LIGHT METAL EFFECTS

BY ROBERT PENFOLD

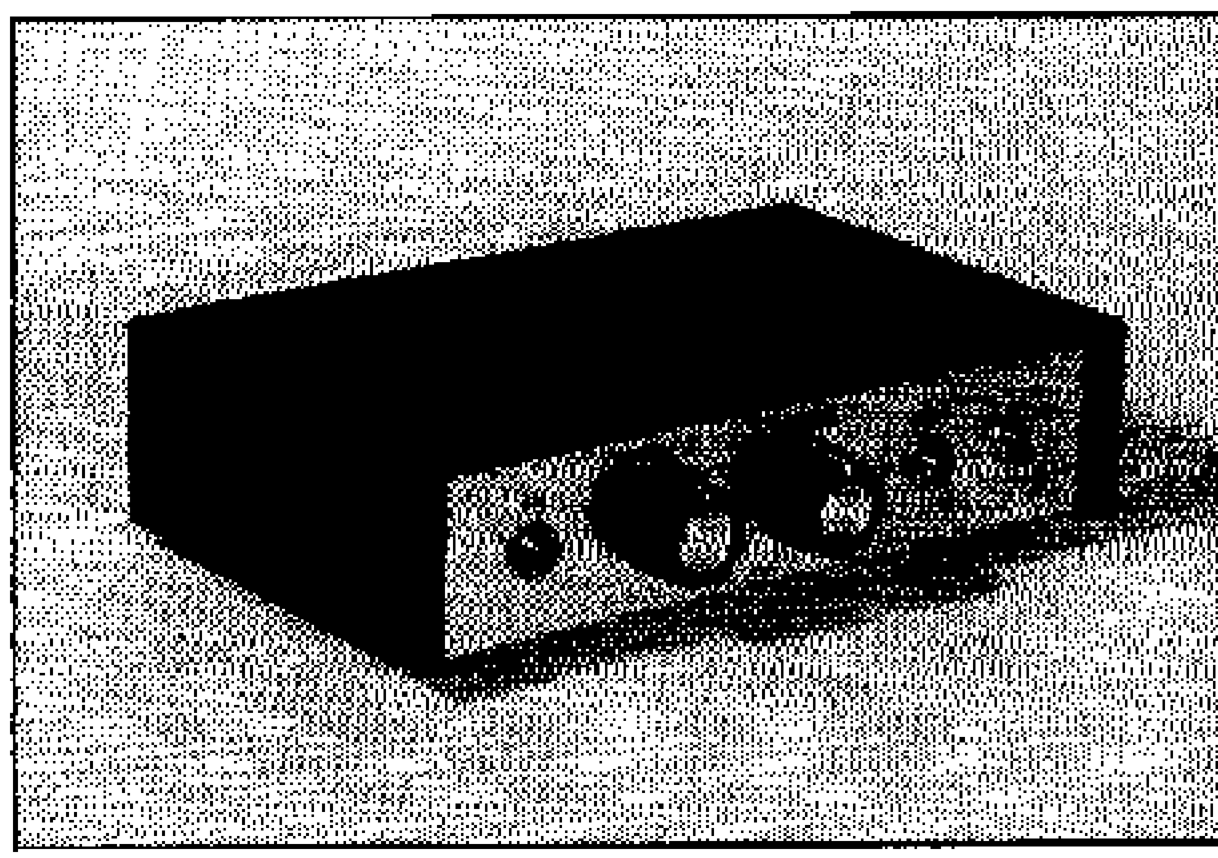
Lord of the rings?

Inspired by the former PE "Guitar Tracker", this project uses a vco and vca to produce a ring modulated sound which can be adjusted to follow the guitar's input at a chosen musical interval.

Probably most people who are "into" electronic music will be familiar with ring modulation, and its use in the production of metallic sounds (bells, gongs, etc.). A metal effects pedal is really just a ring modulator plus a built-in oscillator which is used to modulate the input signal. By setting the oscillator at a pitch which is a suitable musical interval from the input note, some quite harmonious metal sounds can be obtained. Unfortunately, a change in the input note will change the musical interval separating the two tones, and it may or may not produce a pleasant sounding output signal. For this reason the metal effect is generally used in moderation, or by those of more extreme musical tastes.

This unit was designed to overcome the rather hit and miss nature of the effect generated by a conventional ring modulator unit, and to give consistent results over a wide range of pitches. If you get a pleasant effect on one note from your guitar, then all the other notes should give more or less the same effect. What would I describe as a light metal effect rather than a heavy one. On the other hand, if you like the unharmonious sounds that can be produced by ring modulation, then the unit can be adjusted to give an equally discordant effect on every note (very heavy metal? – *For a lead guitar perhaps? Ed.)*

It operates in what is basically the same manner as a conventional metal pedal. The input signal is ring modulated by an oscillator, and the resultant signal is mixed with the unprocessed signal at the desired strength. The difference

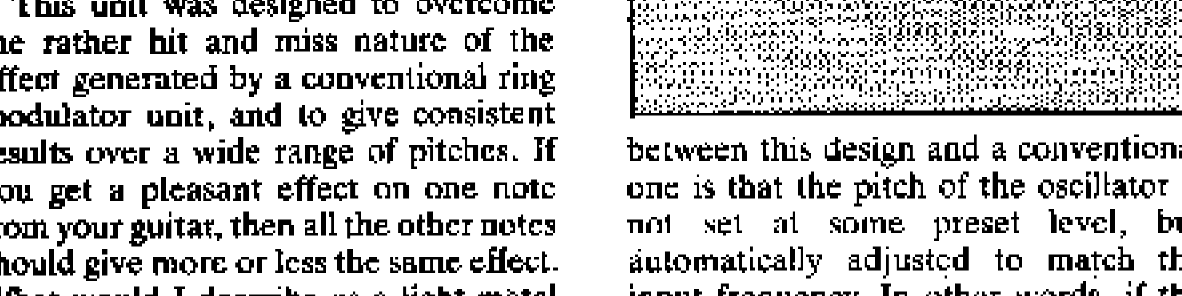


between this design and a conventional one is that the pitch of the oscillator is not set at some preset level, but automatically adjusted to match the input frequency. In other words, if the oscillator is set a fifth higher than the input at one input frequency, then it will automatically adjust its pitch on other notes so that it remains a fifth higher.

SYSTEMS OPERATION

The block diagram of Fig.1 shows the general arrangement used in the unit, and helps to explain the way in which it functions. The unit has similarities with the *"Guitar Tracker"* project described in PE June 1986, and it is a development of that project.

Fig 1. Block diagram for the light metal effects unit.



The input signal is taken to a buffer amplifier, and then to a voltage amplifier stage which ensures there is a high enough signal level to drive the subsequent stages properly. Some of the output from the amplifier is fed to a mixer stage and from here to the output socket. The output from the amplifier also drives a trigger circuit, and the roughly squarewave output signal from this circuit is split two ways. The first route is to one input of the ring modulator, where the signal is mixed with the signal from a vco (voltage controlled oscillator).

The second route is to the input of a monostable multivibrator, and this acts as the basis of a simple frequency to voltage converter. The output pulse duration of the monostable is set by a CR timing circuit, and so the average output voltage depends on the number of times the monostable is triggered in a given period of time. The greater the number of times it is triggered, the higher the average output voltage. This may seem like a rather crude system of frequency to voltage conversion, which I suppose it is, but actually gives extremely good linearity. The output from the monstable is smoothed by an active lowpass filter to give a dc signal to control the vco The operating frequency of the vco is therefore moved up and down in sympathy with the pitch of the input signal.

There is a slight problem with this basic system in that it only provides a control voltage to the vco while an input signal at a reasonable level is present. Noises from the guitar if the fingering and playing is anything less than perfect can also give problems. To overcome these difficulties an electronic switch is used to connect the monostable to the lowpass filter for only a fraction of a second at the beginning of each new note. While this does not absolutely guarantee perfect results every time, it greatly reduces the risk of any mistracking. The lowpass filter is based on an ultra-high input impedance amplifier, and it therefore acts as a "hold" circuit which maintains the control voltage to the vco during the periods when the electronic switch is cut off.

to the mixer stage at the output, but this would not give entirely satisfactory results. The main problem is with breakthrough of the vco at the output of the ring modulator, but there is also a secondary problem in that the modulated signal is at a constant level, and does not vary in level in the same way as the input signal.

Both problems are overcome by feeding the ring modulated signal to the mixer by way of a vca (voltage controlled amplifier). This is driven from the output of the smoothing and recitifier circuit via a buffer amplifier. The amplitude of the ring modulated signal therefore varies in sympathy with the strength of the input signal.

The basic action of the ring modulator is to generate sum and difference frequencies from the input frequencies. two or three dimensional in nature, and it is this that gives them the strong output at non-harmonic frequencies. They are effectively resonating at two or more frequencies, and interacting in a way that I suppose is roughly analogous to ring modulation.

THE CIRCUIT

Fig.2 shows the circuit diagram for the input, frequency to voltage conversion, and vco stages, while the rest of the circuit is shown in Fig.3.

I will not dwell on the operation of the circuit of Fig.2 here, since it is much as the equivalent stages in the "*Guitar Tracker*" project referred to earlier. Details of the way in which it functions can be found in this earlier article.

Turning our attention to Fig.3, IC7a acts as the basis of the ring modulator, and this is one section of an LM13600N dual operational transconductance amplifier (ota). The signal from the vco is coupled to both the inverting input and the output of the ota, and this balances out the signal which consequently fails to appear at the output. The amplified guitar signal is fed to the control input of IC7a. It therefore varies the gain of this amplifier, giving only minor breakthrough at the output. This varying of the gain affects the cancelling of the vco signal at the output of the circuit, and provides the complex mixing needed to generate the sum and difference signals while suppressing the input signals. VR4 is adjusted to minimise breakthrough of the input signals at the output. The output is buffered by a built-in Darlington Pair emitter follower in IC7a.

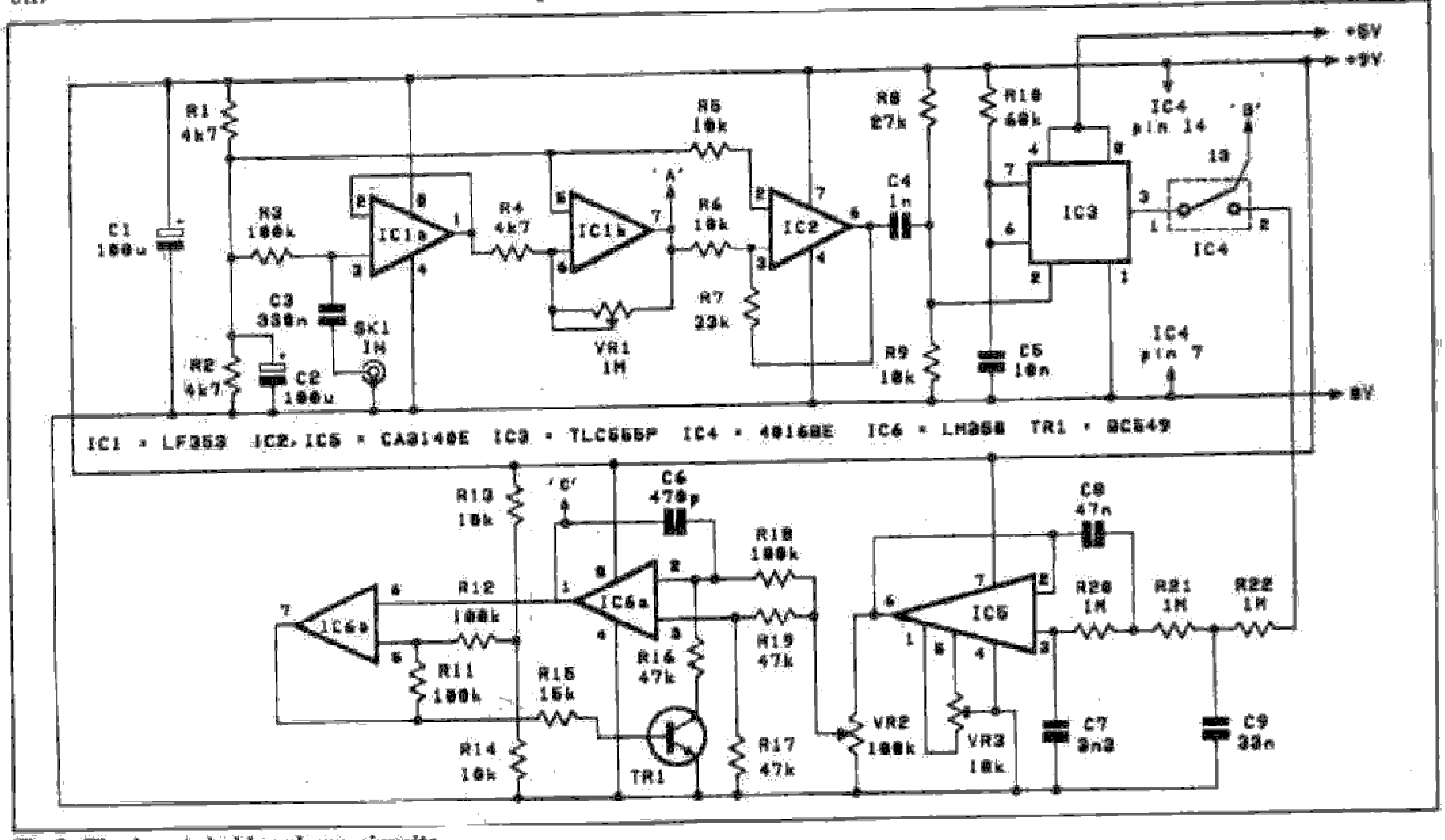


Fig 2. The input, hold and vco circuits.

The control signal for the switch is obtained by first rectifying and smoothing some of the output from the amplifier stage, so as to obtain a dc signal at a voltage which is proportional to the amplitude of the input signal. This dc signal is fed to a trigger circuit which is adjusted so that its output only triggers to the high state at the beginning of each note, when the signal from the guitar is at or close to its peak level. This gives a brief pulse which is used to trigger a monostable, and this circuit provides a gate pulse of suitable duration to the electronic switch.

This set up gives an oscillator which tracks up and down, following changes in the input frequency, and it ring modulates the vco's output with the input signal. The output from the ring modulator could simply be fed through

As a simple example, with the two inputs fed with frequencies at 400Hz and 600Hz the output frequencies would be 1kHz (400Hz plus 600Hz = 1000Hz or 1kHz) and 200Hz (600Hz − 400Hz = 200Hz). In theory the input signals are balanced out and do not appear at the output, although with practical circuits there is usually significant breakthrough of at least one of the signals, and at least slight breakthrough of both. The sounds that result from this form of modulation are metallic in character due to the output containing strong signals at non-harmonically related frequencies.

Most western instruments use strings or similar vibrators that are essentially one-dimensional, and this gives very little output at frequencies other than the fundamental and it harmonics. Metal instruments such as gongs and bells are

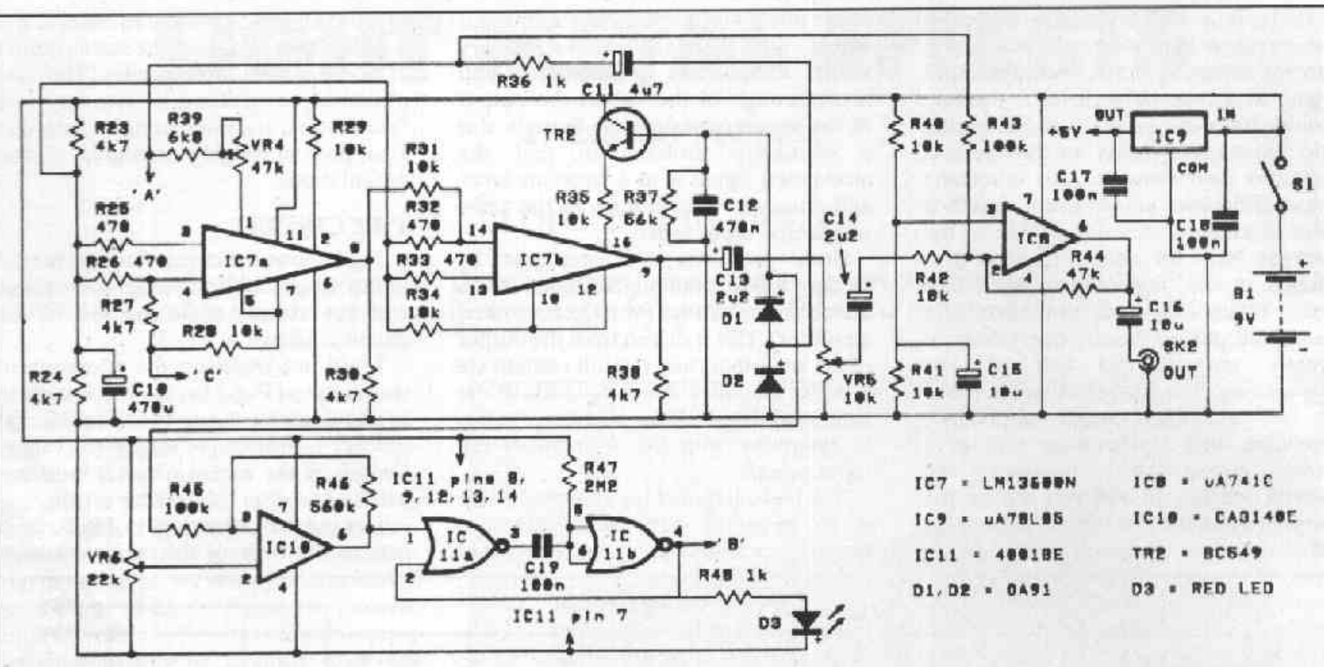


Fig 3. Circuit for the modulator, vca, trigger and mixer stages.

The other section of IC7 is utilised as the vca, and this is a conventional ota type. The amplified guitar signal is rectified and smoothed by D1, D2 and C12, and then fed to the control input of IC7a via buffer amplifier TR2. The envelope shaped output signal from IC7b is fed via level control VR5 to a conventional summing mode mixer circuit. Here it is combined with the amplified guitar signal in a standard summing mode mixer and then fed through to output socket SK2.

IC10 acts as the trigger circuit which is fed from the rectifier and smoothing stages. This is a simple operational amplifier type with the trigger level controlled using VR6 and a substantial amount of hysteresis provided by R46. The monostable is based on two of the cmos NOR gates in IC11, and it is a positive edge triggered, non-triggerable type. Note that the other two gates of IC11 are left unused, and their inputs are simply tied to the positive rail. Apart from driving the analogue gate, the output of the monostable also drives led indicator D3. This indicator is not much value in normal use, but it is helpful when initially testing and setting up the unit.

The unit is powered from a 9 volt battery, but the supply to the monostable in the voltage to frequency converter must be well stablised to avoid drift in the vco as the battery voltage falls due to ageing. The supply for the monostable is therefore derived through a 5 volt monolithic voltage regulator (IC9). The current consumption of the circuit is fairly high at around 20 to 25 milliamps, and the use of a medium or high capacity battery is recommended. I use six HP7 size cells in a plastic holder.

CONSTRUCTION

Refer to Fig. 4 for details of the printed circuit board. Several of the integrated circuits are mos types (IC2, IC4, IC5, IC10 and IC11) and require the normal anti-static handling precautions to be observed. It is probably best to use sockets for all the dil integrated circuits, mos types or not. Take care not to overheat D1 and D2 when soldering them into circuit as these are germanium devices. As such they are much more vulnerable to heat damage than are the more familiar silicon variety. A heatshunt should not be necessary, but do not apply the iron to the joints for any longer than is really necessary.

Although an LM13600N is specified for IC7, some suppliers only seem to stock the virtually identical LM13700N. Either device should function properly in the IC7 position of this circuit. If the

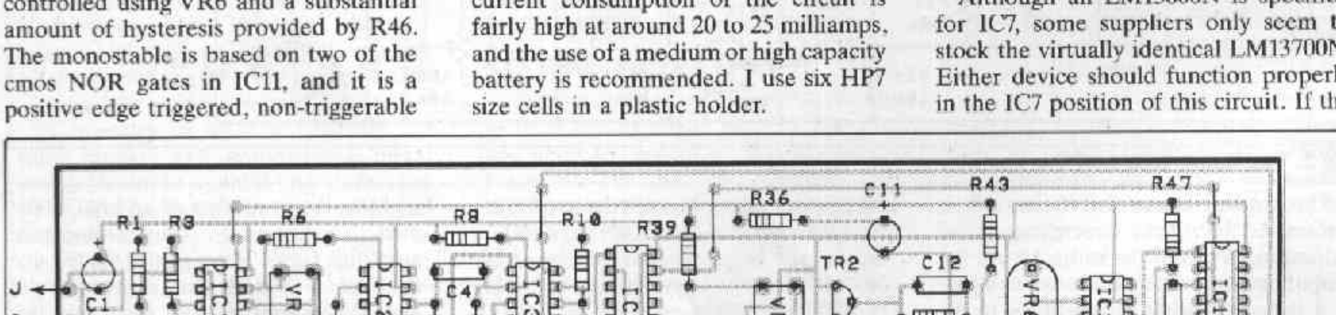


Fig 4. Printed circuit board details.

components are to fit onto the board easily it is essential to use modern miniature components, especially the capacitors which, with the only exception of C6, should be printed circuit mounting types.

I used a metal instrument case about 200 millimetres wide as the case for this project. The length of the printed circuit board and the need for a fairly large battery preclude the use of a case very much smaller than this. The controls, sockets, and led indicator are mounted in a row along the front panel, preferably in an arrangement which matches up well with the positioning of their connection points on the printed circuit board. SK1 should certainly be positioned close to its connections points on the board, or a screened lead should be used here. The printed circuit board should be positioned well towards the front of the case so as to leave sufficient space for the battery at the rear of the unit. Of course, the board must be mounted on stand-offs to keep the connections on the underside of the board well clear of the metal case.

On my prototype the on/off switch is a set of normally open contacts on the input socket (SK1). The unit is therefore switched on when the guitar lead is plugged into SK1, and switched off again when it is unplugged. This is quite common with effects units, and reduces the risk of the unit being accidentally left switched on. Presumably jack sockets will be used as the input and output connectors, and a socket of this type having a set of normally open contacts would not seem to be available. However, types with dpdt contacts are obtainable, and two contacts from one of these can be used to give the required switching action. Of course, it is quite in order to use an ordinary on/off switch such as a miniature spst toggle switch if preferred. The wiring to SK1 and the controls is shown in Fig.5 (which must be used in conjuction with Fig.4), and it is assumed here that a combined input socket and on/off switch are used.

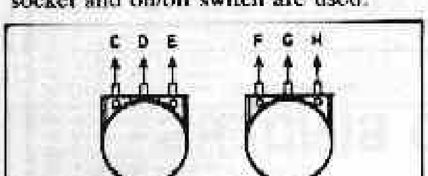


Fig 5. Control wiring

COMPONENTS

RESISTORS

R1,R2,R4, R23,R24,R27, R30,R38	4k7 (8 off)
R3,R11,R12, R18,R43,R45	100k (6 off)
R5,R6,R13, R14,R28,R29, R31,R35,R40, R41	10k (10 off)
R7	33k
R8	27k
R9,R34,R42	18k (3 off)
R10	68k
R15	15k
R16,R17,R19, R44	47k (4 off)
R20,R21,R22	1M (3 off)
R25,R26,R32, R33	470R (4 off)
R36,R48	1k (2 off)
R37	56k
R39	6k8
R46	560k
R47	2M2

POTENTIOMETERS

VR1	1M sub-min hor preset
VR2	100k lin
VR3	10k sub-min hor preset
VR4	47k sub-min hor preset
VR5	10k log
VR6	22k sub-min hor preset

CAPACITORS

C1,C2	100µ 10V radial elect (2 off)
C3	330n polyester layer
C4	1n polyester layer
C5	10n polyester layer
C6	470p polystyrene
C7	3n3 polyester layer
C8	47n polyester layer
C9	33n polyester layer
C10	470µ 10V radial elect
C11	4µ7 63V radial elect
C12	470n polyester layer
C13,C14	2µ2 63V radial elect (2 off)
C15,C16	10µ 25V radial elect (2 off)
C17,C18	100n ceramic (2 off)
C19	100n polyester layer

SEMICONDUCTORS

IC1	LF353
IC2,IC5,IC10	CA3140E (3 off)
IC3	TLC555P
IC4	4016BE or 4066BE
IC6	LM358
IC7	LM13600N or LM13700N
IC8	µA741C
IC9	µA78L05
IC11	4001BE
TR1,TR2	BC549 (2 off)
D1,D2	0A91 (2 off)
D3	Red panel led

MISCELLANEOUS

S1	Part of SK1
SK1	Standard jack with dpdt contacts
SK2	Standard jack socket
B1	9 volt (eg 6 x HP7 in holder)

Instrument case about 203 x 127 x 51mm, printed circuit board, battery connector, 8 pin dil ic holder (7 off), 14 pin dil holder (2 off) control knob (2 off), wire, solder, etc.

CONSTRUCTOR'S NOTE:
The PE PCB Service can supply the printed circuit board.

ADJUSTMENT

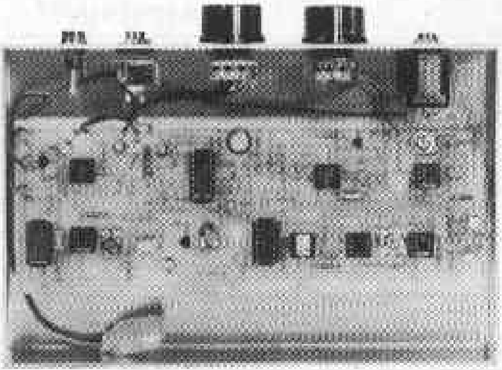
There are four presets to be set up correctly before the unit is ready for use. VR1 must be adjusted to give a level of gain from the voltage amplifier that gives reliable triggering of the unit. It is a matter of using the lowest sensitivity (clockwise adjustment gives decreased sensitivity) that gives reliable triggering of the unit. Higher gain is undesirable as it could result in the signal being clipped at the output of IC1b, and it could also lead to spurious triggering of the unit.

VR3 is the offset null control for IC5, and it is adjusted to optimise tracking accuracy at low frequencies. The output tone from the vco needs to be monitored in order to do this, and something as basic as wiring a crystal earphone between IC6 pin 1 and the negative supply rail will suffice. It is a matter of first adjusting VR2 to match the vco frequency to the input frequency when using a high input frequency (ie about 1kHz). Then, using a much lower frequency (around 100Hz), adjust VR3 to match the pitch of the vco to the input note. Repeat this procedure a few times to get the tracking as accurate as possible. In this application very precise tracking is not really essential, and the setting of VR3 does not seem to be very critical.

The effect obtained varies somewhat with the setting of VR4. Although its main purpose is to minimise breakthrough of the vco and input signals, you can settle for any setting that gives an effect you like.

Initially VR6 should be set at about half maximum resistance, and the unit will probably work quite well at this setting. However, it is worthwhile experimenting with VR6 at slightly different settings, and readjusting VR1 to compensate, in order to find a combination that gives optimum results.

The unit produces some good "thicker" sounds, but to my ears anyway, it is at its best with VR5 set for a



moderate amount of ring modulation. Remember that the signal from the modulator contains little output at the guitar frequency. Using a large amount of modulation you may find that the output notes are not the same as the ones you play on the guitar. As it stands the unit does not have any in/out switching. This could easily be added though, and all that is needed is a switch in series with C13 to cut the signal path of the modulation, or a switch to connect pin 16 of IC7 to earth and cut off the vca. An external foot-switch might be the best type of switch to use.