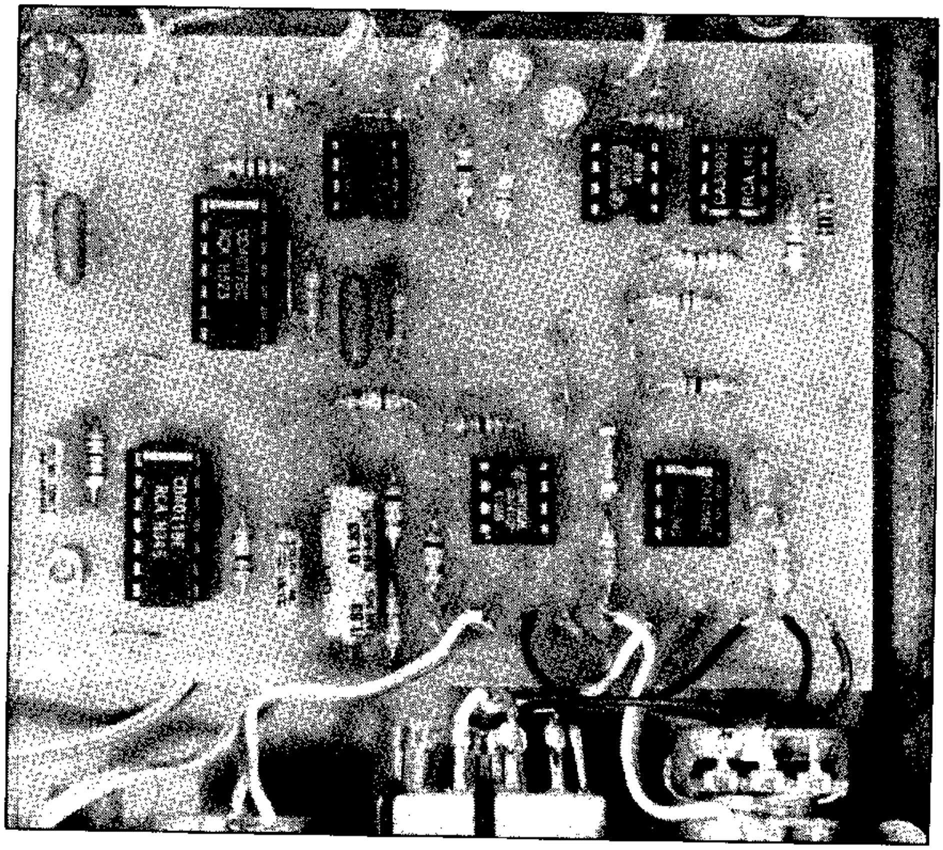
Semiconductors

IC1	4069BE hex inverter
IC2	4070BE quad 2 input XOR gate
IC3	4011BE quad 2 input NAND gate
IC4	4077BE quad 2 input XNOR gate
IC5, 8	741C op amp
IC6	1458C dual op amp
IC7	CA3080E transconductance op amp
IC9	CA3240E dual MOS op amp
D1	IN4148 silicon signal diode

Miscellaneous

S1	3 way 4 pole rotary switch
S2	SPST miniature toggle switch
MIC 1	Crystal microphone insert
SK1, 2	3.5mm jack sockets
B1	9 volt

205 by 140 by 40mm case; printed circuit board; 9 volt battery and connector; four 14 pin DIL IC sockets; five 8 pin DIL IC sockets; fixing, wire, etc.



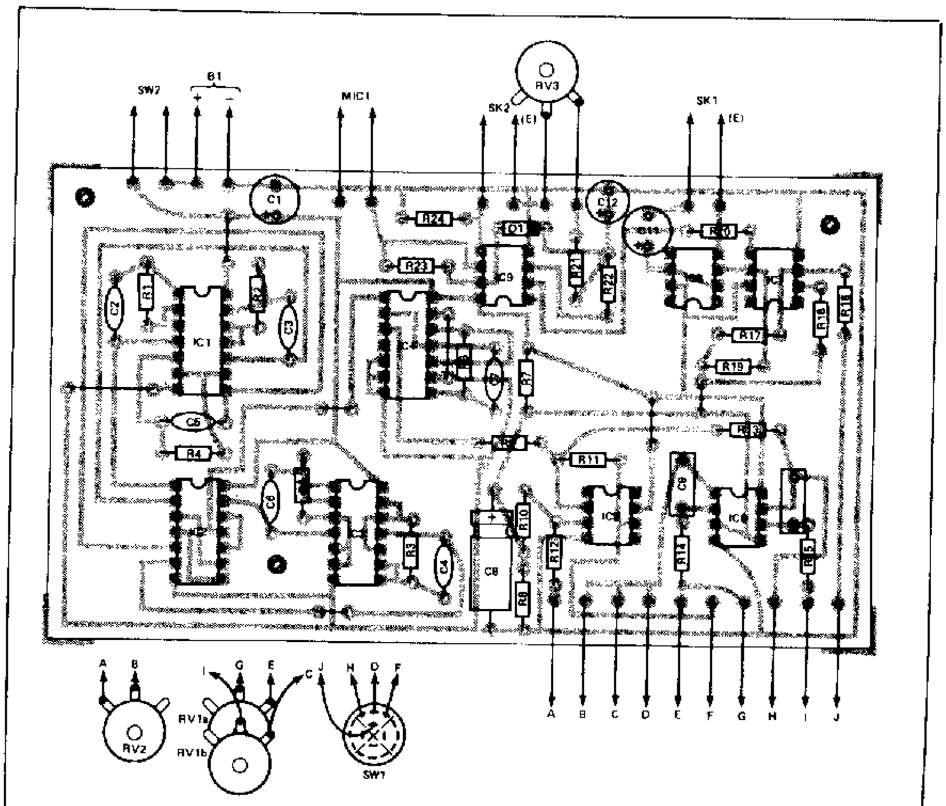
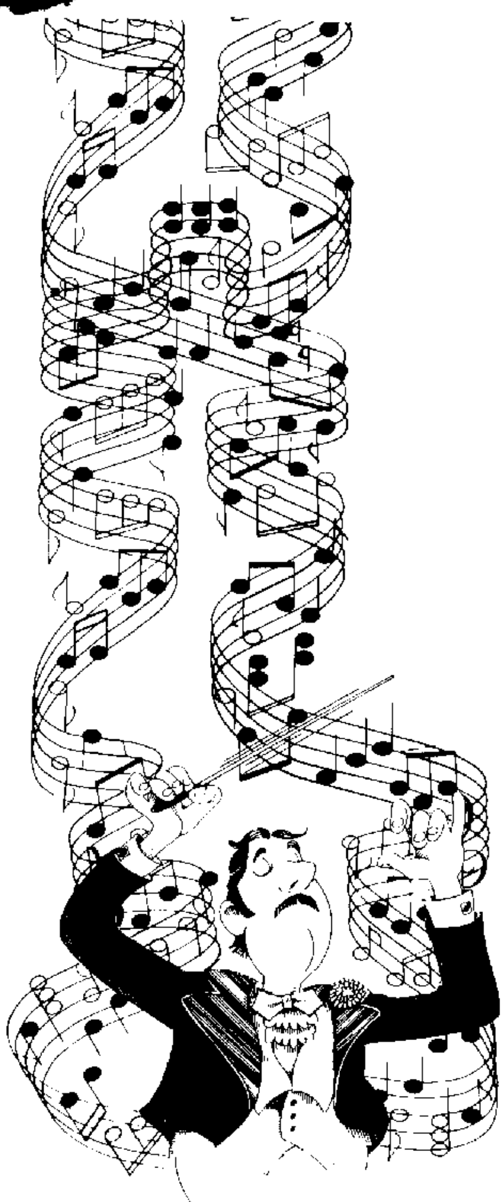


Figure 4. The PCB overlay. Assembly is straightforward, considering the size of the board. Use IC sockets to protect the MOS ICs (see text).



Cymbal Synth

Beat your own drum with this status cymbal.

By D. Stone

THIS cymbal synthesizer, being a two chip affair, has the virtues of simplicity but is sufficiently adaptable to provide a useful adjunct to any drumkit. With a tunable noise output and a variable decay rate, the circuit could even be built into several units to form a more-or-less complete drum and cymbal kit, although, in all fairness, you'd be severely restricted as far as bass effects and touch sensitivity go. The unit does allow pure white noise to be fed to the envelope generator, which means it can be used for gunshots and similar effects. A degree of touch sensitivity is incorporated.

The prototype was built for live stage work, where it has proved very useful and rugged. If toughness is not a major criterion, the circuit could be built into any suitably sized and resonant container. The home or studio recordist could make good use of it as a crash cymbal or snare-type drum.

Construction

The construction of the unit is straightforward if the recommended PCB is used. The assembly should follow the usual format of passive components first, followed by the semi-conductors and integrated circuits. The use of IC sockets is recommended to prevent damage to the chips by overheating and to ease the removal of chips should this become necessary. The microphone was fitted to the circuit board near IC1 in the prototype with double sided sticky fixing pads.

The prototype unit was housed inside an 8" Tambour. The Tambour has a removable drum skin which allows easy changing of the battery. Tambours can be bought from any good music shop. A base was fitted to the Tambour with white modellers' 'Plasticard'. The whole unit was then sprayed with enamel paint and labelled with rub down letters. As an alternative housing, for a number of these

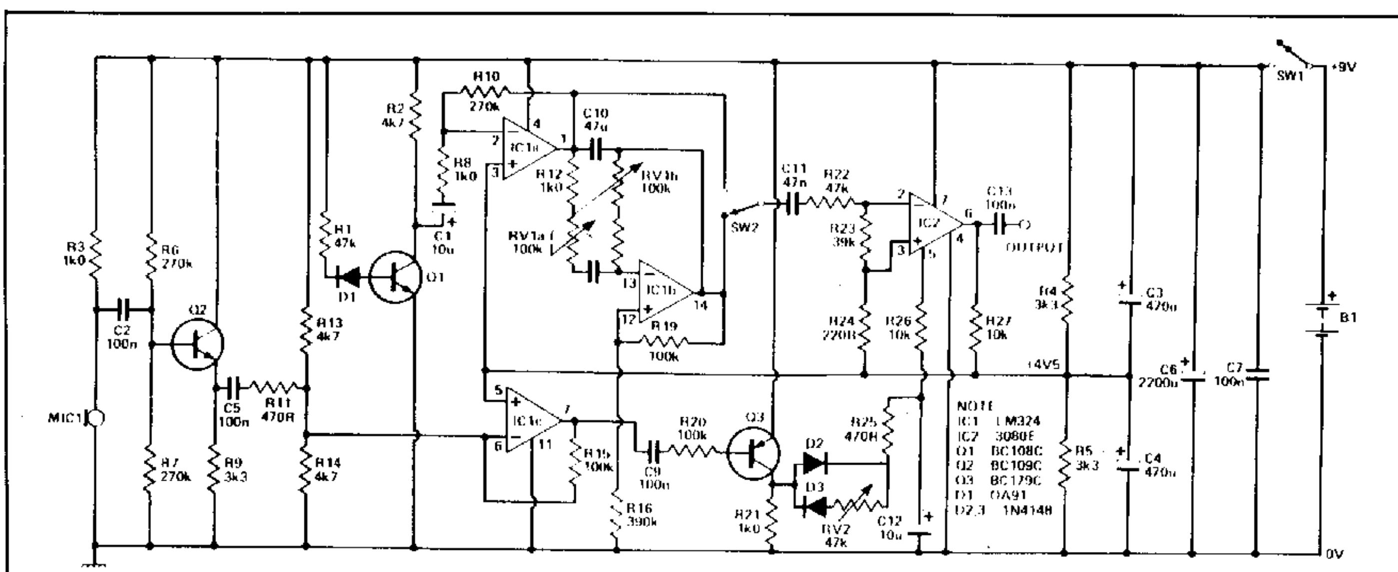


Fig. 1 Circuit diagram of the crash cymbal.

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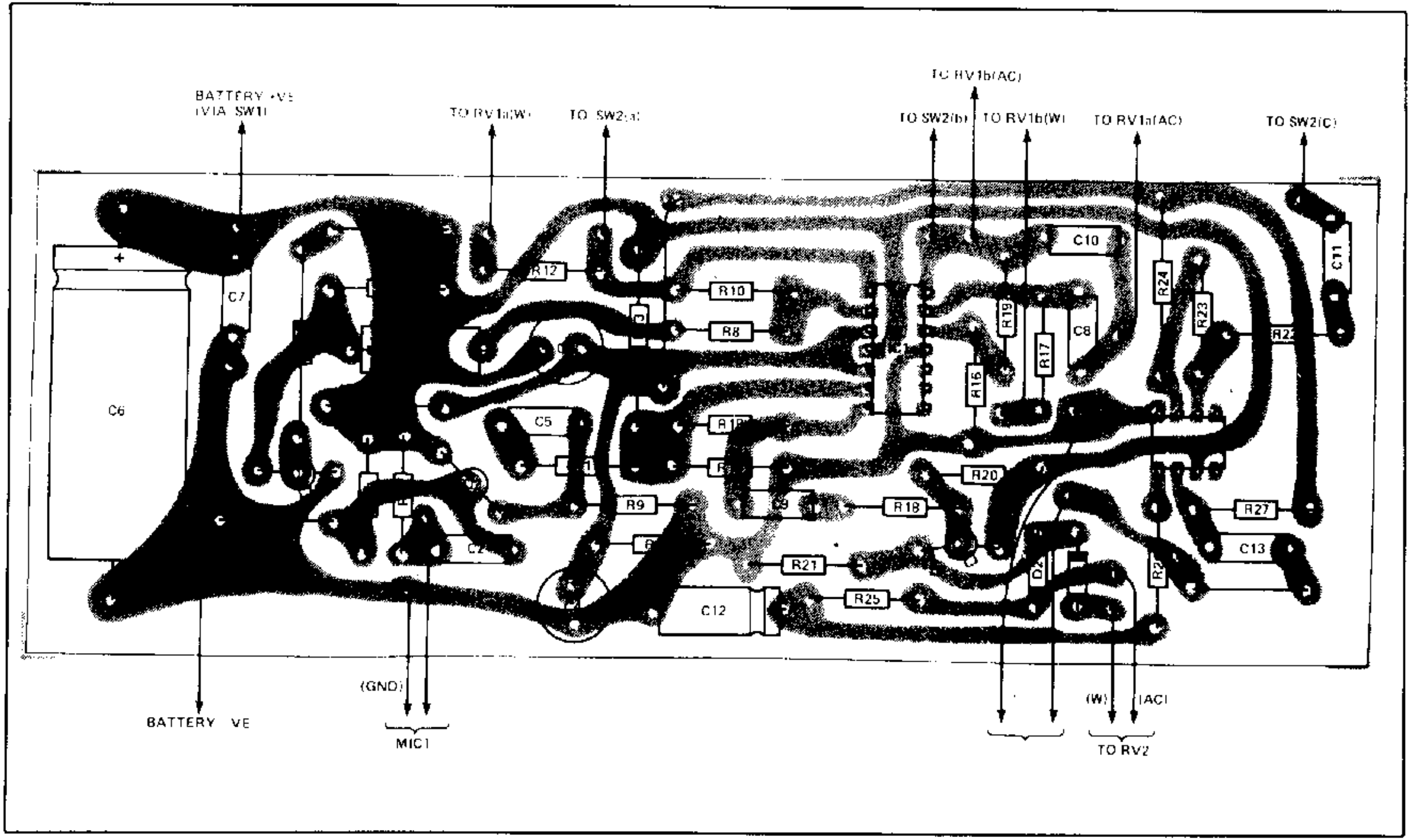


Fig. 2 Component overlay of the crash cymbal.

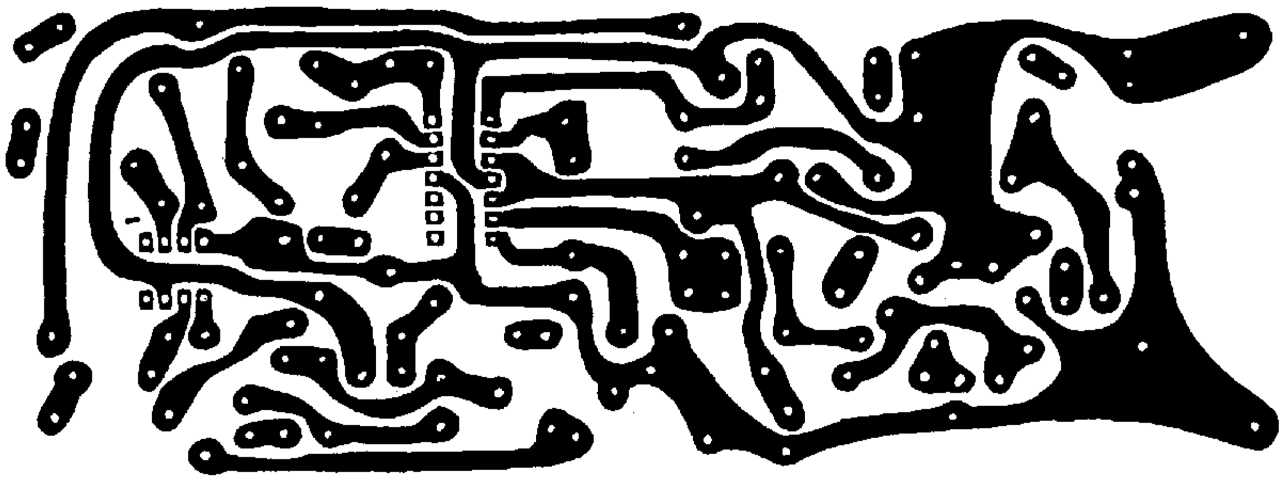
units, matching two litre ice-cream cartons could be used, and give a space-age effect when painted in suitably futuristic hues. Mounting the units in playing positions is left to the reader.

How It Works

The circuit associated with Q1 is the white noise generator, amplifying the noise produced in the diode D1 as a result of reverse leakage current. A germanium diode is used as the leakage current is higher than that of silicon fora given voltage, producing a higher noise signal level. This amplified signal is coupled by capacitor C1 to a further amplifying stage built around the op amp, IC1a.

IC1b is a constant bandwidth bandpass filter. The filter centre frequency is set by the dual-ganged potentiometer, RV1. This is a classic second order bandpass filter of the multiple-feedback tuned type, which turns the white noise into variable frequency range noise. SW2 is to choose either the filtered noise or the unfiltered white noise. The filtered noise is inaccurately described as pink.

The voltage controlled amplifier (VCA) is built around the 3080E transconductance op amp, IC2. Output current is a function of the control current fed to pin 5 of the package and the difference in voltage between the two input pins. The output current of the device is converted into a signal voltage by R27 and the signal is capacitive coupled to the output by C13.



The Cymbal Synth foil pattern.

The signal from the microphone is first amplified by Q2 and then fed to a pulse amplifier built around IC1c. This section inverts the signal and amplifies it to give a negative going pulse at its output whenever a sound is picked up. The duration for which the pulse remains negative depends, to some extent, on the volume of the input signal to the mic. This gives some sensitivity to the impact of a beat. The negative going pulse is fed to Q3 which, with C12 and its associated circuit, forms a simple envelope generator.

When the pulse is received by Q3, the transistor turns on. C12 charges up rapidly through the transistor, D2 and R25, giving the fast attack which is characteristic of a drum. The transistor then turns off and C12 discharges through R25, RV2, D3 and R21. This gives a variable decay, considerably slower than the attack. The voltage is converted into a current by R26 and fed to pin 5 of IC2, the VCA.

C6 provides necessary supply capacity to eliminate any power thump which may find its way into the circuit when the drum is struck. C7 provides high frequency supply decoupling. A false signal ground is supplied in the form of a decoupled 4.5V rail. This rail is formed by C3, C4, R4 and R5, and eliminates the need for a two battery split rail supply.

There is a spare op amp on IC1 available, should any adventurous constructor feel the need to expand the unit in some way.

Parts List

Resistors

R1,22	47k
R2,13,14	4k7
R3,12,17,21	1k
R4,9	3k3
R6,7,10	270k
R11,25	470R
R15,18,19,20	100k
R16	390k
R23	39k
R24	220R
R26,27	10k
RV1	100k dual ganged log pot
RV2	47k lin pot

Capacitors

C1,12	10u, 25V
C2,5,7,9,13	100n film
C3,4	470u, 10V
C6	2200, 16V
C8	10n film
C10,11	47n film

Semiconductors

D1	1N34, 1N60
D2,3	1N4148, 1N914
Q1,2	2N3904 NPN, etc
Q3	2N3906 PNP, etc
IC1	LM324
IC2	LM3080E

Miscellaneous

Condenser mic insert, on-off switch, 1 pole 2-pos switch, DIP sockets, 1/4 inch jack, knobs, wire, 9V battery and clips, casing.