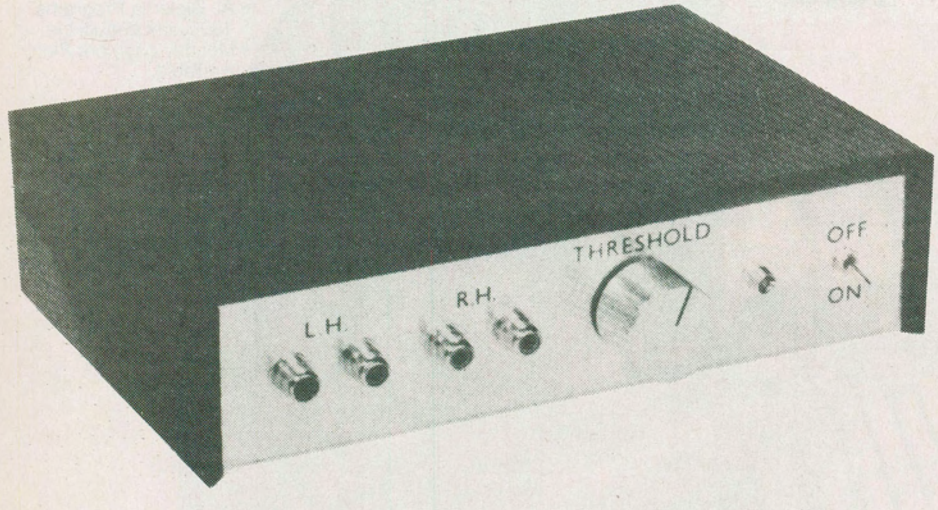
Stereo Noise Gate

Clean up your act and make sure you get your message across to your audience loud and clear.

ROBERT PENFOLD



A noise gate is extremely simple in essence, and the basic idea is to have an electronic switch which enables the input signal to pass through to the output, but cuts the signal path when no signal is present. Units of this type are normally used on signals which contain a fair amount of noise, either in the form of background hiss or mains hum. The noise would tend to be very obtrusive during pauses in the main signal, and switching it out during these periods can therefore make a worthwhile improvement in the subjective quality of the signal.

Noise gates are used in various applications, but are mainly used in communications systems to clean up noisy voice links, or in electronic music systems. In the case of the latter they are often needed to combat the mains hum that is present on the output of some instruments, or which occurs due to ground loops which prove to be difficult to eradicate, but may also be used to combat tape noise or hiss type noise from other sources such as certain types of effects unit.

Noise gates are sometimes utilized as a form of effects unit themselves, and can be used to give an abrupt cutoff to an instrument which has a long decay time. In this role the unit is really operating as an envelope modifier rather than as a noise gate, although it is still the noise gate name which is normally applied to units of this type.

Zero Point Switching

Although simple in theory, some noise gate designs are quite complex. It is one of those things where a basic design can be built using a handful of components, but one which gives really good results needs to be much more involved.

The main problem with very basic types is that they tend to generate switching clicks as they switch on and cut off again. The importance of this depends on the application, but a design which does not generate these glitches will almost invariably sound noticeably better than one which does, and in some electronic music applications the difference can be very noticeable indeed.

There are two main approaches to avoiding the switching glitches, and these are predictive switching and zero point (or crossover) switching. With predictive switching the gate appears to predict that the signal is about to commence, and switches on just before it does so.

What is actually happening is that the

switch is being activated in the normal way by detecting the commencement of the input signal, but the signal to be gated is fed to the switch via a delay line so that the switch has time to close before the signal reaches it. This system can still produce a switching glitch when the signal is cut off, although in most cases the signal is not switched off until it has decayed to a very low level, and any switching glitch is then likely to be so small as to be unnoticeable.

This noise gate design uses the alternative of zero point switching, which is slightly more simple and less expensive to implement, and which seems to give better overall results. With this method it is accepted that by the time the circuit has detected the start of an input signal it will have already reached the electronic switch, but switching glitches are avoided by holding off the switching on of the gate until the signal passes through the zero volts crossover point.

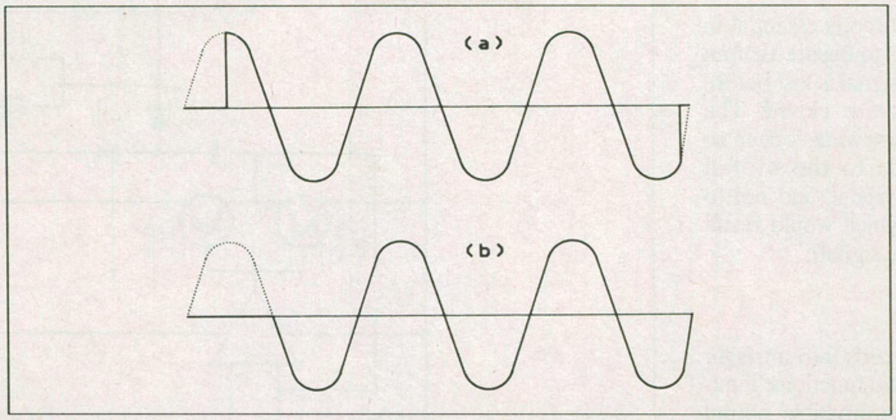


Fig.1. In waveform (a) the signal is cut on and off near its peak level, producing "clicks" that are absent from the waveform shown in (b).

The waveforms shown in Fig. 1 helps to explain the way in which this eliminates the switching clicks. In Fig. 1(a) there is no zero point switching, and the gate actually switches on at the worst possible time, which is at the peak of a half cycle. This gives a signal which rises almost instantly to the peak level, and in doing so it produces strong high frequency components which give the switching click sound.

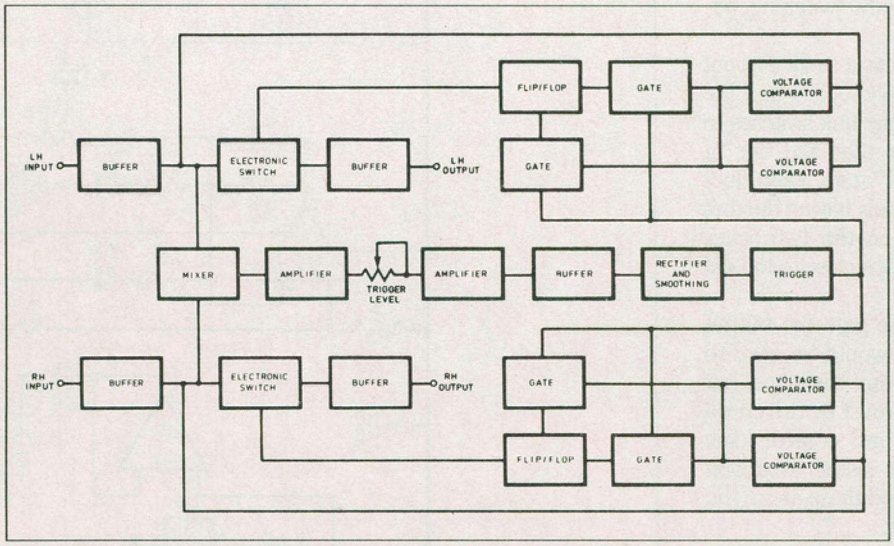


Fig.2. The block diagram for the Stereo Noise Gate. Although it looks quite complex the actual operation is quite straightforward (see text).

With a combination of high amplitude and high frequency components this glitch will stand out clearly against most types of signal. Of course, the signal will not always be switched on when it is at or near its peak level, but in practical tests with a variety of signals a simple noise gate was found to generate strong switching glitches far more times than they were very weak or absent.

With the zero point switching waveform of Fig. 1(b) the switch-on has been held off until the end of the half cycle, so that the output signal from the gate starts at the beginning of a half cycle. There is no sudden rise in the signal to a high level, and no click will be evident on the output signal. This system is less than perfect in that a few milliseconds at the beginning of the signal are lost, but in practice it is highly unlikely that this would ever be noticeable.

Switching glitches can also occur when the signal is switched off again. These are caused by a similar effect, with the output signal suddenly being switched from (possibly) a high amplitude to zero. Often the signal will be at a low level by the time it is switched off, but ideally the zero point switching should also be active at switch-off so that a high cut off threshold can be used if desired, without the risk of any significant switching glitches.

System Operation

The block diagram of Fig. 2 shows the general arrangement utilized in the Stereo Noise Gate, and although this looks rather involved, the basic means of operation is actually quite straightforward.

Each channel has an electronic switch which is used to switch the input signal through to the output, or to block its path, depending on the input signal level. A buffer amplifier ahead of each switch provides the unit with a reasonably high input impedance while a buffer stage following each switch gives the unit a low output impedance.

The basic function the noise gate must provide is to generate a signal to turn on the switches if the input exceeds a certain threshold level, or to switch them off if the signal is below this level. With a stereo noise gate it is normal for the two channels to be switched in unison as the action of the unit becomes much more apparent if they operate independently. Therefore, the output of each input buffer amplifier is coupled to a mixer stage, and the gating signal is derived from the output of the mixer.

With this system there is actually no rigidly defined level at which the gate is activated in the sense that the threshold level is the sum of the input levels, rather than at a certain level on one or other of the inputs. This gives perfectly good results in practice though, and helps to simplify the unit slightly.

Amplifier

It will often be necessary for the gate to be activated at quite low signal levels of around -40dB or less, and a large amount of amplification is needed after the mixer in order to produce a strong enough signal to drive the switch control circuits properly. Two stages of amplification are used, with a gain control fitted between these two stages. This acts as the trigger level control.

A buffer stage follows the second amplifier, and the purpose of this is to provide a very low output impedance so that the next stage can be driven properly. This stage is a smoothing and rectifier circuit, and the low drive impedance permits a very rapid attack time of under a millisecond to be achieved.

A very fast attack time is essential in this application in order to ensure that an insignificant amount of signal is lost before the electronic switches are closed. The decay time must be somewhat longer so that the unit responds to the overall amplitude of the input signal, and not to individual half cycles (which would result in severe chopping of the signal).

Trigger Levels

The smoothing circuit feeds into a trigger circuit which provides two functions. Firstly, it provides a logic compatible output from the input signal which will be at non-logic voltage levels and will vary relatively slowly rather than cleanly switching between two levels.

Secondly, it introduces a small amount of hysteresis, which simply means that the threshold level at which the unit switches to the "on" state is higher than the one at which it reverts to the "off" state. This reluctance to change state avoids having the unit rapidly switching between the two states when the input signal drops close to the cut off point.

With a simple noise gate the output from the trigger circuit would be used to directly drive the electronic switches, but in this case the switches must be driven via zero crossing detector and control logic circuits. Each electronic switch is driven from a flip/flop circuit, and these are of the basic S/R (set/reset) type.

A flip/flop of this type has two inputs called the "set" and "reset" inputs, and there are two outputs called the "Q" and "not Q" outputs. The outputs always have the opposite states to one another, and in this case only the Q outputs are used. These are set high by a positive pulse to the set input, and set low again by a positive pulse to the reset input. In this case, the set pulses close the electronic switch, and the reset pulses open it again.

Voltage Comparator

Two voltage comparators provide zero

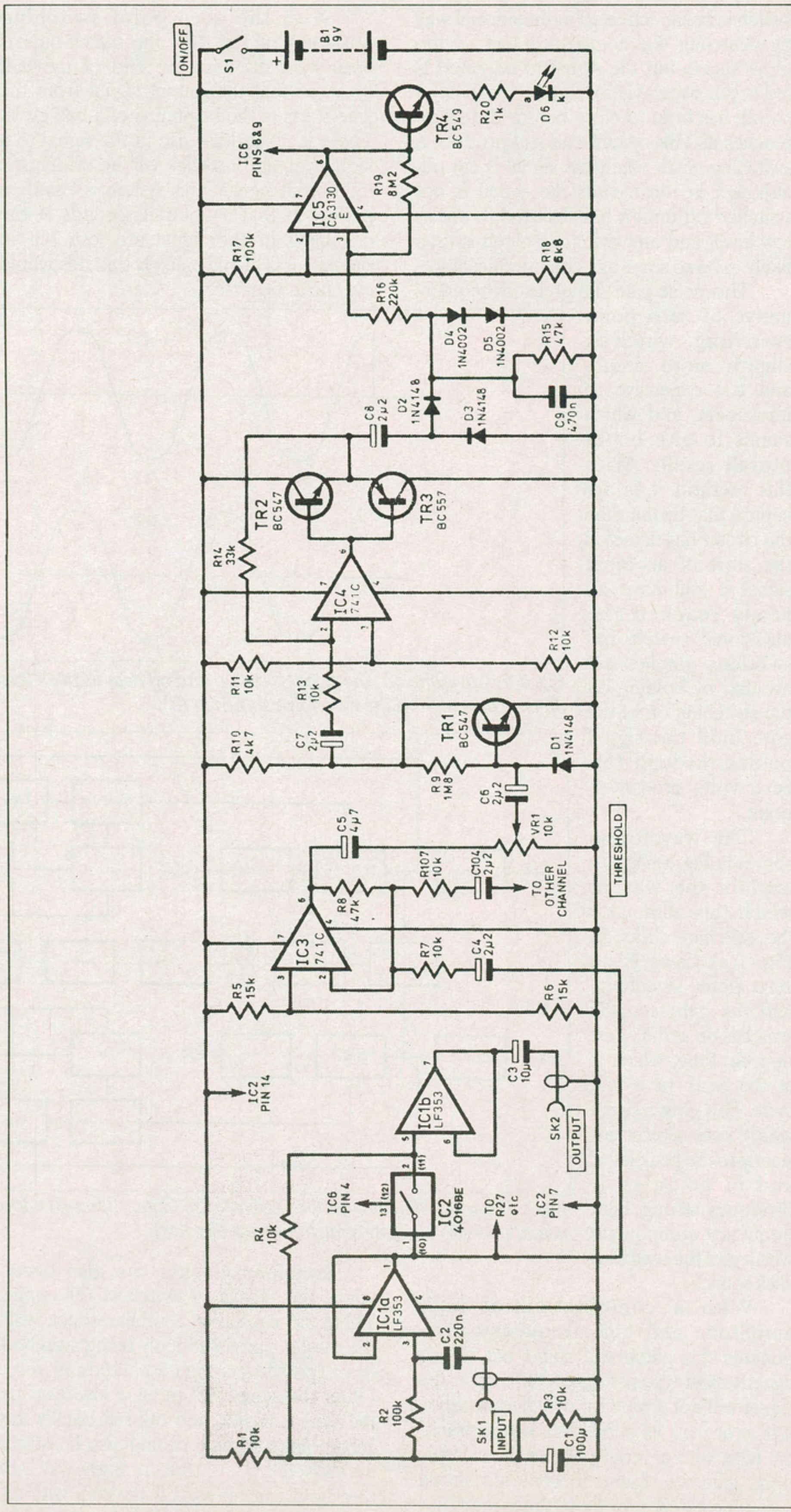


Fig.3. The main cicuit diagram for the Stereo Noise Gate.

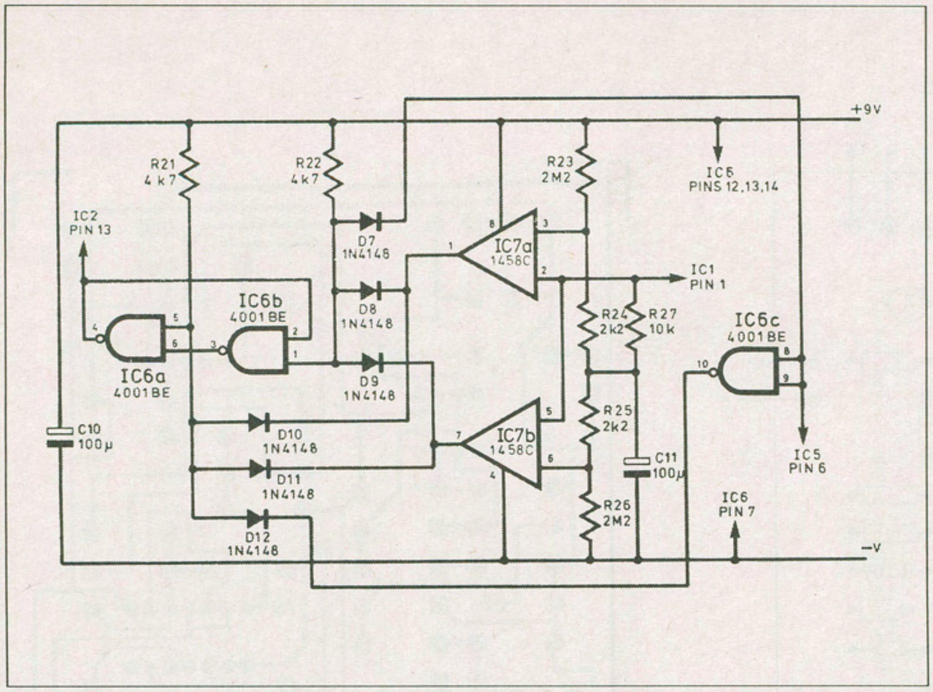


Fig.4. Circuit diagram for the zero crossing detector, gate and flip/flop stages. This circuit is repeated for the stereo channel.

crossing detection, and these are set up in such a way that both their outputs go high if the input voltage is within a few millivolts of zero volts. The two outputs are fed to a gate circuit, along with the output from the trigger circuit.

The gate is designed to provide a positive output only if all three inputs are high, and it provides the set signal for the flip/flop. In other words, the desired action is obtained, with the trigger output going high, but the electronic switch not being activated until the signal reaches the zero crossover point and the outputs of both comparators go high as well.

The reset pulse is produced by a second gate circuit, and it is fed from the same sources. However, it differs from the other gate in that it generates a high output level when the outputs of the voltage comparators are high, and the trigger outputs is low (not high). Thus the electronic switch is turned off when the trigger output goes low, but only when the comparators detect that the input signal has entered the zero crossing zone.

As the signal in each channel will normally be different, a separate zero crossing detector and control logic circuit is needed for each channel. This means that the two channels will not be switched precisely in unison except when the two signals just happen to pass through the zero point simultaneously. However, the time difference between the two channels switching will usually be no more than a few milliseconds, and is unlikely to be noticeable.

Circuit Operation

The main circuit diagram of the Stereo Noise Gate appears in Fig. 3, with the zero crossing detector gate circuit shown separately in Fig. 4. Note that this circuit is for ONE channel only, and that for stereo operation much of the circuitry is duplicated in the second channel.

The input and output buffer amplifiers IC1a and IC1b (Fig. 3) are both standard non-inverting types. The input impedance of the unit is nominally 100k. IC2 is the electronic switch and this is a CMOS 4016BE quad SPST type. One of the four switches is used in the other stereo channel, but the other two are simply ignored.

The input of IC1b must not simply be left floating when IC2 is switched off, as it would almost certainly drift away from the normal bias level, and this would cause a switching click each time the switch was activated. Resistor R4 is therefore used to bias IC1b's input to half the supply voltage during the periods when IC2 is open.

The mixer stage IC3 is a conventional summing mode type. It is designed to have a certain amount of gain, and it therefore doubles as the first of the amplifier stages.

The potentiometer VR1 is the Threshold control, and this feeds into the second amplifier which is a high gain type which has TR1 operating in the common emitter mode. This amplifier will often be considerably overloaded, and diode D1 is needed to prevent this from driving the biasing well off its correct level, which could cause the circuit to occasionally malfunction.

The buffer amplifier uses IC4 in the inverting mode with TR2 and TR3 as a discrete class-B output stage which gives the circuit a high drive current capability. The circuit does exhibit a small amount of voltage gain, but only about 10dB (just over three).

Decay Time

Diodes D2 and D3 are the rectifier circuit, and capacitor C9 is the smoothing capacitor. Resistor R15 sets the decay time, and with the specified value this is quite short (less than 100ms). The decay time can be altered by changing the value of R15 though, or a potentiometer could be used here to give an adjustable decay time. The decay time is proportional to the value of R15.

Diodes D4 and D5 limit the voltage produced across capacitor C9 to no more than about 1.3V, and this helps to give consistent results. Without this limiting some signals would generate a very strong voltage on C9 which would take a long time to fall to the switch-off threshold voltage, and this would give inconsistent decay times.

IC5 operates as the trigger circuit with positive feedback and hysteresis introduced by resistor R19. The LED indicator D6 is driven from the output of IC5 by way of emitter follower buffer TR4, and D6 indicates when the gate has been activated.

Zero Crossing Detector

Focussing our attention on the zero crossing circuit, Fig.4, IC7 is a dual operational amplifier but in this circuit both sections are connected to act as voltage comparators. The resistor/capacitor network (R23 to R27 plus C11) provides suitable reference voltages, but note that the circuit is not strictly speaking a true zero crossing detector. What it is really detecting is when the signal voltages is close to its quiescent bias level, which is about half the supply voltage.

The two gates are both 3-input AND types formed from three diodes and a resistor. In the case of the gate that generates the reset signal, the input that is fed from the trigger circuit's output is preceded by an inverter (IC6c), so that

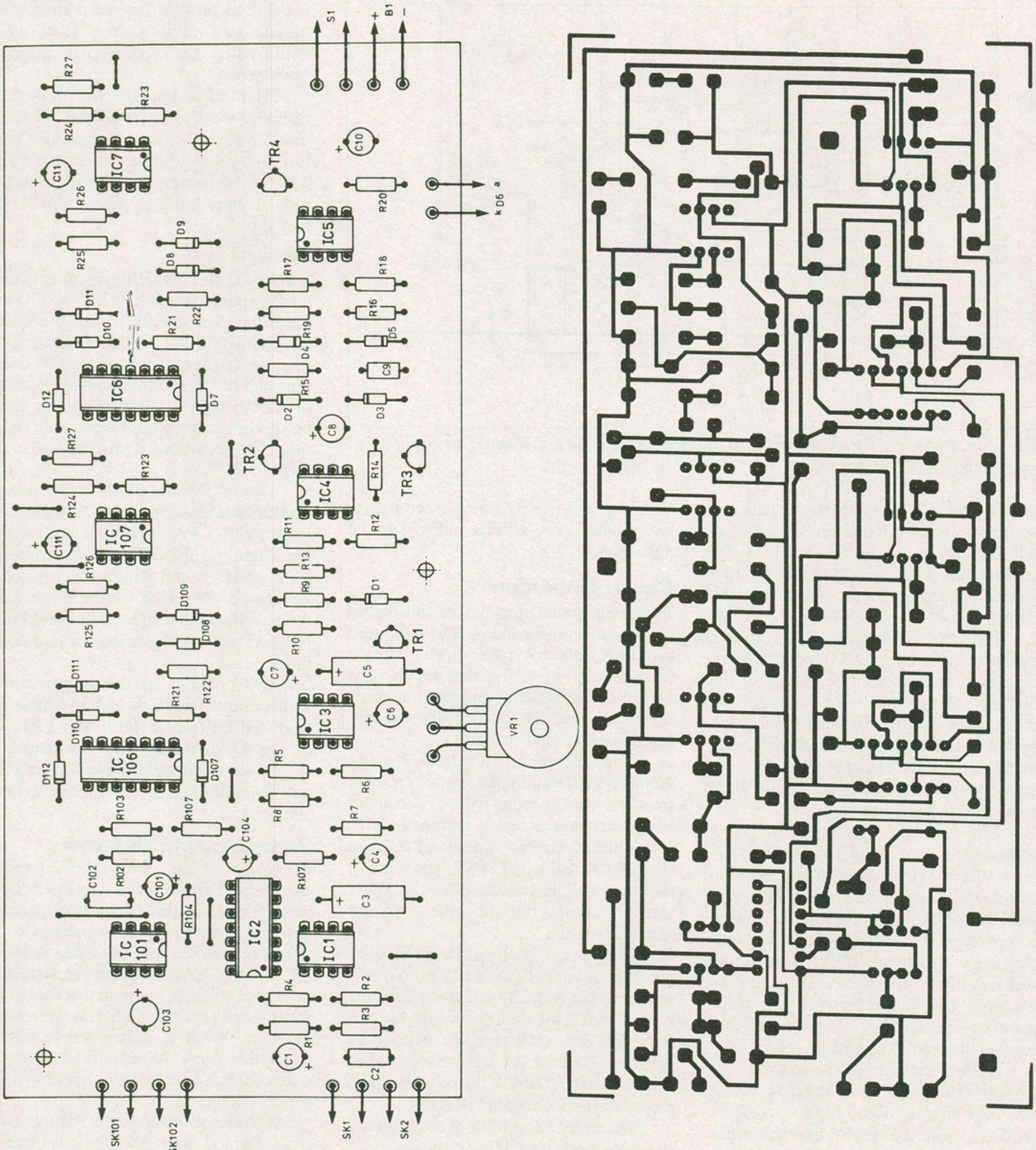


Fig.5. Component layout and full size printed circuit board copper foil master pattern ofor the Stereo Noise Gate. The components with annotations of one hundred added are for the second channel.

when the trigger provides a low output level the input to the gate goes high and generates the reset pulse.

The flip/flop is a conventional CMOS type formed by cross coupling a couple of 2-input NOR gates, IC6a and IC6b. One of the other gates in IC6 is used as the inverter mentioned above, but the other gate is left unused.

The current consumption of the circuit is about 18mA when in the standby state, and around 25mA when activated (and the LED indicator switches on). Power is supplied by a fairly high capacity 9V battery, such as a PP9 type of six HP7 size cells held in a plastic battery holder.

Construction

Apart from the usual off-board components such as the sockets and the controls, the components are all mounted on the printed circuit board, as detailed in Fig. 5. There are quite a few components to fit onto the board, but provided things are taken steadily with no undue rushing there should be little difficulty in constructing the board successfully.

Be careful to fit the electrolytic capacitors and semiconductors the right way around, and bear in mind that IC2, IC5, and IC6 are MOS input types. These require the normal antistatic handling precautions, and the most important one of these is to use sockets for these devices and not to plug them into the circuit board until all other construction is completed.

A number of link wires are required, and these can be made from about 20swg tinned copper wire, or trimmings from the resistor leadouts are suitable if suitable wire is not to hand. Fit pins to the board at the points where connections to the off-board connections will eventually be made.

With this project we are using the convention of having the component numbers in the second stereo channel equal to those in the first channel but with one hundred added. Of course, many of the components in this case are common to both channels, and therefore only appear with the basic indentification numbers. If a monophonic noise gate is required, build up the board in the normal way but omit any components which have identification numbers more than one hundred.

Case

An instrument case having dimensions of about 203mm by 127mm by 51mm is used as the housing for the prototype, but any case of around the same size would probably be equally suitable. Bear in mind though, that the board is almost 190mm wide, and the width dimension of 203mm represents something approaching the minimum that is usable.

The printed circuit board is mounted on the base panel of the case, and I used self-adhesive nylon supports, but obviously conventional mounting pillars or spacers and mounting bolts can be used if preferred. Fit the board well forward so that there is sufficient space for the battery at the rear of the unit, but leave enough room to accommodate front panel mounted components. The sockets specified in the components list are phono types, but an alternative audio connector may well be more convenient with your particular set up, and the sockets should be changed to a more suitable type if necessary.

There is little in the way of hard wiring, and there should be no real problems in completing this. Ideally, the leads from the board to the input and output sockets should be screened, but this is not essential provided these leads are kept reasonably short.

In Use

With the Threshold control VR1 well backed off the effect of the unit should be readily apparent with the signal being coupled through to the output only during a fairly high level. If VR1 is set in a fully anticlockwise direction the signal should be continuously cut off. D6 should switch on and off in sympathy with the signal being cut on and off. With VR1 well backed-off the unit is only really usable as a musical effects unit, and it would not normally be set up in this way for true noise gate applications.

To adjust the unit for use as a noise gate the unit must first have the signal source connected to its input. There should be no signal present through, just the background noise that must be suppressed.

With the Threshold control VR1 well advanced D6 should light up. VR1 should then be backed-off just far enough to switch-off D6, or if D6 does not switch on even with VR1 fully advanced, then VR1 should be left fully advanced.

Subjectively, results might be better with VR1 back-off slightly from the point where the unit only just cuts off the signal before it fully decays. It is worthwhile experimenting a little with the setting of VR1 to determine the setting which gives the best results in practice. ■

PARTS LIST

Resistors

R1,R3,R4,
R7,R11,R12,
R13,R27,R101 .... 10k (3)
R103,R104
R107,R127
R2,R17,R102 .... 100k (3)
R5,R6 .... 15k (2)
R8,R15 .... 47k (2)
R9 1M8
R10,R21,R22
R121,R122 .... 4k7 (5)
R14 33k
R16 220k
R18 6k8
R19 8M2
R20 1k
R23,R26,R123,R126 .... 2m2 (4)
R24,R25,R124,R125 .... 2k2 (4)

All 0.25W 5% carbon

Capacitors

C1,C10,C11
C101,C110 .... 100u elec.10V (5)
C2,C102 .... 220n (2)
C3,C103 .... 10u elec.25V (2)
C4,C6,C7,C8,C104 2u2 elec.63V (5)
C5 .... 4u7 elec.63V
C9 .... 470n

Potentiometer

VR1 .... 10k log.

Semiconductors

IC1,IC101 ....LF353 dual op amp (2)
IC2 ...4016BE CMOS analog switch
IC3,IC$ .... 741 op amp (2)
IC5 .... CA3130E CMOS op amp
IC6
IC1064001BE CMOS NOR gate (2)
IC7,IC107 .....1458c dual op-amp (2)
D1,D2,D3,
D7-D12
D107-D112N4148 silicon diode (15)
D4,D5 .....IN4002 rectifier diode (2)
D6 .... Red panel LED
TR1,TR2 .....BC547,2N3904 npn (2)
TR3 .... 2N3906 pnp
TR4 .... BC549, 2N3904 npn

Miscellaneous

B1 .... Six 1.5V cells
in plastic holder (see text)
SK1,SK2
SK101,SK102 ....Phono socket (4)
S1 .... SPST submin. toggle

Instrument case about 203x127x51mm; printed circuit board; control knob; battery connector (9V type); 8-pin DIP socket (7); 14-pin DIP (3); pins, wire, solder,etc.