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# Single Board **SYNTHESISER**



## TRANSCENDENT 2000



THE SYSTEM BLOCK DIAGRAM is shown in Fig 1. The system is pre-patched, but is capable of generating a vast variety of different effects by virtue of its 9 switch functions, 22 pots and 6 input jacks.

The VCO is the primary sound source. It produces either a ramp or a square waveform. A ramp waveform has both odd and even harmonics, the square wave has only the odd ones.

However, the VCO has a shape modulation circuit which can turn the ramp into a triangle or the square wave into a thin pulse. Thus, a wide range of harmonic structures is available. Also, this shape modulation can be controlled by a sine wave produced by the slow oscillator. By dynamically modulating the shape of this waveform, it is possible to greatly enrich the sound quality of the VCO. (For instance, if the mark space ratio of the squarewave is modulated at about 1HZ, the output can sound like two VCO's.)

### Pitch It Well

The pitch of the VCO can be controlled by several sources. A 'pitchbend' pot enables notes to be bent up or down by about 1/2 an octave. A dead band in the centre of the motion enables the turning to be restored. An external input socket with a sensitivity of 1V/octave allows a sequencer to be connected.

A manual tuning pot, (screwdriver adjustment), is provided so that the synthesiser may be tuned to the pitch of other instruments. Vibrato may be added, the speed being that of the slow oscillator. The squarewave also from this oscillator can be used to produce 'two tone' effects.

The VCO pitch can be controlled by the ADSR envelope or by random pitches generated by the noise sample and hold circuit. All these controls can produce a wide variety of interesting sounds but the machine really comes alive when it is controlled by the keyboard. This keyboard is a 3 octave, (37 note), C to C device.

It is monophonic, that is it only plays one note at a time, this being the highest note selected. It generates two outputs, a pitch signal and a gate voltage. The gate controls the AD and ADSR sections, the pitch, the VCO and the VCF.

The pitch voltage is a transitional piece of information which has to be remembered in an analogue memory, a sample and hold device. The droop rate of this S & H is about 15 minutes per semitone. This is quite good.

# MUSIC SYNTHESIZER

**Designed for ETI by Tim Orr, late of EMS and father of some of their range, our new Transcendent 2000 is a new concept in DIY synthesizers — a single board design! Apart from the PSU all the circuitry is contained on one easily assembled PCB. Ideal as on-stage machine, the 2000 has plenty to offer the experimenter as well.**



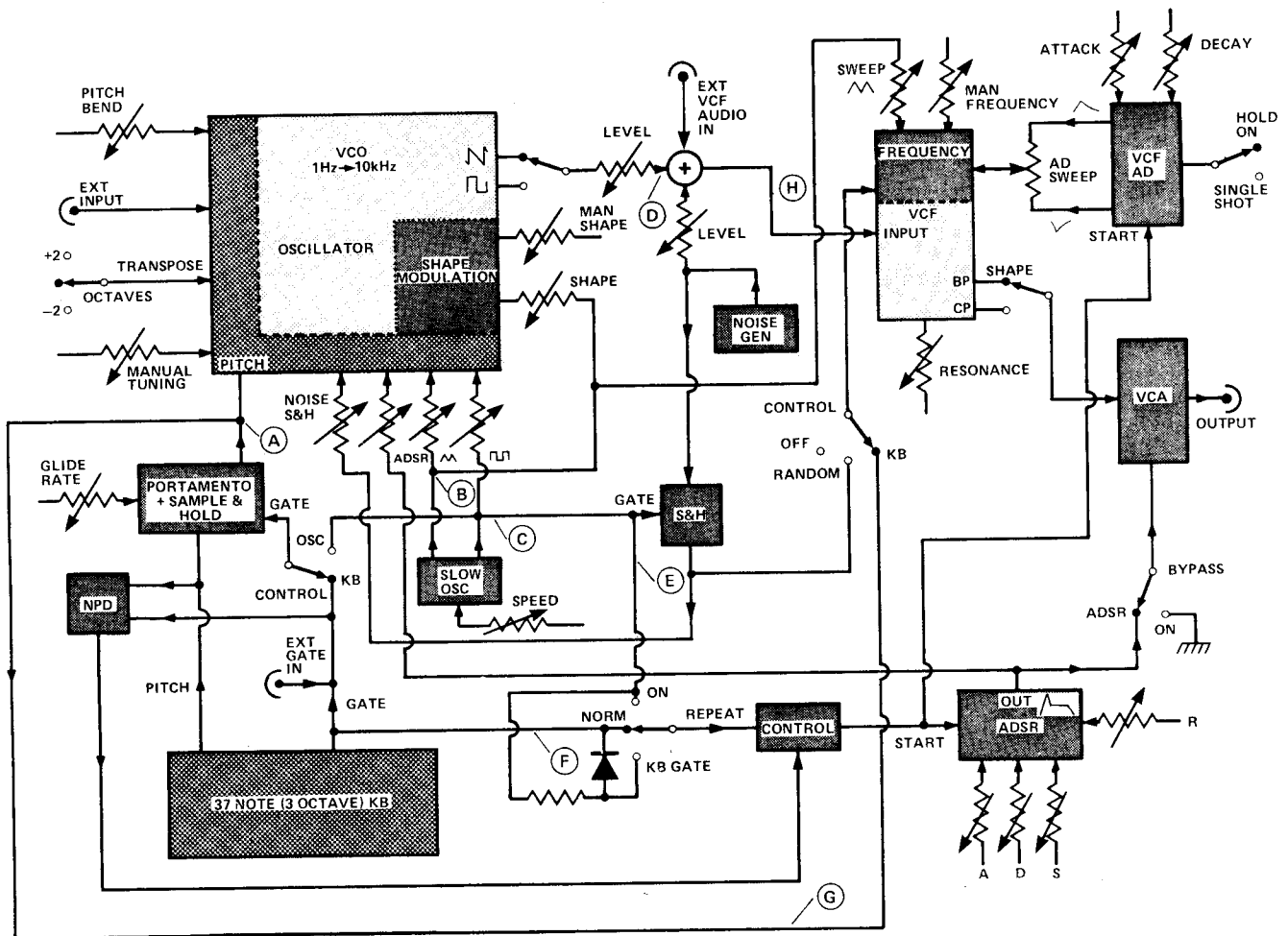
### Gliding In

A portamento circuit has also been included into the sample and hold so that glides, as opposed to abrupt changes, between notes can be produced. A transponse switch,  $\pm 2$  octaves operates on the VCO. This gives an effective keyboard control range on the VCO of 7 octaves. The keyboard S & H can be controlled by either the keyboard gate or by a pulse from the slow oscillator. This latter mode of operation makes the VCO pitch move in a series of exponentially decreasing steps between the notes played on the keyboard.

### Noisy Output

The output of the VCO is mixed with a noise signal and an external audio signal and fed into the VCF. This is a voltage controlled state variable filter, with both bandpass and lowpass outputs. The resonance is manually controllable from a Q of 1 to infinity, (self oscillation).

The resonant frequency may be controlled by either a manual pot, a sweep voltage from the slow oscillator, an external footpedal control, the keyboard voltage or a random voltage or an attack decay envelope.



**Fig 1. Block diagram for the Transcendent 2000 synthesiser. Each of the separate circuit blocks is described in detail in the appropriate section. The letters in circles correspond to the points where we broke up the circuit to make it easier to**

**understand. These references are also given on each of the block circuits where appropriate. So if you wish to stick the whole thing together you can do so. All the components which make up this block diagram are assembled on a single PCB.**

There are very few musical instruments that have any sort of dynamic filtering. The Attack/Decay envelope can be used to produce a rising or falling frequency sweep in the VCF, and by varying the AD time constants, a wide variety of sounds may be generated.

The output of the VCF passes through a voltage controlled amplifier to the output socket. This can be on all the time, or it can be controlled by an ADSR envelope. This in turn amplitude modulates the VCF signal so that the output has the envelope of the ADSR voltage.

### Sustaining Interest

The ADSR is a waveform generator, and is initiated by the arrival of a gate voltage. When this arrives it generates a rising RC exponential waveform with a time constant determined by the Attack pot.

When it reaches a predetermined level it then begins a RC decay towards a sustain voltage. The 'decay' rate is controlled by the 'Decay' pot and the sustain level is set by the 'Sustain' pot.

It sits there until the gate is removed, (when the keyboard is released), whereupon it decays towards ground with a release time constant, this being determined by the 'Release' pot.

If at any time the gate is removed the ADSR goes into its release mode. Time constants of 5 mS to 2 S and sustain levels of full on to completely off are obtainable.

### On Key

The ADSR can be started by the keyboard, or it can be continuously repeated by the slow oscillator, or it can be repeated by the slow oscillator gated by the keyboard, as can the

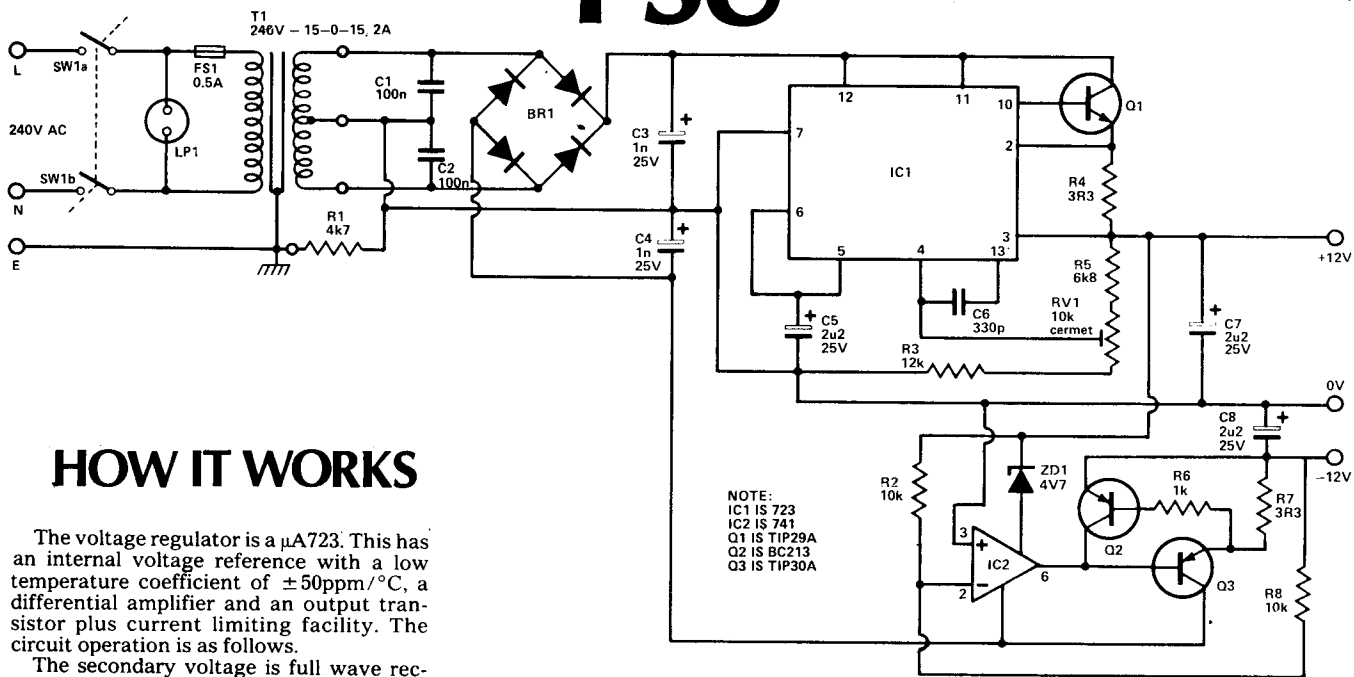
Attack Decay. (AD), circuit.

This has two modes of operation: single shot, whereby it attacks to a predetermined level and then decays on its own to ground, or HOLD ON, whereby it only decays upon the removal of the gate signal. Sometimes when playing pieces, it may be necessary to release a key before a new note can be generated. If the piece is particularly fast then errors, in the form of missing notes can occur. However, a device called the New Pitch Detector (NPD), can help eliminate this. When a new pitch is detected, it generates an additional gate signal which is used to reset both the AD and the ADSR.

### Repeating?

Both the AD and ADSR circuits can be controlled by the REPEAT function. This is a single piece of electronics to enable repeating envelopes to be

# PSU



## HOW IT WORKS

The voltage regulator is a  $\mu$ A723. This has an internal voltage reference with a low temperature coefficient of  $\pm 50\text{ppm}/^\circ\text{C}$ , a differential amplifier and an output transistor plus current limiting facility. The circuit operation is as follows.

The secondary voltage is full wave rectified and smoothed by C3 and C4. This provides positive and negative unregulated rails.

IC1 is the voltage regulator. A reference voltage of about +7V5 is fed into the noninverting terminal, pin 5.

An external power transistor Q1 is used to regulate the positive supply rail so that IC1 remains cool. Short circuit current limiting at 200 mA is provided by R4. Either or both output rails may be shorted out without damage.

Negative feedback to the inverting terminal pin 4, IC1 sets the output voltage. C5 reduces noise on the supply, C7 reduces the impedance at high frequencies. RV1 sets the output voltage and this should be set to +12V000! (or as near as you can measure) RV1 is a cermet preset, which has a low temperature coefficient.

**Fig. 2. The circuit diagram for the synthesiser PSU. This is capable of supplying a higher current than is really needed here, in order that it is not 'stretched'. A stable supply is essential in a synthesiser design with any pretensions to quality at all.**

**The components for this are made up onto their own PCB, and will not appear on the main overlay.**

The negative rail tracks the positive rail. The power is handled by Q3, the current limiting by Q2 and the feedback by IC2. Resistors R2, 8 determine the negative rail voltage. As they are both 10k, 0.5% tolerance, the negative rail should be the same magnitude as the positive rail to within 0.5%.

A very stable power supply is needed for a synthesiser. A small power supply voltage variance can produce alarming effects on the oscillator pitch. Also, if the machine gets hot inside, the oscillator will drift in

pitch. The current drain per rail is only 80 mA and the heat dissipated by Q1 and Q2 is 0.9 watt each. This will not cause any heating problems.

On load the unregulated rail is 23 V (at 250 VAC input), and so the mains can drop to about 190 VAC before PSU drop out occurs. The unregulated ripple is 500mVpp and so the output will be less than 0.5mVpp.

When there is no load on the power supply, a small high frequency sawtooth can be seen on the -12 V output, but this goes away completely when loaded.

generated. The outputs from this circuit then drive the AD and ADSR. With the repeat switch in the ON position, the slow oscillator square wave output continuously gates the AD and ADSR.

In the NORM position, the Keyboard gate is the control. In the KB GATE position, the slow oscillator is only allowed through when the keyboard is pressed. Using the REPEAT function it is possible to simulate a fast plucking 'banjo' effect.

### A DeeEssAhh?

The ADSR is similar in operation to the AD circuit except that it has two more parameters to play with.

Upon receipt of the keyboard gate the waveform attacks until it reaches a predetermined level. Then it decays to a level known as the sustain level, which is manually controllable. When the keyboard gate is removed, the

release mode occurs. The A, D, R are all time constants, the S is a level. Whenever the keyboard gate is removed the device goes into its release mode.

This type of envelope is particularly useful and versatile. With the sustain level at 10, there is no DECAY phase and so an ATTACK, HOLD ON, RELEASE envelope is generated. When the sustain is set at 4, there is an attack and a decay to the sustain level, which is held as long as the keyboard is held down and then a release. Using this setting it is possible to simulate a piano sound, by using a fast attack moderately slow decay and a faster release.

The faster release simulates the damping of the strings as the piano keyboard is released. When the sustain level is set at 0, then the unit becomes an attack decay envelope which can be used to produce short sharp plucked sounds. To get a new

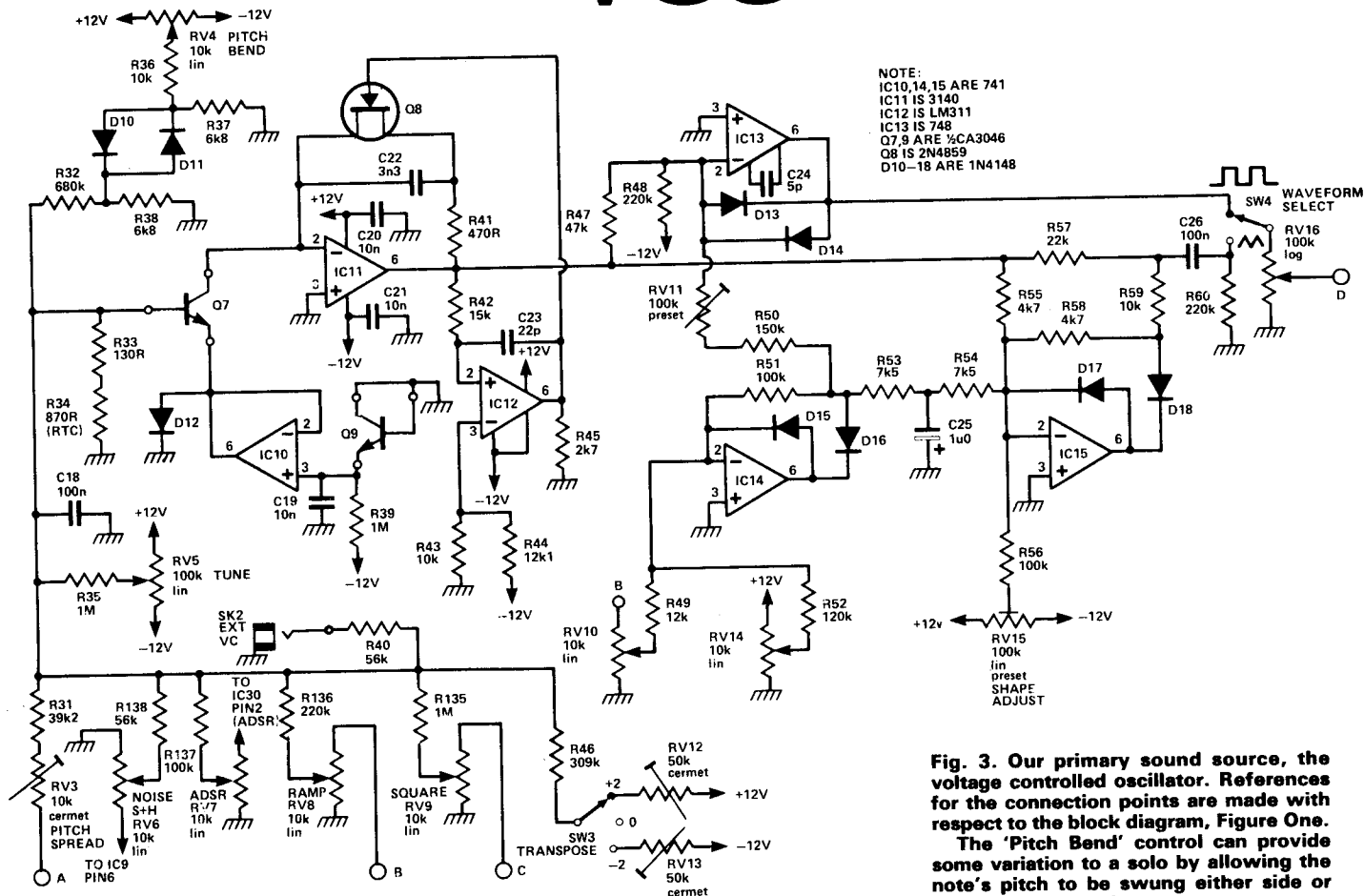
envelope it is necessary to get a new keyboard gate signal. This either means lifting your finger off of one note before pressing the next, or a new gate can be automatically generated by switching to the NPD mode.

### Moving On

The pre-patched nature of the design is intended to suit stage and other performance applications. The resulting sound from the synthesiser can be quickly and easily modified once the function of the controls and their effect has been mastered. Take a look at the diagram on page 44 for starters.

Another helpful aid to using a synthesiser is a 'program sheet'—simply a way of recording clearly but instantly a particular set of control settings to allow you to reproduce that sound again at a later date. Such sheets will be available for the Transcendent 2000—details next month.

# VCO



**Fig. 3. Our primary sound source, the voltage controlled oscillator. References for the connection points are made with respect to the block diagram, Figure One.**  
 The 'Pitch Bend' control can provide some variation to a solo by allowing the note's pitch to be swung either side or correct during playing.

## HOW IT WORKS

The VCO is a logarithmic relaxation oscillator generating a ramp waveform. This waveform is then modified to give a square wave or a triangle wave output. The oscillator section is IC10, Q9, IC11, IC12 and Q8.

The voltage coming out of IC11 pin 6 is fed into IC12. This is an LM311, a fast voltage comparator. A voltage of +5V43 is set up on its inverting input, (pin 3) and the ramp from IC11 is fed into its non-inverting input, (pin 2). When the ramp voltage exceeds +5V43, the comparator's output, (which was at -12V) leaps up to 0V.

This voltage turns on the FET switch Q8 which shorts out C22 and discharges it to almost 0V. Q8 has a very low ON resistance and hence the discharge time is relatively short, about 800 nS.

However, once the discharging has started, you would expect the comparator output to drop back to -12V. Well it would do if it wasn't for the monostable built around it, (C23, R42). This monostable makes Q8 turn on for a fixed period of time, sufficient for the discharge process to be completed.

Note that the power supply to IC11 is locally decoupled to help protect the VCO from pitch jitter caused by fluctuating power supplies. The reset period causes the VCO to go flat at high frequencies.

As the frequency of the VCO increases then so does the C22 charging current. But this current has to flow through R41. This makes the voltage of the ramp, (IC11 pin 6) increase in size as the ramp speed is in-

creased. This in turn means that the ramp is reset prematurely and so the pitch of the VCO will tend to go sharp at high frequencies.

If we get the size of this tendency to sharpness correct, then it can be used to cancel out the reset tendency to flatness. The overall effect will be to maintain the tuning of the keyboard up to a frequency which it could not do without R41.

The current that drives the VCO is sunk by the transistor Q7. This is used to produce the logarithmic law necessary to convert the linear voltage intervals from the keyboard into musical intervals which are logarithmically spaced. A  $V_{be}$  increase of about 18 mV will cause the collector current to double, (the VCO goes up an octave), so therefore the voltage per semitone is about IV5. This is a very small voltage indeed.

IC10 is a voltage follower and merely buffers the bias voltage to the emitter of Q7. Should IC10 go berserk, during the power up say, it might try to reverse bias the emitter of Q7 and cause it to zener. This process would corrupt the logarithmic characteristic of the transistor and so destroy its ability to produce musical intervals. D12 prevents this zenering. Q7 has to be run at relatively low currents for two reasons.

Firstly, the log law goes flat at high currents, (1 mA). This is due to the effect of the intrinsic emitter bulk resistor in the transistor. The effective voltage drop across this bulk resistor is subtracted from

the  $V_{be}$  voltage and so the net effect is less collector current than was expected. Therefore to get a good musical performance, the collector current must be kept as low as possible.

Secondly, large currents will cause self-heating, which will make the VCO pitch drift, although in this circuit the collector voltage is a virtual earth and so the power dissipation is relatively small anyway.

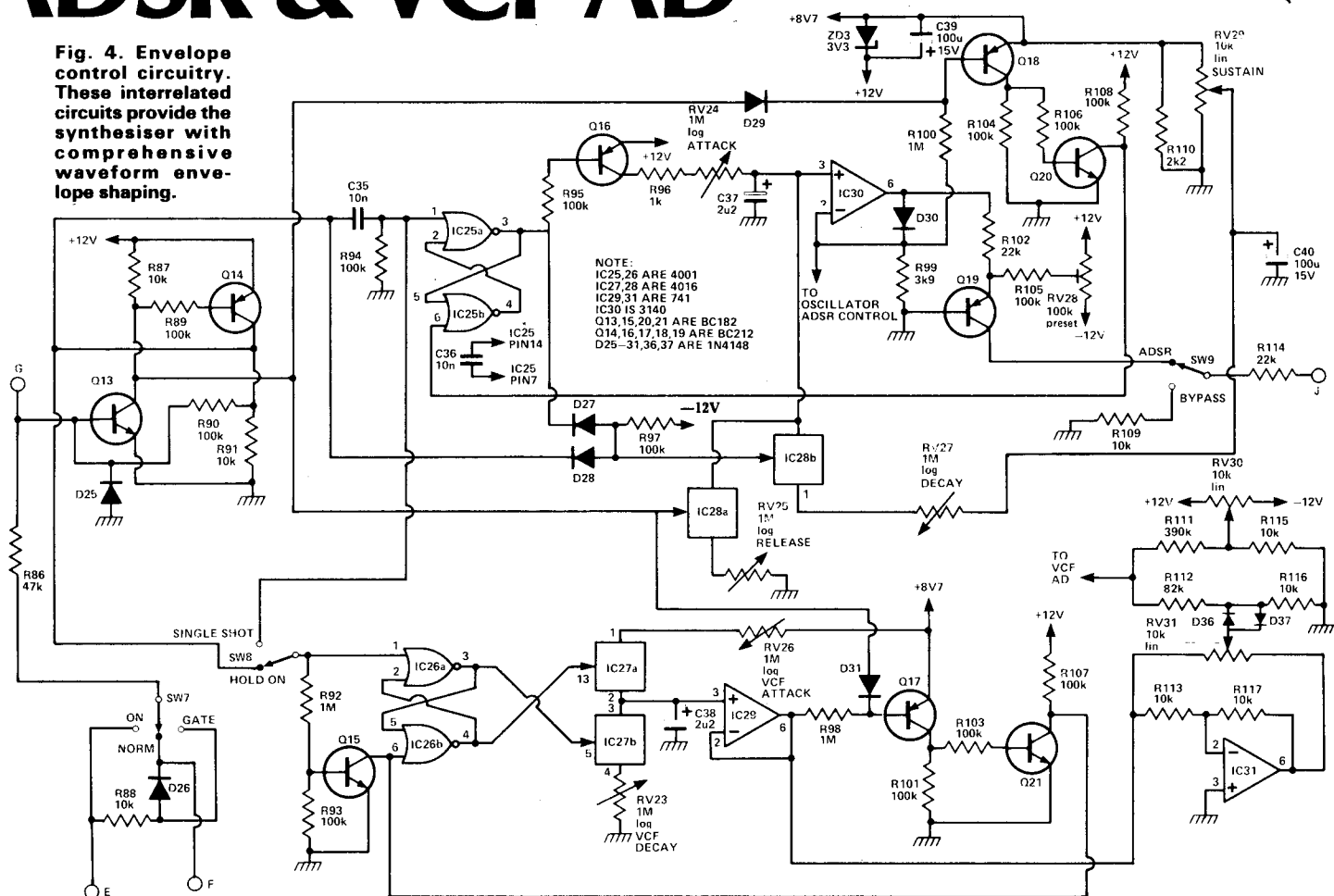
Even though the second transistor compensates for the temperature change  $V_{be}$  problems there is another temperature effect to be dealt with. The pitch spread, that is the number of millivolts per octave, is temperature dependent. To compensate for this effect, the resistor pair R33, 34 must have a temperature coefficient, (TC) of +3400ppm/°C. There is no element with this coefficient, although an alloy could be concocted to produce it.

However, it just so happens that copper has a TC of +3900ppm/°C. Therefore a 870R copper wire wound resistor in series with a 130R metal oxide resistor looks like a 1k resistor with a +3400ppm/°C TC. There is an American company, (Tel Labs) that makes a Q81 resistor, 1k 1% made just for the job and this could be used instead of R33, 34, that is if you can obtain them.

This resistor with the special TC is mounted close to the transistor pair so as to be at the same temperature. Some manufacturers actually glue the resistor to the transistor for best thermal contact.

# ADSR & VCF AD

**Fig. 4. Envelope control circuitry.** These interrelated circuits provide the synthesiser with comprehensive waveform envelope shaping.



## HOW IT WORKS

### AD generator:

The AD waveform is made up out of two simple CR charge and discharge curves, Q15, Q17, Q21, and IC26, 27, 29, 31 form the generator circuit. The AD is started by the arrival of a positive voltage at IC26 pin 1. This is a SET, RESET flip flop made out of two 2 input NOR gates. A high at pin 1 sets pin 3 low and pin 4 high. These two outputs drive two analogue transmission gates, IC27. A high at the control input (13 and 5) will open the gate, a low will close it. Only one gate is ON at any one time. The event sequence is as follows: IC26 pin 1 goes high, IC26 pin 4 goes high, IC26 pin 3 goes low. C38 is charged up via IC27 pin 1, 2, 13 and RV26 towards a positive (+8V7) reference voltage. RV26 determines the charging up time (ATTACK).

The voltage on C38 is buffered by IC29, a voltage follower. Assuming that the AD generator is in its HOLD ON mode then the capacitor C38 will be charged up towards +8V7 until the gate input is removed.

When this happens the flip flop will change state and the capacitor C38 will be discharged towards 0 V via the other analogue gate and RV23.

The setting of RV23 will determine the discharge time (DECAY). The purpose of Q15 is to generate the HOLD ON by disabling the SINGLE SHOT circuitry, Q17, Q21. Imagine the voltage on C38 is +2 V and charging up. Q17 and Q21 will be turned ON. When the voltage on C38 reaches +8V1, Q17 and Q21 will start to turn OFF.

The voltage at Q21 collector, which is the RESET control of the flip flop, will try to rise positively (previously it was at 0 V), but it is prevented from doing so by Q15. Only when the gate input is removed can the flip flop be reset and the decay occur.

When the single shot mode is selected only a positive going pulse is delivered to IC26 pin 1, and so Q15 cannot disable the reset. The waveform charges up to +8 V, resets the flip flop and then discharges. If however the keyboard gate is removed before the attack phase has been completed, the circuit is kicked into its decay mode by diode D31 which resets the flip flop. This means that no matter what mode the circuit is in, it always reverts to its decay mode when the keyboard is released (also true for the ADSR).

The AD waveform is inverted by IC31 and these complementary signals are fed to the AD sweep pot RV30. This waveform is only used to sweep the VCF and does not control anything else. Fast ATTACKS and DECAYS are of the order of 4 ms time constant and slow settings are approximately 2 S.

### ADSR:

The circuit is very similar to that of the AD generator. IC25 is a SET RESET flip flop. IC28 and Q16 control the ATTACK, DECAY, RELEASE time constants by enabling the three control pots. A keyboard gate voltage generates a positive going pulse

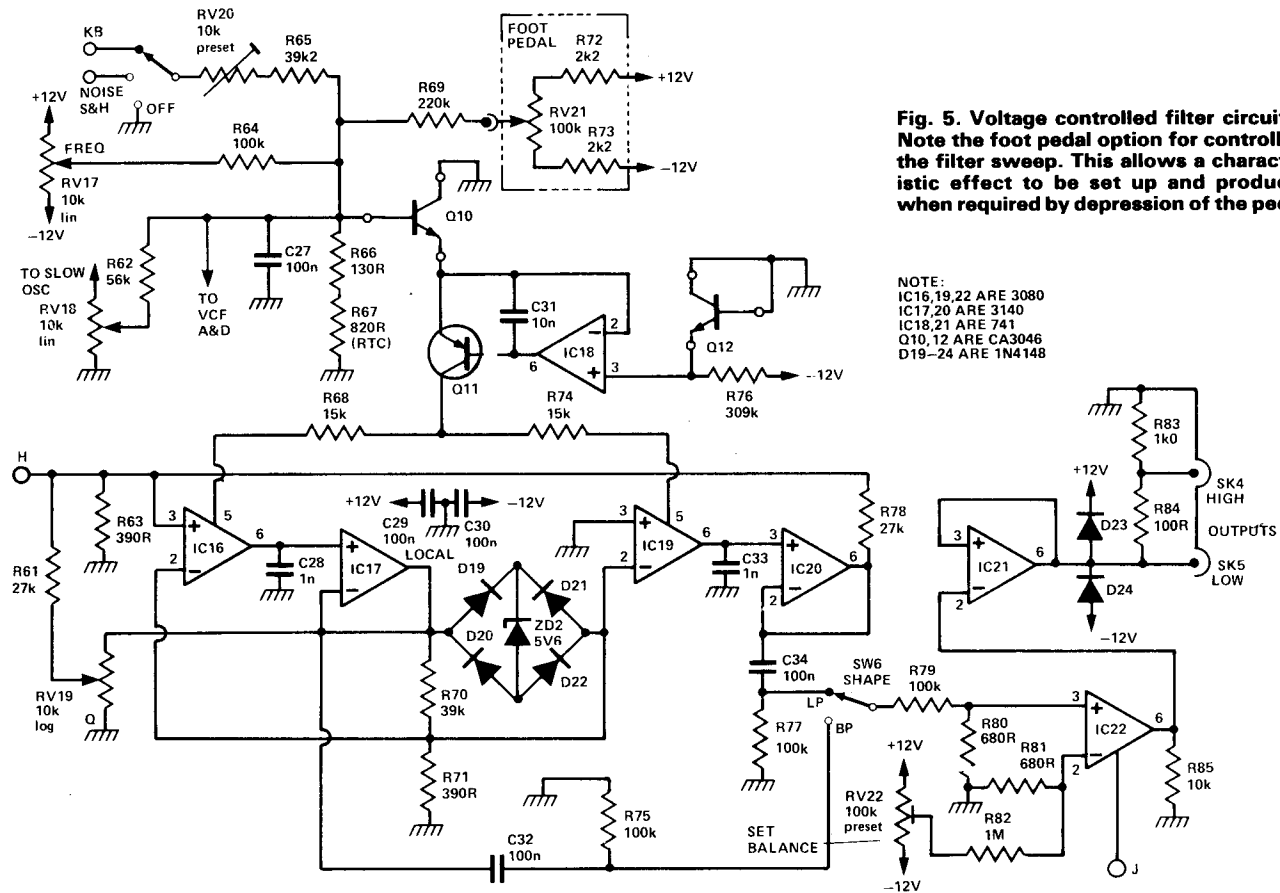
IC25 pin 1, causing IC25 pin 3 to go low. This then turns on Q16 and thus C37 is charged up via RV24, the attack pot. IC30 is a high input impedance voltage follower, which controls the output VCA but which is also linked to Q18 via R100.

When C37 has charged up to 8 V, Q18 begins to turn off and in doing so, turns off Q20. The collector goes high and RESETS the flip flop. Q16 is thus turned off and the analogue transmission gate IC28 pin 1, 2, 13 is turned on via D27.

Now C37 is connected via the decay pot to the sustain voltage, the wiper of RV29 and so it will discharge to that voltage and remain there until the keyboard gate is removed. When this happens the IC28 pin 1, 2, 13 transmission gate is turned off via D28, and IC28 pin 3, 4, 5 is turned on. Now C37 is discharged towards 0 V via the release pot. Also, when the keyboard gate is removed, a RESET is generated by the diode D29, so that the flip flop is ready for another cycle.

The ADSR voltage is used to control the VCO pitch and the signal level at the synthesizer's output. The ADSR is converted into a current by Q19, D30, R102, R99 and is used to drive a CA3080 acting as VCA. The OFF level of this circuit is adjusted using RV28.

The attack, decay, release time constants are variable over a range of 5 ms to 2 S. The sustain QUIET position should provide at least 40 dB attenuation.



**Fig. 5. Voltage controlled filter circuitry.** Note the foot pedal option for controlling the filter sweep. This allows a characteristic effect to be set up and produced when required by depression of the pedal.

NOTE:  
 IC16,19,22 ARE 3080  
 IC17,20 ARE 3140  
 IC18,21 ARE 741  
 Q10,12 ARE CA3046  
 D19-24 ARE 1N4148

## Voltage Controlled Filter

The VCF is a voltage controlled state variable filter. This particular design generates both low pass and bandpass outputs. It has the same voltage response as the VCO, i.e. it is logarithmic, as opposed to linear. A CA3046 transistor array converts the control voltage into a log current using very similar circuitry to that which was employed in the VCO to minimise temperature effects.

The control current needs to be sourced to the VCF, in fact to pin 5 of IC16 and IC19 which are both at about -11V4. This is accomplished with Q11 and IC18. The current that comes out of the logging transistor flows into the emitter of Q11 and about 99% of it comes out of the collector, the other 1% flows out of base. As long as the  $h_{fe}$  doesn't vary too drastically as a function of the collector current, then this source of error will not be greatly significant.

The tracking accuracy of the VCF is much less of a problem than for the VCO. VCF tracking errors will only result in a slight change in tone, not pitch.

IC18 maintains Q12 at a fixed bias vol-

tage of approximately -0V62. The control current that comes out if Q11 collector splits equally down R68, 74 and into IC16, 19 respectively. These devices are CA3080's, a two quadrant multiplier which is used as a variable gain cell to tune the filter resonance.

In fact they are gain controlled integrators, where C28, 33 are the timing capacitors. The outputs are current outputs and are therefore high impedance. IC17, 20 are very high input impedance voltage followers and they unload the outputs of the integrators. IC16, 17, 19, 20, 23 is in fact an analogue model of a second order differential equation, (i.e. a tuned circuit or a mechanical resonator).

The loop gain, which is controlled by IC16, 19, is linearly proportional to the resonant frequency, therefore by varying the current into IC16, IC19 the resonant frequency of the model is controlled. Note that there is both negative and positive feedback around IC16, IC19. The negative feedback is fixed but the positive feedback is variable via the resonance pot RV19.

As more positive feedback is applied the model becomes more resonant, the Q factor increases. Too much feedback and the

circuit will oscillate. In fact stable, low distortion sinewave oscillations can be produced by turning the resonance pot fully clockwise. The diode bridge amplitude limits the signal excursions and will thus stabilise the signal level when the VCF is in its oscillator mode.

The VCF can therefore be used as a low distortion oscillator or as a filter. However, the signal level in the oscillator mode is much louder, (about 10 dB) than in the filter mode.

## VCA

The CA3080 is used as a two quadrant multiplier. That is the gain of the device is controlled by the current flowing into pin 5. As this current has the same contour as that of the ADSR, then any signal flowing through the VCA will have its amplitude modulated with the ADSR contour. The output is buffered by a voltage follower providing a high level output (typically 0dBm) and a low level output (typically -20dBm). By putting a fixed DC current in, a constant output level is produced (BY-PASS ON), unaffected by the ADSR.

## HOW IT WORKS

# WHAT DOES WHAT AND WHERE

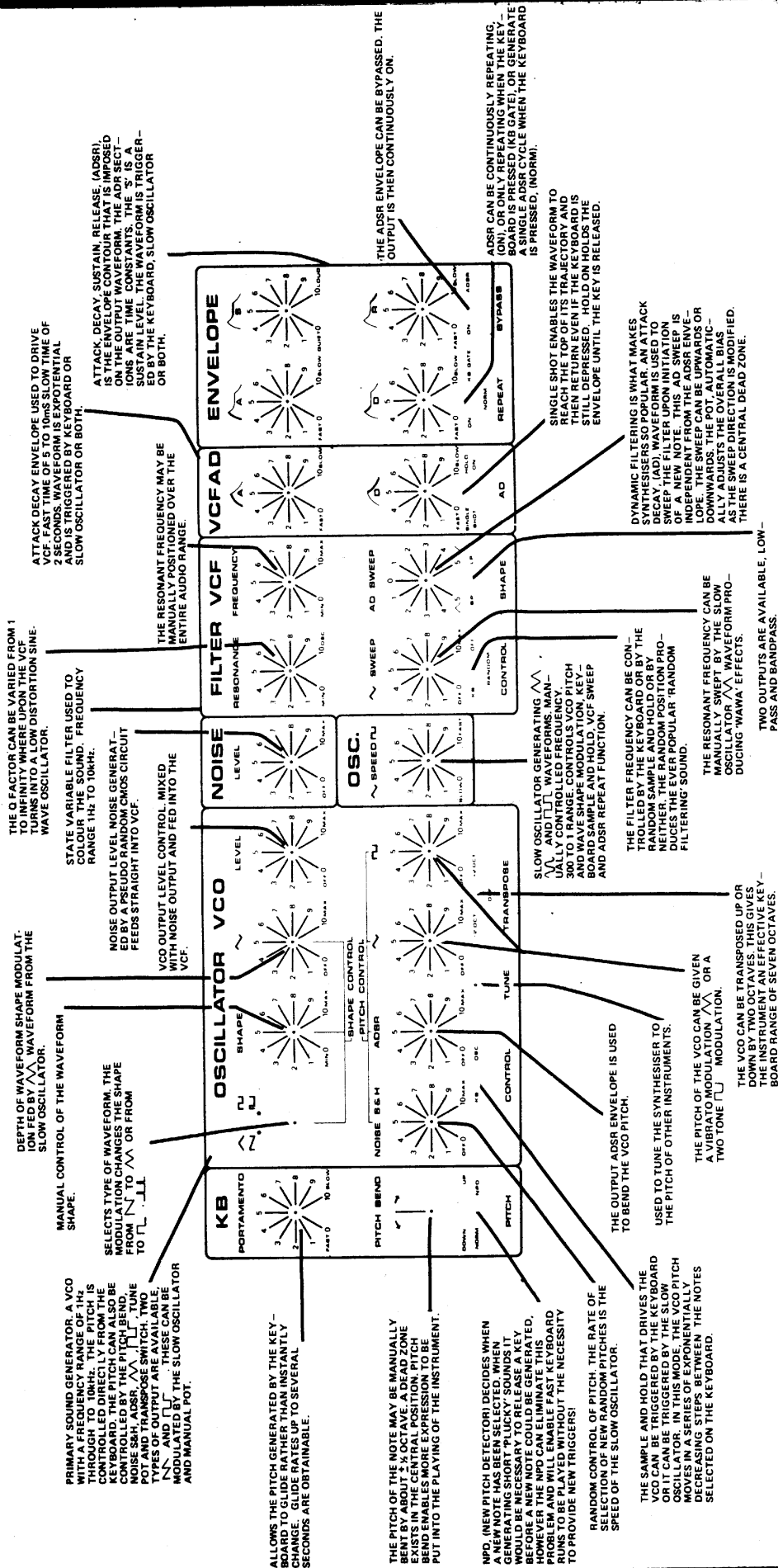
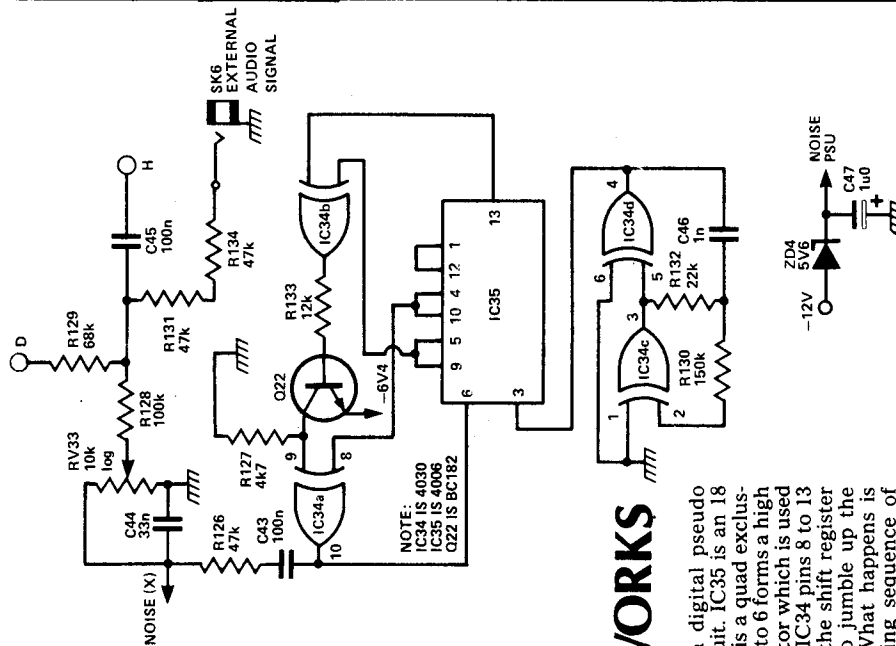


Fig. 6. The front panel layout and what to do with it. This drawing should show the newcomer to sound synthesis what to expect from the various circuit blocks, and give the expert an idea of the versatility of the Transcendent 2000 design. The keyboard, a 37 note unit, is not shown, but reference is made to its control effects where appropriate.



# NOISE GENERATOR



**Fig. 7. The digital noise circuit is locally decoupled by C47, and the supply rail stabilised by ZD4 as shown right. The external audio signal level should be about 1V for best results.**

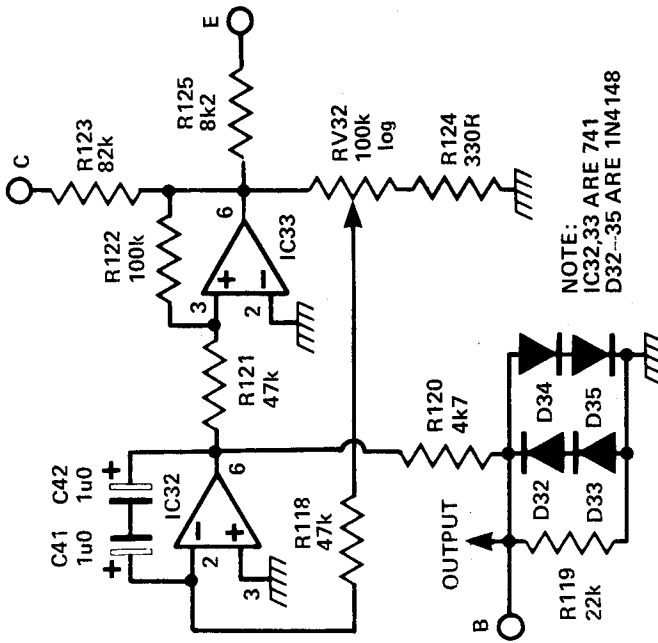
## HOW IT WORKS

The noise generator is a digital pseudo random shift register circuit. IC35 is an 18 bit shift register and IC34 is a quad exclusive OR device. IC34, pins 1 to 6 forms a high frequency (30 kHz) oscillator which is used to clock the shift register. IC34 pins 8 to 13 provide feedback around the shift register and are so arranged as to jumble up the data that is circulating. What happens is that a continuous repeating sequence of '0's and '1's flows around the register but the sequence is so very long that it only repeats about once every second. This repetition is inaudible. However the output has a fairly flat spectrum.

The noise output is mixed into the audio input of the filter (RV33) and is also taken to the Random sample and hold. The noise is the signal that is sampled and the gate is

generated by the slow oscillator. The output is a sampled DC signal of random voltage, the sampling rate being that of the slow oscillator. This random voltage can be used to control the frequency of the VCO and VCF.

# SLOW OSCILLATOR



NOTE:  
IC32,33 ARE 741  
D32-35 ARE 1N4148

**Fig. 8. Full circuit diagram for the slow oscillator block. Although very simple on paper, this circuit has a great deal of influence on the performance of the machine as a whole. The range is about 300 to 1, and the oscillator exercises control over the voltage controlled oscillator pitch, the VCO waveform modulation, the keyboard sample and hold function, the voltage controlled filter sweep rate and the ADSR repeat facility.**

## HOW IT WORKS

IC32 and IC33 form a triangle square wave oscillator. IC32 is an integrator the output of which ramps up and down between the hysteresis thresholds set by the schmitt trigger IC33. The square wave output of IC33 is fed back to the integrator via RV32 which determines the oscillator frequency, providing a range of 0.06 Hz to 20 Hz (300 to

1). The triangle is bent by D32-35 to form a sine wave which is used as a frequency shape modulator for the VCO. The square wave output is used to perform a repeat function with the AD and ADSR circuits. Also it is used to frequency modulate the VCO and to provide sampling pulses, for the two sample and hold circuits.

## HOW IT WORKS

The keyboard generates two outputs. A pitch output and a gate voltage. This is then fed via R14, C12 (reduces contact bounce), to a schmitt trigger IC4. When a key is pressed the output of IC4 goes high, when it is released it goes low. This gate voltage is used to operate the keyboard sample and hold and the AD and ADSR units.

The keyboard voltage is generated by passing a constant current through a precision resistor chain. Thus a series of precise voltages is set up along the chain which can be picked off by the keyboard contacts. The constant current is generated by IC3, R9. R9 puts 2.526 mA into the node at IC3 pin 2. This then adjusts its output so that almost exactly 2.526 mA flows down the resistor chain.

When a key is pressed, a voltage appears which tells the synthesiser which key has been pressed. If more than one key is pressed, then the voltage is  $(2.526 \times 27.4 \times N)$  mV where N is the number of resistors between the top note pressed and IC3 pin 2.

Thus the keyboard always generates the voltage of the highest note selected, and this is fed via R13, RV2, Q4 to C13 where it is stored. Q4 is a FET switch which has an on resistance of a few hundred ohms and a Pinch off resistance of a few hundred megohms.

It is turned on and off by the keyboard gate voltage. The sequence of operation is as follows.

The keyboard is pressed. A pitch voltage is selected. A gate voltage is produced. Q4 is turned on and C13 is charged up to that

voltage via R13 RV2. The keyboard is released, the gate voltage dies, Q4 is turned off, and the voltage on C13 remains where it is. IC6 is a very high input impedance (1000 M), voltage follower, and so buffers the voltage on C13 to the rest of the electronics.

A PCB guard ring surrounds C13 so that surface leakage droop rate was about 0.1 mV/S which means that it would take 6922 seconds to drift one semitone or 8305 seconds for an octave.

The measured droop rate was about 0.1 mV/S which means that it would take 692 seconds to drift one semitone or 8305 seconds for an octave.

Portamento effects are obtained by varying RV2, anticlockwise the charging time of C13 is about 0.2 mS, when clockwise this becomes 330 mS, and the effect is to produce a slewing between notes.

If the keyboard contacts are badly out of alignment, a pitch change at the start of notes can be produced. If the first contact to close is the gate pair then this might cause a problem. The sequence of events is as follows:

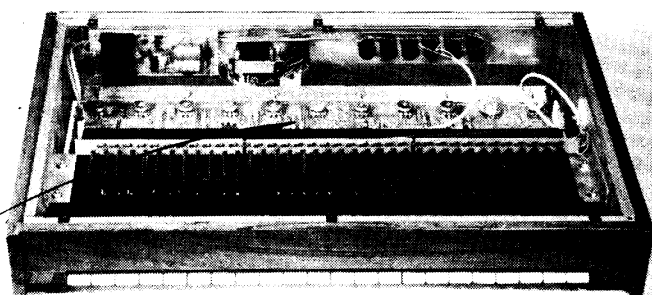
The gate contacts close. An envelope with the VCO at the previous pitch is produced. Then 10 or 20 mS. later the pitch contact is made and the sample and hold, and hence the VCO jumps to the correct pitch. The result is a pitch 'hiccup' at the start of some notes. If this is noticeable on any notes then the gate contact should be carefully bent so that it doesn't make contact before the pitch contact.

### New Pitch Detector Circuit

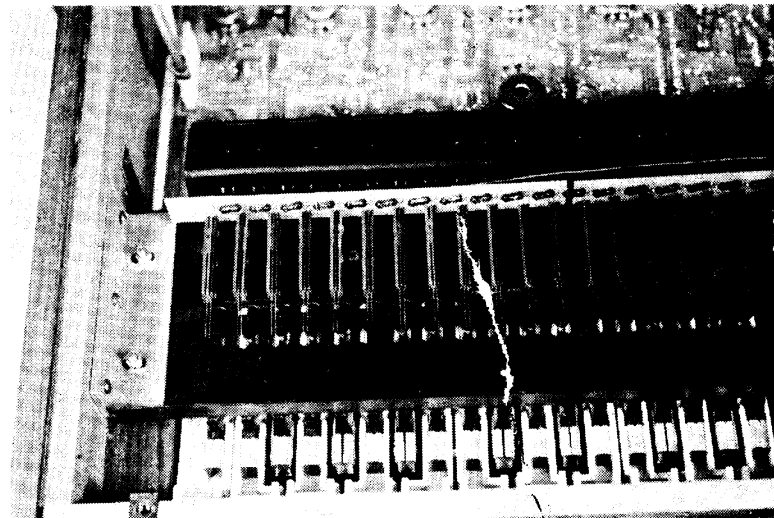
This circuit decides whether or not a new higher note has been played, even though the gate output signal (IC4 pin 6), has remained high all the time. IC5 is a high gain amplifier which looks at the voltage on the pitch contacts. If the pitch changes, the AC component of this change will be amplified by IC5.

If the output goes positive, a pulse is produced which passes through C14, D7 and ends up across R23. If the output of IC5 goes negative, the pulse goes through C14, D6, is inverted by IC7 and passes through D9 into R23, again as a positive pulse. This pulse then drives IC8 which is a schmitt trigger. Its output is normally low, and the arrival of the pulse makes it go high for a short while and then returns to its low state. Thus an ascending or descending scale of notes will cause a series of short pulses (at IC8, pin 6) to be generated, one per new note. When the last note held down is removed there is no pulse produced. When the same note is repressed, the pitch not actually being any different, a pulse is generated (this is what is wanted) via C11 from IC4 pin 6. This route only generates pulses on +ve edges, that is the start of a new gate voltage. The pulse output from IC8 is used to turn Q6 on and off. This in turn is used to momentarily turn off the AD and ADSR circuits. Thus the NPD can be used to provide a retrIGGER of the AD and ADSR circuits.

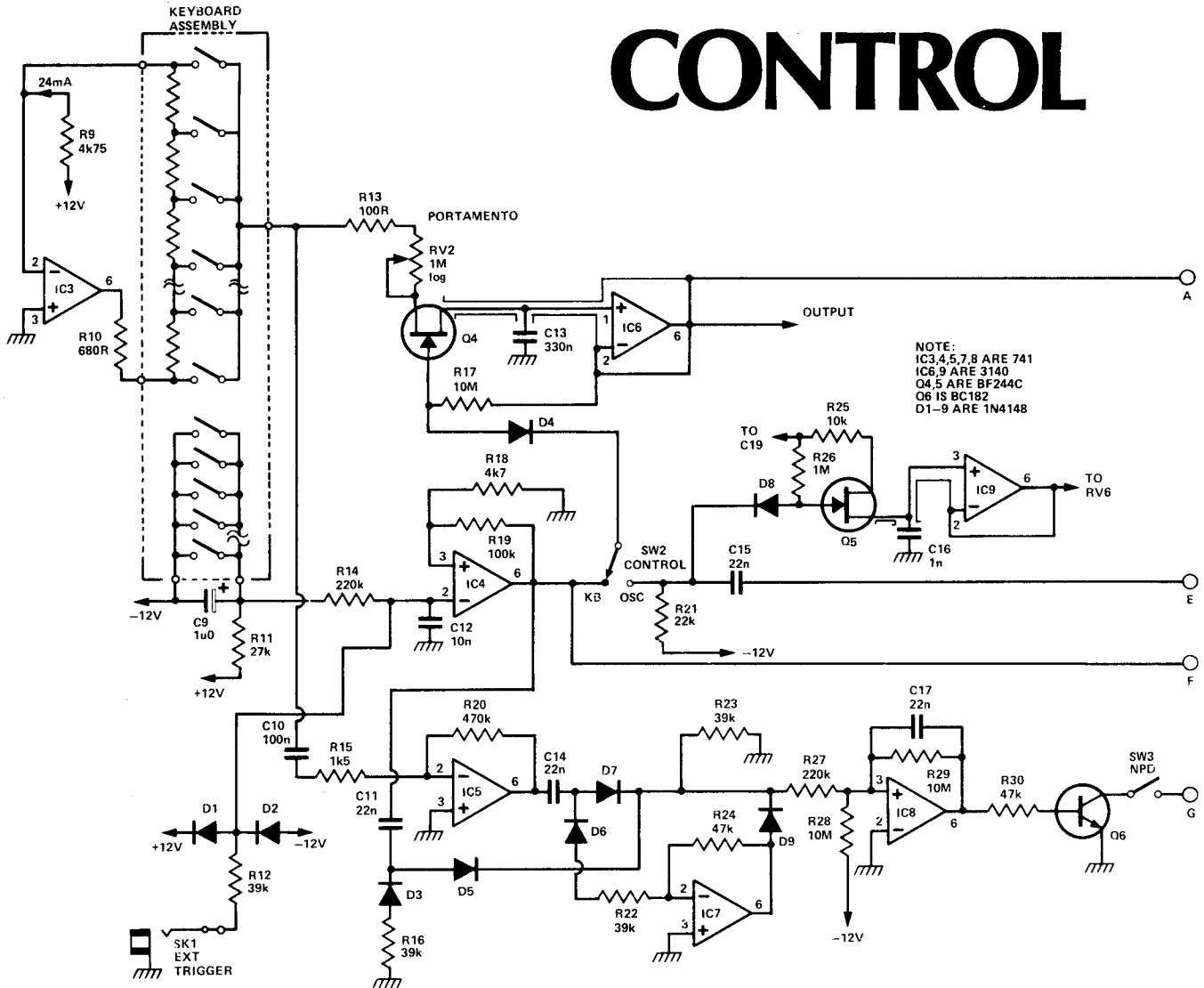
**Fig. 9.** On the right is shown the circuitry associated with the keyboard functions. Note the resistor chain for the keyboard is mounted remotely to the main PCB and fits into the contact block mounting board. The Ext Trigger input allows a sequencer to be wired to the synthesiser.



Above and right: a denuded synthesiser. Next month we go on to give full construction details of the design, but as you can see from the photos, it really couldn't be easier. The photo on the right shows the keyboard contact block mountings in close-up. This is perhaps the trickiest part of any synthesiser to build yourself, but as you can see ours is very straightforward.



# KEYBOARD CONTROL



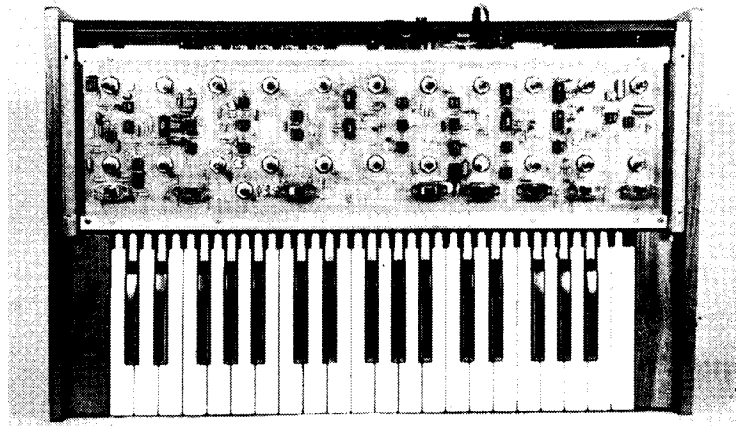
## BUYLINES

A complete set of parts for this project, including all woodwork, metalwork, nuts and bolts, PCBs and components will be available from Powertran Electronics.

The machine used to illustrate this article was assembled using this kit, and constructional details will be based upon it. Kits will **only** be available from Powertran, as will the PCB. Because the design is based upon a single board construction, we cannot offer advice to people wishing to modify the synthesiser to a 'modular' form.

The price of the complete kit, including keyboard will be £186.50 + VAT. However if you're quick and put in your order before July 30th you can take advantage of an introductory offer at an even lower price of £172 + VAT.

Powertran Electronics, Portway Industrial Estate, Andover, Hants.



Above: the lid removed to show the main PCB. It is worth noticing that all the controls and switches mount directly onto this, drastically reducing the interwiring necessary

Next month we conclude the article with all the constructional details of the Transcendent 2000 synthesiser, including keyboard fixing and alignment procedures.

# MUSIC SYNTHESIZER

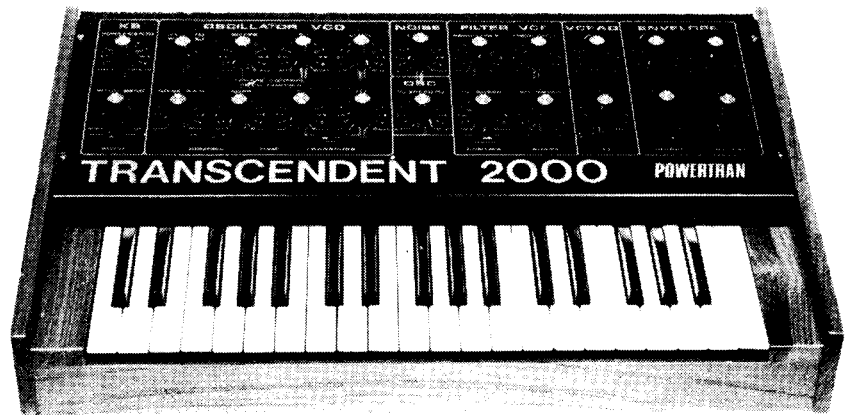
## PART 2—CONSTRUCTION

In this concluding part of the article we cover the assembly procedure for this compact design.

DESPITE the high complexity of this project, its construction should pose no *electronic* problems to the competent hobbyist. As with any synthesizer however, fitting the keyboard and its associated mechanics will prove the most onerous task.

### Getting Board

Since you have to start somewhere, the PCBs are the obvious place. There are five boards all together; power supply, keyboard contact mounting (X3) and main synthesiser. The keyboard board we will deal with later.



Above: the finished article all set to be played. This prototype was assembled using the Powertran Electronics kit, which includes the woodwork. Below: an internal view showing the alignment of PCB and keyboard. Note very carefully

the relation of the two as there is not much space to spare. As you can see from this photo, we used IC sockets on all devices as it makes things so much easier if anything untoward should occur.

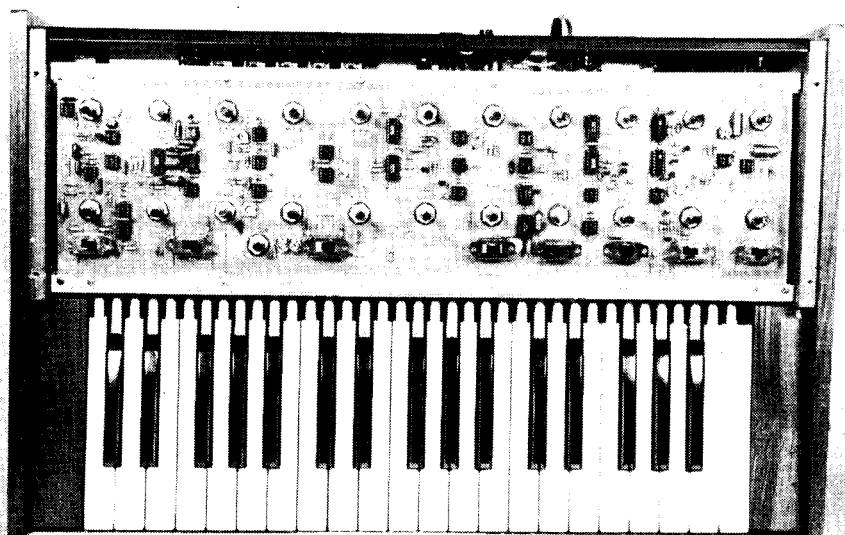
Assembly of the PSU board is very straightforward, but take care fitting the heatsinks to Q1 and Q3. Wire up the board to the transformer, and check that you can obtain the correct voltages at the output. Adjust RV1 until +12V is obtained on the red output wire.

Set to as close +12V as you can possibly measure. Check that an accurate -12V is present on the blue output wire. The power supply is now complete.

### Main Line

For the main assembly we're going to assume that you're using the Powertran board. Fitting the components to this is straightforward with the exception of the switches and pots.

In order to line up the switches with the front panel and pots, it is necessary to space these from the board — the kit contains suitable



spacers for this purpose. Non-kit types have to work out the height of their front panels from the board and act accordingly. The switch toggles must come level with the pot spindles, when cut to take the control knobs.

In either event glue the spacer to the board — use some powerful adhesive such as Super-Glue etc.

Cut the pot spindles before you fix them to the PCB: it's just too big to handle and too expensive to crack. The terminals should be top soldered onto the board, as should the chirpins used to mate up with the connector. Take care the solder does not run down the pins, else the plug may not fit at all.

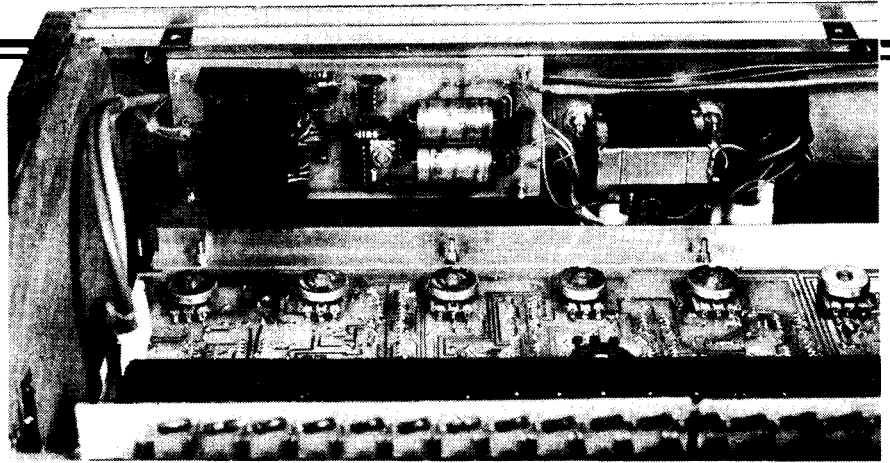
Use insulated wire to link the dual gang pot RV30 and the waveform switch to the board. The PCB cannot be mounted into place until the alignment procedures have been carried out, so there is no excuse for not checking the assembly very carefully indeed, especially the IC orientation and soldering quality. This is a BIG board which means there is more space to be careless:—check it!

### Powerfull Mount

Following the rear panel wiring diagram, fit the hardware onto the case, taking care to mount the transformer as low down—away from the main PCB—as possible. This will lessen the chance of hum being induced into the circuit.

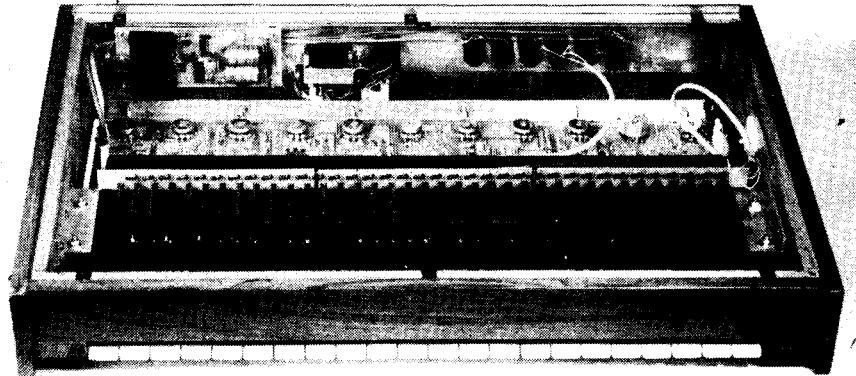
Insulate the mains wiring wherever possible, and take careful note of the earth wiring arrangements—lest the demon hum return to plague thee! Anything with mains voltage on should have a rubber sleeve over it.

The photograph shows the arrangement of PSU and transformer on the back panel.



**Above:** close up of the PSU board mounting within the case. Positioning the transformer is important to reduce the risk of hum. Mount this as low down, away from the board, as possible. In the foreground the resistor chain for the keyboard can be seen. **Below:** overall

view of the machine, to give an idea of what goes where in the box. Note the three Chiri connectors which fit onto the PCB on the end of these wires snaking across the photo. The black area to the front is the line of keyboard contact blocks.



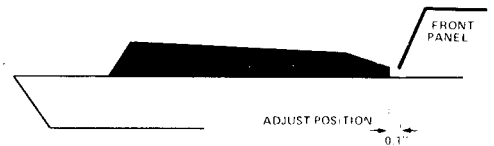
### Keyed Up?

Now for the tricky bit. The keyboard. This has to be mounted in the casing first. For this the front panel should be in position. Fix the brackets to the ends of the keyboard assembly, and lower it into place. Follow the diagram below to adjust the spacing at either end of the keyboard. If the

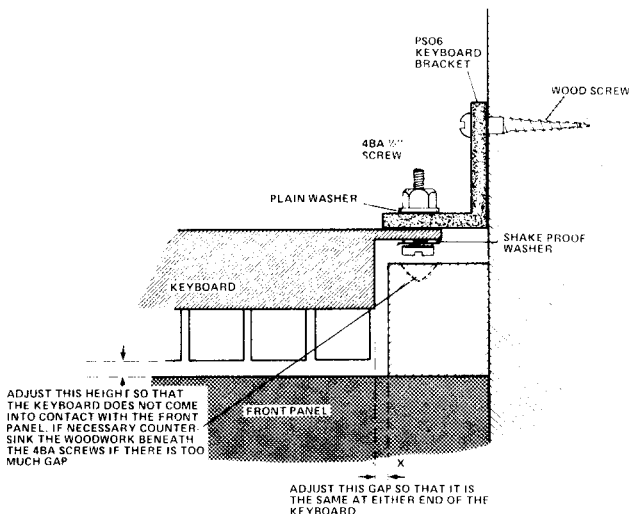
gap is more than 0.1", the woodwork underneath the fixing screws will need countersinking.

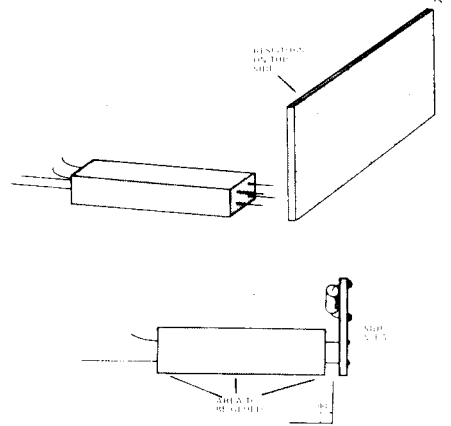
Set the gap between the black notes and the front panel as shown.

Once the alignment is correct, screw the brackets into the woodwork.

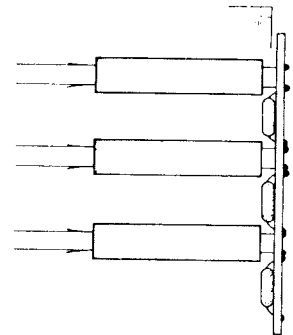
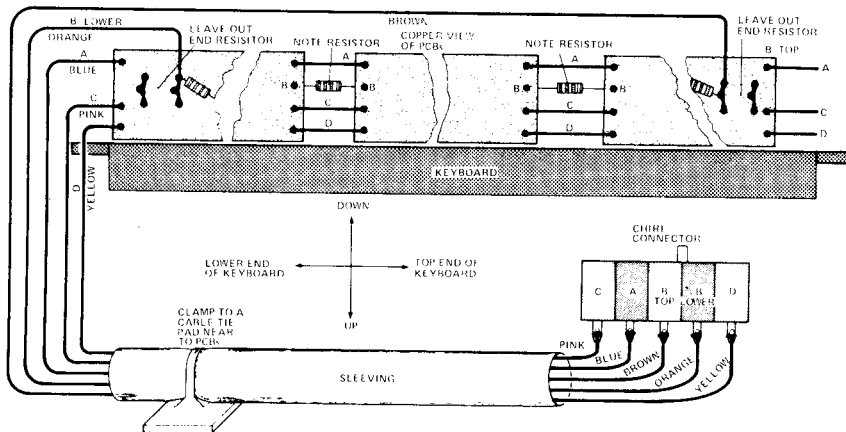


On the left is the diagram you'll need to line up the keyboard assembly with the casing and front panel. Follow this as carefully as you can, as if the keys are not in the right places, the contact blocks will not line up with the plungers, and the keys themselves will probably foul the front panel. Above is shown the alignment of keys and panel.





Contact blocks and resistors and where to put 'em. Follow the drawing above to fit the block to the PCB, and then line up the angle as shown below. On the lower left is the keyboard wiring diagram which shows the connecting together of the boards and the placing of the two spare resistors. The photograph shows what it all looks like when you've finished.



Onto the contacts. Fit and solder the 27R4 resistors to the three PCBs as shown on the diagram above. One will be full with 12 resistors and the other two have eleven each, one missing at the right end on one PCB, and one missing at the left end of the other. (There are two resistors left over at this stage.)

### Close Contacts Of The Key Kind

Solder in the contact assemblies, but make very sure that right angles exist between the block and the PCB. This is important. Graph paper may help in lining up.

Leave out a contact block where the resistors are omitted the diagram may help.

All three PCBs are wired together as shown in the keyboard wiring diagram taking care to place the 'gaps' correctly. Get the spacing correct by lining up the contact blocks with the keyboard plungers. Note the positioning of those two spare resistors.

Sand down one side of the contact strip, and lay some contact adhesive all over it, and the same with the soldered-in contact blocks. Make very sure that before you affix the strip onto the blocks that you have lined it up properly, as once the glue gets hold you've had it.

The contact blocks are very delicate, so handle them carefully, and don't touch the wires with your

fingers. If you do you'll leave a deposit behind which may well cause malfunction. When satisfied that the assembly is O.K. position it over the keyboard plungers, and screw it down to the metalwork. Check that every plunger operates a contact, and that both contacts in each block operate when the key is depressed.

Keyboard completed — wasn't that bad after all (was it?)

The contact assembly for the keyboard should be the last thing you fit into place before wiring up all the boards as per the interconnection and wiring diagrams. With this in place fit the base plate.

Alignment is best carried out with the front panel removed, and the PCBs fixed in. Before commencing alignment though, check everything very carefully.

When attaching the front panel to the machine, check that it does not foul the keyboard, and that the gap between it and the woodwork is the same at either end.

## Alignment

This will be dealt with in sections. To aid setting up and alignment procedures, test point waveforms are given for important nodes throughout the design.

## VCO Alignment

There are several pitch controls for the VCO. All control voltages are injected via large resistors and are thus suitably attenuated. The pitch bend pot uses a couple of diodes to produce a dead zone in the middle of its motion. This control voltage is then fed in via a 180k resistor and mixed with all the other control voltages.

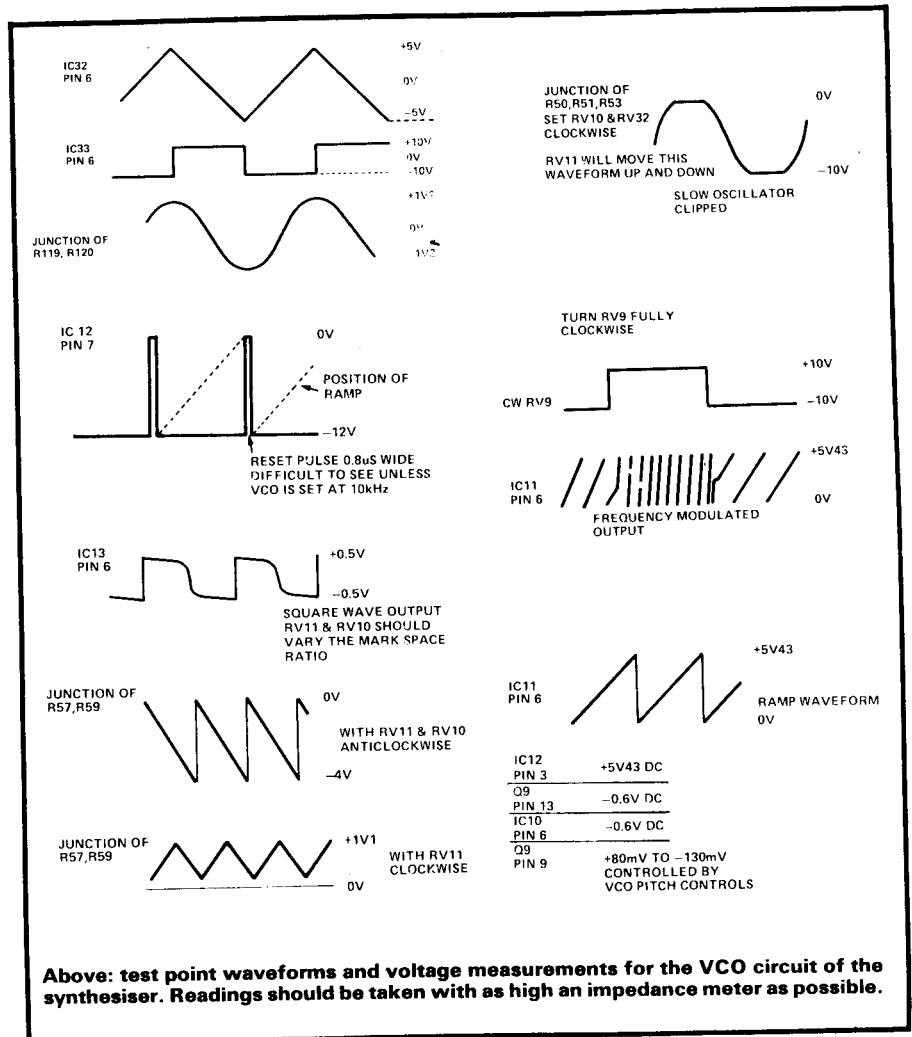
## Pitch Spread

The keyboard sample and hold produces 830mV/octave. This has to be attenuated to 18mV to produce octaves. To do this, a resistor of 46k is required. R31 and RV3 constitutes a variable resistor (39k2 to 49k2) that should enable the keyboard pitch spread to be aligned.

Turn RV6, 7, 8, 9 fully anticlockwise. Put the transpose switch in its central position. Set RV5, 4 to their central position. Play the top note on the keyboard and measure its frequency, using a scope or a frequency meter, or maybe if you are a musician just listen to it! Now play a note one octave below it and adjust RV3 until the interval is one octave below it and adjust RV3 until the interval is one octave. Recheck the top note and then try the tracking for two or three octaves down, making any necessary adjustments to RV3. Note that the top note on the keyboard is not affected by RV3 adjustments. Now put the transpose switch to + 2 octaves and adjust RV12 for a 2 octave increase. Then switch to -2 octaves and adjust RV13 for a 2 octave decrease.

## VCO Shape Modulation

IC14, 13, 15 is the VCO shape modulation circuitry. IC14 is a half wave rectifier, and is used to sum together the manual shape voltage



Above: test point waveforms and voltage measurements for the VCO circuit of the synthesiser. Readings should be taken with as high an impedance meter as possible.

(RV14), and the sine wave voltage from the slow oscillator. The output from this circuit is limited to a range of 0 V to about -10 V. As the manual shape pot is rotated clockwise the waveform at the junction of R57, R59 will change from a ramp into a triangle, this being due to the full wave rectification. With RV14 fully clockwise and RV15 anticlockwise adjust RV15 so that the waveform is a symmetrical triangle.

The last shape generator is a fast comparator. The ramp waveform plus the modulation voltage are fed into the comparator input. The modulation voltage shifts the DC level of the ramp and in doing so the comparator levels change resulting in a varying markspace ratio output, IC15 pin 6. The diodes limit the voltage excursion to about  $\pm 0.5$  V.

Set the VCO to + 2 octaves, tune the keyboard high and play the highest note. Now set RV10 anticlockwise, RV14 clockwise and monitor

the squarewave output, IC13 pin 6. Adjust RV11 until a very thin pulse is generated. Rotate RV14 anticlockwise and the markspace ratio will revert to 1 to 1. Now set RV14 to 5 on the dial and slowly rotate RV15. The markspace ratio will be modulated at the speed of the slow oscillator.

There may be some problems with control breakthrough in the VCA but this can be minimised with a preset adjustment, RV22. Turn the VCO and noise levels to 0. Make sure that the filter is not oscillating. Put the ADSR on a fast repeat with fast attack and decay and no sustain level. Set the BY-PASS switch to ADSR and look at the synthesiser output. There will probably be some control break through caused by the ADSR, which will sound like a series of thumps. By adjusting RV22 a minimum in the thump level will be found. Just like the 3080s in the VCF, best performance can be obtained by carefully selecting IC22.

PARTS LIST

RESISTORS (all 1/4W 5% unless stated)

R1, 18, 55, 58, 120, 127	4k7	
R2, 8, 43	10k	(0.5%)
R3, 49, 133	12k	
R4, 7	3R3	
R5, 37, 38	6k8	(1%)
R6, 83, 96	1k0	
R9	4k75	(1%)
R10, 80, 81	680R	
R11, 78, 61	27k	
R12, 16, 22, 23, 70	39k	
R13, 84	100R	
R14, 27, 48, 60, 69, 136	220k	
R15	1k5	
R17, 28, 29	10M	
R19, 51, 56, 64, 75, 77, 79, 89, 90, 93-95, 97, 101, 103-108, 122, 128, 137	100k	
R20	470k	
R21, 57, 102, 114, 119, 132	22k	
R24, 30, 47, 86, 118, 121, 126, 131, 134	47k	
R25, 36, 59, 85, 87, 88, 91, 109, 113, 115-117	10k	
R26, 35, 39, 82, 92, 98, 100, 135	1M0	
R31, 65	39k2	(1%)
R32	680k	
R33, 66	130R	
R34	870R	(RTC)
R39	1M	(0.5%)
R40, 62, 138	56k	(2%)
R41	470R	
R42, 74	15k	
R44	12k1	(1%)
R45	2k7	
R46	309k	(0.5%)
R50, 130	150k	
R52	120k	
R53, 54	7k5	
R63, 71	390R	
R67	820R	(RTC)
R68	15k	
R72, 73, 110	2k2	
R99	3k9	
R111	390k	
R112, 123	82k	
R124	330R	
R125	8k2	
R129	68k	
Keyboard chain (37 off)	27R4	(0.5%)

POTENTIOMETERS

RV1, 3	10k	cermet
RV2, 23-27	1M	log
RV4, 5, 15, 21	100k	lin
RV6-10, 14, 17, 18, 28, 29	10k	lin
RV11, 22, 28	100k	lin preset
RV12, 13	50k	cermet
RV16, 32	100k	log
RV19, 33	10k	log
RV20	10k	lin preset
RV30, 31	10k	lin (ganged)

CAPACITORS

C1, 2, 10, 18, 26, 27, 29, 30, 32, 34 43, 45	100n	polyester
C3, 4	1000u	25V electrolytic
C5, 7, 8, 37	2u2	25V tantalum
C6	330p	polystyrene
C9	1u0	25V electrolytic
C11, 14, 15, 17	22n	polyester
C12, 19-21, 35, 36, 31, 48	10n	polyester
C13	330n	polystyrene
C16, 28, 33, 46	1n0	polystyrene
C22, 44	3n3	polystyrene
C23	22p	ceramic
C24	5p0	ceramic
C25, 41, 42, 47	1u0	25V tantalum
C39, 40	100u	25V electrolytic

SEMICONDUCTORS

IC1	uA 723C	
IC2, 3-5, 7, 8, 10, 14, 15, 18, 21, 29, 31-33	741	
IC6, 9, 11, 17, 20, 30	CA 3140	
IC12	LM311	
IC13	748	
IC16, 19, 22	CA3080	
IC25, 26	CD 4001	
IC27, 28	CD 4016	
IC34	CD 4030	
IC35	CD 4006	
Q1	TIP 29A	
Q2	BC 213	
Q3	TIP 30A	
Q4, 5	BF 244C	
Q6, 13, 15, 20-22	BC 182	
Q7, 9, 10, 12	CA 3046	(2 off)
Q8	2N 4859	
Q11, 14, 16-19	BC 212	
D1-37	1N 4148	
ZD1	4V7	400mW
ZD2, 4	5V6	400mW
ZD3	3V3	400mW
BR1	RS 261 772	(1A at 400V)

SWITCHES

SW1	DPDT 250V AC
SW2, 3, 6, 8, 9	single pole slide changeover
SW4	1 pole (2 way) rotary
SW5, 7, 10	double pole slide
changeover	

MISCELLANEOUS

Five 1/4" mono jack sockets, one 1/4" stereo jack socket (all panel mounting), 37 note keyboard with contact blocks, woodwork and case to suit, PCBs, three core mains lead, knobs to suit, 0A5 fuse with holder, 240V to 15-0-15V at 200mA transformer, three five-pin Chiri connectors, eight spacing blocks for switches, one foot pedal unit with cable (optional), grommets.

VCF Alignment

The VCF pitch spread should be set up as follows. Turn off RV16 and RV33. Switch the filter 'CONTROL' to KB, the 'RESONANCE' to 'OSC' and the 'AD SWEEP' to 0. Play the top note on

the keyboard and adjust the 'FREQUENCY' pot to give a 1kHz sinewave output. Now play a note, one octave below the top note and adjust the present RV20 for a one octave decrease. Check the lower octaves making any necessary adjustments to RV20.

Turn the Resonance pot anticlockwise until the filter stops oscillating. Turn up the VCO level and insert a ramp waveform at a frequency of about 100Hz. Now switch the VCF 'Control' to RANDOM. The tone of the filtered signal should now vary randomly.



**Main overlay for the Transcendent 2000 synthesiser design. As you may notice only a little over half the board is shown here. The other half you'll find over the page.**

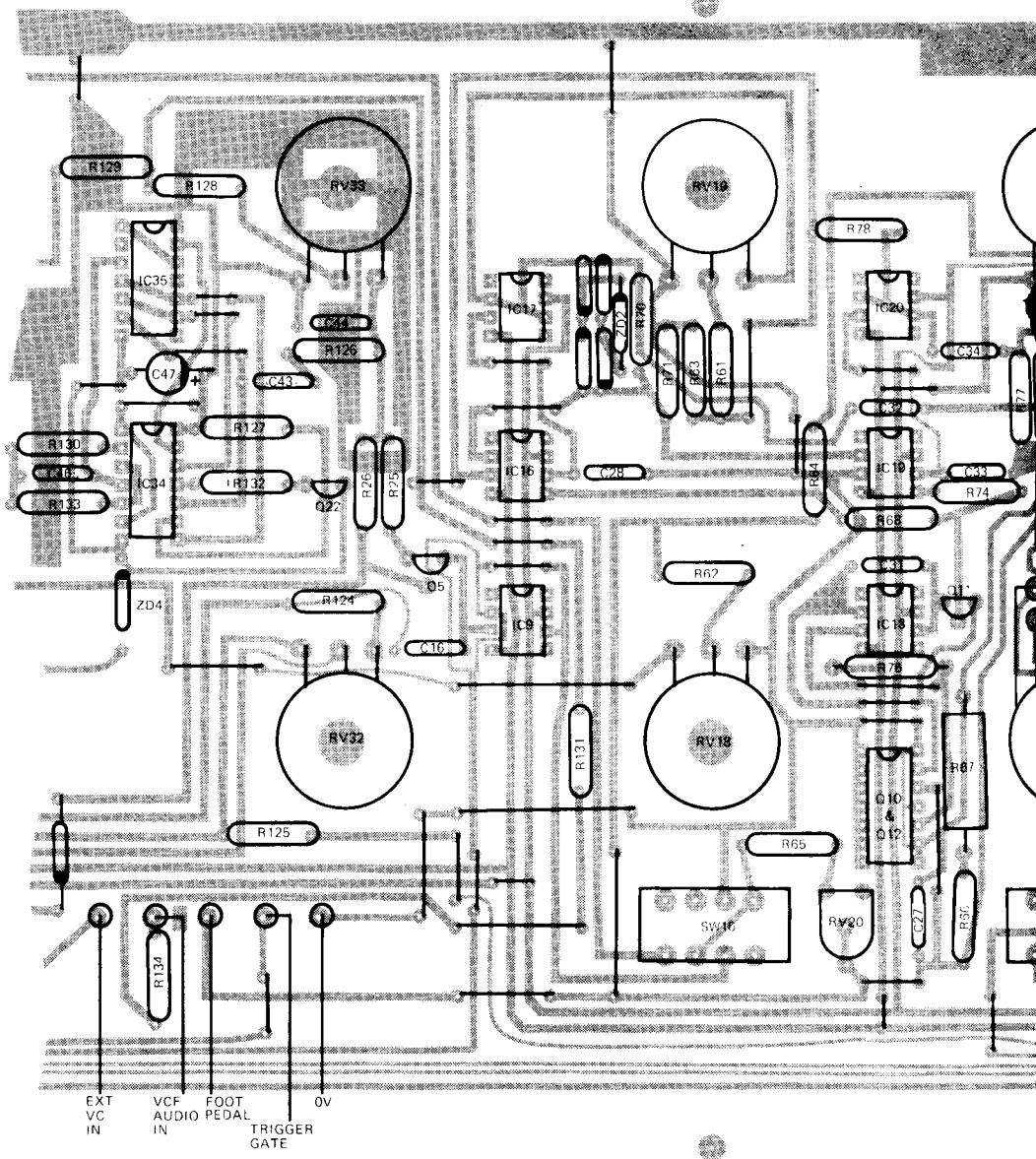
The reason for this is simply that with a PCB of this size our pages are too small to hold the diagram and still have it readable.

Foil patterns are not shown here, and the PCB is available from Powertran — see BUYLINES for details.

The two sets of contacts shown are mated with the Chiri connectors from the back panel wiring. Make sure the pins are straight, and that no solder has run down from the board, or the plug will not fit properly.

On the lower right is shown the PSU board overlay. Note that Q3 and Q1 require to be heat-sunked for correct operation.

Both the boards should be checked very carefully during assembly, and make sure you use the switch spacers on the main PCB. Cut the pot spindles *before* mounting them.



### Problems?

Any problems in the VCF circuitry are likely to emanate from IC16 or IC19. If there are any large input offset voltages or current mirror imbalances or output leakage currents, then these will degrade the VCF performance. What will probably occur is that there will be a large DC offset voltage on the outputs that varies as the resonant frequency varies. This may cause severe signal dipping at certain frequencies and will only be cured by replacing the errant 3080.

The filter has two outputs, a bandpass and a lowpass. The signal volume will generally be less from the bandpass output because this output

attenuates all but the harmonics that lie close to its own resonant frequency, whereas the lowpass output has a flat response area which extends from somewhere just below resonance down towards low frequencies, and harmonics in this region are not affected.

### Sweeping Statement

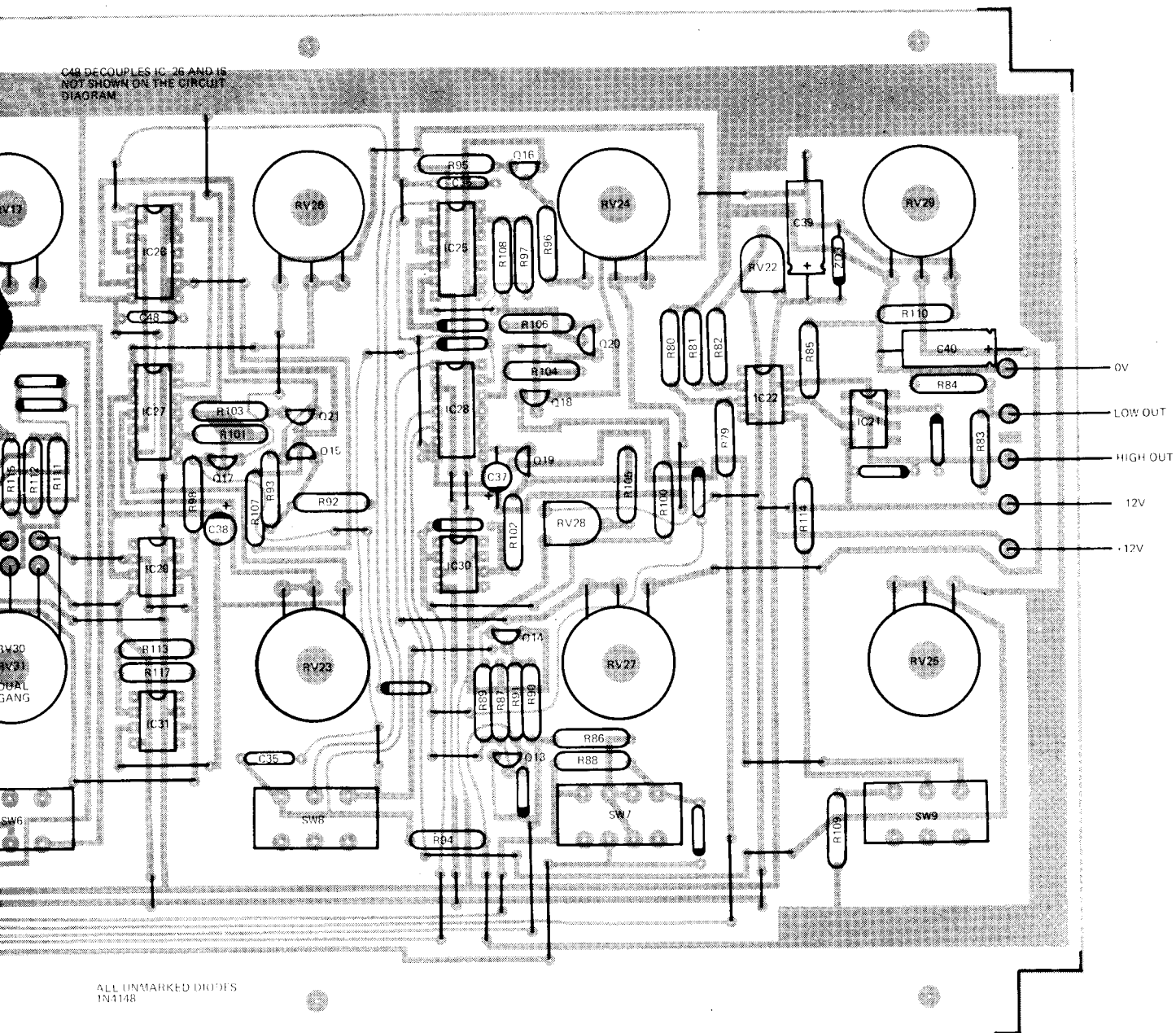
The 'synthesiser sound' is generated by sweeping the VCF resonant frequency with an AD waveform. This sweep voltage is variable in both depth and direction. The sweep pot is a dual pot; on one of its tracks there is an AD waveform at one end and the inverse at the other. Thus the wiper

will pan from a sweep going upwards to one going downwards. Two diodes provide a dead zone in the middle so that a pot position of No Sweep can be easily found. The second track on the AD sweep pot is used to provide a compensating DC level shift so that the frequency pot doesn't need to be retuned when the AD sweep depth is altered.

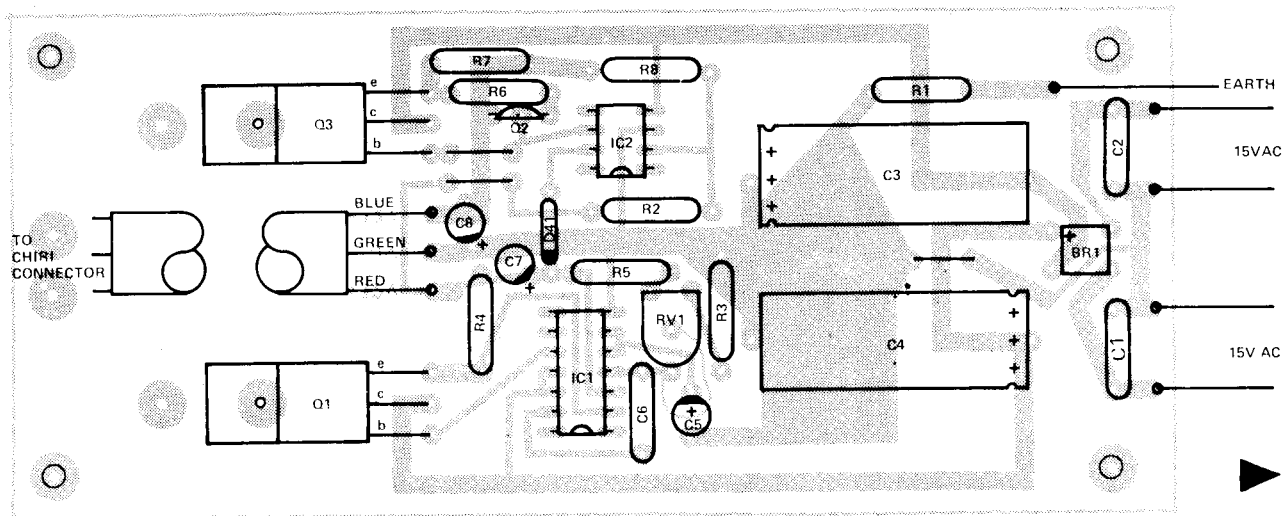
### ADSR Alignment

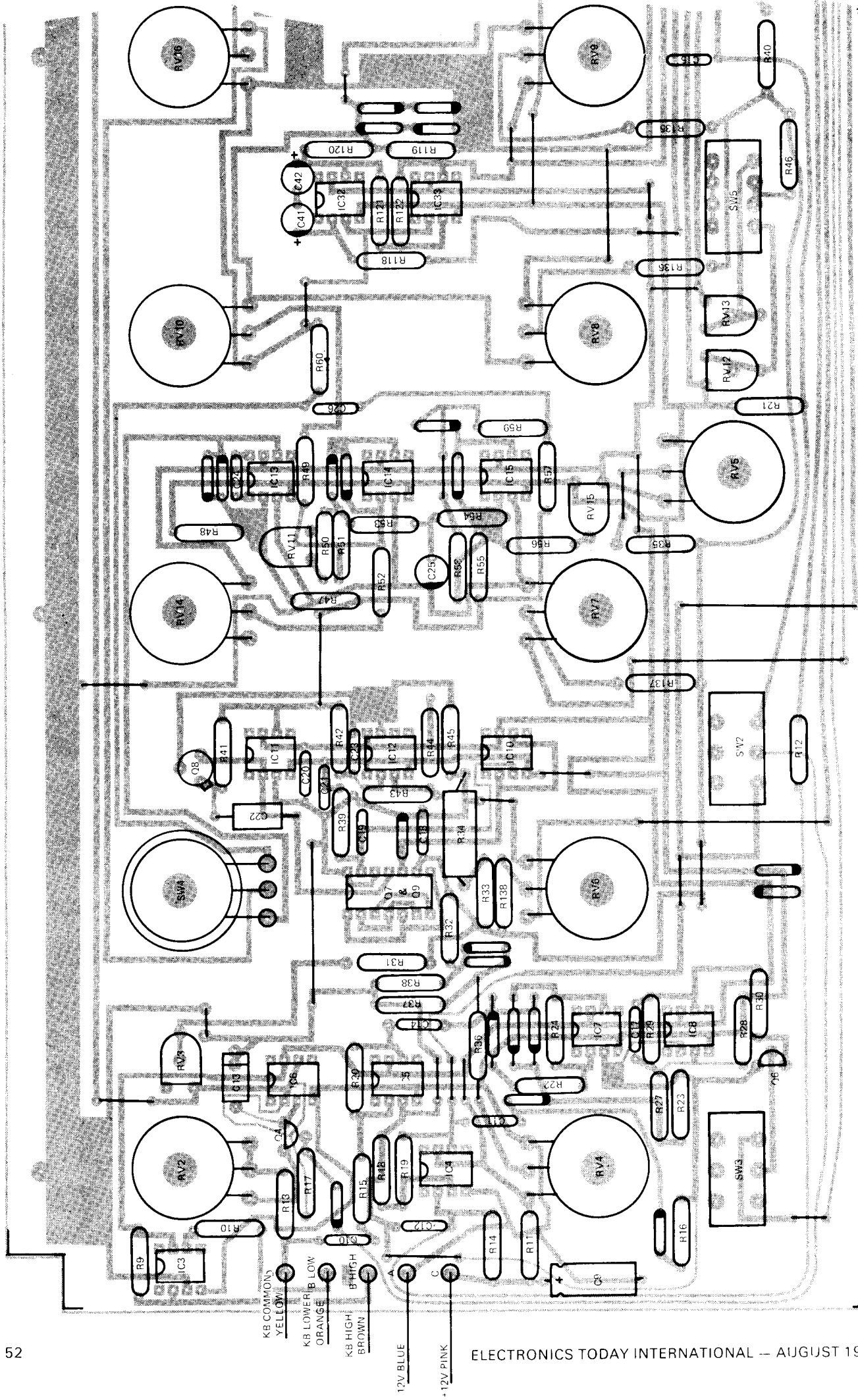
Set up the VCO and VCF so that a ramp waveform at 500 Hz is presented to the VCA. Turn the RELEASE pot fully clockwise and put the BYPASS switch in the ADSR position. Listen to the VCA output

C48 DECOUPLES IC 26 AND IS NOT SHOWN ON THE CIRCUIT DIAGRAM



ALL UNMARKED DIODES 1N4148





KB COMMON  
YELLOW

KB LOWER  
ORANGE

KB HIGHER  
BROWN

12V BLUE

-12V PINK

Above: the other half of the synthesiser PCB Connections is made to the pins in the upper left-hand corner by the keyboard wiring Chiri connector.

ALL UNMARKED DIODES  
1N4148

and adjust RV28 so that the signal only just disappears. Now you can play the keyboard and experiment with different sounding envelopes.

**This completes the alignment procedures for the design, and the front panel can now be fitted over the main PCB and the control knobs added.**

**Take care with the panel and keyboard positioning. See the diagrams where applicable.**

### Program Sheets

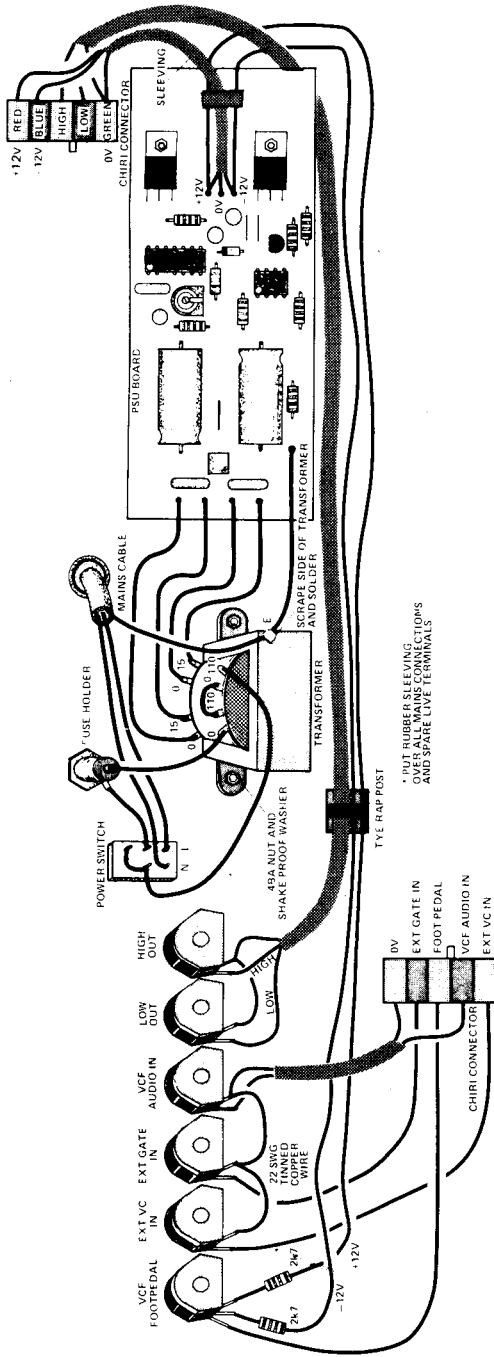
Once your machine is up and running, you will find that if you use it frequently, some method of recording various settings would be useful. This gives the ability to return to a particular sound very quickly and can be particularly useful in stage work.

As an aid to usage ETI is making available Program Sheets for the Transcendent 2000. These allow all control settings to be recorded for any configuration, and each sheet will record three completely independent sound settings. These cost 50p for six, including postage, from our 25-27 Oxford Street address. Mark the envelope "2000 Program Sheets".

### Clearing Points

Play testing since last month's article has shown that the synthesiser works better if (numbers referred to circuit diagrams and overlay) C17 is changed in value to 4n7, as this increases the NPD sensitivity and C9 is removed entirely from the circuit, this preventing 'clicking' which sometimes arose upon operation of the keyboard.

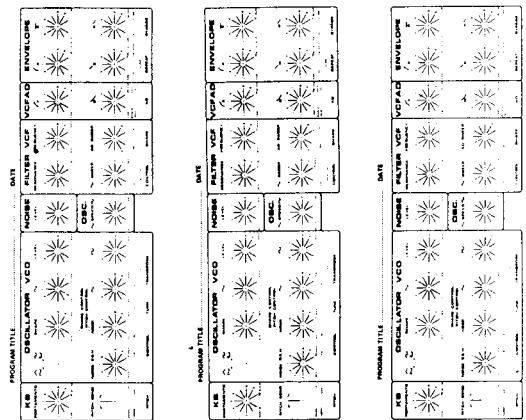
Two minor gremlins to be laid to rest. Last month we gave (on the circuit) the circuit reference for the Transpose switch as SW3. It should be SW5. Also the undesignated KB/Noise switch is in fact SW10. **ETI**



**Above: back panel wiring diagram. The connectors attach to the main PCB as shown on the overlay. The mains switch supplied with the kit contains a neon and the wiring takes account of this. Below: an example of the program sheets for the Transcendent 2000. These are used by simply marking on the settings for each control.**

### ETI TRANSCENDENT 2000

PROGRAM SHEET



## BUYLINES

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