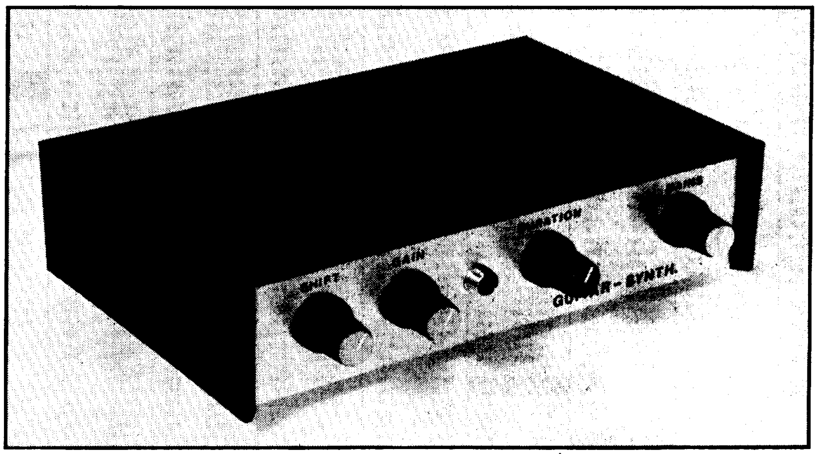
Much cheaper than a proprietary system, and an ideal way to use up those unwanted analogue synths, this interface uses a +5V gate signal to trigger a synth over at least three and a half octaves.

GUITAR TO SYNTH INTERFACE

BY ROBERT PENFOLD

Turn your axe to ivory



Electric guitars remain very popular, but have perhaps given way slightly to keyboard instruments in recent years. One likely reason for this is the greater versatility of electronic keyboard instruments. Obviously there are a great many effects units that can modify the sound produced by a guitar, but even with a dozen of these the range of sounds would probably not equal that of even one of the cheaper keyboard instruments.

Perhaps the obvious answer to the problem is to have a synthesizer controlled from the guitar in some way, rather than to buy numerous effects units. This is a much neater solution which enables the guitarist to obtain any electronic keyboard sound. Unfortunately, it tends to be a rather expensive way of doing things. Quite good results can be obtained using a simple unit such as 'Guitar Tracker' which was described in the June 1986 issue of PE, but a much wider range of sounds can be obtained by interfacing the guitar to a full analogue synthesizer. This is becoming an attractive method as analogue synthesizers now seem to be widely regarded as out-of-date. Many guitarists will have access to an otherwise unused instrument, or secondhand (pre-used?) instruments can be obtained at surprisingly low cost.

This only leaves the problem of a suitable guitar to synthesizer interface, which is the purpose of this project. The device covers several octaves, should handle any note that an ordinary (non-bass) guitar can produce, and provides a standard 1 volt per octave logarithmic output. A gate signal is needed to drive the "gate in" or "trigger in" input of the synthesizer, and two gate outputs are provided. One of these simply provides a gate pulse while the input signal is above a certain threshold level. The other gives an output pulse which has a preset duration of between about 35ms and 750ms. The second gate output is very useful as many synthesizer sounds are dependent on a short gate pulse duration, and a very brief gate signal cannot be obtained reliably from the other gate output.

SYSTEM OPERATION

The block diagram of Fig.1 shows the general set up used in this interface. The top row of blocks are concerned with the generation of the output control voltage, while the lower row of blocks are primarily needed to generate the gate pulses (although these stages do play some part in reliably generating the right output voltage).

Starting with the top row of blocks, the input signal is first fed to an amplifier where it is boosted to a high enough

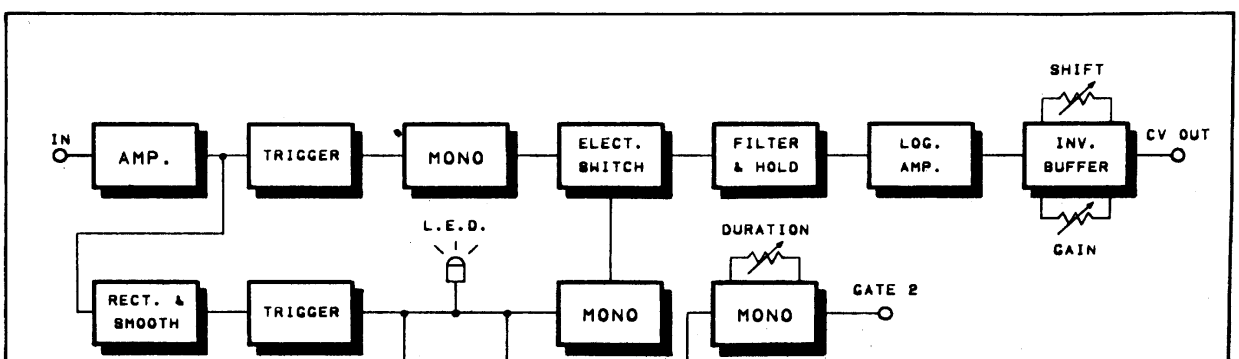


Fig.1. *Block diagram for the Guitar To Synth Interface.*

level to drive the next stage properly. This is a trigger circuit which has a large amount of hysteresis. The latter is essential due to the unusual and ever changing waveform produced during the course of each guitar note. The hysteresis ensures that the output from the trigger circuit is a pulse waveform at the same frequency as the fundamental input frequency.

The next stages form a simple frequency to voltage converter, and the monostable multivibrator forms the basis of this section of the unit. The monostable is a retriggerable type, but it is preceded by a simple pulse shaper circuit which always provides brief trigger pulses, regardless of the mark-space ratio of the output signal from the trigger circuit. The output pulse duration of the monstable can therefore be regarded as fixed and independent of the input signal. The pulse frequency is equal to the frequency of the input signal. Therefore, as the input frequency increases, the monostable's output pulses become bunched closer and closer together, and the average output voltage increases. In fact there is a linear relationship between the input frequency and the average output voltage. This section of the unit is actually very much the same as the circuit in the 'Guitar Tracker' project referred to earlier, and this article should be consulted if more concise information on operation of the frequency to voltage converter is required.

If we ignore the electronic switch for the moment, the next stage of the voltage to frequency converter is a lowpass filter. This simply smooths out the pulses from the monostable to give a d.c. output having a reasonably low ripple level. This part of the unit differs somewhat from the equivalent circuit in the 'Guitar Tracker' project, where a simple single stage passive filter was used, followed by a high input impedance buffer amplifier. The latter gives a 'hold' action, so that the output voltage is maintained when the electronic switch is opened and the signal from the monstable is cut off.

In this article a third offer (18dB per octave) active filter is used, but this is based on a buffer amplifier which has an extremely high input impedance so that it still gives a 'hold' action when the signal from the monostable is cut off. The advantage of the active filtering is that it enables the unit to respond rapidly to changes in the input frequency, but with a very low ripple level on the output voltage still being obtained. This ripple is not of great importance in itself, as it tends to have no noticeable effect on the output from the synthesizer. It can indirectly produce a noticeable effect though, when the signal from the monostable is disconnected by the electronic switch. The output voltage is then maintained at whatever level it happened to have at the instant the electronic switch was opened, and any ripple can result in the 'held' output voltage being slightly above or below the correct level. This is reflected in the note from the synthesizer being slightly off-tune. Active filtering enables the unit to respond to changes in the input frequency with suitable rapidity without having to compromise the pitch accuracy on 'held' notes.

The output voltage from the filter and hold circuit has a linear characteristic (i.e. the voltage doubles for each octave increase of the input frequency). Some older synthesizers have control voltage inputs that are compatible with a linear input signal, but most instruments require a 1 volt per octave (logarithmic) control voltage. The output from the filter and hold circuit is therefore fed to a logarithmic amplifer which makes the necessary voltage conversion. In fact the output from this circuit requires some further processing, as it inverts the signal, and does not give a properly scaled output anyway. An inverting amplifier having gain and voltage shift controls is therefore used to process the output from the logarithmic amplifier and give a signal that drives the control voltage input of the synthesizer properly.

The 'gate 1' output signal is generated by rectifying and smoothing some of the output from the input amplifier. This gives a d.c. output signal which is roughly proportional to the audio input level. This signal is fed to a trigger circuit which provides a high gate signal if the input signal is above a certain level. The output level from a guitar can be slightly erratic, and so this trigger circuit is given a certain amount of hysteresis so that problems with multiple gate pulses on each note are avoided. A l.e.d. indicator shows the signal level on the 'gate 1' output, which can be quite helpful, especially when initially setting up.

This gate signal is fed to the inputs of two non-retriggerable monostable multivibrators. One has a fixed output duration and is used to drive the electronic switch, while the other has an adjustable pulse length and provides the 'gate 2' output signal.

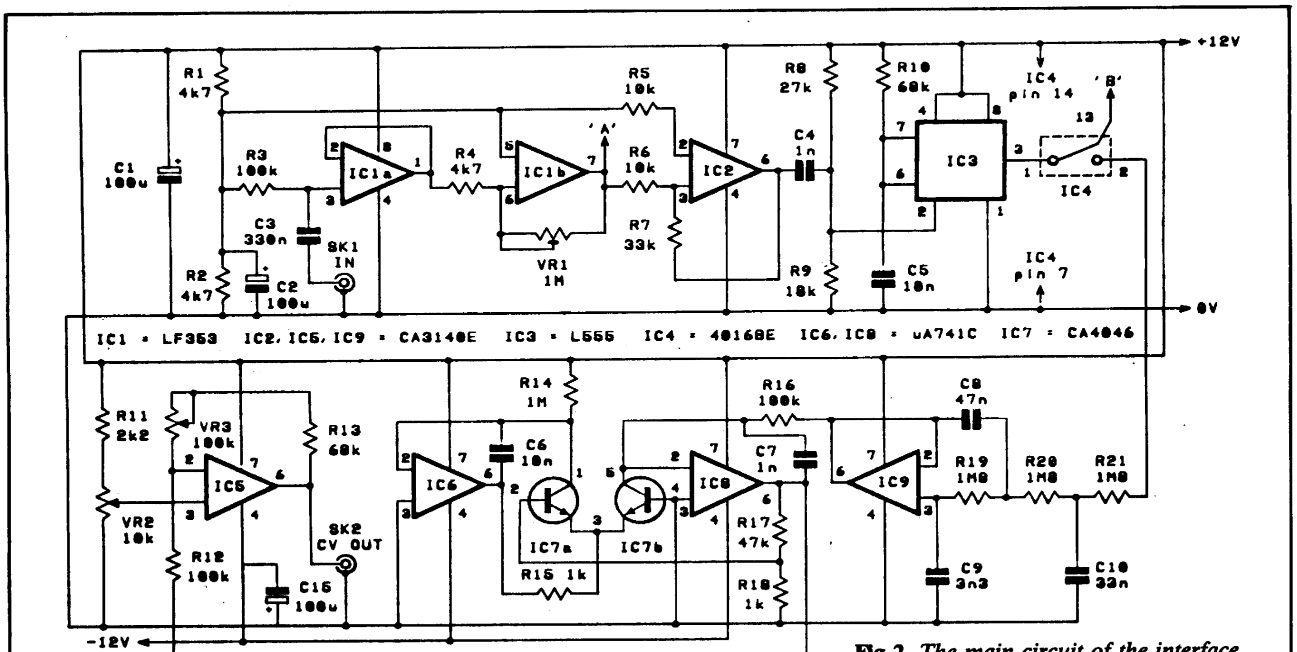


Fig.2. *The main circuit of the interface.*

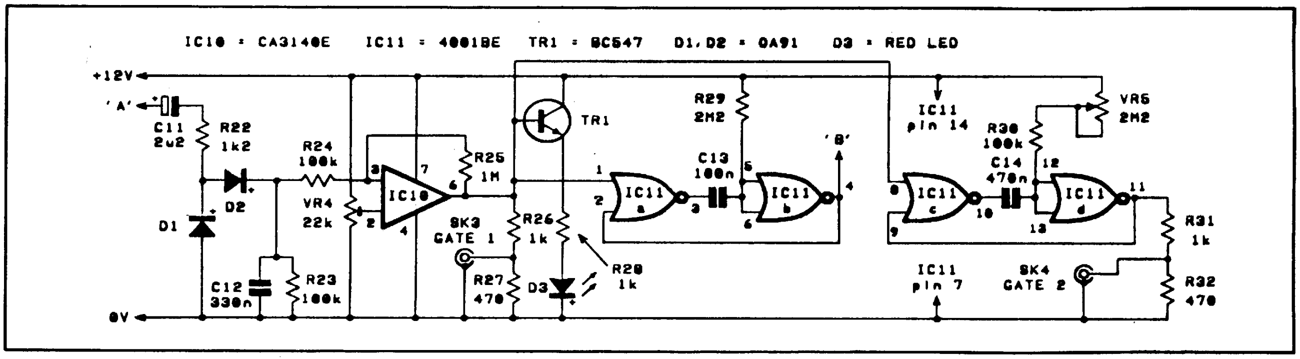


Fig.3. *The gate pulse generator circuit.*

At first sight the electronic switch and the 'hold' circuit might seem to be irrelevant, since the guitar will normally provide a significant output level while it is being played. In practice there are a couple of problems if these circuits are omitted. One is simply that the synthesizer will be capable of producing a wide variety of envelope shapes, including some with quite long release periods. With an envelope shape of this type there is a real danger of the note from the guitar ceasing before that from the synthesizer has fully decayed. With the 'hold' circuit included this does not matter, since the output voltage will be maintained for a reasonable period of time regardless of whether or not the guitar is still providing a significant output level.

The second problem is one of spurious output signals from the guitar while it is being played. Even an accomplished player is unlikely to play each note perfectly, instantly snapping from one note to the next. This does not tend to be noticeable on the direct output from the guitar, as any spurious signals are accepted by the listener as ordinary and acceptable guitar sounds. The result on the output from the synthesizer can be slightly catastrophic though, with the pitch tending to jump all over the place during the transition from one note to the next. This gives an output signal that can be far from musical, and in an extreme case can be more reminiscent of cats in the night than a musical instrument.

The system used here has the electronic switch closed briefly at the beginning of each new note. This gives the filter and hold circuit time to adjust to the new frequency, and it then holds this level until a new note is triggered. Any spurious 'buzzes' or other sounds in the intervening period will not affect the output voltage. This system does not absolutely guarantee a perfect output from the synthesizer, but in practice most problems seem to result from one note being damped prior to the start of the next one. This system eliminates the damping problem and seems to give very reliable results. It can only be defeated by some very inept fingering, or 'machine gun' style playing which is simply beyond the tracking ability of the unit.

CIRCUIT OPERATION

Fig. 2 shows the main circuit diagram for the guitar to synthesizer interface, but the gate pulse generator circuit is shown separately in Fig. 3.

The amplifier, trigger, and monostable stages are virtually identical to those in the 'Guitar Tracker' project, the only difference being that VR1 has been made slightly higher in value so as to boost the maximum available gain. This gives a very wide gain adjustment range, and the circuit can be set up to work reliably with almost any guitar pick-up. There is actually another minor modification to the original circuit in that R10 has been made somewhat lower in value. This increases the maximum input frequency that the unit can handle. This frequency is the one where each output pulse lasts more than one input cycle. This results in the monostable only triggering on every other input cycle, and the average output voltage drops to only half the correct level. With the specified timing component values the circuit will operate properly with input frequencies of up to around 1.35kHz, which should be adequate in practice.

A CMOS analogue switch acts as the electronic switch, and this works well in the present application where an extremely high 'off' resistance is required. The switch is one of the four SPST types in a 4016BE package, and the other three switches are simply ignored.

IC9 acts as the buffer amplifier in the filter and hold circuit, and this is a MOS input device which provides an input resistance of about 1.5 million megohms. This is high enough to ensure that the 'held' output voltage is maintained accurately for at least a few seconds, which should be more than adequate in practice. The filter is really just a standard third order type, but the filter components have been given values that produce a very low cutoff frequency of only about 6Hz. The cutoff frequency has to be a compromise between fast response time and good smoothing of the d.c. output signal, and 6Hz seems to be about the optimum cutoff frequency. Note that the CA3140E used for IC9 is a type that will operate properly without a negative supply, and that few other types have the correct characteristics for correct operation in this circuit.

The logarithmic amplifier is based on IC6 to IC8. In common with most circuits of this type, it relies on the forward transfer characteristic of a silicon diode to give the right input/output voltage conversion. When forward biased in the manner shown in Fig. 4, a silicon diode (or transistor base-emitter junction) produces an output voltage that is around 0.65 volts. Although circuits of this type are often used as low voltage regulators, the output voltage does in fact increase by about 60 millivolts per decade increase in the bias current. This is normally considered to be a flaw in the efficiency of the voltage regulator circuit, but it provides what is essentially the right kind of conversion for this application. However, in a practical circuit there are two problems to be overcome. One is simply to boost the output voltage to give the required scaling and to remove the offset voltage.

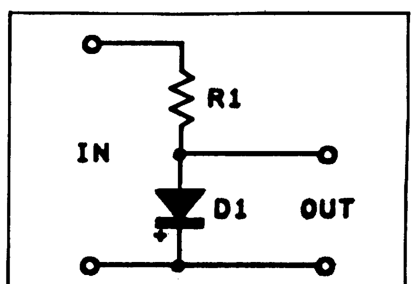


Fig.4. *The basis of a lin./log. converter is just a forward biased silicon diode.*

The other problem is more difficult to combat, and is severe temperature drift that occurs with the basic circuit. Circuits of the type shown in Fig. 4 are often used as temperature sensors, and give a reduction in output voltage of about 2 to 3 millivolts per degree Celsius increase in temperature. The change in output voltage due to temperature drift is not very large, but voltage changes are considerably amplified in this case, and without some form of temperature compensation this type of circuit is practically unusable. In this case a form of bridge circuit is used, with one section providing the voltage conversion and the other giving temperature compensation. The two transistors are part of the CA3046 integrated circuit which is a five transistor array. Having the two transistors on the same chip gives more effective temperature compensation than using discrete transistors.

IC5 acts as the inverting amplifier, and this has VR2 and VR3 as the shift and gain controls respectively. The general idea is to adjust VR2 for the correct output voltage with a low frequency input, and then to adjust VR3 for the right output potential with a much higher pitched input. By repeating this procedure a few times the unit can be made to track correctly over a wide range of notes. Even with the aid of temperature compensation and using stabilised supply rails, the unit cannot be guaranteed to be drift-free. VR2 and VR3 have consequently been made front panel controls rather than preset types so that the unit can easily be retrimmed from time to time if this should prove to be necessary.

Turning now to Fig. 3 and the gate pulse generators, the amplified signal from IC1 is rectified and smoothed by D1, D2, and C12. The attack time of the smoothing circuit is very short, and although substantially longer, the decay time has also been kept fairly short (about 30ms). For the unit to operate properly it is essential that the voltage across C12 decays significantly during the brief pause between one note and the next, so that the electronic switch is reactivated on each new note. Failure of the unit to trigger on a new note will result in the old note voltage being held, as well as no new gate pulse being generated. IC10 is the trigger circuit, and is a standard operational amplifier type with hysteresis provided by R25. VR4 is the trigger sensitivity control, and this is adjusted to give optimum reliability. D3 is a l.e.d. indicator which is switched on when the output of IC10 is high, and it is driven via emitter follower buffer amplifier TR1. IC10 is powered from a +12 volt supply, but most synthesizers require a +5 volt trigger pulse. R26 and R27 form an attenuator which reduces the output voltage to a suitable level.

The two monostables are both based on CMOS 2 input NOR gates connected in a conventional non-retriggerable configuration. IC11a and IC11b form the monostable which drives the electronic switch, and this circuit has a fixed output pulse duration of around 150ms. This circuit must provide a pulse length that is adequate to let the output voltage adjust to the correct level before the electronic switch is cut off, but it must also be short enough to guarantee that the pulse ceases before another note commences. A time of about 150ms seems about right for my playing, but a different pulse length can be used if necessary. The pulse duration is proportional to the value of R29.

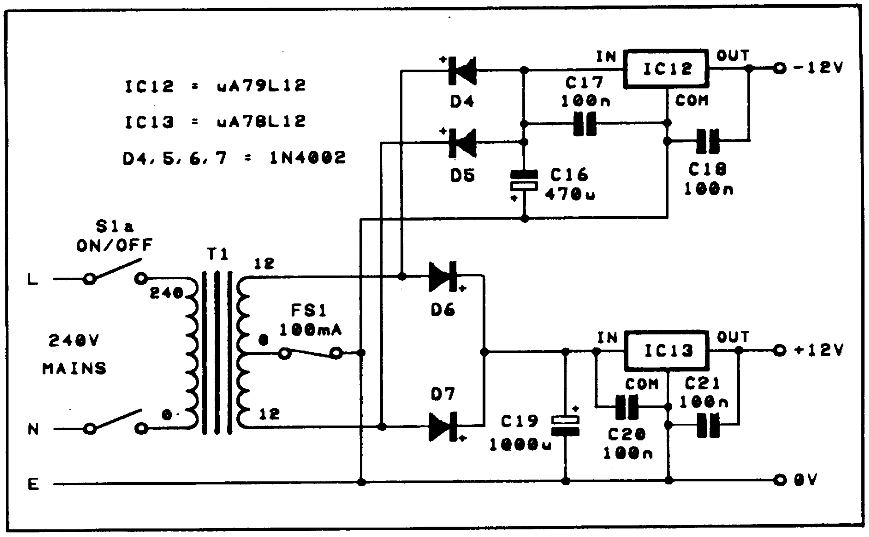


Fig.5. *The circuit diagram for the mains power supply.*

IC11c and IC11d form the monostable that provides the alternative gate pulse signal. VR5 is the gate pulse duration control, while R31 and R32 are an attenuator which provide an output level that is compatible with standard 5 volt logic circuits.

POWER SUPPLY

The unit requires dual balanced 12 volt supplies which must be well smoothed and stabilised. Fig. 5 shows the circuit diagram of the mains power supply unit.

The circuit uses two push-pull style full-wave rectifier and smoothing circuits; one to provide the negative supply and one to give the positive supply. Regulation of the negative and positive supply rails is provided by IC12 and IC13 respectively. These are 100 milliamp types, and these are more than adequate as the current consumption from neither rail approaches anything like this figure.

CONSTRUCTION

Most of the components fit onto the two printed circuit boards. One board accommodates the main circuit (Fig. 6) while the other is for the power supply (Fig. 7). Construction starts with the boards, and the power supply board is very simple indeed. However, the two electrolytic capacitors must be reasonably compact printed circuit mounting types if they are to fit onto the board correctly.

The main printed circuit board is very much more complex, and is less straightforward to build. The first point to keep in mind is that IC2, IC4, IC9, IC10, and IC11 are all MOS input devices, and that the normal anti-static handling precautions should be observed when dealing with these components. I would recommend the use of sockets for all eleven integrated circuits on the main board — MOS types or not. D1 and D2 are germanium diodes, and these tend to be somewhat less hardy than the more familiar silicon variety. They are slightly more vulnerable to physical damage, but of greater importance, they are much more easily damaged by heat. I have not found it necessary to use a heatshunt when fitting germanium semiconductors, but the soldered joints should be completed with the soldering iron being kept in place for no longer than is really necessary.

Several link wires are needed, and 22 s.w.g. tinned copper wire is suitable for these, or trimmings from resistor leadouts can be used. If the capacitors are to fit onto the board neatly it is essential that they are of the correct types. The electrolytic capacitors are all radial (single-ended) components, and the polyester capacitors are 7.5 millimetre (0.3 inch) pitch printed circuit mounting components. At this stage only single-sided pins are fitted to the boards at the positions where connections to off-board components will eventually be made.

The case I used is a metal instrument type having approximate outside dimensions of 200 by 130 by 50 millimetres. This represents the smallest size of case that will house all the components without having to resort to an imaginative layout in order to find space for everything. The four sockets are mounted on the rear panel, and standard jack sockets are probably the most convenient type to use. However, you can obviously select any type that fits in well with your other equipment. The panel mounting fuseholder is also mounted on the rear panel, well towards the left hand end of the panel (as viewed from the rear). It is advisable to mount SK1 right at the other end of the panel so that the input

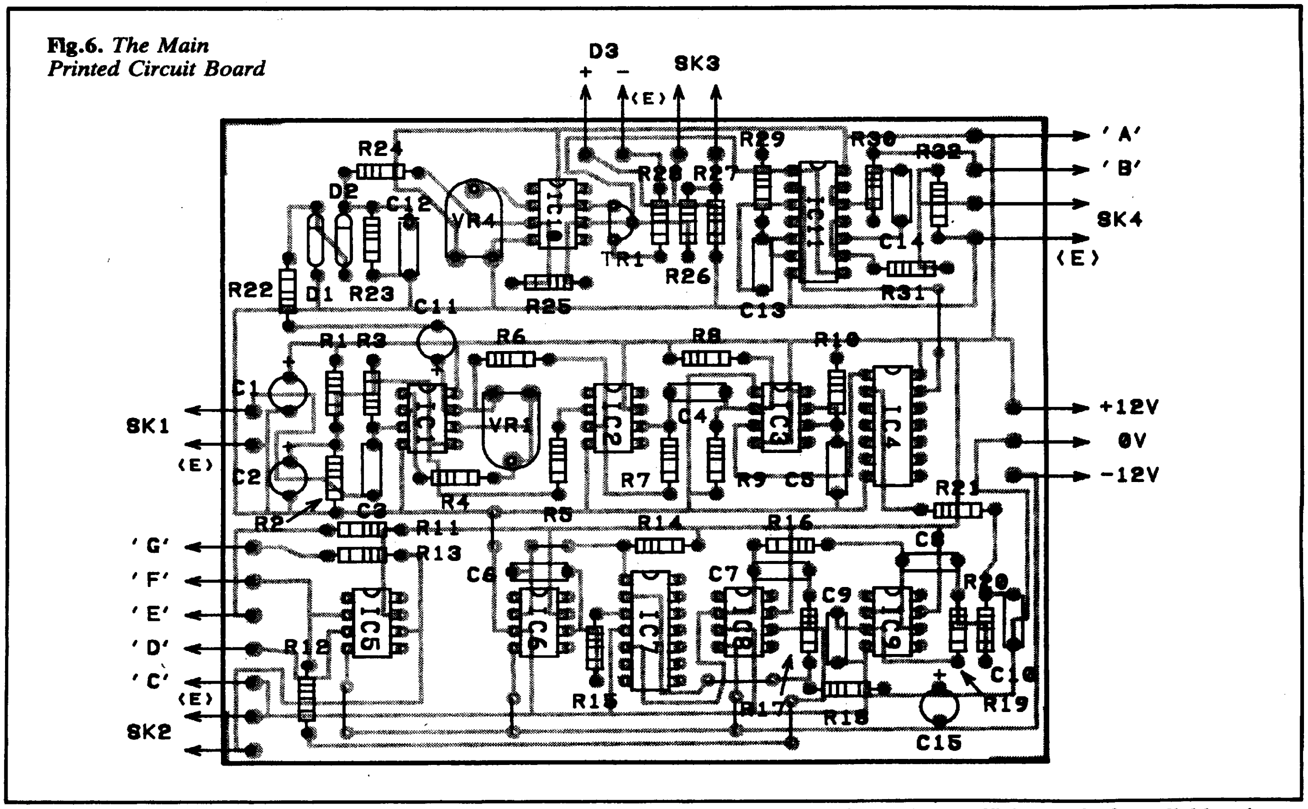


Fig.6. *The Main Printed Circuit Board*

wiring is kept well away from the power supply wiring. An entrance hole for the mains lead is drilled alongside the fuse-holder, and this hole should be fitted with a p.v.c. grommet to protect the cable.

The controls and l.e.d. indicator are mounted on the front panel, with S1 well towards the right hand end of the panel and well separated from the other front panel mounted components. The two printed circuit boards are mounted on the base panel with the main board as far over to the left hand side of the unit as possible. This leaves sufficient space for the other board and T1 at the other end of the unit. Either spacers must be used over the mounting bolts for the boards or plastic stand-offs must be used to mount them. A soldertag fitted on one of T1's mounting bolts provides a chassis connection point.

The hard-wiring is fairly simple, but Fig. 8 should help to clarify any minor difficulties. The most likely cause of confusion is mains transformer T1. Most mains transformers these days seem to have twin secondary windings instead of the centre tapped arrangement. However, these can be used as centre tapped types by bridging a '0' and '12' tag (to act as the centre tap), as shown in Fig. 8.

TESTING

With any project it is advisable to have a thorough check over the wiring prior to switching on, but this is even more important with a mains powered project such as the present one. SK1 connects to the guitar by way of a standard jack lead, and initially no connection to the synthesizer is needed. Start with VR1 and VR4 at roughly mid settings. Playing notes on the guitar will probably cause D3 to flash on each time a note is played, but if not, try setting VR1 for a higher resistance (which gives increased gain). The ideal setting for VR1 is one which gives sufficient gain for reliable triggering, but does not give so much gain as to produce unwanted triggering of the unit. Try VR4 at various settings as well, in an attempt to find the optimum settings for these two presets. Setting VR4 for a high level of sensitivity (the wiper well towards the earth end of the track) is unwise as the trigger circuit may have a reluctance to switch off between notes. At the other extreme, the trigger circuit may fail to operate, or it may be rather slow in doing so.

When correct triggering of the unit is obtained, try connecting the control voltage output and one of the gate outputs to the relevant inputs of the synthesizer. Remember that the synthesizer may not automatically switch over to automatic control, and that some manual switching might be needed in order to enable external control. The synthesizer's manual should give details of the correct switch settings where appropriate. Aligning the unit is quite simple, and it is a matter of first hitting a low note on the guitar and adjusting VR2 for the correct note from the synthesizer. Then play a much higher note and adjust VR3 for the correct pitch from the synthesizer. Repeat this procedure a few times until the synthesizer is tracking the guitar properly.

With most analogue synthesizers it is possible to switch the unit up or down by one octave, or even two octaves. A little experimentation might therefore be needed in order to find the right setting to give correct tracking over a

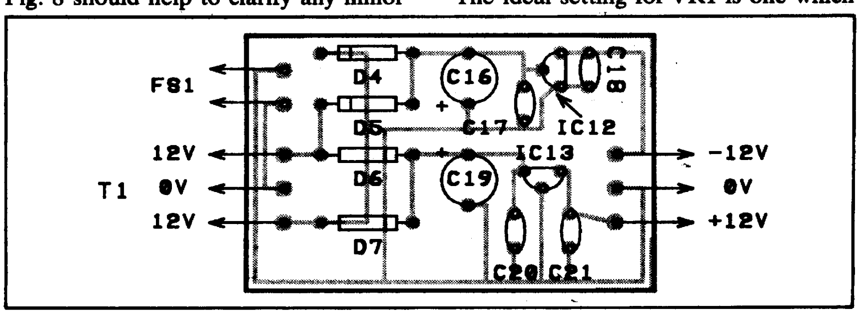


Fig.7. *Details of the power supply board.*

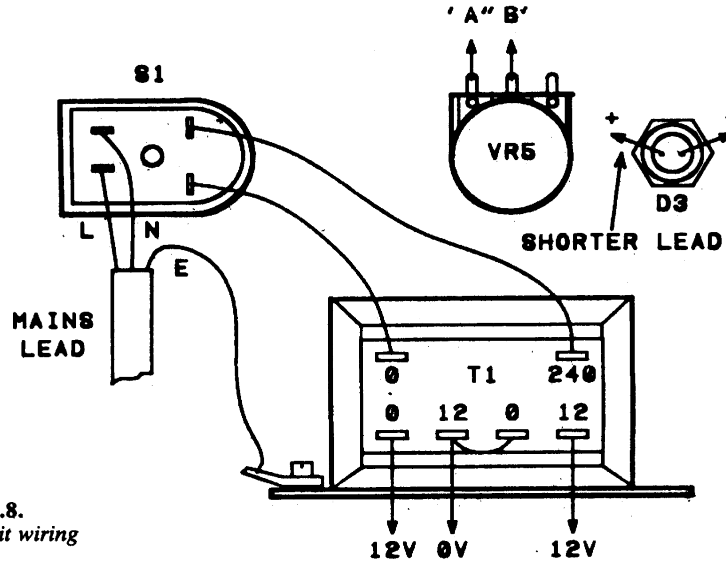


Fig.8.
Unit wiring

THE PRINTED CIRCUIT BOARD IS AVAILABLE THROUGH THE PE PCB SERVICE AND A FULL KIT OF PARTS MAY BE BOUGHT FROM MAGENTA (ADDRESS IN ADVERT)

COMPONENTS...

RESISTORS

R1,2,4	4k7 (3 off)
R3,12,16, 23,24,30	100k (6 off)
R5,6	10k (2 off)
R7	33k
R8	27k
R9	18k
R10,13	68k (2 off)
R11	2k2
R14,25	1M (2 off)
R15,18,26, 28,31	1k (5 off)
R17	47k
R19,20,21	1M8 (3 off)
R22	1k2
R27,32	470 (2 off)
R29	2M2

All resistors ¼ watt 5% carbon

POTENTIOMETERS

VR1	1M sub-min hor preset
VR2	10k lin
VR3	100k lin
VR4	22k sub-min hor preset
VR5	2M2 lin

CAPACITORS

C1,2,15	100µ 16V radial elect (3 off)
C3,12	330n poly layer (2 off)
C4,7	1n poly layer (2 off)
C5,6	10n poly layer (2 off)
C8	47n poly layer
C9	3n3 poly layer
C10	33n poly layer
C11	2µ2 63V radial elect
C13	100n poly layer
C14	470n poly layer
C16	470µ 25V radial elect
C17,18,20,21	100n ceramic (4 off)
C19	1000µ 25V radial elect

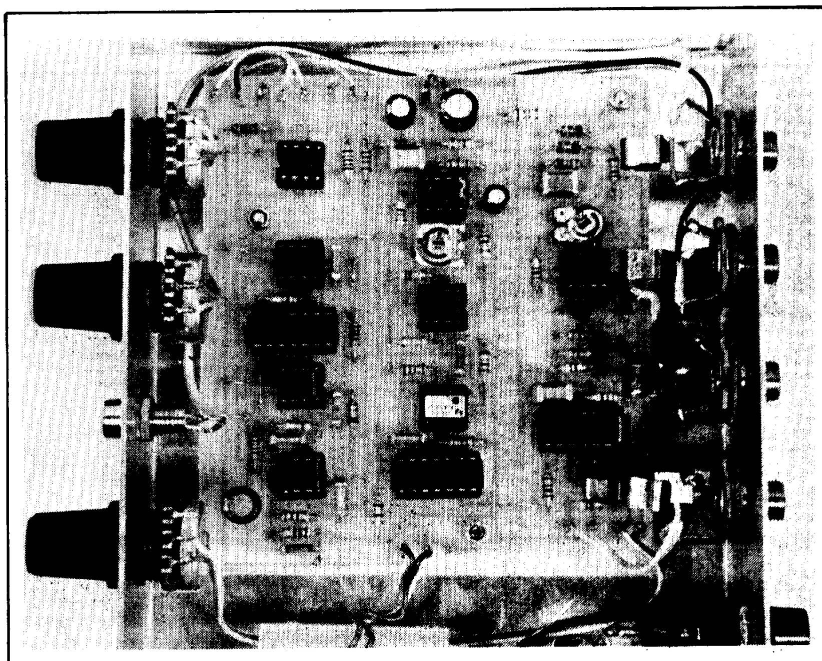
SEMICONDUCTORS

IC1	LF353
IC2,9,10	CA3140E (3 off)
IC3	L555
IC4	4016BE
IC5,6,8	uA741C (3 off)
IC7	CA3046
IC11	4011BE
IC12	uA79L12 (−12V 0.1A reg)
IC13	uA78L12 (+12V 0.1A reg)
TR1	BC547
D1,3	OA91 (2 off)
D3	Red panel l.e.d.
D4,5,6,7	1N4002 (4 off)

MISCELLANEOUS

SK1,2,3,4	Standard jack socket (4 off)
S1	Rotary mains switch
T1	12–0–12V 250mA mains transformer
FS1	100mA 20mm anti-surge

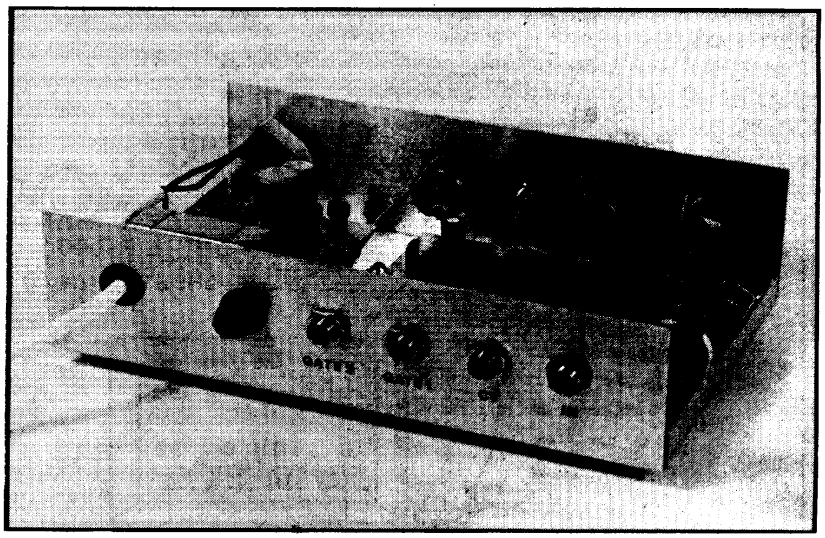
Metal instrument case about 200 × 50 × 130mm, printed circuit boards (2 off), 20mm panel mounting fuseholder, control knob (4 off), 8 pin DIL IC holder (8 off), 14 pin DIL IC holder (3 off), fixings, wire, solder, mains lead and plug.



wide frequency range. Of course, it is quite in order to have the synthesizer playing a different octave to the guitar, or with any offset you desire that is within the capabilities of the instrument.

TRIGGER HAPPY

Most synthesizers will trigger properly from the +5 volt gate signals. Some instruments require a +15 volt gate signal, but they are mostly +5 volt compatible as well. If necessary though, a higher output voltage can be obtained by removing R27 and R32, and replacing R26 and R31 with shorting links. Some synthesizers require a 'short-to-ground', gate signal, and these can be triggered by omitting R26, R27, R31, and R32, and using a driver circuit of the type shown in Fig. 9. A few synthesizers require a negative gate signal, and these could only be driven from the unit properly if a suitable voltage shifting circuit was added at each gate output. It should be possible to properly drive a synthesizer having a linear control voltage characteristic if the logarithmic amplifier and inverter are omitted, and the control voltage is taken from pin 6 of IC9. However, in order to obtain usable results it would probably be necessary to add some processing in order to give a suitable output voltage range. PE



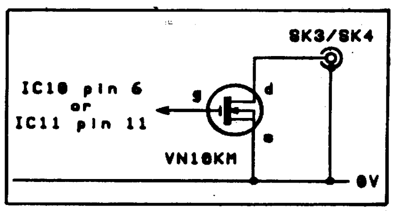
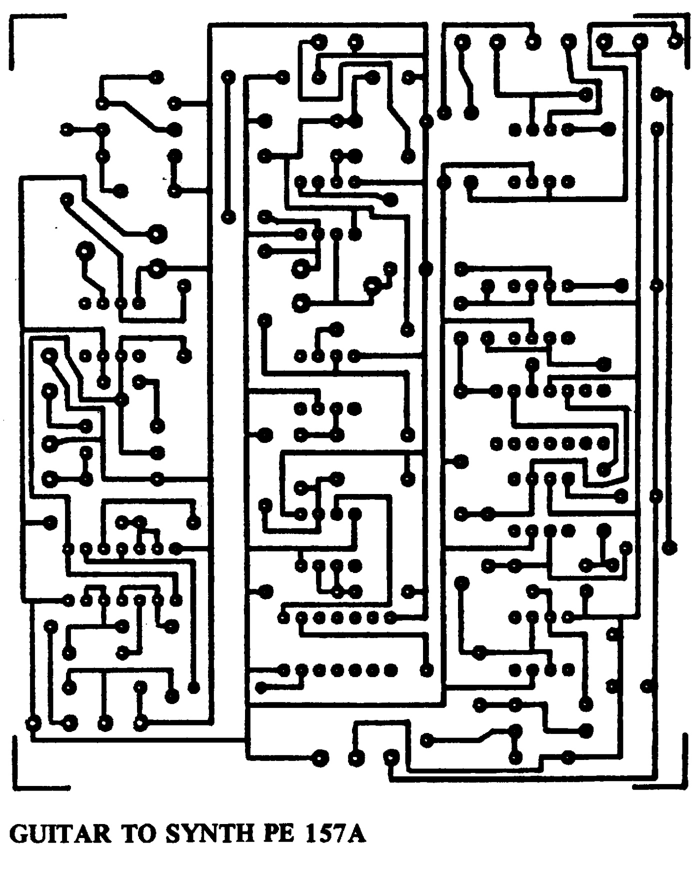


Fig.9. *A short-to-ground output stage.*

PHOTOGRAPHS OF THE GUITAR TO SYNTH INTERFACE: ABOVE, THE REAR OF THE UNIT. BELOW, THE FRONT PANEL



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