Envelope Shaper

Keyboard players and guitarists are sure to make a big impact with this low cost sound effects box.

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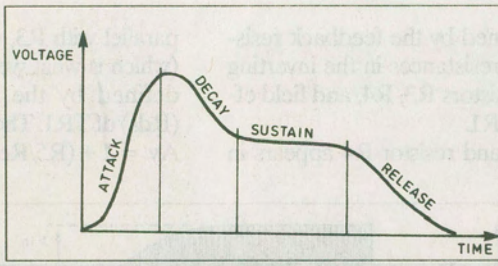


Fig. 1. A generalized sound waveform envelope showing the four controlled periods used in the synthesis of sound.

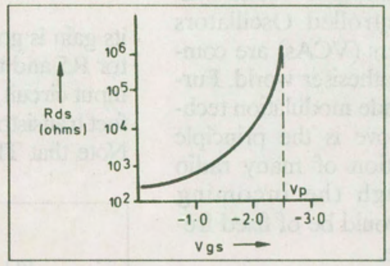


Fig. 2. How the drain-source of an n-channel FET varies with gate voltage.

Although there are a large amount of devices on the market to enhance (or disguise) the guitarist/keyboard players' sound, the author has not come across this device in stores – at least not in such a simple and inexpensive form as this one. The effect produced is best described as that obtained by playing a tape backwards – the natural "envelope" (or waveform profiles) are all reversed.

A guitar, for example, with its natural short sound rise time and long fall time would sound more like a violin, with its long attack time. Some players produce this effect simply by winding the volume control up and down.

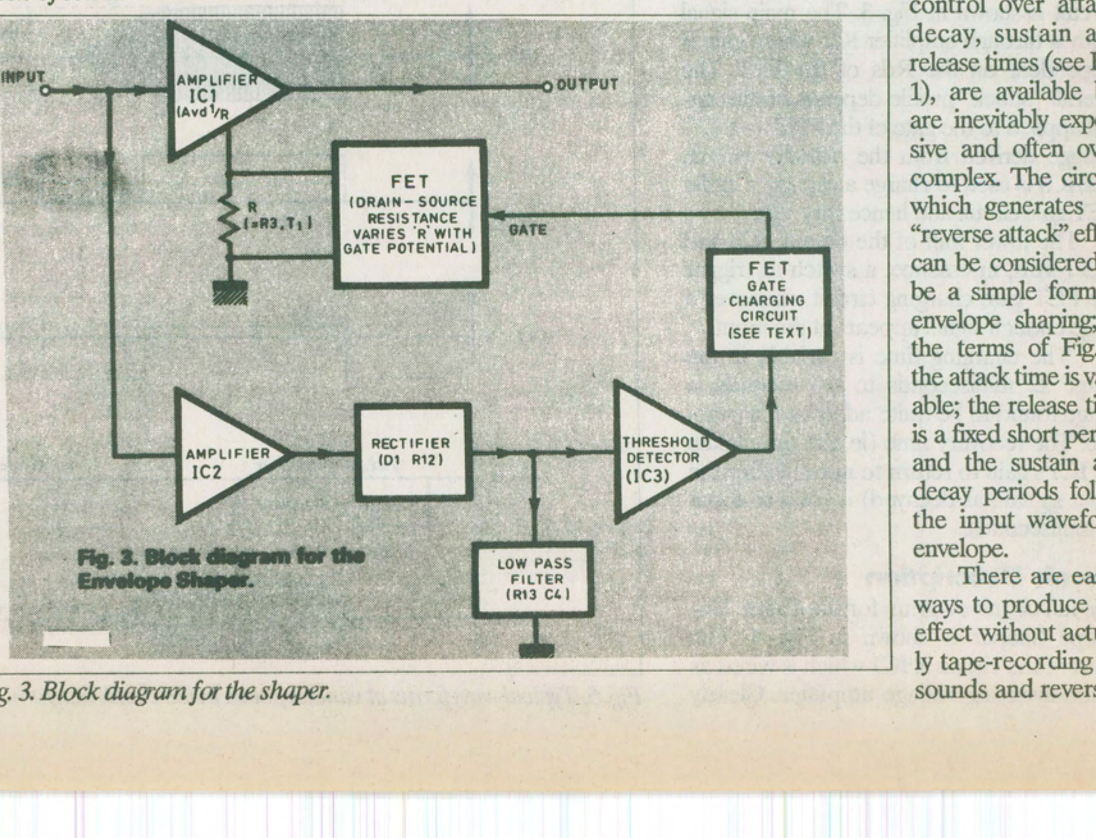


Fig. 3. Block diagram for the shaper.

Envelope Shaping

Envelope shaping, as this technique is called, has been around for a long time: commercial envelope shapers giving control over attack, decay, sustain and release times (see Fig. 1), are available but are inevitably expensive and often overcomplex. The circuit, which generates the "reverse attack" effect can be considered to be a simple form of envelope shaping; in the terms of Fig. 1, the attack time is variable; the release time is a fixed short period and the sustain and decay periods follow the input waveform envelope.

There are easier ways to produce this effect without actually tape-recording the sounds and reversing them, or wearing out your volume control. This project employs an op amp whose gain is varied to amplitude-modulate the incoming waveform.

Op amps are convenient to use here, because their gain can be changed by varying either the feedback or the source resistor. In this circuit, a field effect transistor (FET) is used as a variable resistor inserted as one of the gain defining resistors in the op amp circuit. By changing the Gate-Source Voltage (Vgs) the effective Drain-Source Resistance (Rds) is also changed.

A graph of Vgs against Rds to illustrate this effect is shown in Fig. 2. When Vgs exceeds a value known as the "pinch-off" voltage (VP), the FET becomes cut-off and Rds is virtually open-circuit. The minimum Rds value, when Vgs = 0 however, is less well defined and depends on the FET manufacturing process; the exact value is not critical in this circuit.

To digress a little, the idea of using DC levels to control sound in this way is actually the basis of analogue sound synthesis. Voltage Controlled Oscillators (VCOs) and amplifiers (VCAs) are common jargon in the synthesiser world. Furthermore, the amplitude modulation technique mentioned above is the principle used in the generation of many radio wavebands although the incoming waveform (carrier) would be of fixed frequency and amplitude.

How it Works

A block diagram of the Envelope Shaper circuit is shown in Fig. 3. The main signal path is through amplifier IC1 whose gain is dependent on the Rds of the FET The overall "attack" profile depends on the signal applied to the gate of the FET – a DC voltage derived from the detector circuit. IC2/IC3 is used to charge a capacitor in the FET gate circuit and hence vary Vgs.

The lower half of the circuit, IC2 and IC3 forms, in essence, a switch to trigger the FET gate charging circuit whenever a large enough signal appears at the input.

The charging time is variable in the range 22 milliseconds to 0.6 seconds, a range found to be quite adequate in practice. The recovery time (ie, the time taken for IC1's gain to return to normal after the input signal has decayed) is fixed at about 15 milliseconds.

Circuit Description

The full circuit diagram for the Guitar Envelope Shaper is shown in Fig. 4. The heart of the circuit is IC1 which is wired as a non-inverting voltage amplifier. Clearly its gain is governed by the feedback resistor R5 and the resistances in the inverting input circuit, resistors R3, R4, and field effect transistor TR1.

Note that TR1 and resistor R4 appears in parallel with R3, so the overall gain of IC1 (which is what we wish to control), is really defined by the drain-source resistance (Rds) of TR1. The gain of IC1 is therefore:

Av = 1 + (R5/Req)

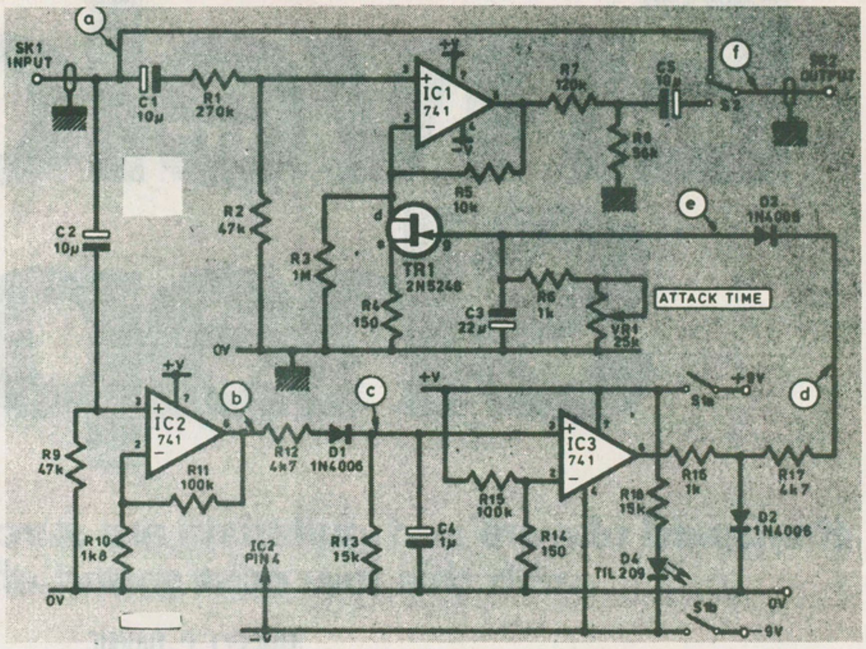


Fig. 4. The complete circuit diagram. The letters inside circles refer to waveforms shown in

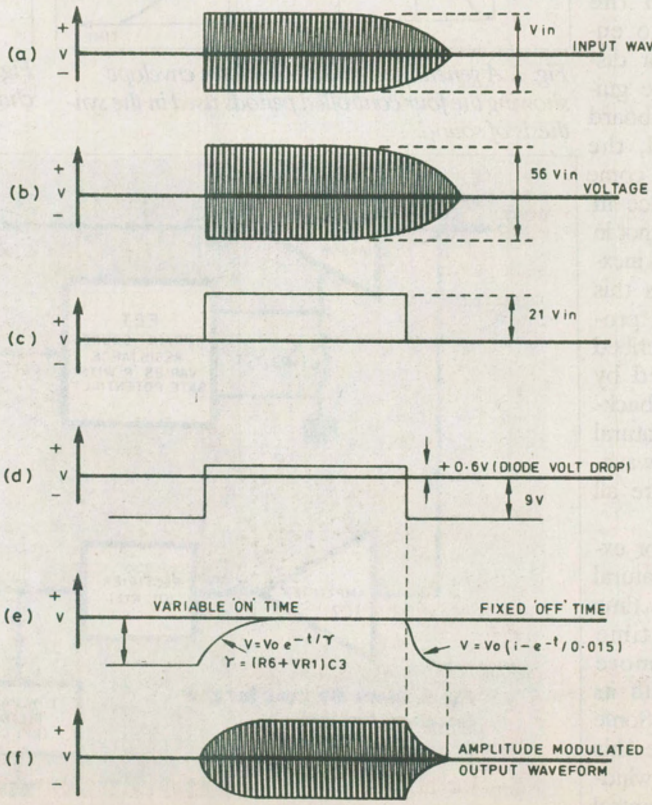
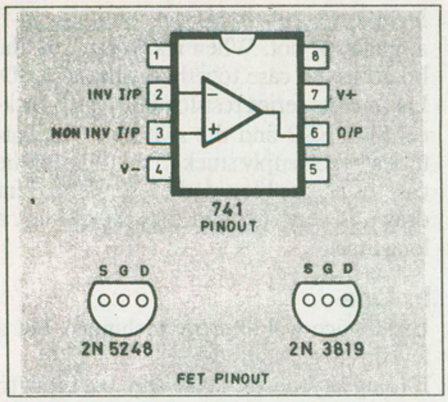


Fig. 5. Typical waveforms at various points in the circuit diagram.



Pinout details for the FET and IC.

where Req is the combined resistance of R3/(Rds+R4).

When an input signal is applied – say from an electric guitar – we require IC1's gain initially low. It can't go to zero, but by ensuring that resistor R5 is a lot less than Req(max) we can make it near enough unity.

Given that Rds(max) is near enough infinity, and Rds(min) is of the order of 500 Ohms, we find:

Req(max) = 1M

Req(min) = 650

Hence, IC1's gains are: Av(max) = 16

Av(min) = 1

A diagram showing voltage waveforms at various points in the circuit should be useful at this stage and is shown in Fig. 5. To vary IC1's gain we need firstly to detect the presence of an input signal. IC2 is another non-inverting voltage amplifier with a fixed gain of 57 simply to boost the signal level. The output is half-wave rectified by diode D1, and smoothed (or low-pass filtered) by C4/R13 to produce a positive DC level proportional to the input waveform amplitude. IC3 is wired as a comparator with a triggering level (set by the voltage divider resistors R14/R15) of about 14mV to prevent the circuit from triggering on noise, etc. from IC2. When the signal level in pin 3 of IC3 exceeds 15mV the output flips up from -9V to +9V

The positive outputs are dumped to ground through R16/D2 so that the FET gate charging circuit sees a rising square edge from -9V to +0.06V. The FET gate potential rises towards 0V at a rate defined by capacitor C3 and (resistor R6+potentiometer VR1). Note that the charging waveform due to capacitor C3 is always exponential – it's only the charging time that is changed by varying the setting of VR1.

Finally, you'll notice an attenuator at the output (pin 6) of IC1. This is necessary to trim the overall gain of the system to suit

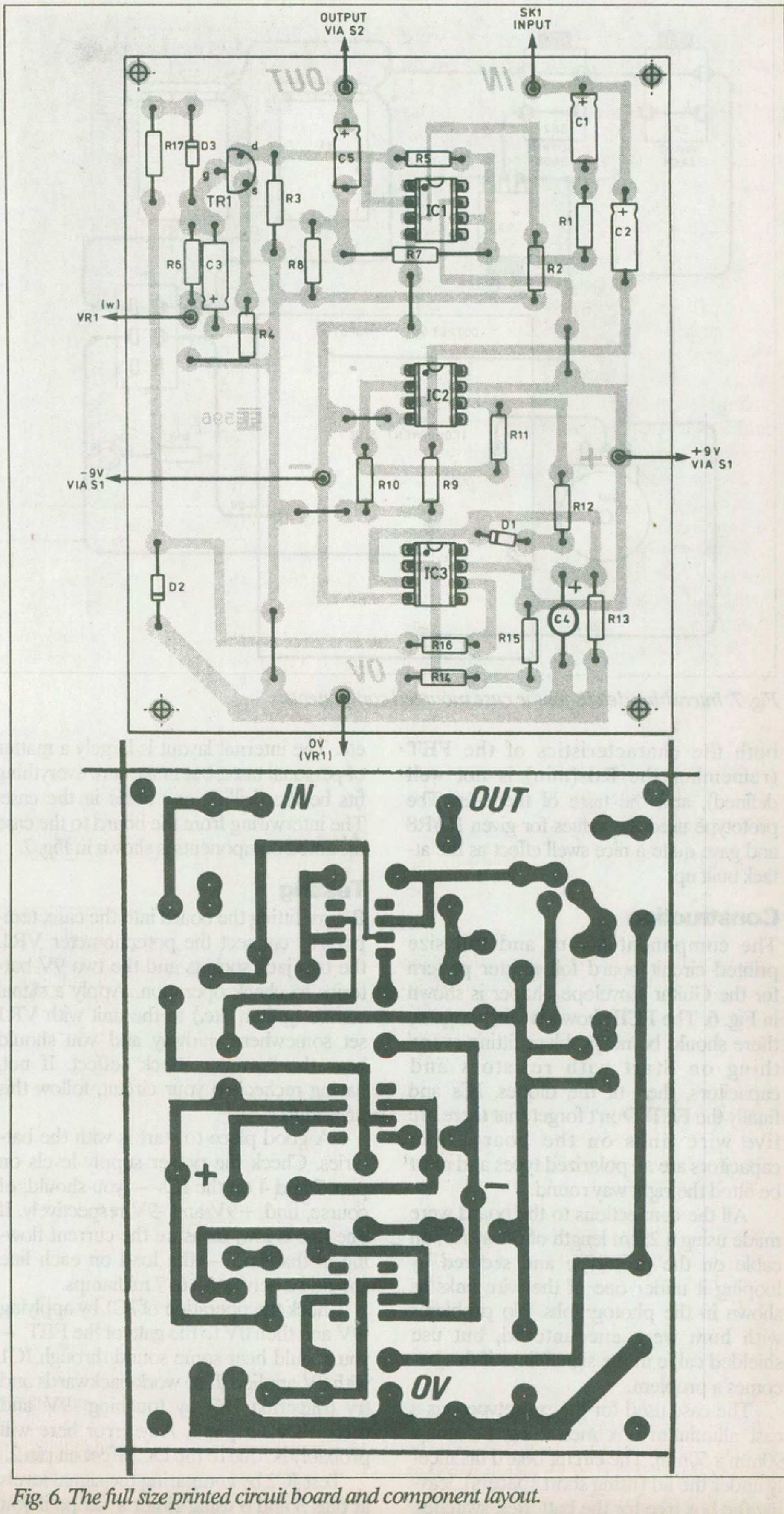


Fig. 6. The full size printed circuit board and component layout.

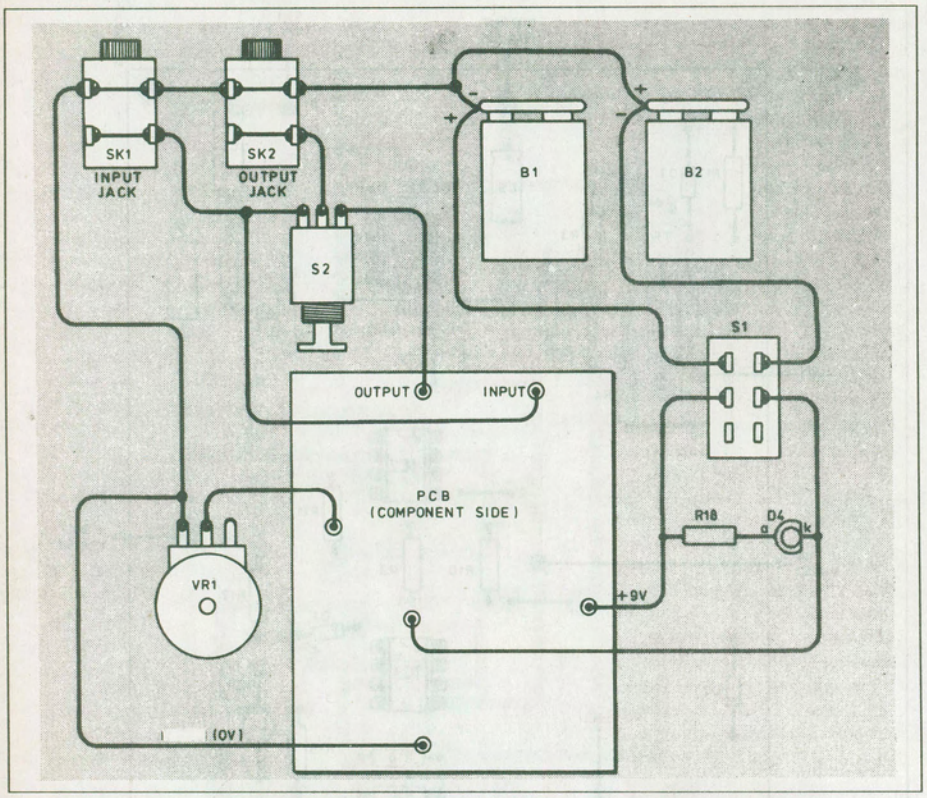


Fig. 7. Interwiring details for the case mounted components.

both the characteristics of the FET (remember the Rds(min) is not well defined), and the taste of the user. The prototype used the values for given R7/R8 and gave quite a nice swell effect as the attack built up.

Construction

The component layout and full size printed circuit board foil master pattern for the Guitar Envelope Shaper is shown in Fig. 6. The PCB shown is fairly large so there should be no problem fitting everything on Start with resistors and capacitors, then fit the diodes, ICs and finally the FET. Don't forget that there are five wire links on the board. The capacitors are all polarized types and must be fitted the right way round.

All the connections to the board were made using a 28cm length of 6-way ribbon cable on the prototype and secured by looping it under one of the wire links as shown in the photographs. No problems with hum were encountered, but use shielded cable in the signal lines if this becomes a problem.

The case used for the prototype was a cast aluminum box measuring 115mm x 90mm x 50mm. The circuit board fits nicely under the lid (using short spacers), leaving the box free for the batteries, switches, etc. The internal layout is largely a matter of personal taste, but make sure everything fits before drilling any holes in the case. The interwiring from the board to the case mounted components is shown in Fig. 7.

Testing

Before fitting the board into the case, temporarily connect the potentiometer VR1, the two jack sockets and the two 9V batteries to check operation. Apply a signal source (guitar, etc.) to the unit with VR1 set somewhere midway and you should hear the "reverse attack" effect. If not, having rechecked your circuit, follow this procedure:

A good place to start is with the batteries. Check the power supply levels on pins 7 and 4 on the ICs – you should, of course, find +9V and -9V respectively. If one line is low, measure the current flowing in that line – the load on each line should be between 3 to 7 milliamps.

Check the operation of IC1 by applying -9V and then 0V to the gate of the FET – you should hear some sound through IC1 with 0V applied. If so work backwards and try triggering IC3 by touching -9V and then +9V on pin 3. Any error here will probably be due to the DC effect on pin 2.

Test IC2 by comparing the signal levels at pins 3 and 6 using either a 'scope if you have one, or the input of your hi-fi amplifier if not. When it's working fit the board in the case together with the LED. D4 (and its series resistor R18), jack sockets SK1, SK2 and the switches. The batteries were simply stuck to the sides of the case using double-sided tape; the current drawn is very low and they should last a long time.

In Use

Experience will improve technique, but a few tips to get started:

If using keyboards, make sure the input to the unit is not so large that it triggers on keyboard output noise.

With guitars, the opposite is generally true – keep the pickup volumes wound up or you won't get much sustain. This is particularly true of the higher notes. Connecting this unit after your amplifier preamp may help here.

Finally, don't overdo it with this device. All sound effects become boring if they're constantly in use, so only switch it on when it's needed. ■

PARTS LIST

Resistors

R1	270k
R2, R9	47k
R3	1M
R4, R14	150
R5	10k
R6, R16	1k
R7	120k
R8	56k
R10	1k8
R11, R15	100k
R12, R17	4k7
R13, R18	15k

All 1/8W 5% carbon

Potentiometer

VR1 25k carbon lin.

Capacitors

C1, C2, C5	10u elec. 40V
C3	22u elec. 40V
C4	1u tant. bead, 35V

Semiconductors

D1,D2, D3	1N4006
D4	Red LED.

TR1 2N3819 n-channel FET (or similar)
IC1, IC2, IC3 741 op amp

Miscellaneous

S1 2-pole miniature slider switch
S2 Single-pole push button changeover switch (push-on push-off)
SK1, SK2 Standard 1/4in. jack socket
PCB, aluminum boxapprox. 115mm x 90mm x 50mm; 9V batteries and connectors; connecting wire; solder; nuts, screws, etc.