# PE Sound Synthesiser 8

# ENVELOPE SHAPER

By G.D.SHAW

One of the fundamental characterising parameters of a sound is that in which the audibility of the sound varies with time. Some sounds become audible very rapidly and almost immediately die away again whilst others make a relatively slow approach to their full volume and take an even longer period to die away. The loudness modulation of any sound is known generally as the envelope and is very important in providing a feature which allows of recognition. Changes in the envelope format of an otherwise well-known sound can often change the character of the sound completely.

A simple experiment designed to illustrate this latter point involves the use of a tape recorder and a piano. Make a recording of a series of notes or chords selected from various parts of the piano register and repeat these with the sustain pedal held down. The recording should now be replayed backwards. With a four track recorder the simplest way of doing this is to unthread the recorder without rewinding, reverse the position of the spools and thread up again putting a twist in the tape so that the shiny, or backing side of the tape is towards the heads. This particular method results in a considerable loss of sound quality but illustrates the characteristic quite well. If the constructor is fortunate enough to own a mono or two track recorder in addition to a four track the recording should be made on the former machine and replayed, with spool positions reversed, on the latter.

## PIANO ENVELOPE FORMAT

The change in the original sound of the piano, on reverse replay, will be found to be quite remarkable and, depending on the octave and sustain given to the original note or chord, will be found to bear a close resemblance to other musical instruments such as the organ or cello.

The piano is particularly suited to this form of experiment due to the nature of its envelope format which is characterised by a rapid rise to full volume followed by a relatively long period, dependent upon sustain pedal use, during which the volume is gradually diminishing. Fig. 8.1 illustrates a simplified form of piano envelope.

The peak volume followed by a rapid partial decay to the gradually diminishing sustain is a characteristic common to many musical sounds which are initiated by a form of percussion. Instruments such as the triangle, timpani, cymbal, glockenspeil and so on, all display similar basic characteristics in their envelopes.

Apart from the particular form of the percussive envelope the majority of sound envelopes will fall somewhere within the range of shapes illustrated in Fig. 8.2 all of which may be considered to be derivations of the basic trapezoid shown in Fig. 8.3.

The Envelope Shaper in the Sound Synthesiser is essentially a trapezoid generator in which the attack, sustain, and decay parameters are all adjustable, within the limits of the controls, to provide a range of formats similar to those illustrated in Fig. 8.2.

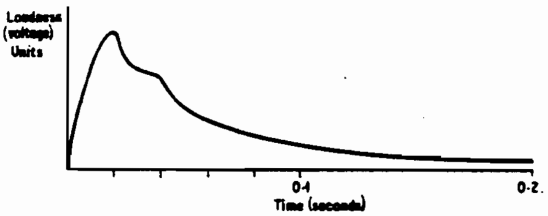



**Fig. 8.1. Typical piano envelope**

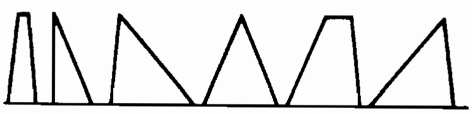


**Fig. 8.2. Simplified range of sound envelope formats**

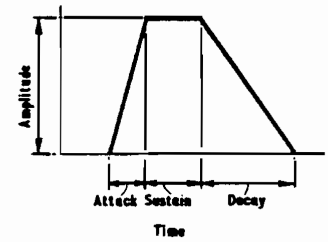



**Fig. 8.3. Basic envelope trapezoid**

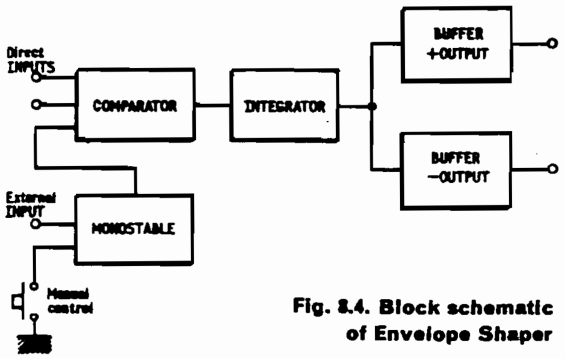



**Fig. 8.4. Block schematic of Envelope Shaper**

## BLOCK SCHEMATIC

A schematic arrangement of the envelope shaper is shown in Fig. 8.4. The heart of the circuit is an integrator which drives two buffer amplifiers providing independent positive and negative going envelopes. The integrator itself is driven by a comparator having a variable reference level and thus any change in the input signal level to the circuit as a whole has no effect on the overall envelope amplitude. The comparator may be triggered directly by an external signal or via a monostable with a variable timing period.

## CIRCUIT DIAGRAM

Fig. 8.5 shows the theoretical circuit of the envelope shaper. IC1 is the comparator which has a reference level set by R5–VR1 and ranging between 0V and −5V. Thus the comparator will recognise only negative going signals which exceed the reference level, and, with no signals present, will normally sit at its negative saturation state. Four triggering modes are catered for and selected by S1.

In the first the comparator is triggered directly by external signals arriving at the inverting input via R1 and R2.

Triggering is accomplished in the second mode by means of the keyboard synchronising pulse which is routed via R3. The pulse level swings between ±10V and will thus override any other trigger signal less than −10V arriving at the comparator via R1 and R2. Equally, it is possible to combine keyboard synchronisation with other external signals providing that the peak value of these exceeds −10V.

In the third mode of operation the comparator is triggered by a capacitatively coupled monostable (IC5) which is, in turn, triggered by negative going transitions in signals arriving at the external socket.

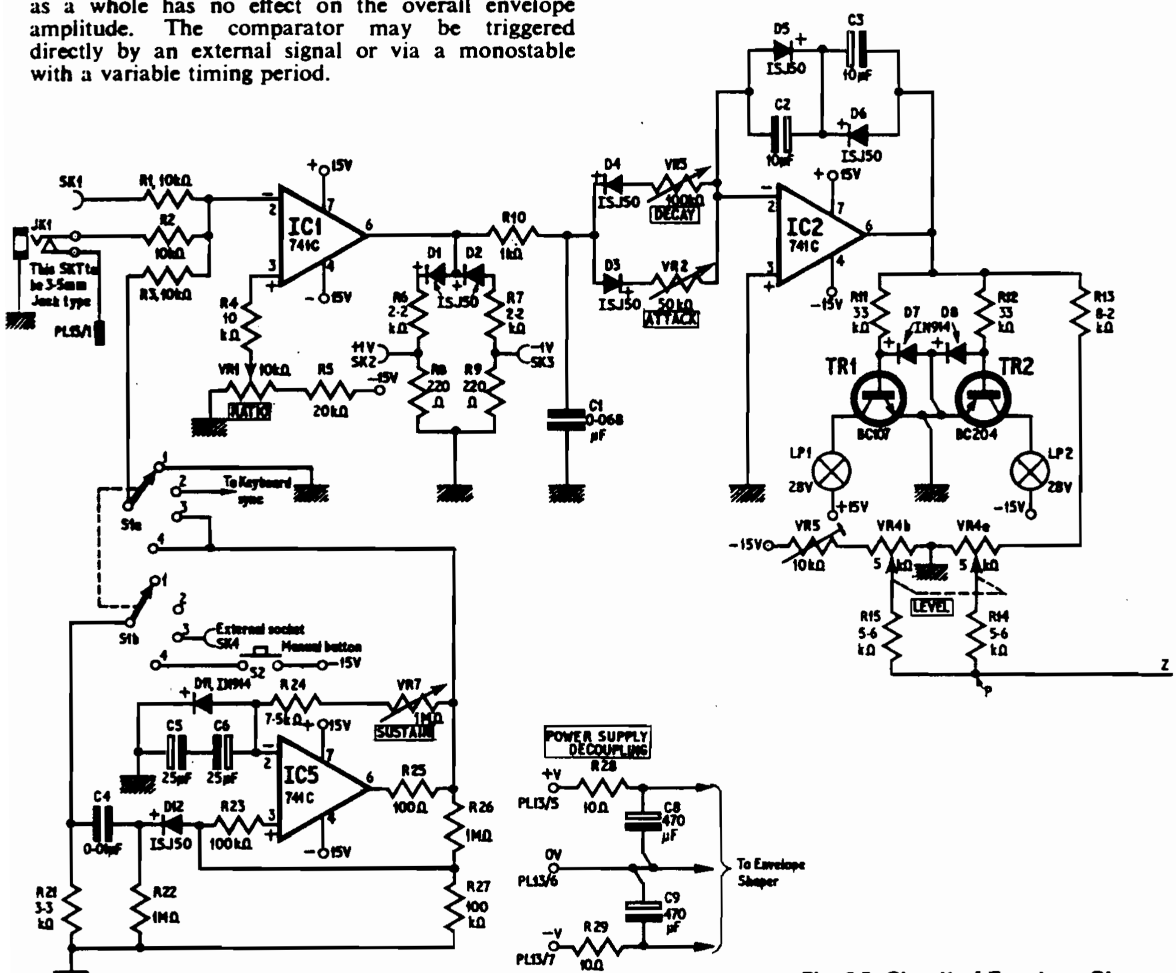



**Fig. 8.5. Circuit of Envelope Shaper**

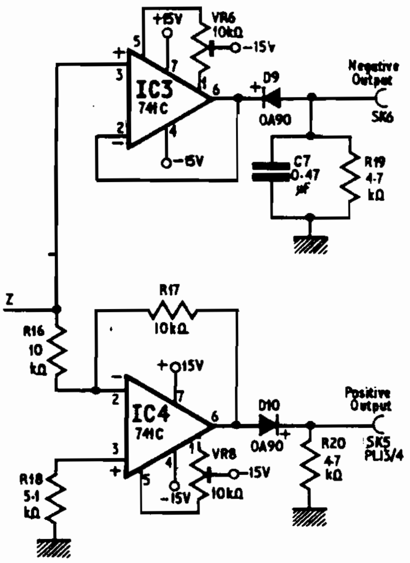
In this latter mode the pulse level of the monostable swings between ±14V and thus effectively overrides all other signals arriving at the comparator inputs.

Finally, in mode four, the monostable is triggered manually by means of a push button. In modes three and four the on period of the monostable is controlled over 100/1 range by means of VR7 and, with the value shown, can be varied between 15mS and 1,500mS. Since the shortest period of sustain is less than the combined fastest attack/decay time of about 20mS the resultant envelope is slightly lower in amplitude than it would otherwise normally be. However, for most purposes this may be adequately compensated for by adjustment of the envelope level control (VR4).

## SIGNAL ROUTING

Output signals from the comparator are routed via R10 and D3/VR2 or D4/VR3 to the inverting input of the integrator built around IC2. In the absence of signals into the comparator, the provision of a negative reference level means that the comparator normally sits at negative saturation and the integrator at positive saturation. A negative-going signal greater than the reference level causes the comparator to change states and the positive going pulse is routed into the integrator via D3/VR2 and charges C3. When the trigger signal is removed, or changes polarity, C3 discharges via VR3/D4 and R10 and the original situation is restored.

The rate at which C3 charges and discharges is governed by the setting of VR2 and VR3 respectively. With both controls at minimum the fastest rate of attack or decay is determined by R10 and, with the values shown, is about 10mS. Thus the attack time can be varied by VR2 between 10mS and 500mS while the decay time can be varied by VR3 between 10mS and 1000mS.




The sustain period of the envelope signal may be varied in two ways. In the first, the on time of the comparator output pulse is determined by the period of that part of the input signal which lies above the reference level. The on time may thus be varied by adjustment of the ratio control VR1 in those instances when the comparator is triggered directly by an external signal.

In the second case the comparator is triggered by a monostable either from within the envelope shaper (IC5) or from the keyboard. In each case the on period is determined by adjustment of the monostable sustain control.

## BUFFER AMPLIFIERS

The output from the integrator is routed to two buffer amplifiers of unity gain. IC3 is wired as a follower whilst IC4 forms an inverting amplifier. Interposed between the integrator and output buffers is a balancing divider network comprising R13, VR4a/b, VR5, R14 and R15.

The purpose of this network is to drop the integrator output swing to a usable level and to balance its maximum positive transition with an equal value negative voltage supplied via VR5/VR4b. Thus with the integrator sitting at positive saturation the output voltage of the network, measured at point P in the circuit, is effectively zero. Taking into account the forward drops of diodes D9 and D10 the buffer outputs will therefore swing between zero and about 3·2V.

## INDICATOR LIGHTS

An indication of the state of the integrator is provided by two lamps which are switched by TR1 and TR2. With the integrator sitting at positive saturation TR1 is turned on and LP1 lights thus indicating an envelope off situation. When the integrator changes state TR1 is biased off thus extinguishing LP1 while TR2 is turned on and LP2 lights up indicating an envelope-on state.

The provision of two indicator lights is useful in those circumstances in which the envelope shaper is being operated by external signals direct into the comparator. Here the lights can provide a visual measure of the envelope on/off times in relation to the frequency of the triggering signal. For the majority of other purposes however the envelope off indicator may be considered superfluous and may be omitted from the circuitry to serve the requirements of economy. The circuit elements involved are LP1, TR1, D7 and R11.

Finally it is often useful to be able to synchronise the beginning and end of an envelope with other modules in the synthesiser. To this end diodes D1 and D2 together with dividers R6–8 and R7–9 provide pulses of 1V amplitude direct from the comparator output. As with the envelope off indicator these particular components are not necessary to the operation of the envelope shaper as such and may be omitted if automatic programming is not to be the principal function of the module.

Fig. 8.6 shows the recommended circuit board layout for the envelope shaper while Fig. 8.7 gives details of front panel and McMurdo plug wiring.

## MODULE CONSTRUCTION

Construction of the module is quite straightforward and the only critical requirement lies in the wiring of VR4a/b and the setting up of the associated

# COMPONENTS . . .

## ENVELOPE SHAPER

**Resistors**

| | |
|---|---|
| R1–R4 | 10k Ω (4 off) |
| R5 | 20k Ω |
| R6, R7 | 2·2k Ω |
| R8, R9 | 220 Ω (2 off) |
| R10 | 1k Ω |
| R11, R12 | 33k Ω (2 off) |
| R13 | 8·2k Ω |
| R14, R15 | 5·6k Ω (2 off) |
| R16, R17 | 10k Ω (2 off) |
| R18 | 5·1k Ω |
| R19, R20 | 4·7k Ω (2 off) |
| R21 | 3·3k Ω |
| R22, R26 | 1M Ω (2 off) |
| R23, R27 | 100k Ω (2 off) |
| R24 | 7·5k Ω |
| R25 | 100 Ω |
| R28, R29 | 10 Ω (2 off) |

All 5% ½ watt carbon

**Capacitors**

| | |
|---|---|
| C1 | 0·068μF polyester |
| C2–C3 | 10μF elect. 25V (2 off) |
| C4 | 0·01μF polyester |
| C5, C6 | 25μF elect. 25V (2 off) |
| C7 | 0·47μF polyester |
| C8–C9 | 470μF elect. 25V (2 off) |

**Potentiometers**

| | |
|---|---|
| VR1 | 10k Ω linear min. moulded carbon |
| VR2 | 50k Ω linear min. moulded carbon |
| VR3 | 100k Ω linear min. moulded carbon |
| VR4 | 5k Ω linear ganged moulded carbon |
| VR5–VR6 | 10k Ω carbon preset (2 off) |
| VR7 | 1M Ω linear |
| VR8 | 10k Ω carbon preset |

**Integrated Circuits**

IC1–IC5 741C (5 off)

**Transistors**

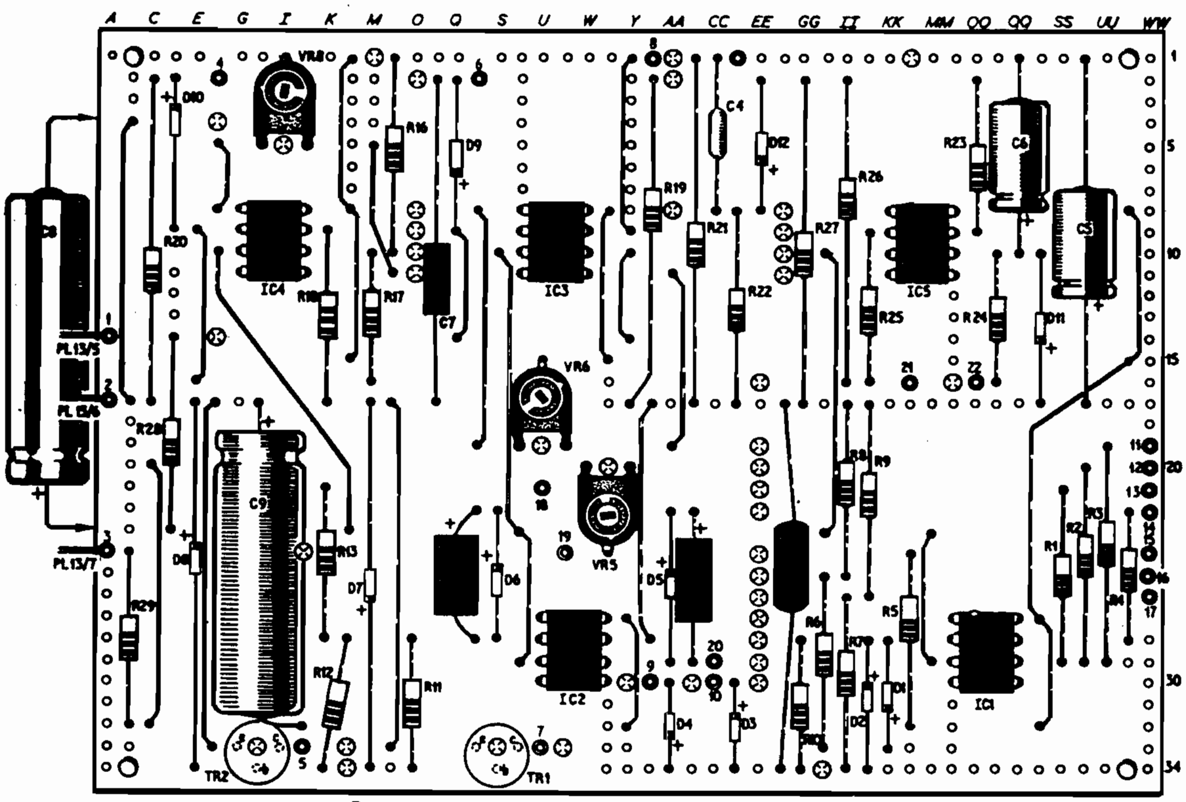
TR1 BC107
TR2 BC204

**Diodes**

| | |
|---|---|
| D1–D6 | ISJ50 (6 off) |
| D7, D8 | IN914 (2 off) |
| D9, D10 | OA90 (2 off) |
| D11 | IN914 |
| D12 | ISJ50 |

**Miscellaneous**

LP1, LP2 28V sub-miniature lamps (2 off)
SK1–SK6 2mm miniature sockets (6 off) JK1–3·5mm miniature jack socket, S1–2 pole 6 way switch S2–miniature push button switch.




Direction of copper track ● Indicates Veropins
⊗ Indicates break in copper track

Fig. 8.6. Board layout and wiring

balancing divider. This may be done as follows. With power on, put S1 in the direct mode and set VR1 to its maximum setting. This will ensure that the integrator is sitting at positive saturation. Set VR5 to near mid-position and with VR4 at its maximum setting connect a high resistance voltmeter (5V range) between point P and ground. The voltmeter should read approximately 2·5V negative. Adjust VR5 to bring the voltmeter reading as close to zero as is possible.

Reset VR4 to minimum and progressively reduce the sensitivity of the voltmeter adjusting VR5 as necessary to maintain a zero-volt reading. This latter manipulation serves to adjust and compensate for the minimum end resistance of VR4 which should remain at its minimum setting for the next stage of adjustment. Remove the high resistance voltmeter and re-connect between the output of IC3 and ground. Connect point P directly to ground and adjust VR6 so that the output of IC3 is zero.

Repeat the measurement with the voltmeter connected between the output of IC4 and ground making any necessary adjustments to VR8 in this case. It should be borne in mind that variation of

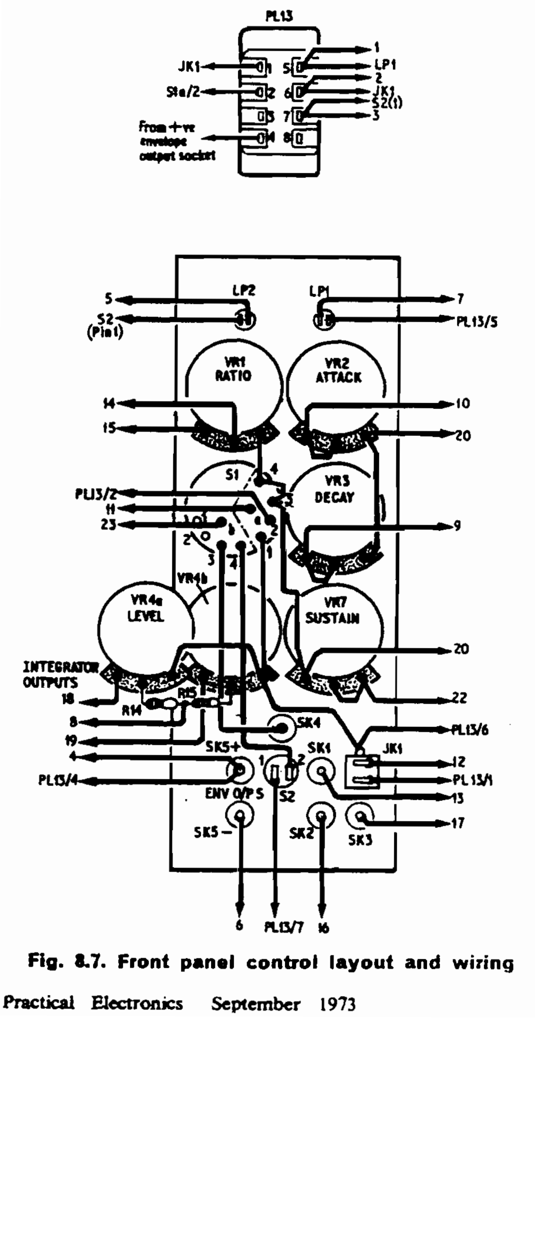



**Fig. 8.7. Front panel control layout and wiring**

the offset presets VR6–8 will result in an output voltage change of only a few millivolts, a 400 millivolt swing being typical when the amplifiers are run at unity gain. If the voltmeter is insufficiently sensitive it will be necessary to use an oscilloscope for this latter measurement. It is important that the measurement be made at the output pin of the buffer amplifiers as opposed to the output socket. Disconnect point P from ground and, with all other controls as initially set, swing VR4 to its maximum position and observe the change in output voltage, if any, at the output pins of IC3 and IC4.

If the overall change is within 400mV the error may be halved by adjustment of VR5 and the remaining 200mV error reduced, or eliminated, by adjustment of the offset controls VR6 and 8 on IC3 and IC4 respectively. If the error is greater than 400mV it will be necessary to adjust the value of R13 accordingly. This latter course, however, is unlikely to be necessary since the two halves of a ganged pot would normally be expected to be taken from the same batch of stators and consequently the resistive tolerance of both halves is likely to be within fairly close limits.

The adjustments detailed above are only critical if it is envisaged that the envelope shaper be used for v.c.o. programming in addition to its main purpose of amplitude modulation.

## USING THE MODULE

In most commercially available synthesisers the envelope shaper usually incorporates a voltage controlled amplifier as an integral part of the circuitry. In the Sound Synthesiser however the envelope shaper is treated as a discrete entity in the interests of simplicity and thus it is not possible to route signals through it in the same way as is featured in the Moog or EMS range of instruments. Thus the description of usage of the module in this particular article will be restricted to v.c.o. programming and covered at greater length in next month's article which deals principally with the Voltage Controlled Output Amplifiers.

Reverting for a moment to the description of the operation of the Envelope Shaper it will be recalled that the envelope is initiated when the comparator switches from one saturation state to the other and that the period of sustain is essentially governed by the time for which the comparator is in its temporary state. Thus, since the attack period of the envelope occurs during the on time of the comparator, it follows that the overall sustain of the envelope is equal to the on time of the comparator less the period of attack.

This particular point is quite important because under certain conditions the set period of attack could be greater than the on time of the comparator. This means that C3 does not become fully charged and thus the envelope does not achieve its full amplitude. Fig. 8.8a illustrates the effect when, with the comparator being triggered by a repetitive signal, its on time is gradually increased either by increasing the period of the triggering signal or by adjustment of the ratio control.

If the input signal is derived from, say, two Ramp Generators and the Sample and Hold in combination and the combined amplitude adjusted such that only the peaks are greater than the comparator reference level, the resultant signal from the envelope shaper will resemble that shown in Fig.

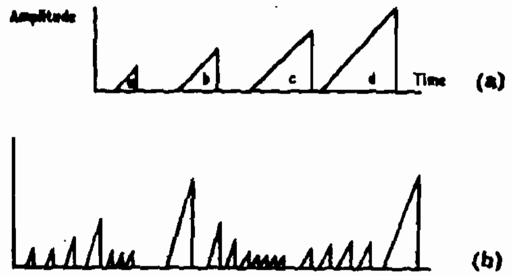



**Fig. 8.8(a). Showing the effect when the attack time is longer than the on time of the comparator. Greatest effect is at 'a' and increasing the on period progressively through 'b', 'c' and 'd' increases the envelope amplitude ; (b) typical envelope series resulting from the above**

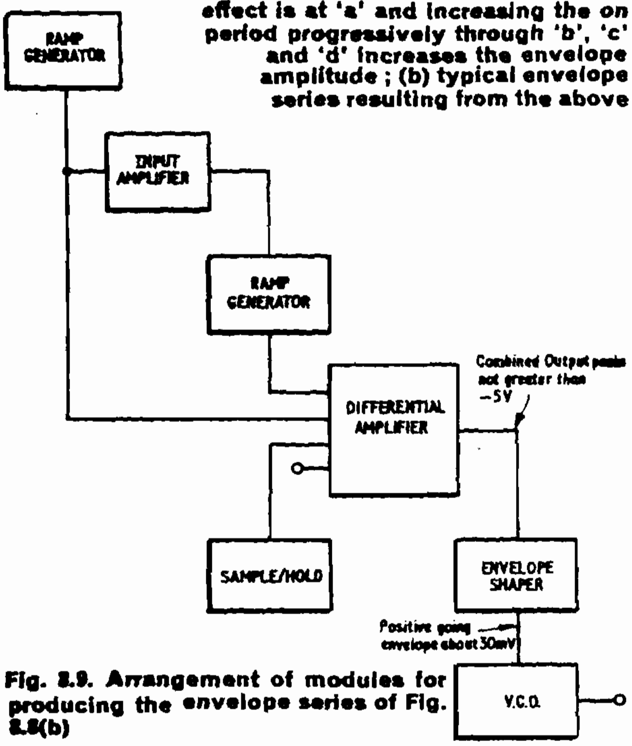



**Fig. 8.9. Arrangement of modules for producing the envelope series of Fig. 8.8(b)**

8.8b. If the positive going waveform is now used to program a v.c.o. which has been manually set to its maximum frequency the resultant output can be adjusted so as to provide a variety of birdsong which is very realistic. Fig. 8.9 shows a typical arrangement of modules for the provision of this type of sound.

## SHIP'S SIREN

Sounds resembling a ship's siren may be synthesised by routing the envelope shaper direct to a v.c.o. and programming the envelope manually. The various controls should be set as follows: SW1 (Mode) = manual; Attack = Maximum; Decay = Minimum; *Sustain* = Midway; Output Level = 1/20 rotation (0·5 on a ten-point, 270 degree calibration). Use the negative going envelope and adjust the programmed v.c.o. to minimum frequency.

If the v.c.o. output is routed via the reverberation amplifier a high degree of realism may be achieved. Remember that the input to the reverberation amplifier should not exceed 500 mV peak-to-peak.

**Next month: The voltage controlled output amplifiers and differential amplifier.**