The theory of electronic music synthesis is largely based on the characteristic of 1 V/octave, which has been used so much over the years that it is now almost universally accepted as the standard. This characteristic defines the relationship between a musical unit (the octave, which is the interval between two frequencies, one of which is twice as large as the other) and an electrical unit (the volt). Because the octave is composed of twelve equal semitones, the volt is also divided into 12 equal fractions. In this way a specific voltage always exists for each note in every octave. This control voltage then feeds various synthesizer modules (principally VCO and VCF) in steps of 83.33 mV, or multiples of this 'step'. The quantisizer described here is used to produce control signals which agree with this characteristic given a signal that is not broken up into steps of 83.33 mV, no matter what its origin! That means that the tonal range which can be generated is almost infinitely variable.

music quantisizer

analogue/digital converter + transcoder + digital/analogue converter = control of musical scales

This quantisizer is not a generator, it is more like an interface between two other synthesizer modules; in fact, it could be better called a converter or transcoder. That means that it is supplied with one signal and it outputs a different one. There is, of course, a relationship between the two signals, the output is a quantized version of the input; this output, then, is 'chopped up' into the famous V/octave characteristic so that it produces the different steps of a musical scale defined by the user.
Figure 2 shows the relationship between the input and output signals of the quantisizer. Here we see the curve of the input signal (in this example it is an envelope, but it could originate from a LFO, a sequencer, a pedal . . . . or whatever), and two examples of output signals from the quantisizer (QOV = quantisizer output voltage). One of these contains all the notes in the musical scale and follows the input quite closely. The other signal, however, contains only the three notes of the major chord.

'Quantisized! What does that mean?

The word 'quantisizer' comes from the combination of 'quantizer' and 'synthesizer'. Quantizing is a process by which a physical size is divided into discrete values which are multiples of a fixed, non-reducible unit. In our case this unit is the musical semitone or the corresponding 1/12 of a volt (83.33 mV). The circuit described here has two fundamental modes of operation (with numerous variants that we do not have the space to deal with here): one with transcoding or range-changing, and the other without. In this latter case, the quantisizer is no more than a precision analogue/digital converter. A voltage applied at the input is converted into a digital value, which is immediately reconverted into an analogue value.
This procedure allows a curve to be modified to the usual V/octave characteristic, or alternatively a characteristic of Y x 1 V/octave could be converted to the standard 1 V/octave, always assuming, of course, that the input signal has the correct degree of accuracy (± ½ LSB). Possibly more interesting for µP owners is the fact that the quantisizer without transcoding provides two good quality, independently addressable converters on the same board.
The other mode of operation is far more spectacular, in so far as it permits some sort of musical order to be assigned to even the least musical of control signals.
Figure 1 shows the block diagram of the quantisizer, consisting of six successive stages for processing the signal. An input amplifier for weak signals also ensures that the alternating signals have d.c. offset compensation. This is followed by the analogue/digital (A/D) converter, which has its own clock. Every 63 µs this converter provides an 8-bit digital code whose magnitude is proportional to the amplitude of the input signal. This data is then stored in a latch (ideally an addressable latch as this would enable the A/D converter to be used with a microprocessor independently of the rest

1

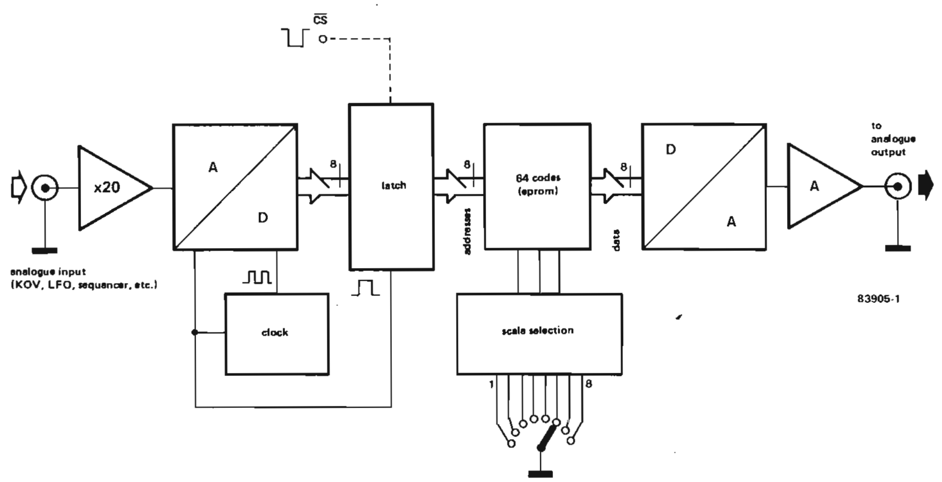

Figure 1. The quantisizer consists of a chain of elements for processing synthesizer control signals. It is of interest not only because of the accuracy of it's V/octave characteristic but also its ability to generate control voltages calibrated according to musical scales or chords. As fas as the ear is concerned it is like a type of 'sequencer-arpeggiator'. Both the A/D and D/A converters can be used independently.

of the circuit). This same eight bit code is applied to an EPROM as the low byte of an address. Each address contains some specific data that is input to the D/A converter, the output of which is proportional to the magnitude of the digital code. The whole significance of the quantisizer lies in the choice of these codes. The high order bits for addressing the static memory are supplied by a musical scale selection circuit that is accessible by the user. The memory area is divided into eight zones, allowing transcoding to 8 musical scales.

Converting to digital form

Part of the circuit for the quantisizer is shown in figure 4. This shows input amplifier IC1, A/D converter IC3, latch IC4 and clock IC2. The signal is input to R4 and thereafter to the non-inverting input of IC1, after being offset by a d.c. voltage set by P1. The A/D converter can only deal with positive voltages. Of course, many of the signals in a synthesizer are alternating voltages (from an LFO for example). The gain of this amplifier is set by means of P2 and can be between twenty and unity. Thus, with this input circuit, the quantisizer is truly universal.

The amplitude of the signal is limited by P3 before the ZN 427 (figure 3a shows the simplified internal diagram of this IC) converts it to digital form. As the internal reference voltage of IC3 is 2.5 V, the maximum possible value of input signal is the same. This IC also needs a clock signal (to pin 3) and a start conversion signal SC (pin 4). The clock generator circuit (N1) provides a signal of 140 kHz. The start conversion signal is a combination of the clock signal and the end of conversion signal, provided by the ZN 427 itself and inverted by N4 before being applied to flipflop N2/N3. With this configuration, the end of each conversion causes the next one to begin, as the diagram of figure 3b shows.

At the start of the conversion, the highest order output bit, 7, *(note: contrary to our normal designation the manufacturer of the ZN 427 calls it bit 1)* is set to logic high and all other bits are set logic low. The voltage to be converted, V_{IN}, is compared with a voltage equal to ½ V_{REF} output from the D/A stage of the ZN 427. The logic level of bit 7 is established definitely at the next successive falling edge of the clock signal. It is high if ½ $V_{REF} < V_{IN}$ and low if ½ $V_{REF} > V_{IN}$. At the same time the following bit (bit 6) is set logic high and its logic value is determined on the next trailing edge as a function of a comparison between the output of the D/A converter and the voltage to be converted.

This procedure is repeated until the logic levels of all eights bits have been set. Immediately after the value of the lowest order bit is established, the EOC output of the IC goes logic high and the digital data appears as the output at the buffers of the converter and it remains there until the new start of conversion signal arrives. This whole sequence takes nine clock pulses. Because the clock cycle is 7.1 μs duration (the frequency is 140 kHz as we said), the total conversion time is 63 μs, which means that the frequency of the sampling signal is 15 kHz. That is more than enough for VLF (Very Low Frequency) and non-periodic signals. But . . . . . . it is a bit low for audio signals (the sampling frequency should be at least twice the highest frequency of the signal to be converted). However, with the minimum conversion time guaranteed by the manufacturer of the ZN 427, 15 μs (with a clock signal of 600 kHz), the sampling frequency is about 60 kHz! Admittedly this has little to do with the quantisizer but the qualities of the circuit merit their being brought to your attention, possibly for future experimentation.

2

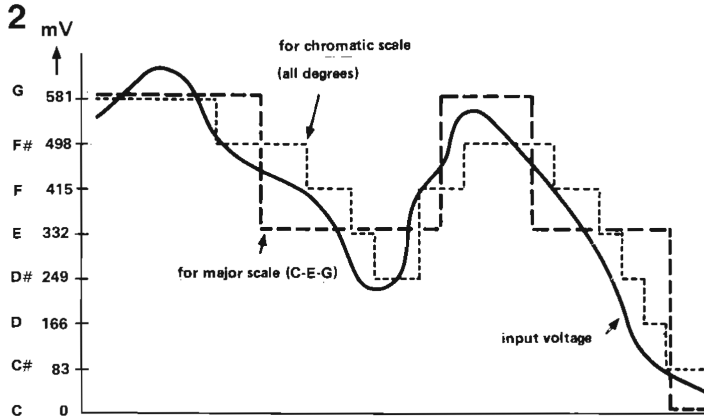

Figure 2. For any given input voltage the quantisizer can deliver eight different output curves, each of which follows a certain musical scale. In the example shown here the light dotted Q0V follows the chromatic scale, and the heavy dotted Q0V voltage only gives the notes of the major chord.

3a

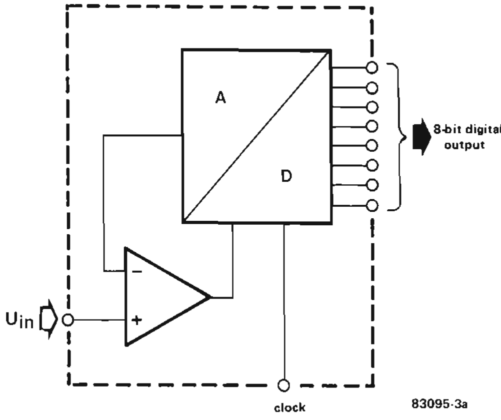

Figure 3a. This is the simplified internal structure of the ZN 427-E8 analogue/digital converter IC from Ferranti. The two important stages are the digital/analogue converter controlled by an external clock and the comparator whose inputs are the output voltage of the D/A converter and the voltage to be converted, V_{IN}.

3b

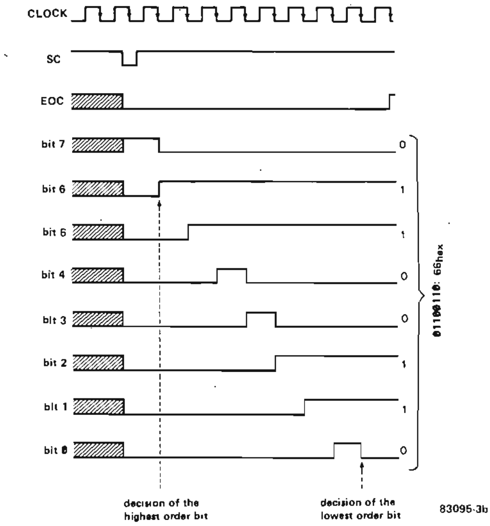

Figure 3b. This is a diagram of the signals during a conversion cycle of the ZN 427. The conversion time is always the same (nine clock cycles) no matter what the value of the voltage to be converted. In our example, the end of conversion pulse emitted by the converter itself produces a new start-conversion pulse.

We intentionally chose an addressable latch with high impedance outputs for IC4. When pin 1 of a 74LS374 is logic high its outputs are 'invisible' to a μP bus to which they are connected. An input has also been provided for an address decoding signal (AD) so that this first section of the quantisizer is autonomous and could even be connected directly to a computer bus. In this case the jumper marked with a * must be removed.

Transcoding

Now that we have the digital code things are starting to become a bit more musical . . . and a bit more involved for those who are not musically inclined. At this level, the digital and the musical are closely interwoven. What we call transcoding occurs in the 2716 EPROM, and, as we have already said, its low order address bits (bits Ø . . . 8) are given by the digital data provided by the circuit of figure 4. The high order address bits are, as figure 5 shows, given by the musical scale selection circuit. The user addresses the eight zones of the EPROM by means of S1 and S3 (or S2). One of the input lines of latch IC7 is set logic low by the common point of rotary switch S1. The other lines are made logic high by the polarising resistors R16 . . . R23. When the user momentarily presses S3 or closes S2 the low logic level applied on pin 11 of the 74LS373 causes these logic levels to be output from the latch. From there they go to IC6 which forms a three bit binary code based on them. These three bits correspond to address lines A8 . . . A10.

Because latch IC7 is not permanently valid, the user can jump from one code to another without 'hearing' the intermediate codes. The new address decoding for the EPROM is only valid while S3 is pressed (or S2 closed) and it is only at this moment that the zone is changed. Inside each of these zones, the same data may occur in several successive addresses, as table 1 shows. This means that for different A/D codes we get the same D/A code, and consequently the same output voltage QOV. Thus, in table 1a the data changes every four addresses so that after D/A conversion QOV increases by 83.33 mV. With this code all the degrees of the chromatic scale are present.

This is the first zone of the 2716, and is accessed by switching S1 to position Ø. If we switch to position 1, we are in a different zone in which not all the chromatic degrees appear (table 1b). In fact it is the major scale, or if you prefer, only the white keys on a piano keyboard. Now the QOV voltage no longer changes by 83.33 mV, but by multiples of this value: first there are two full tones, then a semitone, etc.

It is also clear that there is an order of precedence between the various degrees. In the example of table 1a (the chromatic scale) there were four addresses per note, whereas in table 1b note D has six addresses, while note F has seven and notes C and E each have eight. This implies that the voltages producing these last two notes have statistically more chance of appearing as the QOV output than the former two.

If switch S1 is turned to position 2 (and S3 is pressed) the QOV output is the voltage corresponding to the scale of black notes on the piano (the pentatonic scale). Table 1c is a summary of the organisation of the zones of the EPROM and shows the other scales and musical ratios available.

For the same input signal there are various outputs available from the quantisizer, as is shown in figure 6. Here we see that for the same LFO triangular signal input, the musical phrase output depends on the position of S1.

So we have: tonic C major (S1 = 3), dominant G major (S1 = 5), sub-dominant F major (S1 = 6), the complete major scale (S1 = 1), the chromatic scale (S1 = Ø), the pentatonic scale (S1 = 2), and to finish this example, the relative minor chord (S1 = 4). This diagram also indicates when S3 has to be pressed after changing the position of S1.

The data appearing at the output of the EPROM are applied directly to D/A converter (IC8) and this is straightforward, so it requires no further comment. The output stage is a buffer with offset compensation, using P5, and with a 10 turn pot (P6) for controlling the 1 V/octave characteristic.

Options

We have already mentioned that the transcoder does not have to be used, so if this is the case, EPROM IC5 should be removed. If the aim is to construct a precision A/D-

4

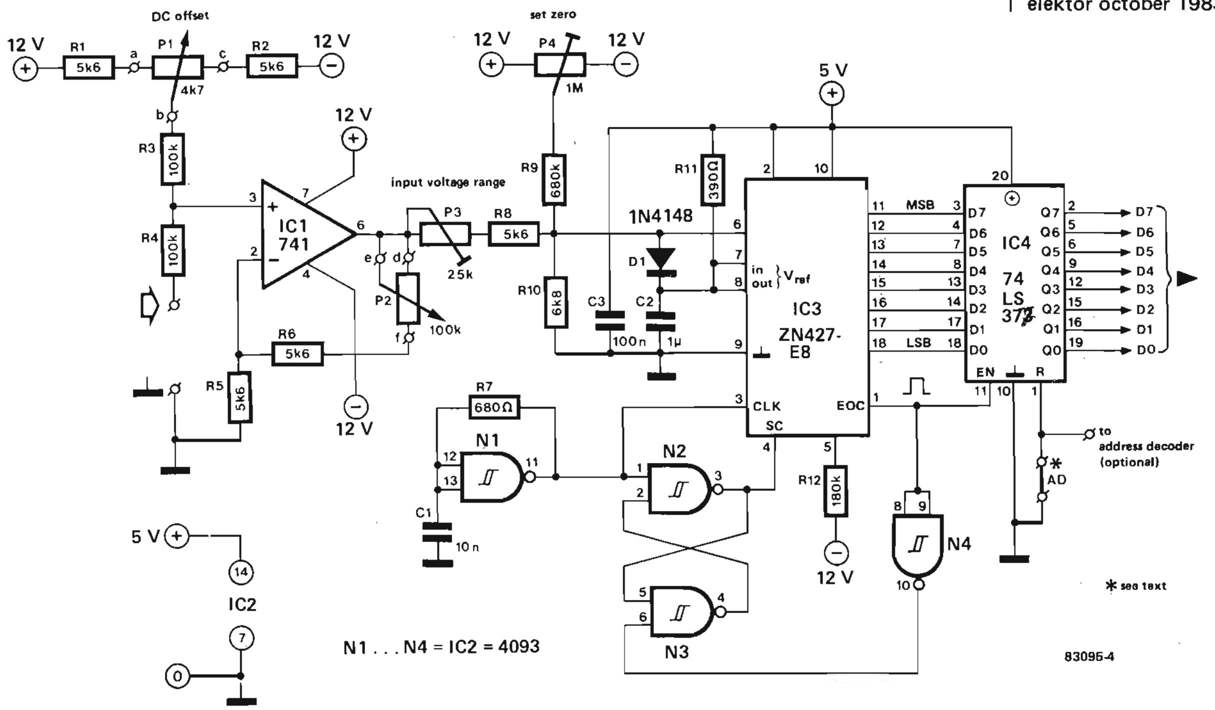

Figure 4. This is the analogue/digital part of the quantisizer circuit. Even though it is on the same printed circuit board as the digital/analogue converter from figure 5, this converter is completely autonomous. The jumper marked with an asterisk can replaced by a checking signal from latch IC4. If outputs DØ . . . D7 are to be connected to a microcomputer bus, this IC must be a 74LS374. This device has three state outputs that are high impedance if pin 1 is logic high.

D/A converter, the six most significant address inputs should be connected to the six most significant data outputs and the two least significant bits to ground. As well as IC5, all the components for scale selection should be omitted (these are marked with an asterisk on the diagram of figure 5). If the converters are to be used individually, all the components just mentioned are omitted as is the jumper marked with an asterisk in figure 4. In this case, the A/D data is available at the first eight address pins of IC5 (not inserted, remember!), while the D/A data can be applied on the eight data pins of IC5. Do not forget to apply a checking signal at point AD (figure 4,

5

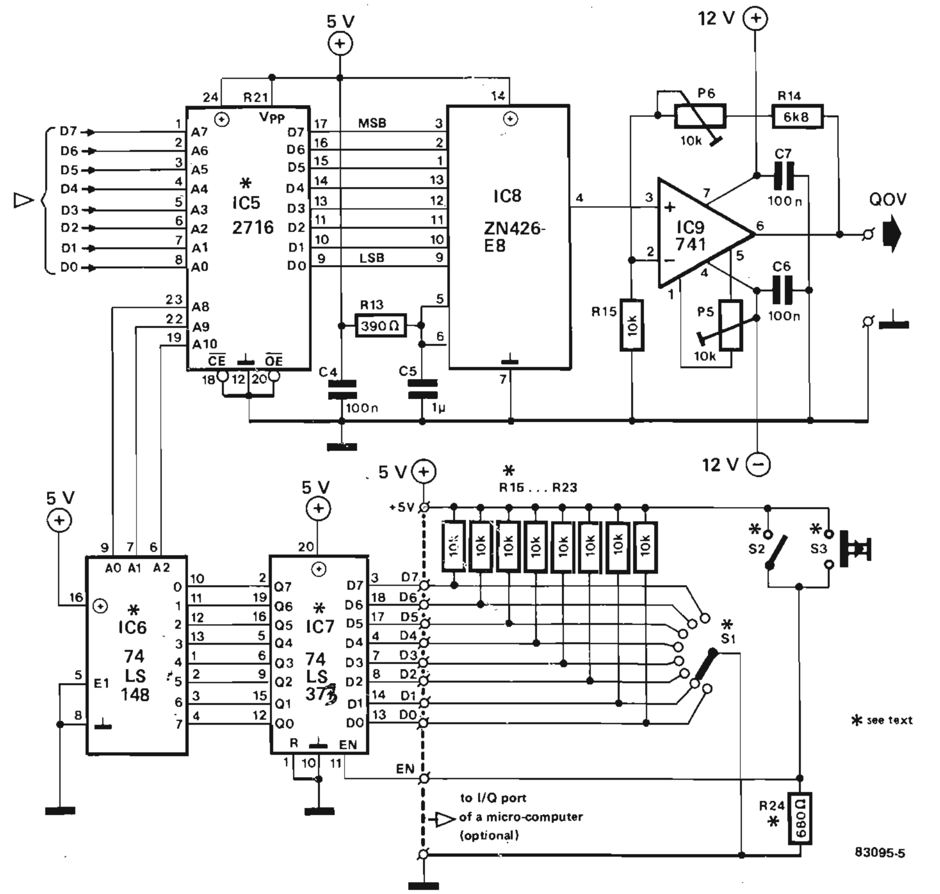

Figure 5. This is the digital/analogue section of the quantisizer. EPROM IC5 contains the digital codes that correspond to various musical scales after being converted into a QOV voltage by IC8 and IC9. The user chooses one of the eight scales using S1 . . . S3. These switches and the associated resistors could be replaced by the output port of a micro-computer.

6

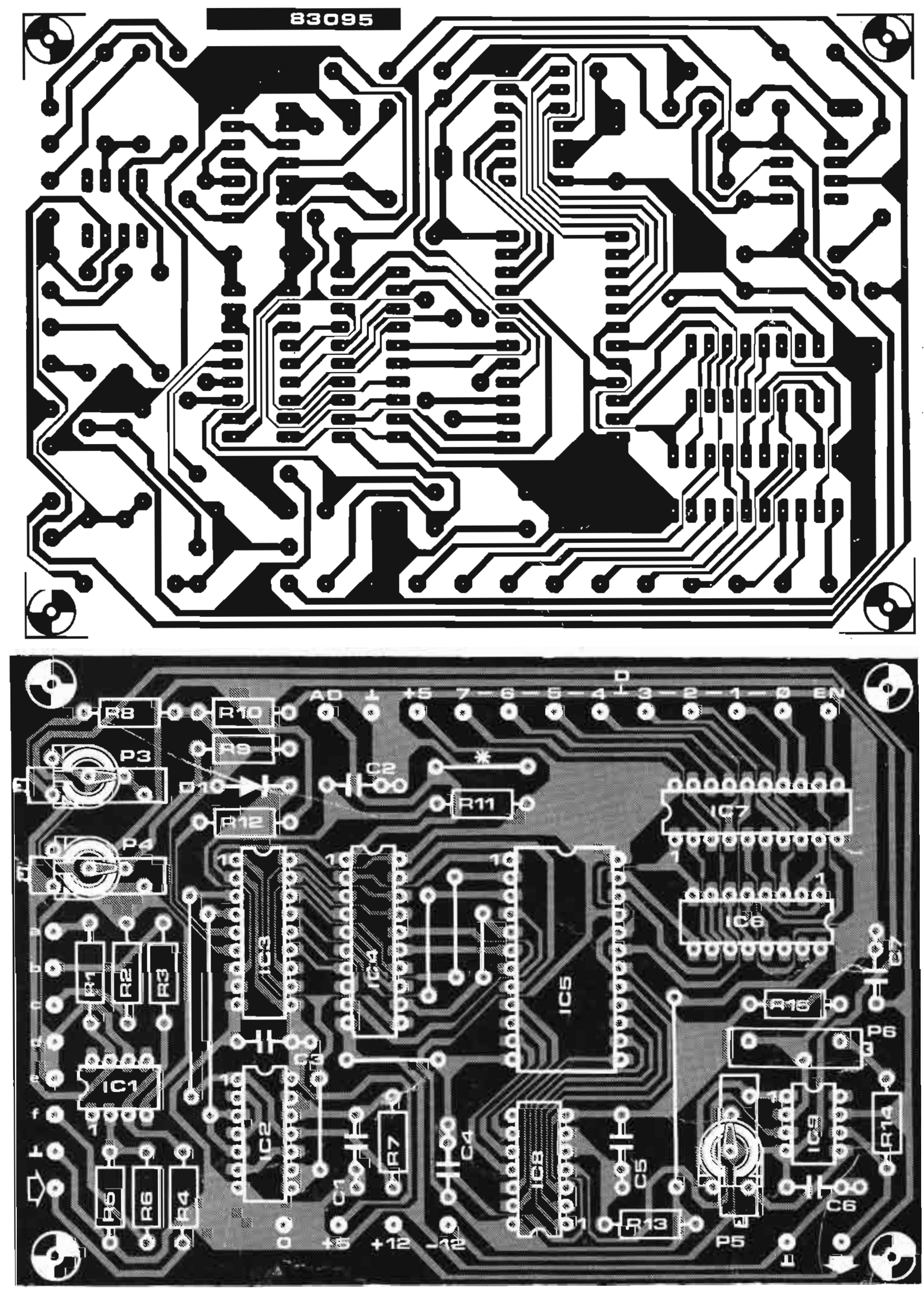

Figure 6. If S3 is pressed at the lowest point of the control signal (triangular output of an LFO) and the position of S1 is switched between two hollows, you change smoothly from one scale or chord to another. It is obvious that the musical phrase follows the contours of the control signal but the degrees are different and occur in greater or lesser numbers for each scale. This, of course, has an effect on the rhythm which is slower if there are less degrees present.

Parts list

Resistors:
R1,R2,R5,R6,R8 = 5k6
R3,R4 = 100 k
R7,R24 = 680 Ω
R9 = 680 k
R10,R14 = 6k8
R11,R13 = 390 Ω
R12 = 180 k
R15 . . . R23 = 10 k
P1 = 4k7 lin.
P2 = 100 k lin.
P3 = 25 k 10 turn pot
P4 = 1 M 10 turn pot
P5 = 10 k 10 turn pot
P6 = 10 k 10 turn pot

Capacitors:
C1 = 10 n
C2,C5 = 1 μ (MKT)
C3,C4,C6,C7 = 100 n

Semiconductors:
D1 = 1N4148
IC1,IC9 = 741
IC2 = 4093
IC3 = ZN 427-E8 (Ferranti)
IC4 = 74LS377 (74LS374; see text)
IC5 = 2716 (pre-programmed, see text)
IC6 = 74LS148
IC7 = 74LS373
IC8 = ZN 426-E8 (Ferranti)

Miscellaneous:
S1 = single pole 8-way rotary switch
S2 = single pole single throw switch
S3 = pushbutton (push to make)

pin 1 of *IC4 = 74LS374!*).
There is a further option: leave out S1 . . . S3 and R16 . . . R24 and control the musical scale selection circuit via the output port of a micro computer!

Construction and adjustment

There should be no problems with constructing this circuit, particularly if the printed circuit board design shown here is used. One important point to note, however, is that resistors R16 . . . R24 are soldered directly to the pins of rotary switch S1. The 2716 EPROM is available pre-programmed from Technomatic Ltd.
Adjusting this circuit begins with setting the output buffer (after the usual checks, of course). IC5 is removed from its socket and pins 1 . . . 3 and 9 . . . 13 of IC8 are connected to earth. The output of the IC should be zero. The output of IC9 (pin 6) should also be zero. If this is not the case, then adjust P5 until it is. Then pins 13 and 1 of IC8 are connected to +5 V and P6 is adjusted until the output of IC9 is 1.00 V. Now pin 13 of IC8 is connected to ground and pin 2 to +5 V (as well as pin 1) and the output from IC9 should be 2.00 V. Any deviation can be corrected using P6. After this adjustment, the 1 V/octave characteristic of the QOV voltage is set. The output of IC9 should be 3.00 V when pins 3 and 13 of IC8 are connected to +5 V and pins 1, 2 and 9 . . . 12 are earthed.
Before inserting the EPROM, IC5 should be checked to ensure that the high order address bits are present on pins 19, 22 and 23. These should, of course, also agree with the position of S1, not forgetting to press S3 after S1 is changed each time.
Now the same adjustment must be carried out on the A/D conversion circuit. IC1 is removed from its socket and pin 6 (or the

7

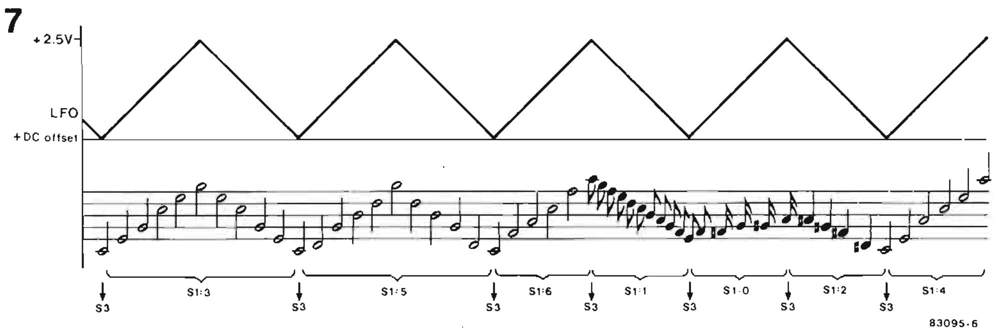

Figure 7. This is the component overlay for the printed circuit board, with all the components from figures 4 and 5, except for resistors R16 . . . R24 and S1 . . . S3.

zones	notes	number of addresses
	major chord	
	C	8
	D	6
	E	8
1	F	7
	G	6
	A	6
	B	7
	pentatonic chord	
	C#	10
	D#	9
2	F#	10
	G#	9
	A#	10
	C major	
	C	16
3	E	16
	G	16
	A minor	
	C	16
4	E	16
	A	16
	G major	
	D	16
5	G	16
	B	16
	F major	
	C	16
6	F	16
	A	16
	D major	
	D	16
7	F#	16
	A	16

addresses: zone Ø	notes	data (hex)
XX = ØØ		
XX = Ø1	do — C	ØØ
XX = Ø2		
XX = Ø3		
XX = Ø4		
XX = Ø5	do # — C#	Ø4
XX = Ø6		
XX = Ø7		
XX = Ø8		
XX = Ø9	ré — D	Ø8
XX = ØA		
XX = ØB		
XX = ØC		
XX = ØD	ré# — D#	ØC
XX = ØE		
XX = ØF		
XX = 1Ø		
XX = 11	mi — E	1Ø
XX = 12		
XX = 13		
XX = 14		
XX = 15	fa — F	14
XX = 16		
XX = 17		
XX = 18		
XX = 19	fa # — F#	18
XX = 1A		
XX = 1B		
XX = 1C		
XX = 1D	sol — G	1C
XX = 1E		
XX = 1F		
XX = 2Ø		
XX = 21	sol # — G#	2Ø
XX = 22		
XX = 23		
XX = 24		
XX = 25	la — A	24
XX = 26		
XX = 27		
XX = 28		
XX = 29	la # — A#	28
XX = 2A		
XX = 2B		
XX = 2C		
XX = 2D	si — B	2C
XX = 2E		
XX = 2F		
for the next 4 octaves, add 30_{hex} per octave		+ Ø4 /½ tone

Table 1a

Address	hex	Data (EPROM (zone Ø))	D/A QOV
Ø Ø Ø Ø	ØØ	Ø Ø Ø Ø Ø Ø Ø Ø	
Ø Ø Ø 1	ØØ	Ø Ø Ø Ø Ø Ø Ø Ø	0 mV
Ø Ø Ø 2	ØØ	Ø Ø Ø Ø Ø Ø Ø Ø	
Ø Ø Ø 3	ØØ	Ø Ø Ø Ø Ø Ø Ø Ø	
Ø Ø Ø 4	Ø4	Ø Ø Ø Ø Ø 1 Ø Ø	
Ø Ø Ø 5	Ø4	Ø Ø Ø Ø Ø 1 Ø Ø	83 mV
Ø Ø Ø 6	Ø4	Ø Ø Ø Ø Ø 1 Ø Ø	
Ø Ø Ø 7	Ø4	Ø Ø Ø Ø Ø 1 Ø Ø	
Ø Ø Ø 8	Ø8	Ø Ø Ø Ø 1 Ø Ø Ø	
Ø Ø Ø 9	Ø8	Ø Ø Ø Ø 1 Ø Ø Ø	167 mV
Ø Ø Ø A	Ø8	Ø Ø Ø Ø 1 Ø Ø Ø	
Ø Ø Ø B	Ø8	Ø Ø Ø Ø 1 Ø Ø Ø	
Ø Ø Ø C	ØC	Ø Ø Ø Ø 1 1 Ø Ø	
Ø Ø Ø D	ØC	Ø Ø Ø Ø 1 1 Ø Ø	250 mV
Ø Ø Ø E	ØC	Ø Ø Ø Ø 1 1 Ø Ø	
Ø Ø Ø F	ØC	Ø Ø Ø Ø 1 1 Ø Ø	
Ø Ø 1 Ø	1Ø	Ø Ø Ø 1 Ø Ø Ø Ø	
Ø Ø 1 1	1Ø	Ø Ø Ø 1 Ø Ø Ø Ø	333 mV
Ø Ø 1 2	1Ø	Ø Ø Ø 1 Ø Ø Ø Ø	
Ø Ø 1 3	1Ø	Ø Ø Ø 1 Ø Ø Ø Ø	
Ø Ø 1 4	14	Ø Ø Ø 1 Ø 1 Ø Ø	
Ø Ø 1 5	14	Ø Ø Ø 1 Ø 1 Ø Ø	417 mV
Ø Ø 1 6	14	Ø Ø Ø 1 Ø 1 Ø Ø	
Ø Ø 1 7	14	Ø Ø Ø 1 Ø 1 Ø Ø	
Ø Ø 1 8	18	Ø Ø Ø 1 1 Ø Ø Ø	
Ø Ø 1 9	18	Ø Ø Ø 1 1 Ø Ø Ø	500 mV
Ø Ø 1 A	18	Ø Ø Ø 1 1 Ø Ø Ø	
Ø Ø 1 B	18	Ø Ø Ø 1 1 Ø Ø Ø	
Ø Ø 1 C	1C	Ø Ø Ø 1 1 1 Ø Ø	

Table 1b

Address	hex	Date (EPROM (zone 1))	D/A QOV
Ø 1 Ø Ø	ØØ	Ø Ø Ø Ø Ø Ø Ø Ø	
Ø 1 Ø 1	ØØ	Ø Ø Ø Ø Ø Ø Ø Ø	
Ø 1 Ø 2	ØØ	Ø Ø Ø Ø Ø Ø Ø Ø	
Ø 1 Ø 3	ØØ	Ø Ø Ø Ø Ø Ø Ø Ø	0 mV
Ø 1 Ø 4	ØØ	Ø Ø Ø Ø Ø Ø Ø Ø	
Ø 1 Ø 5	ØØ	Ø Ø Ø Ø Ø Ø Ø Ø	
Ø 1 Ø 6	ØØ	Ø Ø Ø Ø Ø Ø Ø Ø	1 tone
Ø 1 Ø 7	ØØ	Ø Ø Ø Ø Ø Ø Ø Ø	
Ø 1 Ø 8	Ø8	Ø Ø Ø Ø 1 Ø Ø Ø	
Ø 1 Ø 9	Ø8	Ø Ø Ø Ø 1 Ø Ø Ø	
Ø 1 Ø A	Ø8	Ø Ø Ø Ø 1 Ø Ø Ø	167 mV
Ø 1 Ø B	Ø8	Ø Ø Ø Ø 1 Ø Ø Ø	
Ø 1 Ø C	Ø8	Ø Ø Ø Ø 1 Ø Ø Ø	
Ø 1 Ø D	Ø8	Ø Ø Ø Ø 1 Ø Ø Ø	
Ø 1 Ø E	1Ø	Ø Ø Ø 1 Ø Ø Ø Ø	1 tone
Ø 1 Ø F	1Ø	Ø Ø Ø 1 Ø Ø Ø Ø	
Ø 1 1 Ø	1Ø	Ø Ø Ø 1 Ø Ø Ø Ø	
Ø 1 1 1	1Ø	Ø Ø Ø 1 Ø Ø Ø Ø	
Ø 1 1 2	1Ø	Ø Ø Ø 1 Ø Ø Ø Ø	333 mV
Ø 1 1 3	1Ø	Ø Ø Ø 1 Ø Ø Ø Ø	
Ø 1 1 4	1Ø	Ø Ø Ø 1 Ø Ø Ø Ø	½ tone
Ø 1 1 5	1Ø	Ø Ø Ø 1 Ø Ø Ø Ø	
Ø 1 1 6	14	Ø Ø Ø 1 Ø 1 Ø Ø	
Ø 1 1 7	14	Ø Ø Ø 1 Ø 1 Ø Ø	
Ø 1 1 8	14	Ø Ø Ø 1 Ø 1 Ø Ø	
Ø 1 1 9	14	Ø Ø Ø 1 Ø 1 Ø Ø	417 mV
Ø 1 1 A	14	Ø Ø Ø 1 Ø 1 Ø Ø	
Ø 1 1 B	14	Ø Ø Ø 1 Ø 1 Ø Ø	
Ø 1 1 C	14	Ø Ø Ø 1 Ø 1 Ø Ø	

Table 1c

ADDRESSES	SCALES*
ØØØØ . . . ØØFF	chrometic scale
Ø1ØØ . . . Ø1FF	major chord
Ø2ØØ . . . Ø2FF	pentatonic scale
Ø3ØØ . . . Ø3FF	major chord C-E-G
Ø4ØØ . . . Ø4FF	minor chord A-C-E
Ø5ØØ . . . Ø5FF	major chord G-B-D
Ø6ØØ . . . Ø6FF	major chord F-A-C
Ø7ØØ . . . Ø7FF	major chord D-F#-A

* every scale covers 5 octaves

wiper of P3) is connected to ground. Then adjust P4 so that pins 11 . . . 18 of IC3 are logic low.
Potentiometer P3 could be adjusted by ear as a function of the control signal applied to the quantisizer. The aim is to set this pot until the musical phrase generated by a VCO to which the QOV voltage is fed follows the contours of the control signal without clipping.
Having done that, the quantisizer is almost ready for use. All that remains is to find a suitable supply, whether that is from the host synthesizer or a separate circuit with regulator ICs just for this purpose. The current consumption is about 120 mA at 5 V and much less at ± 12 V.
Elsewhere in this issue we have an article about an 'EPROMmer' using the main board of the Junior Computer. Need we say more about exclusive, custom-made transcoder EPROMs?! ◼

Table 1a. This is an extract from the contents of zone Ø of the EPROM. All the degrees of the chromatic scale are present and the addressing is equally divided among them (4 addresses per note). Obviously, the probability of occurrence of each of the twelve notes is the same.

Table 1b. This is part of the contents of zone 1 of the EPROM. Only the seven degrees of the major scale are present. The addressing is not divided equally among them as some notes have more 'musical weight' than others. This means that some notes occur more often and last longer than others.

Table 1c. The eight zones of the EPROM with the scales and chords obtained in each of them. No matter how many notes per octave are present, the range of QOV produced by each zone is five octaves.