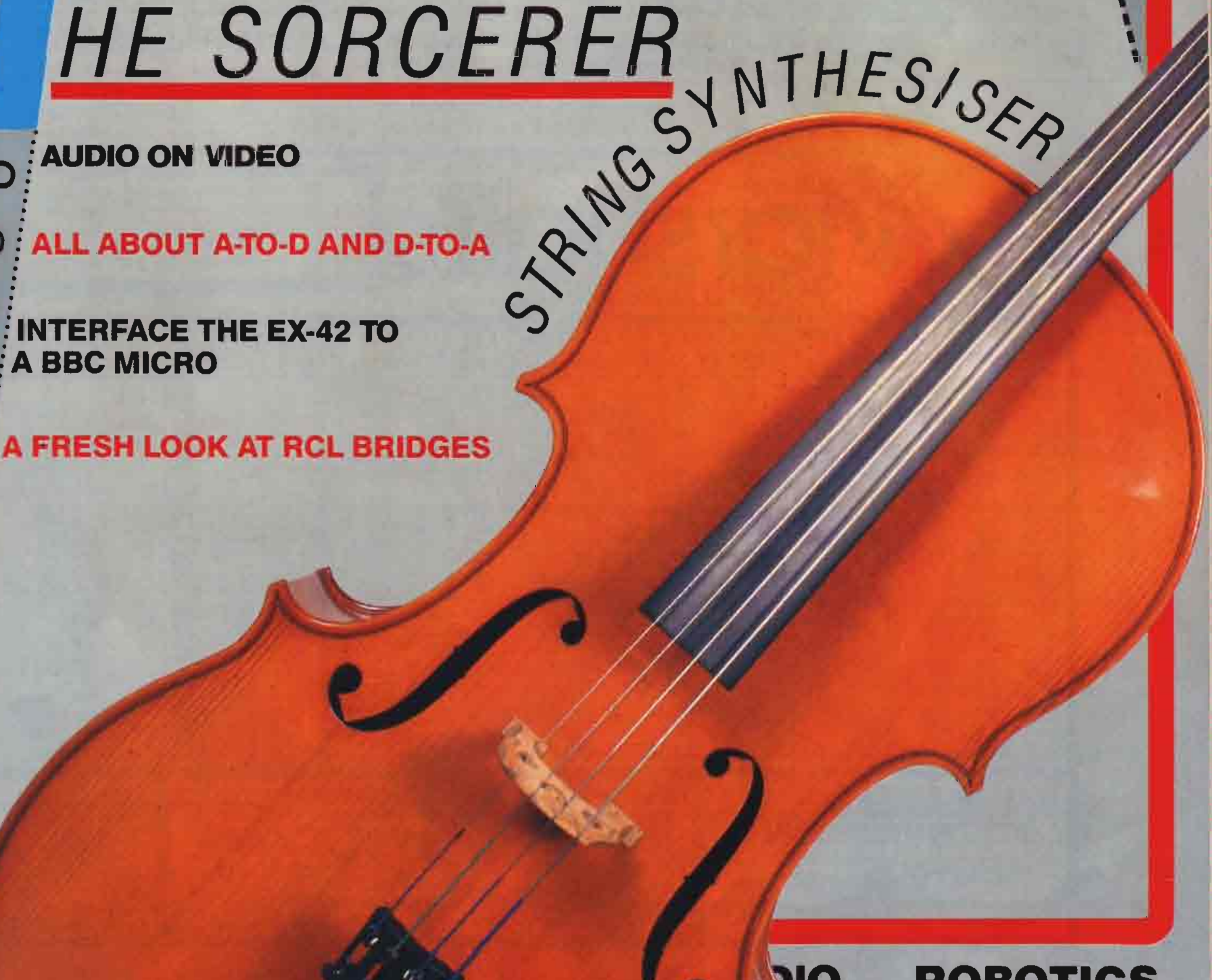
AN ARGUS SPECIALIST PUBLICATION

electronics today INTERNATIONAL

AUGUST 1985 £1.10

THE SORCERER STRING SYNTHESISER



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ETI SORCERER STRING SYNTHESIZER

Contrary to popular belief, writes designer and author Graeme Durant, a string synthesizer is not a machine for making twine. Relax and unwind as the yarn unfolds.

The string synthesizer originated in the 1970s, and perhaps owes more to organ developments than synthesizer technology; the basic instrument being polyphonic with preset sounds, usually generated by an organ-type frequency divider, gating and filtering, followed by a chorus generator to enhance the massed string quality.

Although the string synthesizer is very commonly used in many types of music today, due to its unique ability to fill out the sound of a small band without being too forward, it is usually used as a backing instrument to other keyboards. So, with an average sort of selling price in the order of four hundred pounds for a commercial unit, the string synthesizer is often out of the reach of many amateur musicians, as a mere second instrument.

That is where the ETI Sorcerer comes in. For a mere fifty pounds outlay, the Sorcerer provides this lush backing sound albeit in monophonic form only, but with sufficient power to produce very emotive backdrops.

Facilities

The ETI Sorcerer is unlike most commercial synthesizers in that it is built along the lines of a general purpose analogue synth, using similar circuit blocks such as VCOs and envelope generators. Its variable controls also mirror some of those more often found on analogue synths, providing great versatility and many sound options apart from the more usual string effects.

The basic keyboard is a three octave unit, but Sorcerer provides three switches akin to organ stops, which allow individual or simultaneous selection of three one octave spaced ranges. Selecting all three ranges allows an effect like holding down a bass note, a note an octave up and a note two octaves up. The results are extremely powerful. A glide

The Sorcerer processor.

control allows slewing between played notes and a fine tune control means Sorcerer can be tuned to other instruments. A vibrato effect is included, and controls are available to adjust its speed and depth. There is also an envelope contour generator with variable attack and release rates.

To simulate strings it is not necessary to go to the expense of using a full ADSR envelope generator, as on most analogue synths. An AR generator with a 'sustain on/off' switch is perfectly adequate. To produce the effect of massed instruments, a powerful chorus generator is included in the unit, which can be bypassed if desired for solo playing. The Sorcerer has a line output for an amplifier and a high impedance headphone output for use during recording.

The keyboard is a touch operated unit, chosen primarily for reasons of economy. A conventional keyboard can be used if preferred and the budget allows.

A three octave range is provided for by a PCB keyboard with full width keys. Being electronic, it has been designed to delay its response slightly to simulate the time usually taken for key travel and to ensure reliable detection of touch. As a result, it will not respond to fast playing, but this was not considered a particular disadvantage since Sorcerer was designed for slow backing-type use anyway. The keyboard includes circuits which detect when more than one key is being pressed. These provide a sort of multiple trigger function, similar to 'two key roll-over' found on computer keyboards, so that as long as only one key is pressed, it will be the one which is sounding.

Block Diagram

Sorcerer is built up on six printed circuit boards with a separate power supply board. This allows a modular construction and the possibility of adding new modules for special effects. The keyboard forms two of these boards, producing a key voltage proportional to musical pitch and two timing signals — gate and trigger.

The key voltage goes on to the VCO board. This board centres around a precision voltage-to-frequency converter which outputs a pulse train at a multiple of the desired frequency. A low frequency oscillator provides the modulation for vibrato. The pulse train is divided in frequency to the three required pitches, at one octave spacings, and the square pulses resulting are given the required width characteristics. After passing through octave selector switches, the three signals pass on to the chorus boards. Here, the three signals are individually filtered to produce sounds closer to strings, and then mixed to form one composite signal. The signal is fed either via parallel delay lines to gain a heavy chorus effect or directly off board if the chorus mode is not switched in.

The signal now reaches the final processing board, the envelope circuits. These give the signal the desired amplitude contour for the synthesis and allow variation of the amplitude attack and release rates, as well as selection of the sustain time. Synchronization is obtained from the trigger and gate signals from the keyboard. The output is then buffered and sent to the output jack, and to a low-power amplifier suitable for driving high impedance headphones.

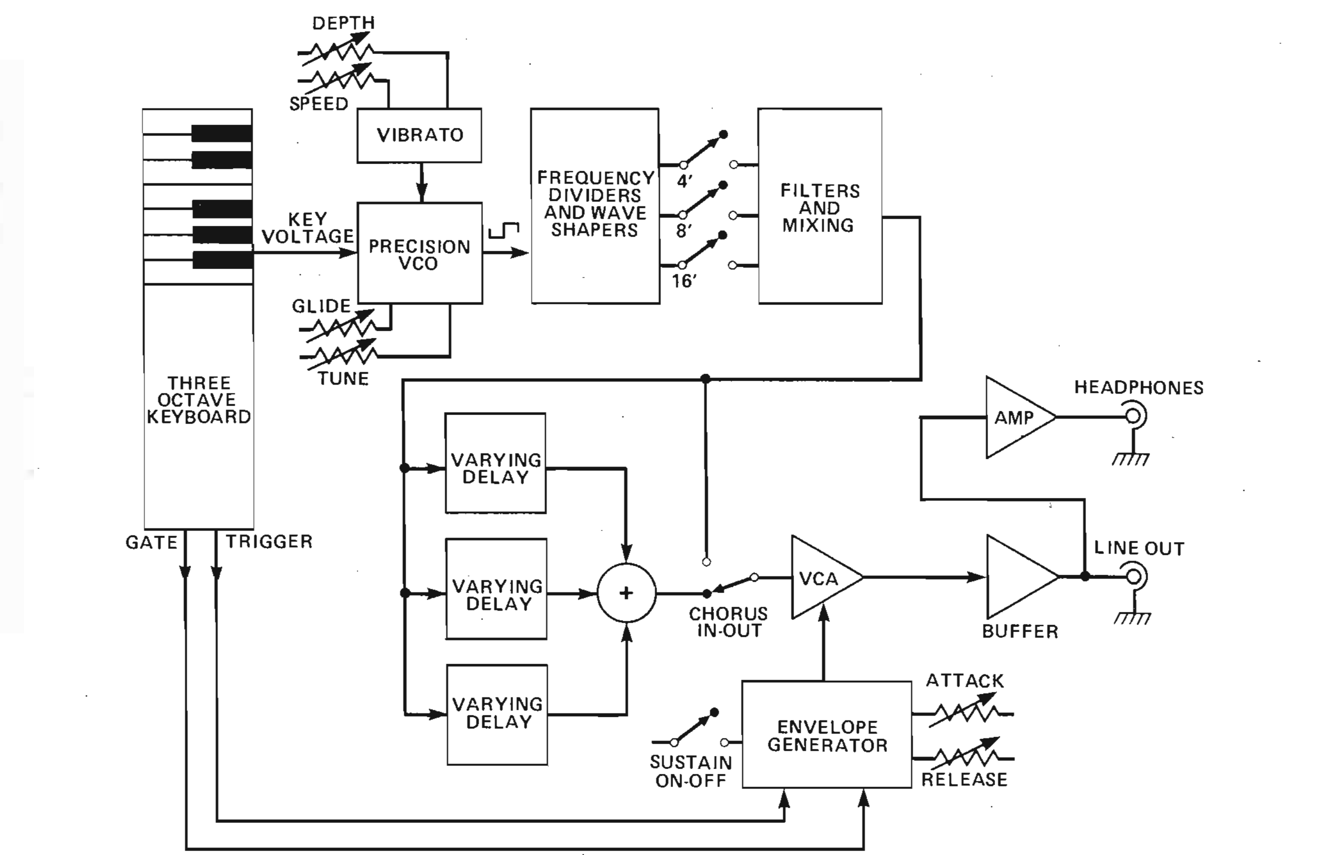


Fig. 1 Block diagram of the Sorcerer.

HOW IT WORKS
VCO SECTION

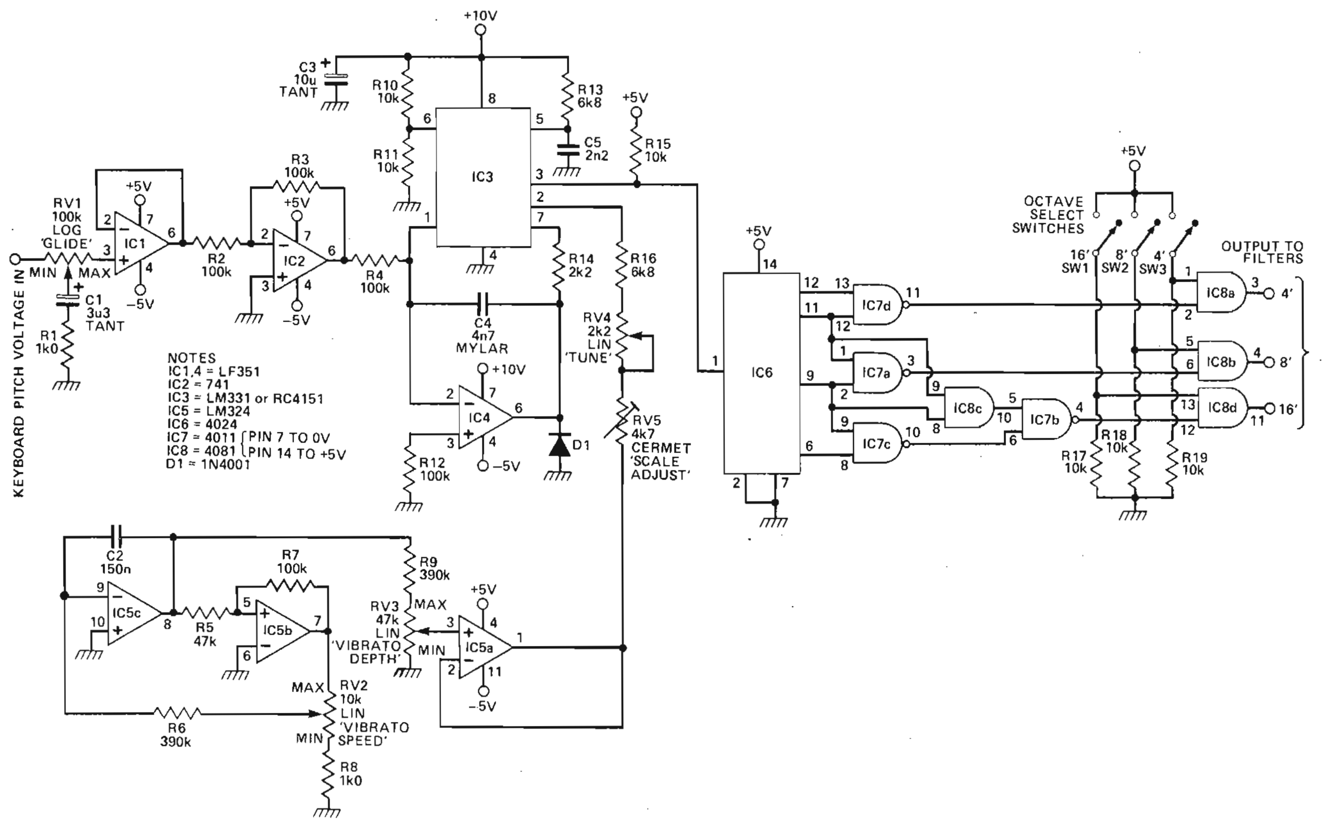


Fig. 2 Circuit diagram of the VCO section.

In Sorcerer, the VCO circuits are primarily concerned with converting the keyboard pitch voltage into a proportional frequency output. They also provide the facilities for glide and vibrato, and generate three one octave spaced pulse train outputs, with the correct mark-space ratios.

The keyboard pitch voltage is applied to one end of RV1, the glide control. C1, a low leakage tantalum capacitor at the slider of RV1, provides the required variable slewing between notes. The other end of RV1 goes via buffer to the rest of the circuit. The buffer, IC1, is required so that the glide control sees a very high impedance (about 10^{12} ohms) otherwise the pitch of the VCO would be affected as the glide control was adjusted. The pitch voltage is then inverted by IC2 wired as a unity gain inverting amplifier. This is necessary since the voltage-to-frequency circuit used requires a negative input voltage.

The voltage-to-frequency converter circuit is based around IC3 and IC4. IC3 is either an LM331 or equivalent RC4151 which is somewhat cheaper. IC4 is another LF351, this time chosen for its low input offset current, and is wired as integrator. A simplified circuit is shown in Fig. 3.

The output voltage of IC4 goes go one input of a comparator inside IC3 at pin 7. The other input, pin 6, goes to a circuit point at half the supply voltage. When the voltage at pin 7 is the greater, the comparator triggers the one-shot timer. This will turn on both the frequency output transistor and the switched current source for a time $t = 1.1R_tC_t$. During this time, a current i will flow out of pin 1 into the input of the integrator. The integrator output will start to ramp down. This current will have an average magnitude of $I_{av} = itF$, where F is the frequency of oscillation. This average current perfectly balances the current due to the input voltage, $-V_{in}/R_{in}$, at the integrator's virtual earth input. At the end of the one-shot timing period, the current source and the output transistor are both switched off. The integrator output will start to ramp positive again, until it exceeds the voltage at pin 6 of IC3, when the cycle will start again.

The frequency of oscillation can be determined from the balanced input current:

$$-V_{in}/R_{in}=I_{av}$$

but

$$I_{av}=itF$$

and

$i=V_{ref}/R_s$ which equals $1.9/R_s$, since $V_{ref}=1.9V$ and is internal to IC3.

Also:

$=1.1R_tC_t$ so that $F=-(V_{in}/2.09).(R_s/R_{in}).(R_tC_t))$ and F is proportional to $-V_{in}$.

In our case R_s is made up from R16, RV4 and RV5. The latter two variable resistors make for fine and course tuning respectively. Instead of connecting the end of R_s to ground, it is fed from a buffer IC5a, driven by a variable low-frequency and variable amplitude triangle wave generator. This standard integrator-Schmitt trigger oscillator generates a triangle wave which is symmetrical about 0V. It slowly varies the frequency of the VC0, cyclically about its programmed pitch, by adjusting the current flowing through R_s. This provides the vibrato function.

The frequency output of IC3 at pin 3 is divided by 2, 4, 8, and 16 at pins 12, 11, 9 and 6 and IC6 respectively, a CMOS ripple counter. These outputs pass through IC7 and IC8c, which convert the squarewave signals to pulse waves with a 25% duty cycle at the 4′ and 8′ outputs and with a 12.5% duty cycle at the 16′ ouput. These particular pulse widths have harmonic contents which much more closely approximate the sound of a violin and cello respectively, and are thus used for the basis of these sounds. The outputs are switched electronicaly using IC8a, b, and d, via front panel switches SW1, 2, and 3, to save routing signals to the front panel. The three, octave-spaced, signals pass on to the filter/chorus boards.

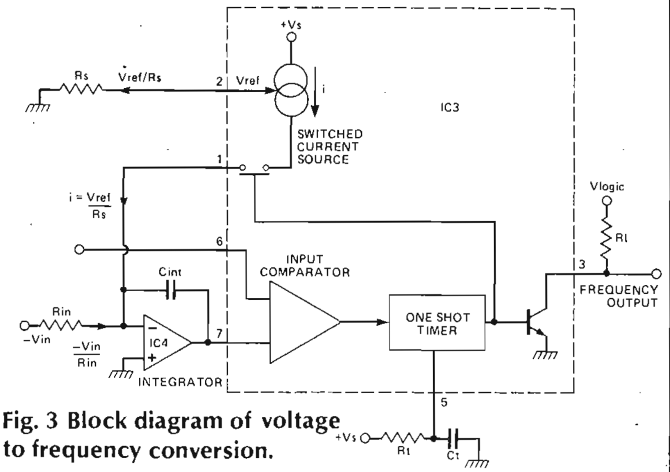


Fig. 3 Block diagram of voltage to frequency conversion.

KEYBOARD UNIT

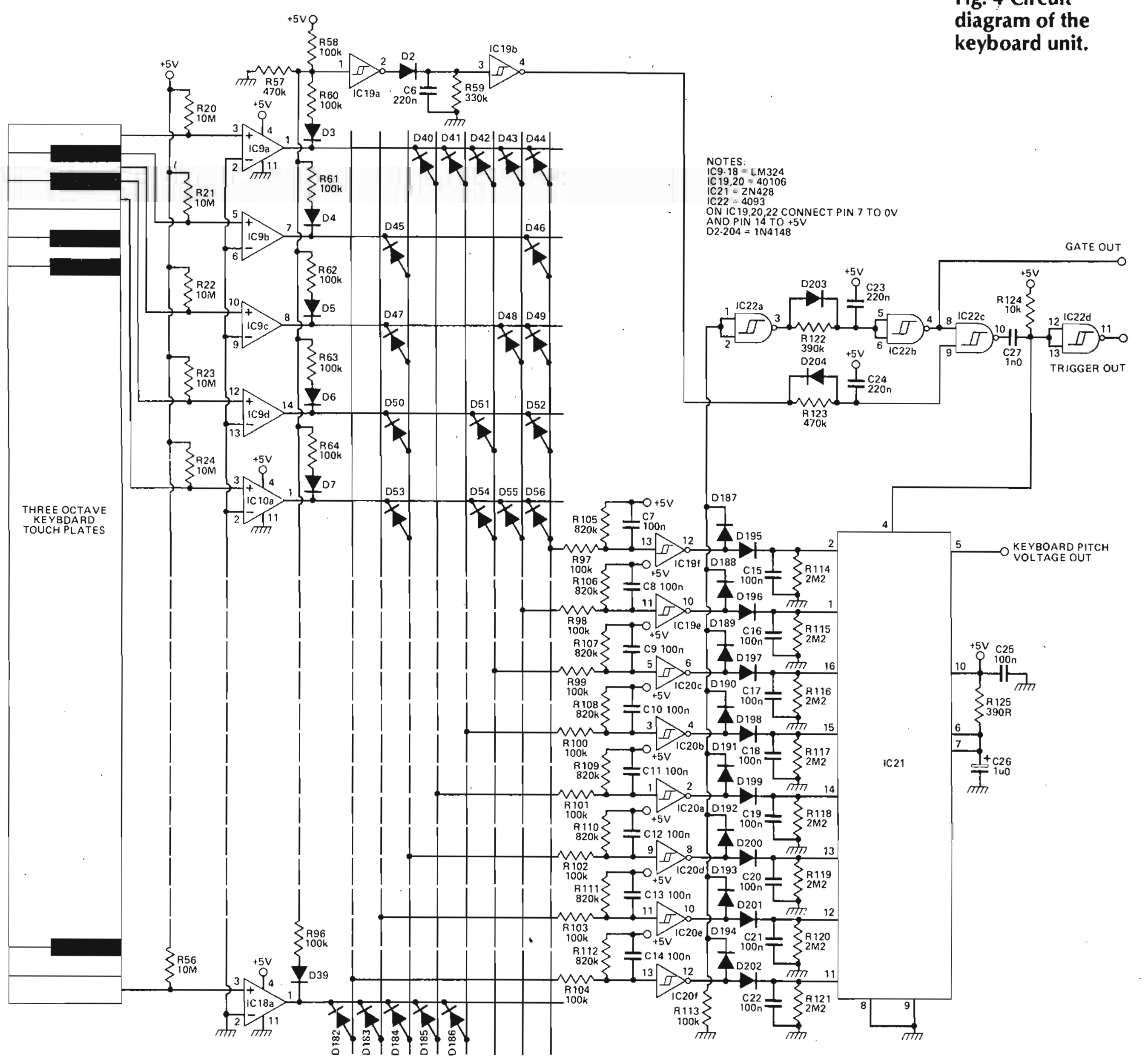


Fig. 4 Circuit diagram of the keyboard unit.

The keyboard unit must take an input from the musician paying the keyboard, and produce information from the key operated, to tell the rest of the synthesizer what to do, and when to do it. This information is a voltage, proportional to the frequency of the required pitch, a trigger pulse produced every time a new note is operated and a gate pulse signal which is a local high for the duration of any key press.

Suitable touch switches come in three types, with different principles of operation. The simplest is the resistive type which detects the change of resistance between two contacts bridged by the fingers. This method was used some years back in an ETI project for a miniature organ keyboard. Although simple, it has serious drawbacks — it is disabled by moisture and does not respond to musicians with dry skin! A much better, but more complex technique is to use the principle that a human body acts just like a small value capacitor with one end grounded, using a finger as the other connection. Such designs usually employ a high frequency oscillator and moderately complex detection circuits — not really suited to being reproduced thirty seven times on a keyboard! The technique chosen for Sorcerer uses hum-detection. The human body acts like a sort of aerial, picking up mains hum which can be detected using a high input impedance amplifier.

Each key is formed by an area of copper on the keyboard PCB, is linked to the non-inverting input of a low-power op-amp and held to the supply voltage by a very large resistor. When the keys are untouched, the resistors pull the non-inverting inputs above the voltage of the inverting inputs, each tied to 0v, and so the op-amp outputs are high. When a key is touched, a 50Hz signal is injected into the non-inverting input of the appropriate op-amp. Since the op-amps are used here as large gain comparators, the output is in the form of a 50Hz pulse train between 0V and 3.5V which must be detected.

Each key is encoded with an eight-bit binary number which will eventually go for digital-to-analogue conversion. The coded numbers must be proportional to the required pitch voltages.

The relationship between the frequency of the successive notes on a musical keyboard is exponential not linear. Each octave is a doubling in frequency and adjacent notes are multiples of the twelfth root of two in frequency! The usual method used in analogue synthezisers to achieve this musical scale is to design a keyboard which produces a linear voltage output, often a standard 1 volt/octave, passing this to a special VCO which responds in an exponential fashion. Thus, a simple keyboard is used to control a very complex and expensive VCO. The linear to exponential conversion technique is very prone to the effects of temperature change and component mismatch. If it can be avoided life becomes much simpler!

Sorcerer solves the problems

KEYBOARD UNIT

of stability and complexity at the price of precision. The keyboard produces an exponentially incremented pitch voltage output, using a series of exponentially related binary keycodes, and drives a linear VCO. Being digitally generated, the keyboard output is very stable, but since it is only limited to eight-bit precision, the voltages have small — but normally unnoticeable — errors referred to the exact voltage required.

The binary codes are programmed using a diode matrix. The key op-amp outputs are connected, where required, to the eight-bit data bus by reversed signal diodes D40 to D186, forming the exponential code (Table 1).

The data on the data bus is still in form of 50Hz pulse trains and must be made into steady logic levels to drive the digital-to-analogue converter. The signals on the data bus are low-pass filtered by R97 to R112 and C7 to C14 to remove the 50Hz component, and drive CMOS inverting Schmitt triggers in IC19 and IC20. If a data line is inactive, the input to the Schmitt is held high by one of R105 to R112. An active line produces a high at the Schmitt trigger output, and an inactive line a low.

The resulting steady codes are passed on to IC21, an eight bit digital-to-analogue converter, to be changed into the output pitch voltage. Diodes D195 to D202 and storage capacitors C15 to C22 ensure that data is valid even if a key is operated for less time than it takes the DAC to latch.

The gate signal is produced by using an eight input diode OR gate (D187 to D194 and R113) connected to the eight logic level data lines. Pin 3 of IC22 will go low when any key is pressed. A delay is produced on this falling edge by R122, D203 and C23, so that the output of IC22b will go high shortly after any key is pressed, giving the data lines time to settle down.

D3 to D39 and R60 to R96 feed a filter-Schmitt trigger circuit using IC19a and b, the output of which will go low if two or more keys are pressed at the same time inhibiting the trigger and latch. This signal has its rising edge delayed by R123, D204 and C24, so that the data lines can settle down when two keys are pressed simultaneously and one is then released.

IC22c, C27 and R124 produce a negative pulse when there is a change from no keys or more than one key being pressed. This pulse is used to update the digital-to-analogue converter latches, and in inverted form, via IC22d, used as the trigger signal for the envelope generator.

NOTE	EXP. COD	BINARY CODE
C	31	00011111
C#	33	00100001
D	35	00100011
D#	37	00100101
E	39	00100111
F	41	00101001
F#	44	00101100
G	46	00101110
G#	49	00110001
A	52	00110100
A#	55	00110111
B	59	00111011
C	62	00111110
C#	66	01000010
D	70	01000110
D#	74	01001010
E	78	01001110
F	83	01010011
F#	88	01011000
G	93	01011101
G#	98	01100010
A	104	01101000
A#	110	01101110
B	117	01110101
C	124	01111100
C#	131	10000011
D	139	10001011
D#	147	10010011
E	156	10011100
F	166	10100110
F#	175	10101111
G	186	10111010
G#	197	11000101
A	209	11010001
A#	221	11011101
B	234	11101010
C	248	11111000

Table 1 Sorcerer keyboard binary key codes.

Usually, one of the most critical parts of a music synthesizer is the power supply unit. In an analogue design most of the synthesizer parameters are supply dependent. A professional machine must have a drift free tuning, and as a consequence the power supply design is very complex.

This is not the case in Sorcerer. All critical parts of this design have local references of their own, most based on very stable band-gap devices in the ICs used. Thus a simply regulated supply is all that is required.

Sorcerer requires three power rails to run, and all of these are mains derived. A dual secondary 9V transformer, rated at 8 VA is used as a source. This is conventionally rectified and smoothed by BR1, C28 and C29. IC42 provides a +5 volt regulated output, and IC43 a −5 volt supply. The other supply required is a +10 volt output. Since it is not common to find fixed ten volt regulators, a low current 5 volt device, IC44, is stacked on top of the main +5 volt rail. D205 ensures that the IC starts up correctly when driving a capacitive load.

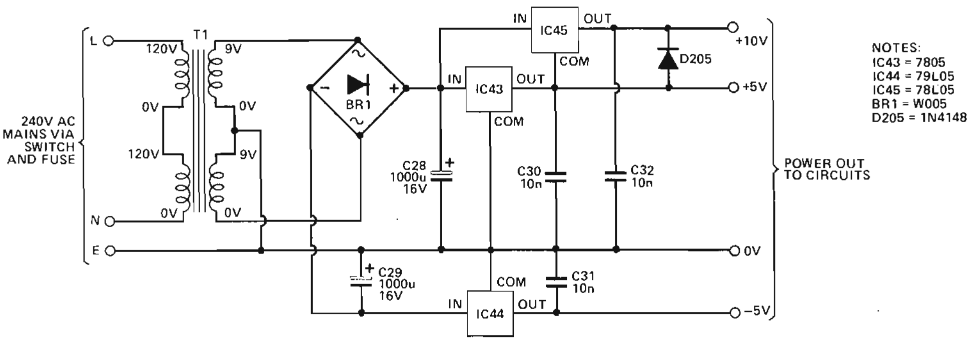


Fig. 5 Circuit diagram of the PSU

Since the Sorcerer is a project of considerable length, we have been obliged — for reasons of space — to split it up into a number of parts. The circuit diagrams and descriptions of the envelope shaping and chorus sections of the synthesizer will appear next month. We hope to publish the PCB foil patterns and component overlays the following month, along with constructional details, information about modifiying the circuit for use with a conventional keyboard, details of the setting-up procedure, parts list and Buylines.

ETI

ETI SORCERER STRING SYNTHESIZER

Graeme Durant's design performs the magic, turning digital strings into violin strings.

In last month's ETI, we introduced the Sorcerer and dealt with the keyboard circuitry and the key encoding system as well as the VCO and the power supply unit. This month, as promised, we deal with the major sound processing facilities — the chorus board and the envelope shaper. The circuits are shown and the principles of operation are handled.

Readers of the first part of the article will recall that so far we have seen how touching a key produces a trigger and a gate voltage as well as a binary number which is converted using a D-A device and a voltage-to-frequency converter into a note (or, rather, into three notes at octave gaps). In this month's enthralling episode, we see how the notes are filtered, delayed and mixed for chorus effect (if desired) and, finally, gated on and off and shaped by the envelope circuitry ready to astound your friends and amaze your neighbours.

Next month, we'll bring you full constructional details, PCB patterns and component overlays and some guidance on how to fit a moving mechanical keyboard to the Sorcerer — not to mention the Parts Lists and Buylines. For now, read on . . .

HOW IT WORKS
CHORUS CIRCUITS

The chorus circuitry takes the pulse train outputs from the VCO, filters them to make a smoother sound and feeds them to a bucket brigade delay line system to provide an apparent multiplicity of sound sources (Fig. 6). Before being fed to the delay lines, the mixed and filtered pulse-trains must go to a low-pass filter to remove the upper harmonics, which prevents aliasing.

The chorus effect is produced here by feeding the signal through three parallel delay lines, and mixing the outputs together. For maximum effect, each line delay time is modulated 120 degrees out-of-phase with the other two. This produces a rich enough chorus to simulate the multiplicity of sound sources required.

The delay times of the lines are deter-

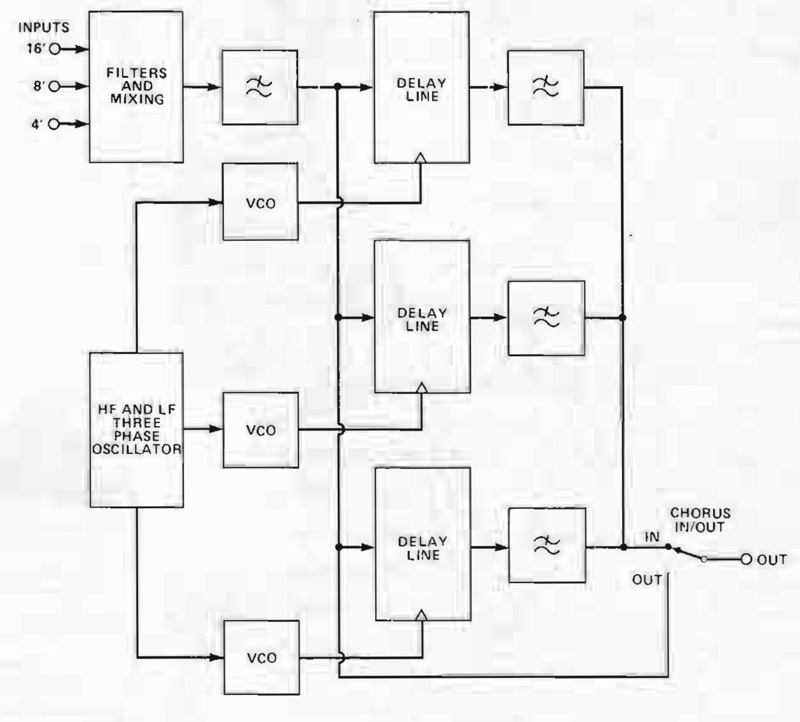


Fig. 6 Block diagram of the chorus section.

mined by the frequency of three VCO clock generators controlled by a three-phase oscillator. The delay line outputs are mixed after being fed through low-pass filters, needed to remove the clock breakthrough onto the signal as a result of the untreated input signal.

The circuit diagram is shown in two parts: the clock generation section (Fig. 7) and the audio section (Fig. 8). IC29 and IC30 (Fig. 7) form two simple three phase oscillators, each made up out of three integrators, wired up in a loop. The circuit is inherently unstable and will always oscillate, the outputs being roughly trapezoidal in shape and 120 degrees out-of-phase with each other. The oscillator built around IC29a, IC30c and d, runs at about 0·5 Hz, whereas the other built around IC29b, IC30a and b, runs at around 5 Hz. The oscillator output pairs are mixed and then filtered by C37, C40 or C43, to produce three roughly sinusoidal outputs, each consisting of a large 0·5 Hz signal with a smaller 5 Hz signal superimposed on top. These are used to modulate the clock VCOs, IC31, IC32 and IC33, and give a realistic tremolo effect.

The VCO ICs used are CMOS 4046 phase-locked loop devices. These contain several building blocks suited to the construction of PLL circuits, but we only use the VCO and an internal exclusive OR gate wired up as an inverter. The delay lines require a two phase clock signal, and the inverters are used to produce a second phase.

The VCOs are programmed by the capacitor across pins 6 and 7, and the resistors on pins 11 and 12. We want to sweep between about 50kHz and 100kHz, to produce delays of between 5ms and 2·5ms respectively. The line delay in the devices used in Sorcerer is equal to 256 divided by the clock frequency and the VCOs are programmed accordingly.

The VCO ICs are powered from +10V and –5V, as are the delay line chips, and the supplies are well decoupled to stop clock signals leaking onto the supply lines. The outputs from the VCOs, at pins 4, and the inverted second phase at pins 2, go to the delay line circuits.

The three octave spaced signals are filtered by passive high and low-pass filters formed by C56 to C64 and R177 to R184 (Fig. 8). The three filtered signals are mixed at the virtual earth input of IC34a and a variable DC bias level is added to the signal by RV10. This is adjusted so that the input signal is at the centre of the delay line's linear operation region. IC34b is wired up as a 10kHz low-pass filter to further eliminate aliasing.

IC35 to IC37 are the delay line devices. Sorcerer uses a little known Matsushita device, the MN3010, which is a dual 512 stage analogue bucket brigade device. Unfortunately, the two lines cannot be independently clocked, because of on-chip intermodulation, although lower noise operation is gained by paralleling the lines in each IC.

Another cause of intermodulation is the coupling of the clock frequencies between channels, via other common connections like the supply rails. This is avoided by very heavy decoupling at every opportunity. C71 to C73 decouple clock frequencies feeding back out of the delay line inputs. The two resistors connected to pin 4 of each delay line hold the gate supply voltage at about one volt above the negative rail.

The signal outputs, via presets from pins 8 and 13 which null out some of the heavy signal clock content, go to more 10kHz low-pass filters (IC38 to IC40) to remove the rest of the clock breakthrough from the signal. The three outputs are combined at IC41 — a virtual earth mixer. IC42 is a quad analogue switch half of which is controlled by the front panel switch SW5 to route either the chorus signal or the pre-chorus signal to the envelope shaper without going to the front panel. C83 blocks the input DC bias, if the pre-chorus signal is selected.

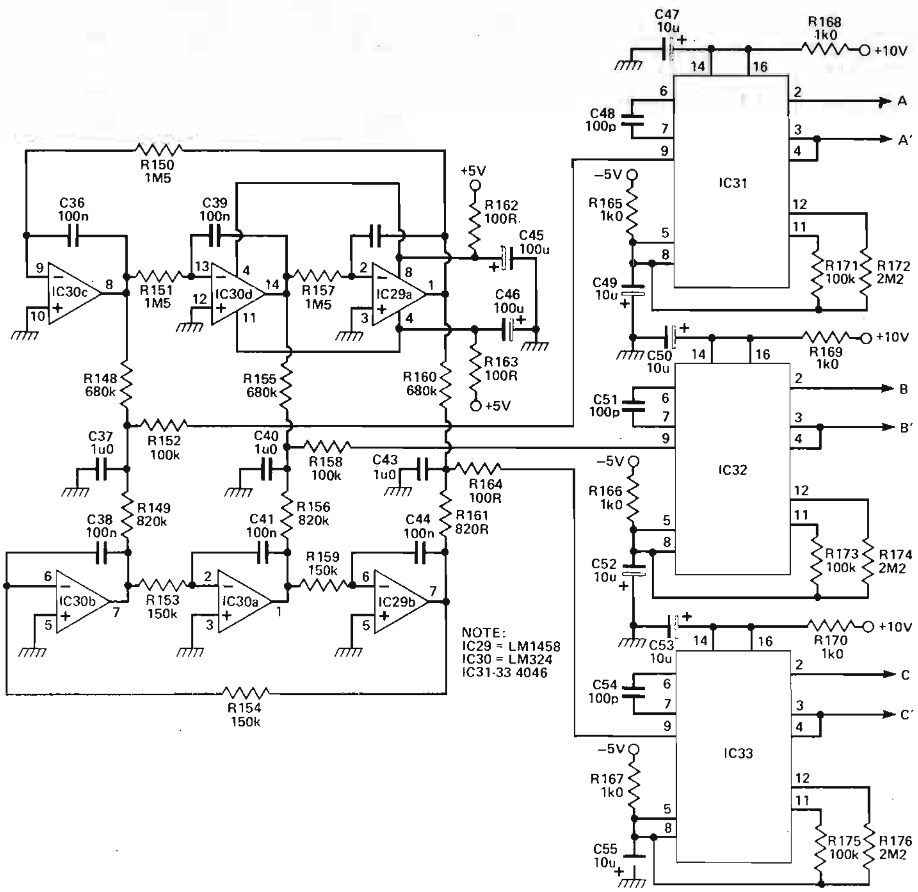


Fig. 7 Circuit diagram of the chorus section clock circuit.

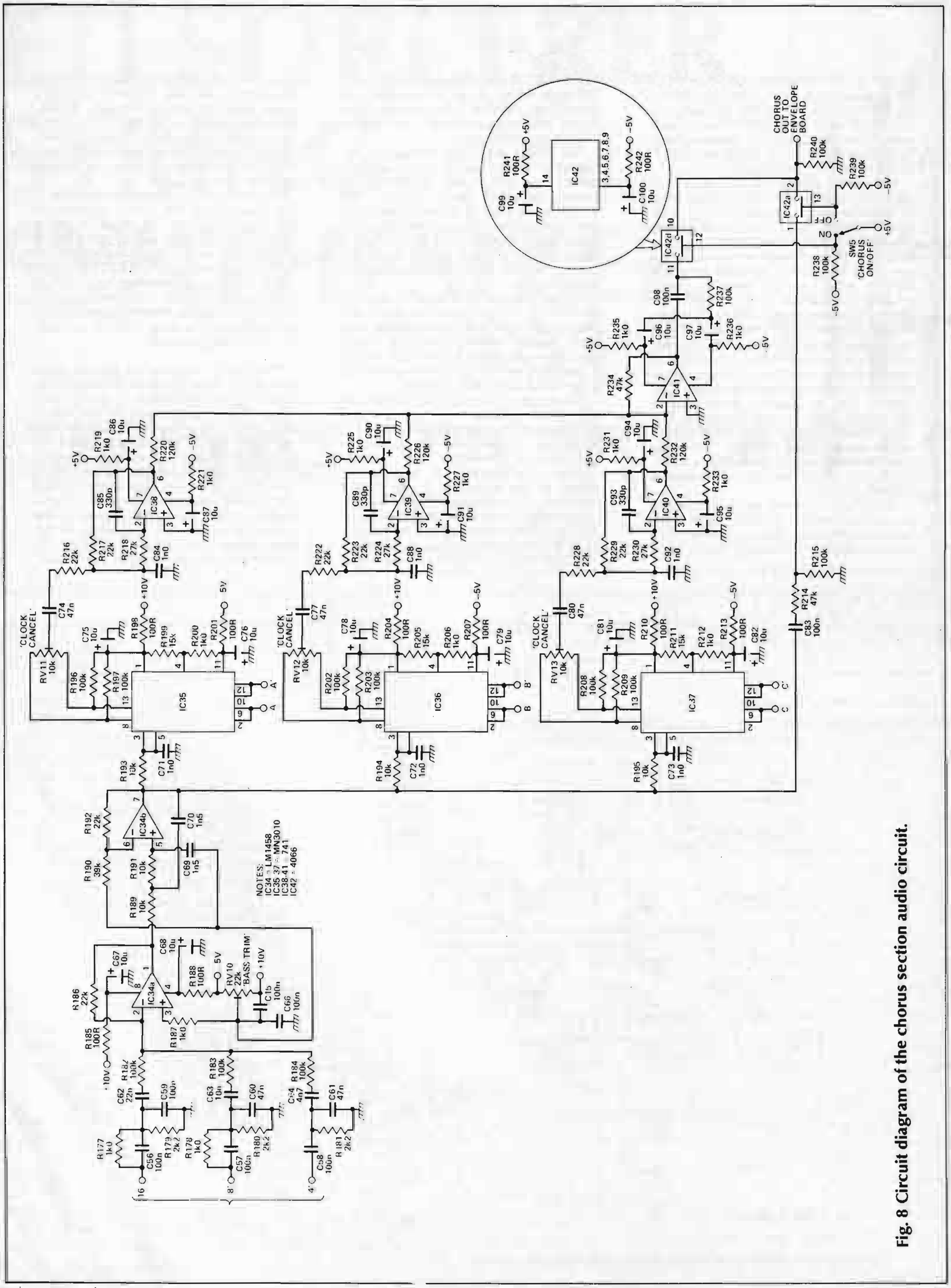
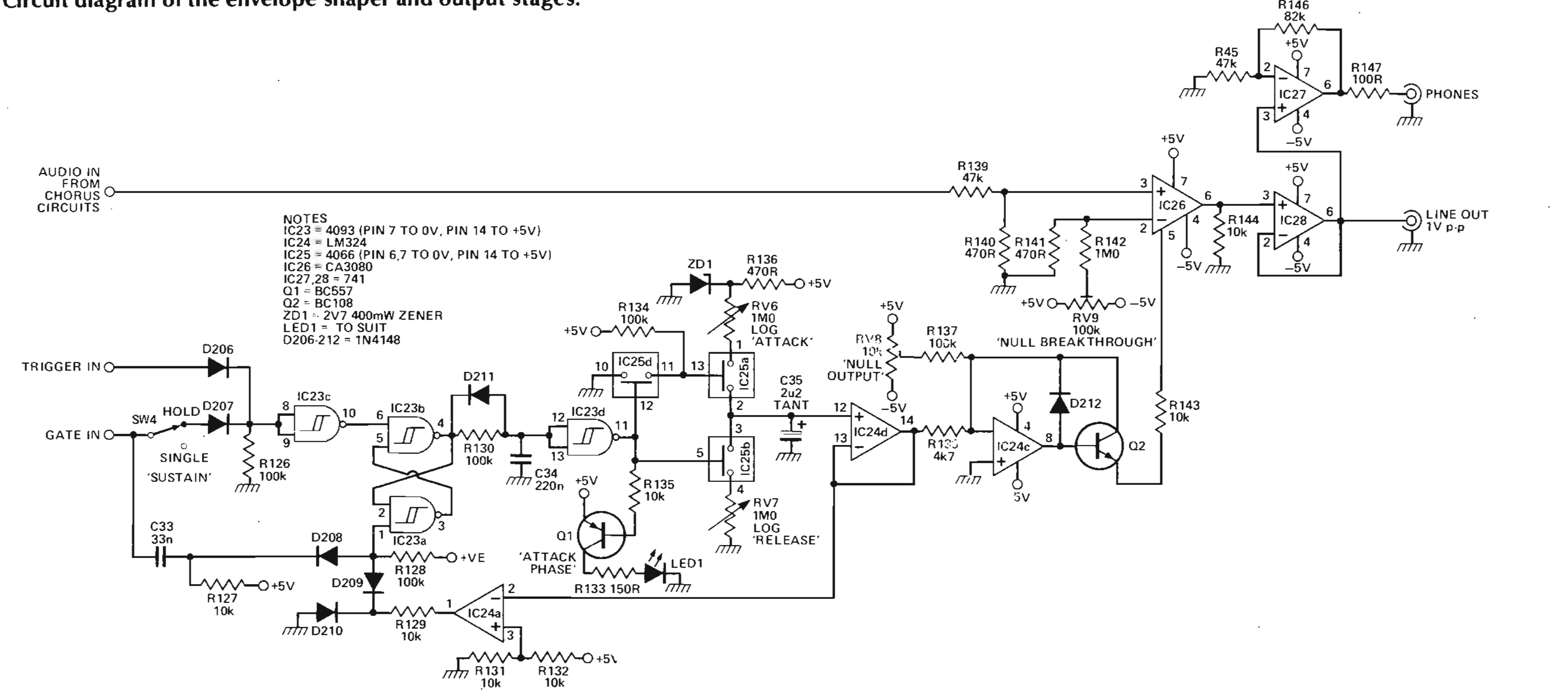


Fig. 8 Circuit diagram of the chorus section audio circuit.

Fig. 9 Circuit diagram of the envelope shaper and output stages.



HOW IT WORKS
ENVELOPE SHAPER

The circuit can be split into two sections: an envelope generator (IC23, 24, 25) which produces a changing voltage proportional to the required amplitude contour and a voltage controlled amplifier (IC26, 27, 28) which uses this voltage contour to control the amplitude of the audio output.

A positive trigger pulse from the keyboard will initiate a cycle of the generator. After passing via D206 (half a diode OR gate) it will be inverted by IC23c and, assuming pin 1 of the IC is high, pin 4 will latch high. After a delay of about 80ms (R130 and C34) pin 11 will go low. The delay allows the VCO to settle to its newly set pitch, avoiding pitch slew.

Now, CMOS switches IC25b and d are turned off allowing pin 13 of IC25 to rise high by R134 and turn on IC25a. C35 will start to charge up via the attack potentiometer RV6, from a 2.7 volt reference based on ZD1 and R136. IC23d also turns on Q1 which lights a front panel LED to indicate the attack sequence. The voltage on C35 is buffered by IC24d and goes to the input of a voltage comparator IC24a. The other input to this comparator is held at about 2.5 volts by R131 and R132. When the voltage on C35 passes this threshold the output of the comparator will go negative, taking pin 1 of IC23 low, resetting the RS latch and taking pin 11 of IC23 high. (The delay being by-passed by D211). IC25b and d are turned on and IC25d turns the attack switch off.

C35 starts to discharge via RV7, the 'Release' potentiometer. If the 'Sustain' switch SW4, is in the 'Hold' position, D207 will hold the latch 'Set' until the gate signal goes low. The envelope shaper stays at full output volume until the key on the keyboard is released. C33 and R127 form a falling edge detector which will reset the latch, ensuring that the release phase always occurs immediately a key is released.

The buffered contour voltage at the output of IC24d goes to a precision voltage-to-current converter built around IC24c and Q2. This drives a proportional current through R143 into IC26, an operational transconductance amplifier whose gain is varied by the current flowing into pin 5. R139 and R140 cut the input signal level to about 20 mV peak-to-peak, avoiding signal distortion. RV9 is a preset used to null out the input offset voltage of IC26. If this were not done a DC voltage similar to the control voltage could appear at the output. RV8 similarly nulls the signal output when C35 is completely discharged.

The current output of IC26 is dumped into R144 to produce a voltage, which is buffered by IC28 to form the line output.

ETI

ETI SORCERER STRING SYNTHESIZER

Having unravelled the circuit diagrams, Graeme Durant wraps up the project and ties up the loose ends.

Construction of Sorcerer should prove to be quite straightforward, especially if the suggested PCB layouts are used.

Each board requires a number of wire links to be fitted, so these should be tackled first. If you are playing safe and using IC sockets, fit these next. Sockets are recommended for the MOS devices, especially the expensive delay-line chips. Now you can solder in the passive components, remembering that all 213 diodes must go in the correct way round! Note also that some resistors must be mounted vertically. Finally, insert the presets and the panel mounting potentiometers. Since the latter are PC mounting, ensure that they are all straight, so that they will go into the front panel cutouts first time.

After scrubbing off all that nasty flux on the backs of the PCBs, with meths, it is time to fit the boards into the main case, which has by now been drilled and punched to accept them. Note that the VCO board and the envelope board are fixed in only by their front panel potentiometers; they require no further fixing, unlike the other PCBs, which must be bolted into the case. It is recommended that the boards are fitted with veropins or similar terminals, prior to encasing them, to ease the job of interwiring *in situ*.

All power connections should be made from each board to a common point at the power supply board. If power connections are strung from board to board, all manner of nasty noise will be the end result. The power supply itself should be connected to mains via a suitable panel on/off switch and a 500mA fuse. Be careful to insulate all points at mains voltages with sleeving. If a metal case is being used, a connection should be made between it and earth, using a bolt and solder tag.

Interconnections must be made between the two chorus boards using tinned copper wire (Fig. 10). Connections to the power supply should be made as shown, using Veropins, but with the interconnection wires still soldered underneath. The chorus boards are stacked and bolted, but plastic spacers must be used to avoid accidental short circuits occuring across the closely spaced tracks on the boards. As a last resort (and I mean a last resort!) use empty plastic biro tubes.

Connections to the front panel switches should be made from the various boards (Fig. 11). The front panel 'Attack LED' is wired between 0V (cathode) and the attack LED pin on the envelope board. Note that none of the connections in Sorcerer are critical and they can all be safely made using ordinary hook up wire.

The keyboard is built on two

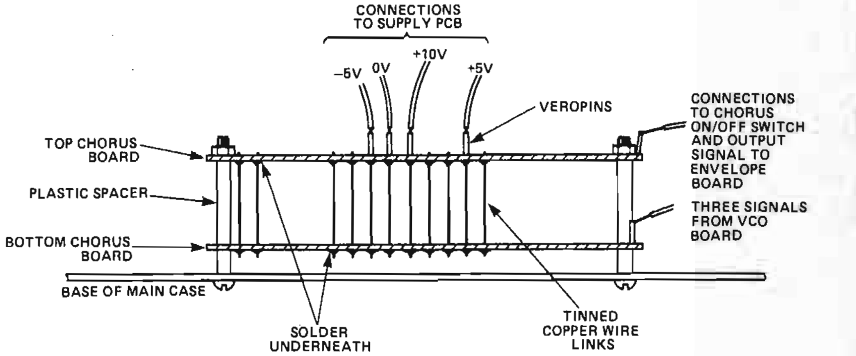


Fig. 10 Interconnecting the two chorus boards.

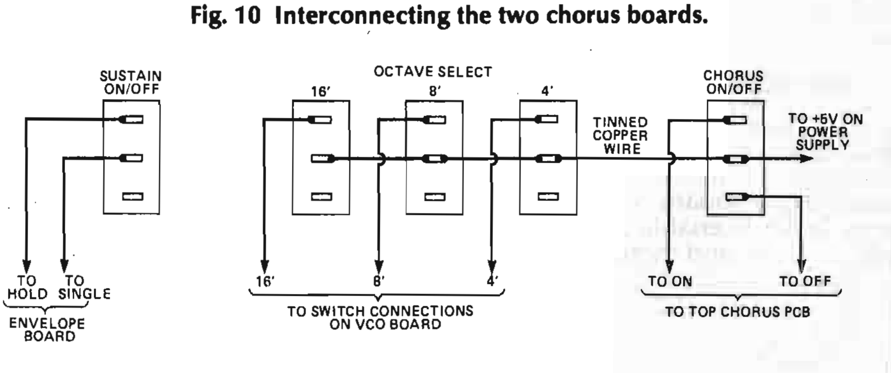


Fig. 11 Connections to front panel switches and pots.

boards. The keyboard interface PCB is the small one, and when complete is stacked about 12mm above the copper side of the main keyboard PCB using spacers and bolts with its copper side up, too. Connections are made to the large board using eleven vertical tinned copper wire links, as on the chorus boards. If the keyboard is to be housed separately to the main electronics, five connections (+5V, 0V, gate, trigger and key voltage) must be made between it and the main unit. In the prototype a five pin DIN lead was used with corresponding DIN sockets, but any suitable method could be employed.

The actual insertion of components is similar to the rest of the boards apart from resistors R60 to R96 and diodes D3 to D39 on the main board. These are soldered together in pairs, in series before insertion into thePCB. (Fig. 12). This was necessary for space reasons.

The keyboard case for the prototype was made from wood and required only simple carpentry skills. The reverse side of the actual keyboard surface of the main PCB was glued, using a contact adhesive, to a strip of chipboard some 12mm thick, the full depth of the keys. From this base, simple wooden ends were glued on, to form the case sides; then a thin strip to form a front edge, to cover up the chipboard, and a rear wider strip to form a back panel, were added. Another thin strip formed the back edge of the keys themselves, then two painted aluminium plates were used as a top and bottom panel. These were fixed using wood screws to allow later removal and access to the circuits inside. Finally, four rubber feet were added to make a stable construction. So, the case is actually built around the main PCB, and should be done carefully after inserting the components.

Modifications

The more serious musician aiming to use the Sorcerer string synthesiser will no doubt prefer to use a real keyboard with moving keys. This will enable the musician to play faster and more reliably, as well as giving a familiar feel.

Such a modification would be quite straightforward. IC9 to IC18 would no longer be required. Instead, a three octave keyboard unit, fitted with single pole 'make' contacts, would be used. One connection to each switch should be commoned to all the other similar ones, and connected to 0V. Each of the other connections to each switch should be soldered to the appropriate key on the solid-state keyboard PCB. Then, to bypass the spaces left by IC9 to IC18, wire links should be inserted, connecting the tracks which originally went to the op-amp non-inverting inputs, to the tracks which went to their outputs. The result is that each row in the diode matrix can be effectively grounded by pressing a key, thus setting up the keycodes as before. Resistors R20 to R56 pull each row up to five volts when that key is unpressed. These resistors could be reduced in value to 100K, for less susceptability to noise and faster matrix switching.

The rest of the keyboard circuitry could remain as before, with perhaps a couple of component value changes. R97 to R112 and C7 to C14 can stay, to debounce the mechanical contacts. IC19a and IC19b detect the presence of more than one key being pressed, and having altered the type of keyboard switching, the sensitivity of this detection circuit must be altered to suit. Simply alter the value of R58 until the output of IC19b goes low for two or more keys pressed, but high otherwise — this could be achieved by fitting a 220k potentiometer. The setting could be measured using a multimeter on the ohms range, and a fixed resistor then put in its place.

Finally, the value of R122 could be experimentally reduced, to allow faster keyboard response. Now that the square pulse signals of the touch detectors have been removed, the reaction delay can be safely reduced whilst still maintainting a reliable response to keys pressed.

Setting Up And Use

Sorcerer contains seven preset potentiometers, so requires a little setting up. Although no test gear is essential, access to an oscilloscope is useful. After having built up all the PCBs, checked for faults and wired up everything except the connections to the power supply outputs, it is time to plug the PSU in to the mains. Check that the PSU outputs are at the correct voltages, then make the final connections between each PCB and the power supply.

Connect the keyboard unit to the main box of tricks and a pair of headphones or an amplifier/ speaker set at low volume to the output. Ensure all seven presets are set to their midway positions. Select the middle octave range on the switches, turn off the chorus effect and apply the power. A sound of some kind may be audible, if it is, do not worry. Press a key. The Attack LED should light, and the sound should get louder

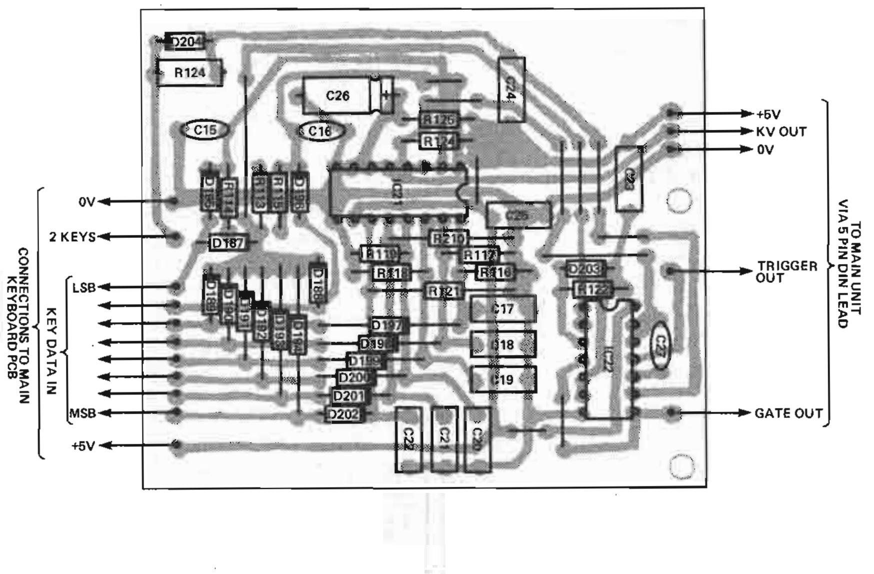


Fig. 12a Component overlay for the keyboard interface PCB.

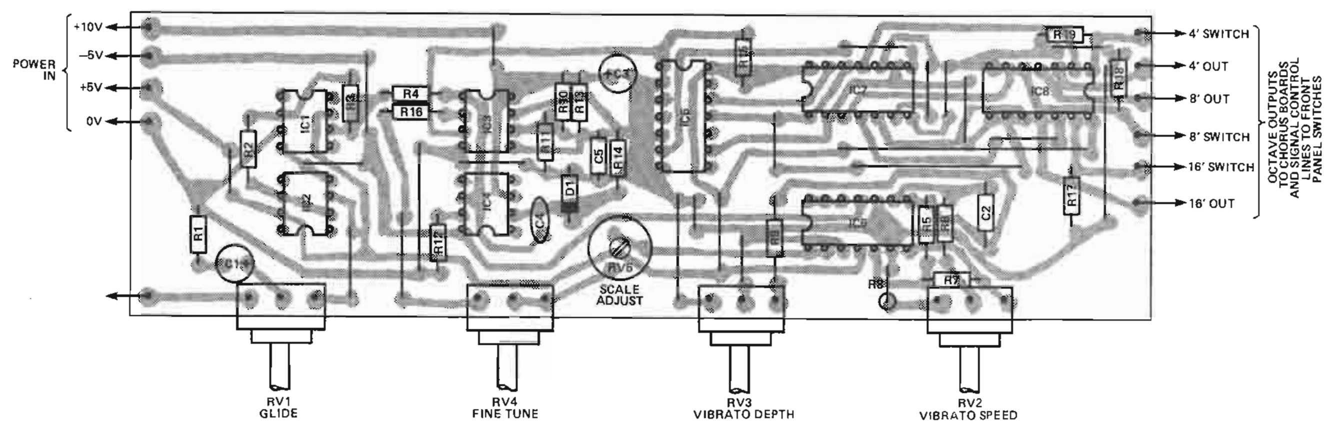


Fig. 13 Component overlay for the VCO board

with an envelope according to the attack and release control settings. If not, turn off. Check your wiring. Check to see if a signal is being produced by the VCO. Check the keyboard output voltage and timing pulses.

If all is OK, try the other octave switches. Try the sustain on/off switch, and different setting of the attack and release controls. Check the vibrato controls work, and the glide and tune functions. Finally, see that the chorus mode has at least some effect (but do not worry about the din it is probably making!).

Once you are convinced that all the functions have some effect, it is time to set the presets. Switch off the chorus effect, and set the attack and release controls to minimum. Turn up the amplifier volume control until you can hear the signal breaking through the envelope shaper, then adjust RV8 on the envelope board until the minimum signal is heard.

Switch out all the octave ranges, then, with the sustain set to off, press a key. A sharp click will probably be heard. Turn RV9 also on the envelope board, until

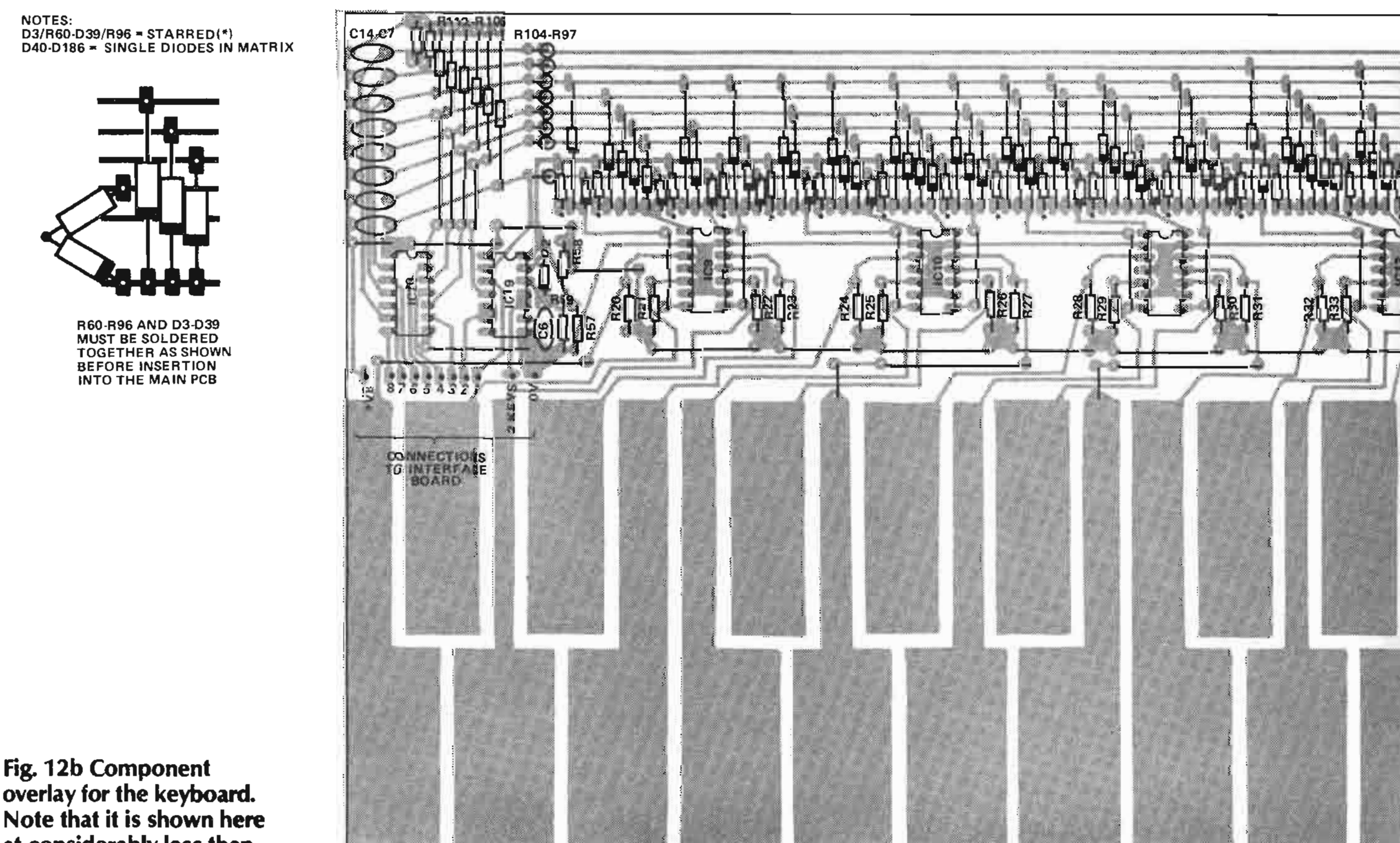


Fig. 12b Component overlay for the keyboard. Note that it is shown here at considerably less than its full size.

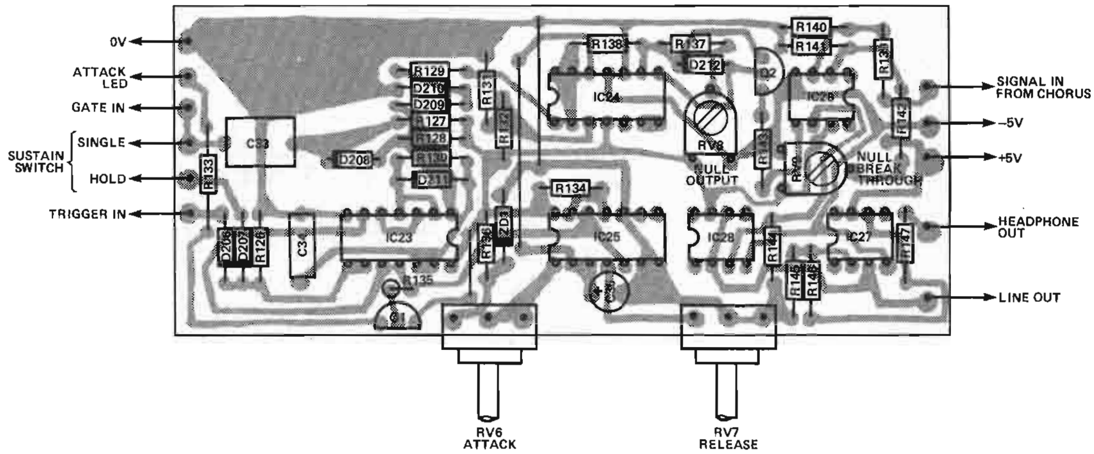
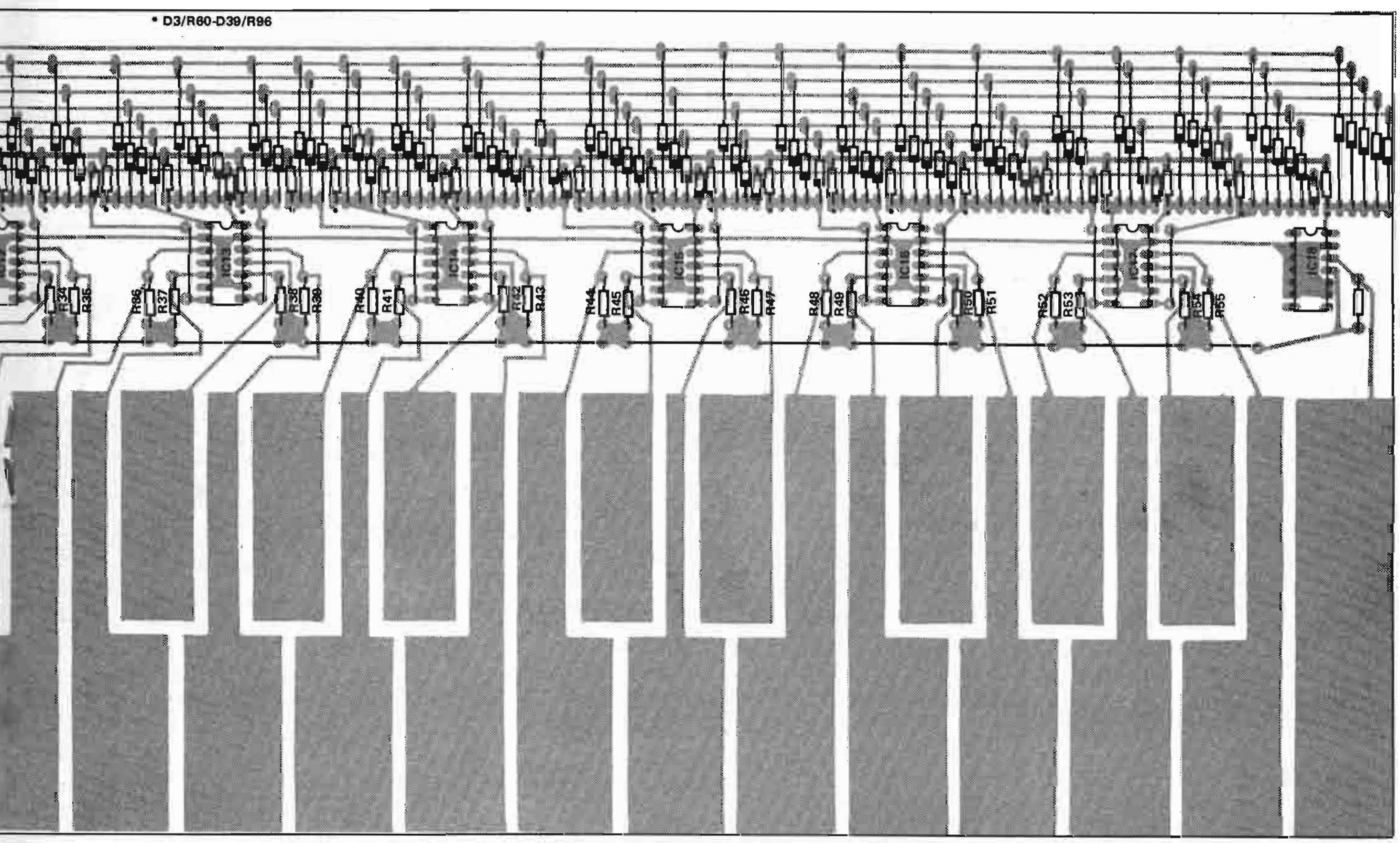


Fig. 14 Component overlay for the envelope board.

pressing a key produces the minimum effect. The envelope shaper is now set up.

Now, reduce the amplifier volume to a reasonable level, and set the attack and release controls about midway. Switch in all the octave ranges. Select the chorus mode, and hold down a note on the keyboard. Turning RV10 through the hole in the top chorus board should, at one extreme, fuzz the sound and, at the other, stop the signal. RV10 sets the operating point of the delay-line chips and should be in the middle of its undistorted range of travel. Finally, we set up RV11, 12, and 13 on the top chorus board. If an oscilloscope is unavailable, set these midway — they are not too critical. Their function is to cancel out some of the high frequency clock signals imprinted onto the outputs of the delay line devices. If an oscilloscope is to hand, connect its input to the slider of RV11, and adjust until the minimum high frequency noise appears on the signal. This may be easier to see with all the octave ranges switched off. Repeat for RV12 and RV13. This completes



the setting up of the chorus board.

The last preset to deal with is RV5, on the VCO board. This simply acts as a coarse tuning control. Set the front panel tune control to its central position, then turn RV5 until the instrument is in tune with a known reference.

The line output is about one volt peak-to-peak and so should drive most amplifiers, but if it is too high, fit an attenuator. The touch keyboard should work in most environments, provided there is enough mains hum around the place. If problems are encountered, try planting both feet firmly on the floor (I am serious, it does work!). If the problems persist, try removing the 10Mohm input resistors on the keyboard, to increase its sensitivity. Also check earth continuity and connection to the 0V line.

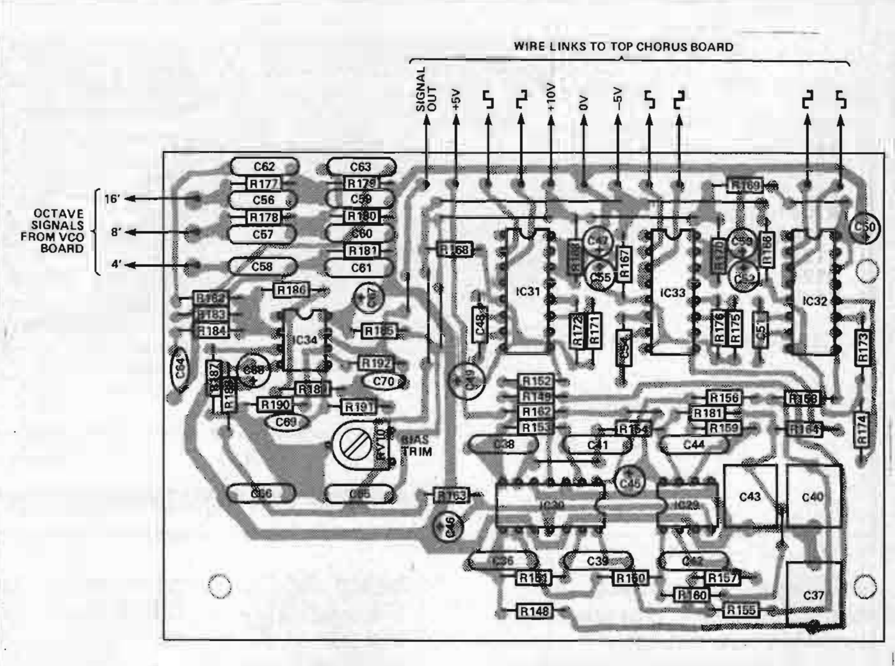


Fig. 15 Component overlay for the chorus clock board.

BUYLINES

Most of the parts used in Sorcerer can be found in any supplier's catalogue, but there are a few more-difficult-to find parts required. The MN 3010 delay line chips are available from Digisound Limited, 14/16, Queen Street, Blackpool, Lancs FY1 1PQ at a cost of £18.98 for the three all inclusive. The MN3010 delay line chips are available from Maplin, as is the ZN428 keyboard D-to-A converter. The particular subminiature single ended electrolytic capacitors used on the chorus PCBs, and the PC mounting potentiometers, were also from Maplin. The case used in the prototype to house the main electronics is one of the Modular 5 range of enclosures available from West Hyde Developments Limited, 9/10, Park Street Industrial Estate, Aylesbury, Bucks, HP20 1ET. The model used was the MD5 AFL and costs £17.33 including postage, packing and VAT. The encapsulated transformer used in the prototype — Clairtronic type 9641 — can be obtained from Verospeed, Stansted Road, Boyatt Wood, Eastleigh, Hants SO5 42Y (tel: 0703 644555). The price is £3.89 and the order code, 89-35985D. The PCBs are available from the ETI PCB Service, but see the note in News Digest.

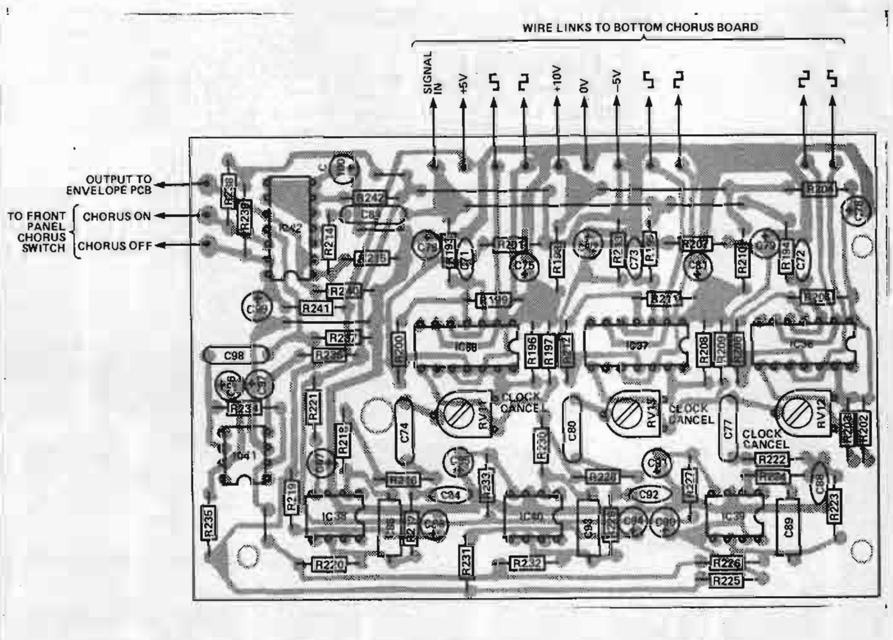


Fig. 16 Component overlay for the chorus audio board.

PARTS LIST
VCO SECTION

RESISTORS	**(all ¼W, 5% unless otherwise stated)**
R1,8	1k0
R2,3,4,7,12	100k
R5	47k
R6,9	390k
R10,11,15,17,18,19	10k
R13,16	6k8 1% metal film
R14	2k2
Rv1	100k log. PC mounting
RV2	10k lin. PC mounting
RV3	47k lin. PC mounting
RV4	2k2 lin. PC mounting
RV5	4k7 Cermet preset
CAPACITORS	
C1	3u3 16V tantalum
C2	150n polycarbonate
C3	10u 16V tantalum
C4	4n7 mylar
C5	2n2 polycarbonate
SEMICONDUCTORS	
IC1,4	LF351
IC2	741
IC3	LM331 or RC4151
IC5	LM324
IC6	4024
IC7	4011
IC8	4081
D1	1N4001

MISCELLANEOUS

PCB; solid tinned copper wire; control knobs; veropins.

PARTS LIST

KEYBOARD

RESISTORS (all ¼W 5%)

R20 to 56	10M
R57,123	470k
R58,60 to 104,113	100k
R59	330k
R105 to 112	820k
R114 to 121	2M2
R122	390k
R124	10k
R125	390R

CAPACITORS

C6,23,24	220n polycarbonate
C7 to 22,25	100n polycarbonate
C26	1u0 axial electrolytic
C27	1n0 polycarbonate

SEMICONDUCTORS

IC9-18	LM324
IC19,20	40106
IC21	ZN428
IC22	4093
D2 to 204	1N4148

MISCELLANEOUS

PCBs; solid tinned copper wire; IC sockets; spacers; bolts; five way connector for keyboard connection to main unit.

ENVELOPE SHAPER

RESISTORS (all ¼W. 5%)

R126,128,130,134, 137	100k
R127,129,131,132, 135,143,144	10k
R133	150R
R136,140,141	470R
R138	4k7
R139,145	47k
R142	1M
R146	82k
R147	100R
RV6	1M0 log. PC mounting
RV7	1M0 log. PC mounting
RV8	10k miniature horizontal preset
RV9	100k miniature horizontal preset

CAPACITORS

C33	33n polycarbonate
C34	220n polycarbonate
C35	2u2 16V tantalum

SEMICONDUCTORS

IC23	4093
IC24	LM324
IC25	4066
IC26	CA3080
IC27,28	741
Q1	BC557
Q2	BC108
ZD1	2V7 400mW zener diode
D206-212	1N4148
LED1	to choice

MISCELLANEOUS

PCB; solid tinned copper wire; control knob; veropins.

CHORUS CIRCUITS

RESISTORS (all ¼W, 5%)

R148,155,160	680k
R149,156,161	820k
R150,151,157	1M5
R152,158,164,171, 173,175,182,183, 184,196,197,202, 203,208,209,215, 237,238,239,240	100k
R153,154,159	150k
R162,163,185,188, 198,201,204,207, 210,213,241,242	100R
R165,166,167,168, 169,170,177,178, 187,200,206,212, 219,221,225,227, 231,233,235,236	1k0
R172,174,176	2M2
R179,180,181	2k2
R186,192,216,217, 222,223,228,229	22k
R189,191,193,194, 195	10k
R190	39k
R199,205,211	15k
R214,234	47k
R218,224,230	27k
R220,226,232	120k
Rv10	22k horizontal miniature preset
RV11,12,13	10k horizontal miniature preset

CAPACITORS

C36,38,39,41,42, 44,56,57,58,59,65, 66,83,98	100n polyester
C37,40,43	1u polycarbonate
C45,46	100u 6.3V sub-min electrolytic
C47,49,50,52, 53,55,67,68, 75,76,78,79, 81,82,86,87, 90,91,94,95, 96,97,99,100	10u 16V sub-min electrolytic
C48,51,54	100p polystyrene
C60,61,74,7,80	47n polyester
C62	22n polyester
C63	10n polyester
C64	4n7 polycarbonate
C69,70	1n5 polycarbonate
C71,72,73,84.88, 92	1n0 polycarbonate
C85,89,93	330p polystyrene

SEMICONDUCTORS

IC29,34	LM1458
IC30	LM324
IC31,32,33	4046
IC35,36,37	MN3010
IC38,39,40,41	741
IC42	4066

MISCELLANEOUS

PCBs; solid tinned copper wire; IC sockets; plastic spacers; veropins.

PSU CIRCUIT

CAPACITORS

C28,29	1000u 16V axial electrolytic
C30,31,32	10n mylar

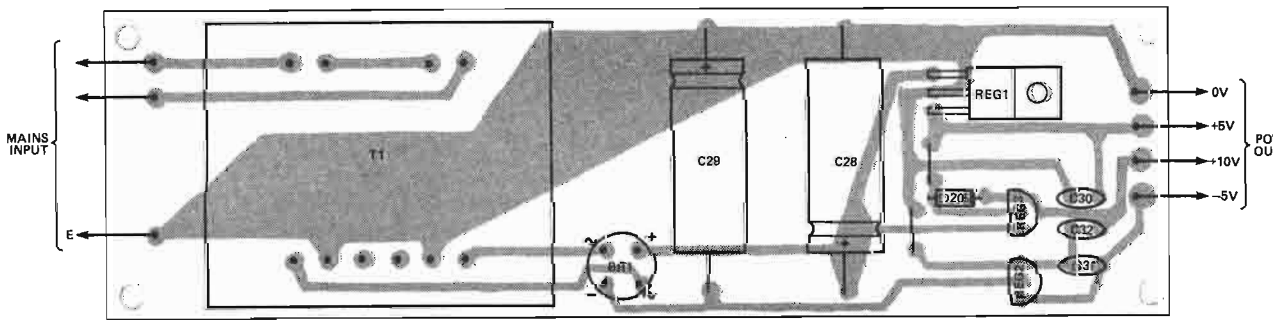
SEMICONDUCTORS

BR1	W005 or similar 1A 50V bridge rectifier
IC43	7805
IC44	79L05
IC45	78L05
D205	1N4148

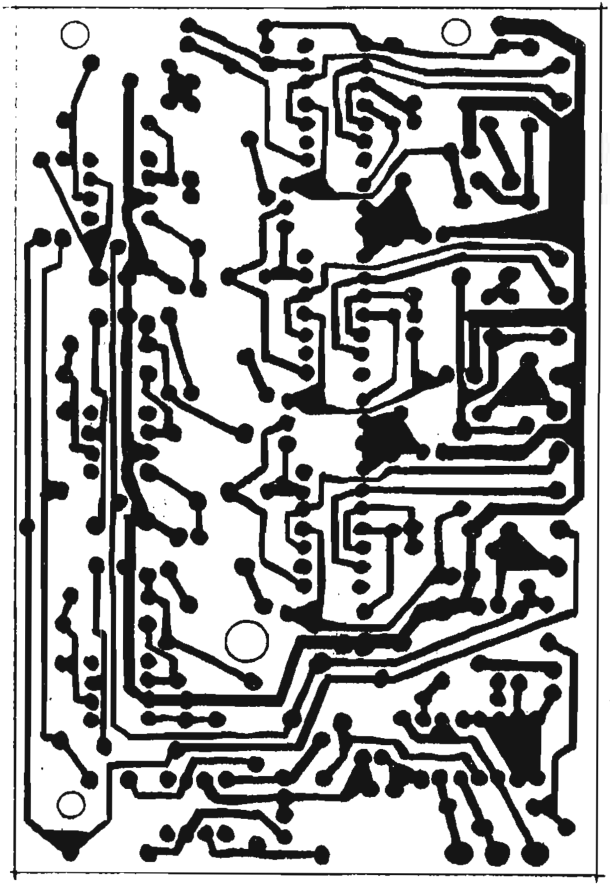
MISCELLANEOUS

T1	9V-0-9V, 8VA PC mounting transformer.

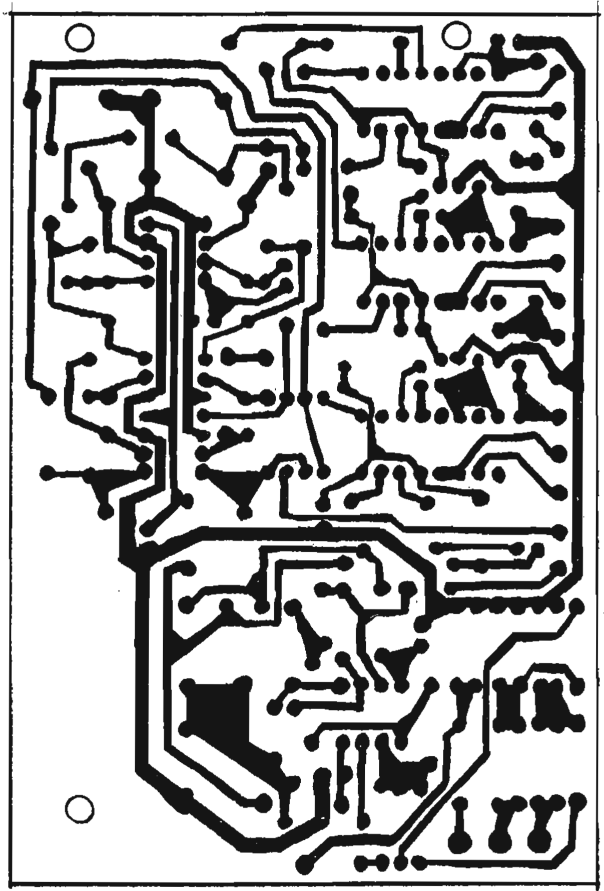
PCB; solid tinned copper wire; mains on/off switch; fuseholder and 500mA fuse; case; cable and connectors to go between keyboard and main unit; five single pole changeover switches (chorus, sustain, three octave select); hook up wire; mains lead; nuts, bolts,etc.



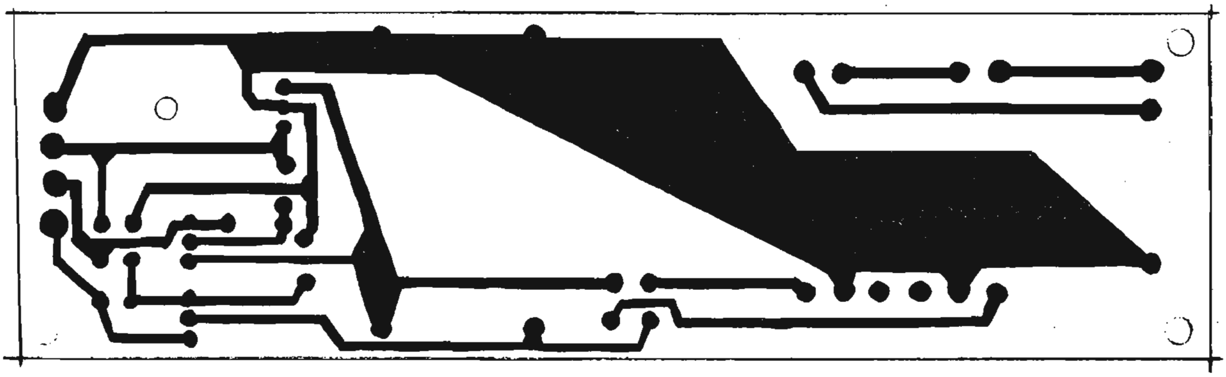
Fig, 17 Component overlay for the PSU.



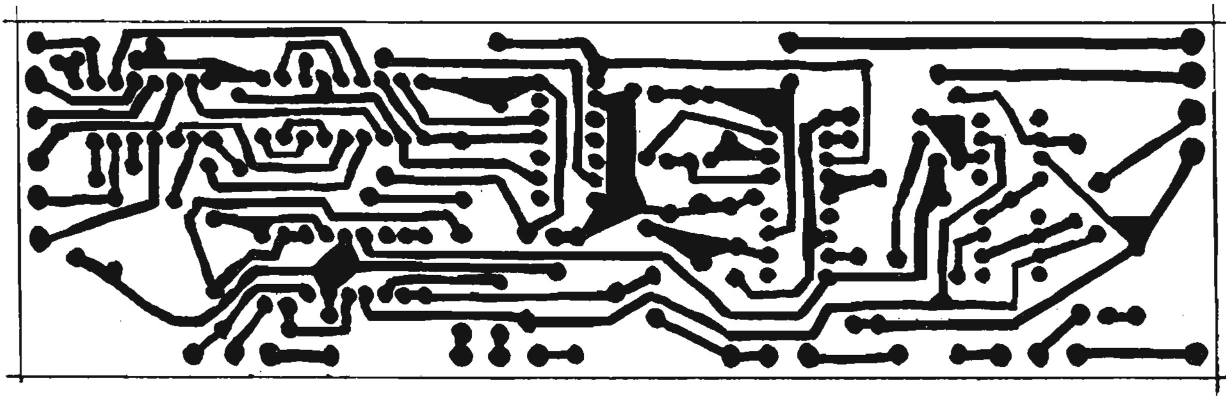
The foil pattern for the Sorcerer chorus audio board.



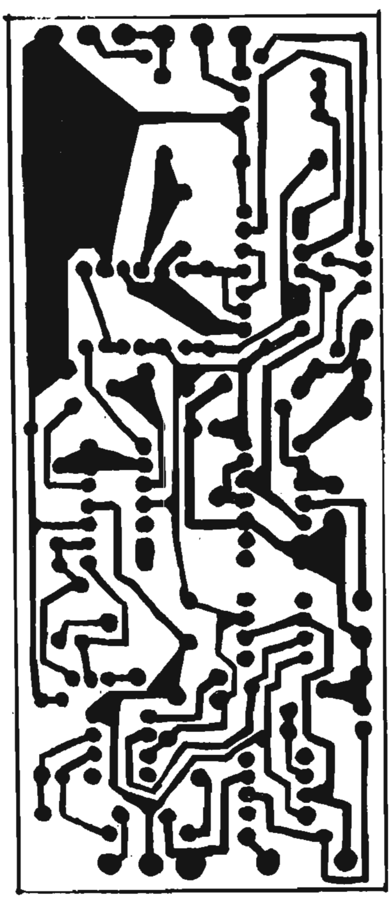
The foil pattern for the Sorcerer chorus clock board.



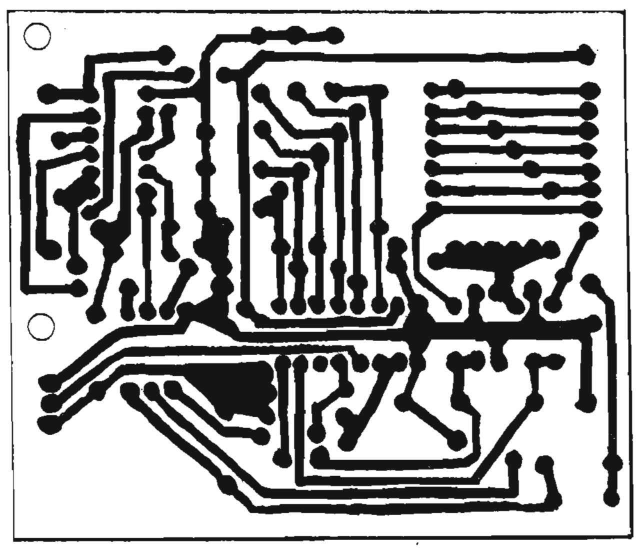
The foil pattern for the Sorcerer power supply board.



The foil pattern for the Sorcerer VCO board.



The foil pattern for the Sorcerer envelope board.



The foil pattern for the Sorcerer keyboard interface board.

The foil pattern for the Sorcerer keyboard is too large to print here (it measures about 500 x 230 mm). It is also too large for us to photocopy. We can prepare clear film copies photographically but the cost is likely to be between £15.00 and £20.00. All in all, it will probably be easier for you to purchase a ready made board from our PCB Service (when it becomes available!)