the NEW Elektor synthesiser

The VCO module

This is the third article in the series relating to the Curtis ICs and the new Elektor synthesiser. Whereas the previous articles were mainly concerned with the 'theory' of the project, we now continue with the practical side of the story.
The voltage controlled oscillator (VCO) is essentially the heart of any synthesiser and the stability of the completed instrument depends to a large extent on the design and performance of this module. For this reason it is important that all the information contained in this article is followed very carefully, especially during the calibration procedure.

A first glance at the circuit diagram in figure 1 will raise some doubts as to how 'simple' this simplified synthesiser really is!
The VCO IC (CEM 3340), already described in the October issue of Elektor, forms the heart of the circuit. Together with six opamps it performs as well as the complete VCO module of the Formant synthesiser. The remaining space is used for the control logic which is necessary for the 'preset' and 'polyphonic' modes of operation. Therefore, it is certainly a simplification in the long run, since all the required components can be mounted on one printed circuit board, thereby saving both time and expense.

The circuit

The first item to consider is the power supply. In contrast to the Formant synthesiser, the VCO described here only requires a symmetrical + and −15 V power supply. The current consumption of the basic version of the instrument (without polophony) is less than 200 mA per supply line.
The positive supply voltage is fed to pins 11 and 12 of the 723 adjustable voltage regulator, IC2. The (11.05 V) output voltage at pin 10 of this IC is fed to pin 16 of IC1. Besides this positive supply, the CEM 3340 requires two further voltages which are generated by opamps A1 and IC5. These provide output voltages of +5 V and

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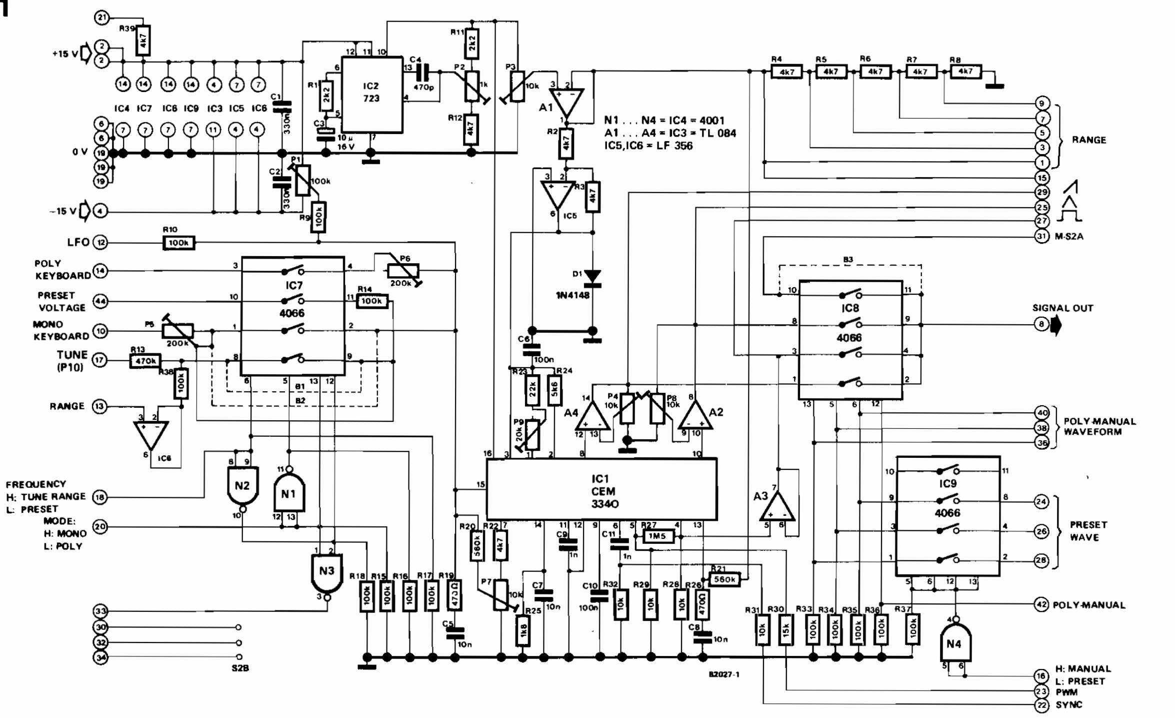

Figure 1. Only a few common ICs and the CEM 3340 are required to construct a precise VCO; the adjustable voltage regulator (723) and 6 opamps. The other ICs are only required when the synthesiser is to be 'programmed' by external stored control voltages.

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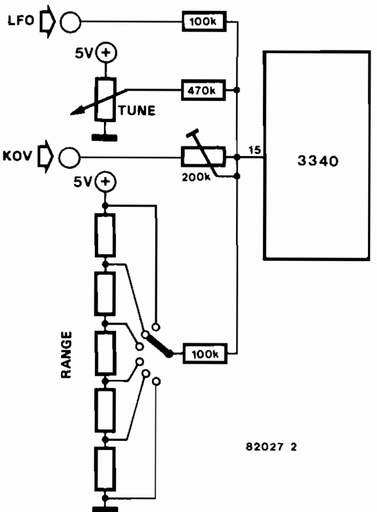

Figure 2. The various control voltages are connected to pin 15 of IC1 via a CMOS analogue switch.

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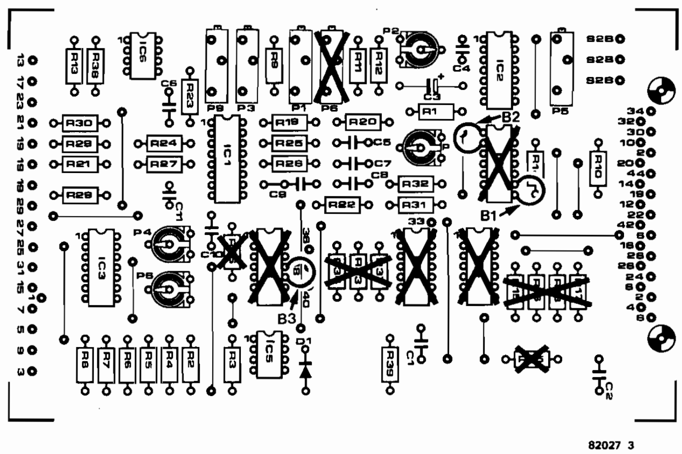

Figure 3. Only the marked components need be mounted on the printed circuit board for the time being.

–5 V respectively. The output voltage of A1 is also used to adjust the frequency range and pitch of the VCO. The output voltage of IC5 provides the negative supply requirement for IC1 and is fed to pins 1 . . . 3 of this IC.

The audio signals (squarewave, sawtooth and triangle) are fed from pins 4, 8 and 10 of IC2 via the buffer stages A2, A3 and A4 and a select switch (S2) before reaching the outside world.

Control voltages

Pin 15 of IC1 is the input for the various control voltages which determine the actual VCO frequency. A bias voltage is applied via a potential divider network (see figure 2). The values of resistors used determine the volt/octave characteristics of the corresponding control voltage source.

The control logic for the 'preset' and 'polyphonic' modes

Although the three 4066 CMOS switches

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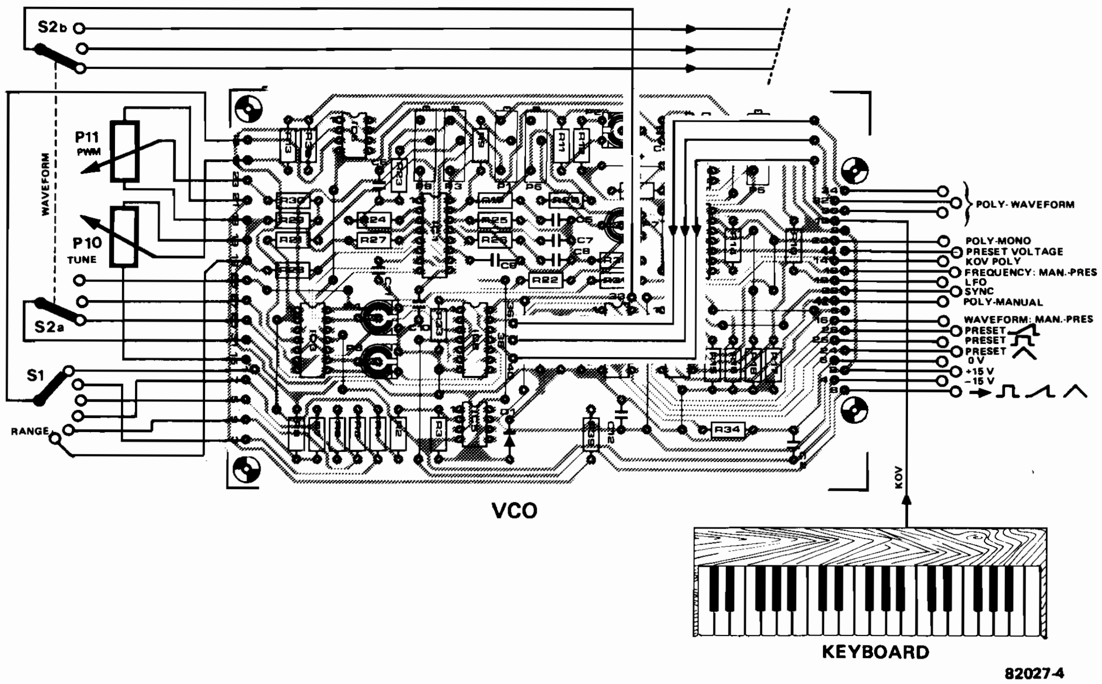

Figure 4. The external wiring of the VCO module.

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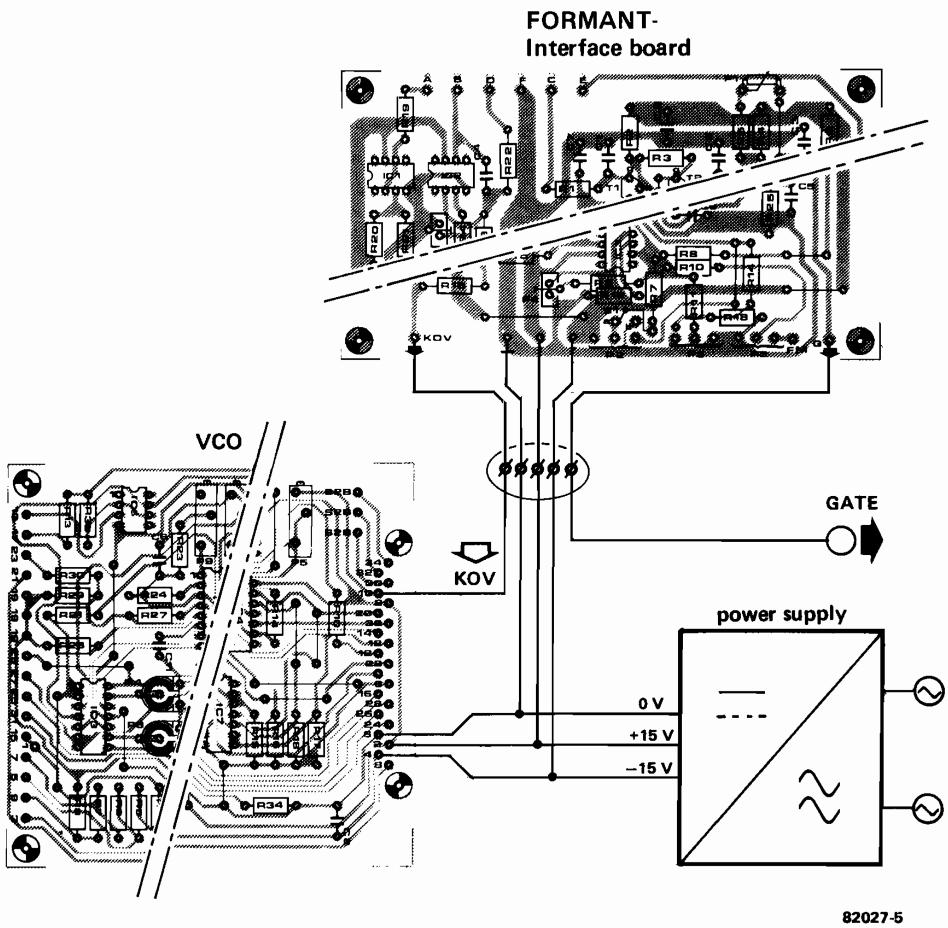

Figure 5. The sample and hold printed circuit board in the Formant keyboard is connected to the VCO module by means of a five-core cable.

and the 4001 are not required for the construction of an 'ordinary' synthesiser, the relevant copper tracks are already on the printed circuit board. Therefore, a future extension will not require the addition of another printed circuit board. Thus, the associated resistors and integrated circuits can be omitted for the time being.

This means that the wire links B1, B2 and B3 should be mounted in the IC socket instead of IC4 and IC7 . . . IC9. Links B1 and B2 supply the VCO with the control voltage from the keyboard, the range switch (S1) and the tune potentiometer P10. Link B3 provides a connection between the wiper of S2 and the output socket (see also figure 3). The wire links must be placed into the following positions:
- link B1; pins 8 and 9 of IC7
- link B2, pins 1 and 2 of IC7
- link B3; pins 10 and 11 of IC8.

A precise description of the function of the CMOS switches and the inverters will be dealt with in a future article

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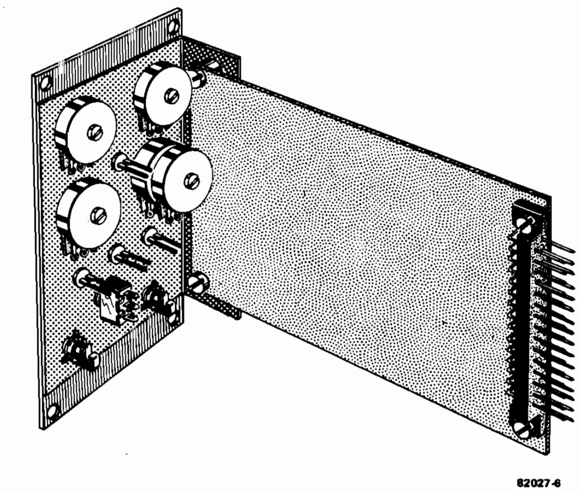

Figure 6. A suggested method of mechanical construction of each module for the synthesizer.

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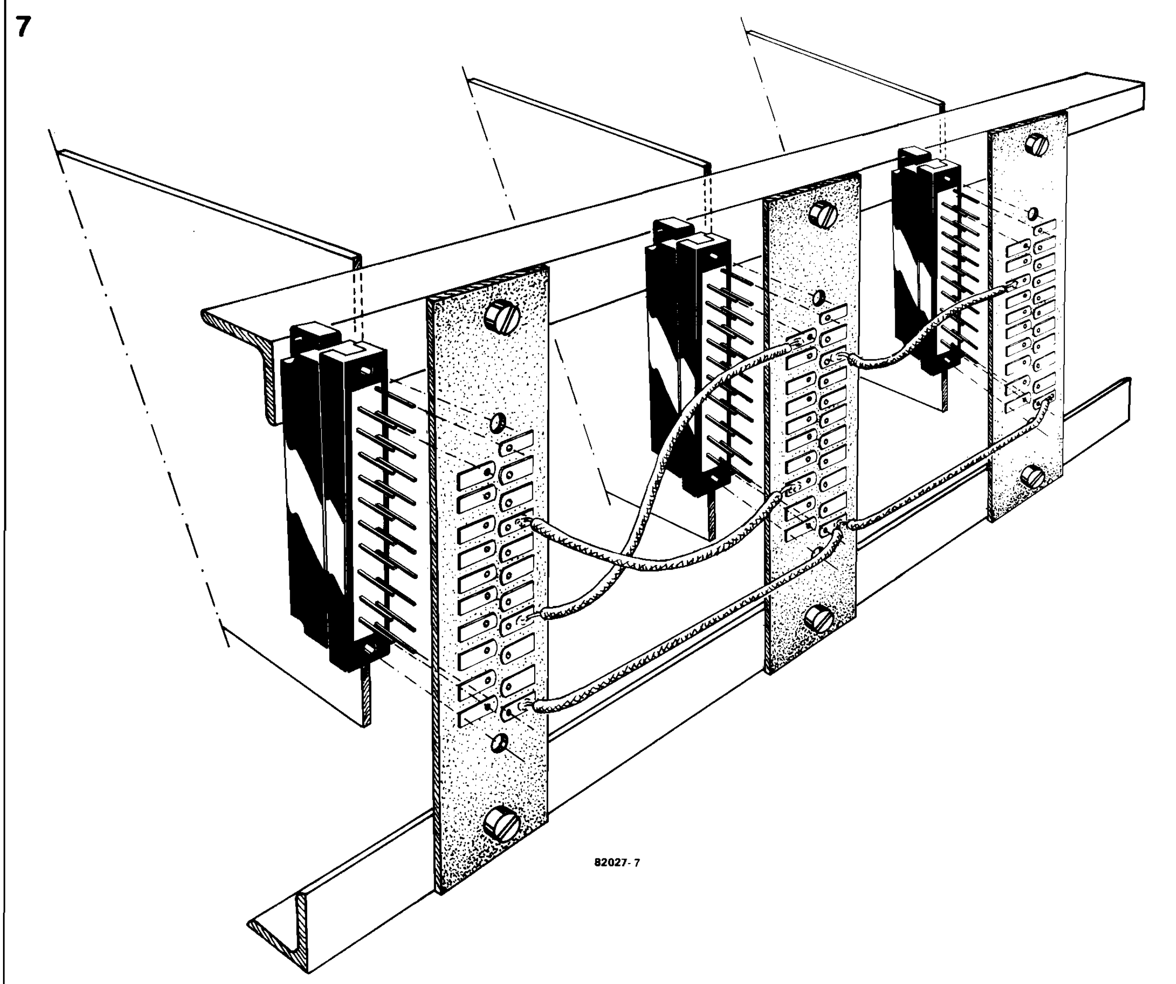

Figure 7. This illustration shows the rear of a card frame and how the connectors of the respective modules are fitted.

table 1

(IC2) 723	Pin 4 :	0 V	
	Pin 5 :	0 V	
	Pin 6 :	0 V	
	Pin 7 :	0 V	
	Pin 10 :	0 V	(IC removed from socket)
	Pin 11 :	+15 V	
	Pin 12 :	+15 V	
	Pin 13 :	0 V	
IC3 (TL084)	Pin 4 :	+15 V	
	Pin 11 :	−15 V	
	Pin 7 :	+15 V	
IC5,6	Pin 4 :	−15 V	

table 2

IC1 (3340)	Pin 1 :	−5 V	
	Pin 2 :	−5 V	
	Pin 3 :	−5 V	
	Pin 15 :	see text	(IC removed from socket)
	Pin 16 :	+11,05 Volt	
	Pin 5 :	see text	
	Pin 12 :	0 V	
	Pin 13 :	5 V	

which will also discuss the preset and polyphonic modes.

Construction

Figure 4 illustrates the printed circuit board for the VCO module with the connections numbered as shown in the circuit diagram. The Formant keyboard can be used to derive melodies from the VCO module. This keyboard contains a sample and hold stage. It has two power supply inputs, one KOV (keyboard output voltage) output and an output for the gate pulse; the latter is not required for the time being. The wiring between the keyboard and the VCO is shown in figure 5.

The tune and pulse width modulation (PWM) potentiometers as well as both change-over switches for frequency and waveform can be mounted on a small aluminium board for the present. This could be incorporated into a 19" rack (figure 6). A mini bus board allows interconnection between the standard-

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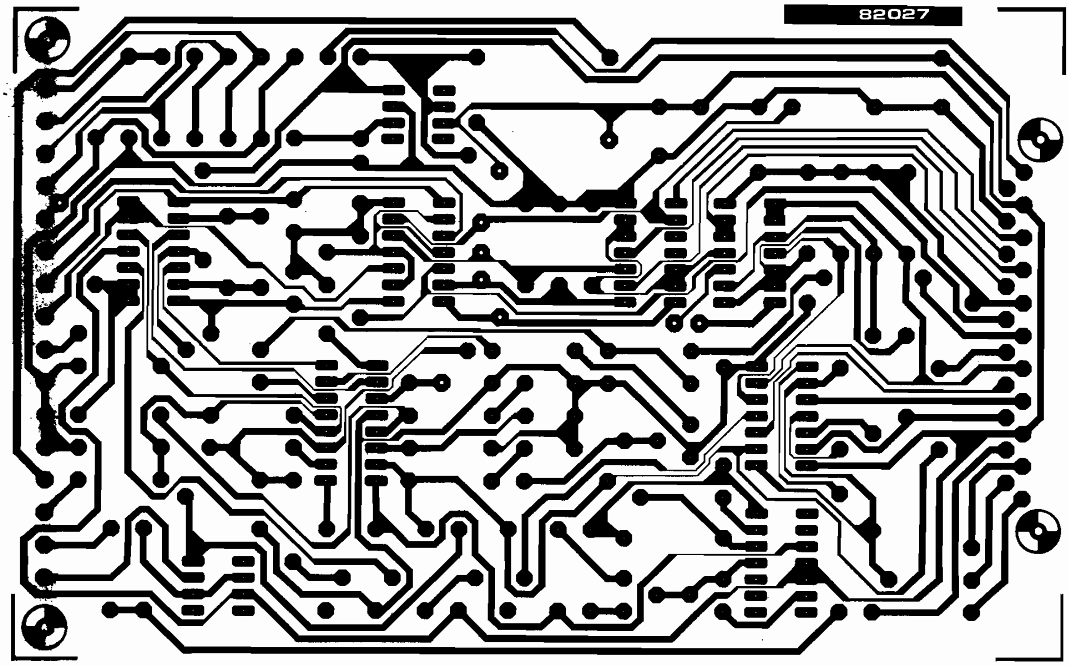

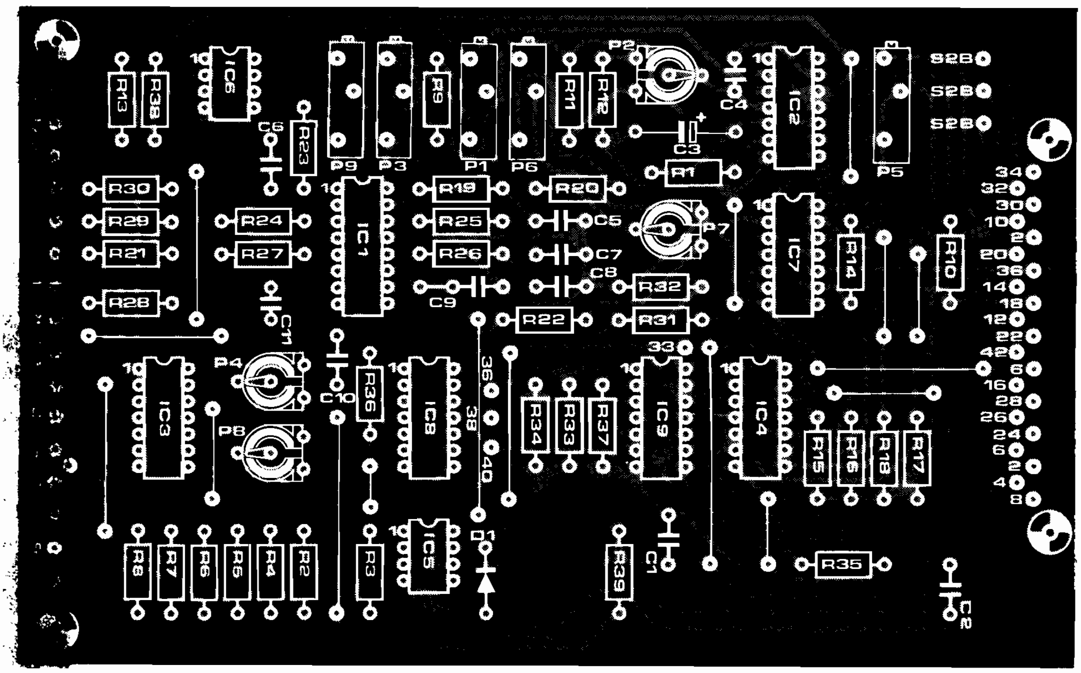

Figure 8. The printed circuit board and component layout for the VCO module. A minor printing error occurred on the component overlay. Connection 36 on the right-hand side should read 44.

ised modules without any problems, however, this may not hold for every card housing (see figure 7).

Operation

The power supply voltage should be connected and checked at the various IC-pins before the ICs are mounted. This avoids the possibility of damage to the expensive ICs if there does happen to be a wiring error or component fault somewhere.
The voltages at the various pins of the IC sockets should then be tested and should correspond to the values given in table 1. If this is the case, you can be sure that the circuit has been constructed correctly.
After disconnecting the supply voltage, IC2 (723) can be placed in its socket. The power supply is then re-connected and the voltage at pin 10 is adjusted to exactly 11.05 V by means of preset potentiometer P2. The voltage at the output of A1 is then adjusted by means of P3 and should be set to exactly 5 V. As opamp IC5 is connected as an inverter, the output of this device will automatically be −5 V. Subsequently, you should check that the voltages of +11.05 V, +5 V and −5 V are present at the corresponding pins of the socket for IC1 (see table 2).
The voltage level at the output of IC6 should change by one volt for each position of the range switch S1. This voltage change can be measured with a digital volt meter (DVM). The voltage at pin 5 of IC1 should be adjustable between 0 . . . 4 V with the aid of potentiometer P11 (PWM).
If all the supply voltages for IC1 are correct, this IC can be inserted into its socket. If you are the owner of a variable power supply, it is advisable to increase the supply voltage slowly. The current consumption can then be monitored to ensure that there is no short circuit.
After having taken all the necessary precautions the calibration can be carried out.

Calibration

The curve of the control voltage/frequency characteristic of the VCO is relatively linear. Consequently, the adjustment to the correct voltage level per octave is limited.
A DVM is required to check that the voltages at the output of IC6 are exactly 0, 1, 2, 3 V etc. For an acoustic check of the circuit, the output of the VCO (connection point 8 on the printed circuit board) should be connected to the input of an audio amplifier. Whereupon the setting of preset potentiometer P9 can be altered very slowly until the VCO frequency changes by an octave for each successive range switch position. Readers who do not possess a frequency counter can use an audio oscillator or a tuning fork. A word of warning: do not depend entirely on your sense of hearing, as it is not precise. (Even Elektor readers are only human!).
The tune potentiometer (P10) can be used to adjust the VCO frequency to give 'zero beat' when an 'auxiliary' sound source (such as a quartz tuning fork) is employed. A clear discord can be heard if the VCO frequency does not alter by exactly one octave.
After a little practice, this adjustment procedure becomes very simple. It is wise to bear in mind that if P9 is altered the frequency of the VCO changes. The latter must then be re-adjusted each time (using the tune potentiometer). A linearity correction in the upper frequency ranges of the VCO can be performed with the aid of preset potentiometer P7. The effect of this preset is very slight; with experimental set-ups the effect was nominal when the wiper of P7 was turned towards ground.
An aural adjustment is very difficult to perform when the keyboard is disconnected, due to the very low VCO frequency. For this purpose P1 should be adjusted so that the lowest octaves can be heard.

Connection of the keyboard

The control voltage output from the keyboard is to be connected to contact 10 (potentiometer P5) of the printed circuit board. This potentiometer is adjusted so that the VCO frequency alters by one octave when two keys having a difference of one octave are pressed one after the other. To be absolutely sure, this procedure should be repeated several times with other keys and different settings of P1 and S1.
The final adjustment of P1 is accomplished as follows:
Select the highest octave with the aid of the range switch. Turn the tune potentiometer, which has an adjustment range slightly greater than one octave, to the mid position. Turn off the 'coarse octave' switch on the Formant keyboard and depress the highest key. Using the tuning fork mentioned previously, the VCO frequency is adjusted by means of P1 until the key producing tone A corresponds to the frequency of the tuning fork.
The overall octave position is a matter of taste; P1 can be adjusted so that the highest note on the keyboard is placed just within the threshold of audibility. Whether this is meaningful or not is another question.
The coarse octave switch on the Formant keyboard enables the VCO frequency to be shifted into other ranges.

Setting the signal amplitudes

Once construction of the circuit is complete, the output waveform from the VCO can be selected by the three position switch, S2. The triangular signal will sound lower in volume than a sawtooth waveform of the same amplitude; due to the smaller [illegible]er of harmonics. When adjusting [illegible] preset potentiometer P8 and P4 th[illegible]wing items should be borne in mi[illegible]8 has to be adjusted so that the a[illegible]de of the triangular signal reaches [illegible]mum without becoming trapezo[illegible] Subsequently, P4 should be adju[illegible] that the audible volume of the [illegible]tooth signal correspond to the vol[illegible]f the triangular signal. The duty c[illegible]f the squarewave signal can b[illegible]usted between 0 and 100% by [illegible]s of potentiometer P11. Both e[illegible]f the triangle waveform and the l[illegible] edge of the sawtooth wavefor[illegible] extremely linear. The trailing edges of the squarewave and sawtooth waveforms are very steep and can therefore hardly be distinguished on an oscilloscope.
If desired, preset P8 can be mounted on the front panel (as a potentiometer) so that the triangular signal can [illegible] trapezoidal for various 'effec[illegible]

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Parts list

Resistors:
R1,R11 = 2k2
R2 . . . R8 = 4k7 (metal film)
R9,R10,R14 . . . R18, R33 . . . R3[illegible]00 k
R12,R22,R39 = 4k7
R13 = 470 k
R19,R26 = 470
R20,R21 = 560 k
R23 = 22 k
R24 = 5k6
R25 = 1k8
R27 = 1M5
R28,R29,R31 = 10 k
R30 = 15 k
R38 = 100 k (metal film)
P1 = 100 k multiturn preset
P2 = 1 k preset
P3 = 10 k multiturn preset
P4,P7,P8 = 10 k preset
P5,P6 = 200 k multiturn preset
P9 = 20 k multiturn preset
P10,P11 = 10 k lin potentiometer

Capacitors:
C1,C2 = 330 n
C3 = 10/25 V
C4 = 470 p
C5,C7,C8 = 10 n
C6,C10 = 0 1
C9 = 1 n polystyrene
C11 = 1 n

Semiconductors:
IC1 = CEM 3340
IC2 = 723
IC3 = LM 324 (TL 084)
IC4 = 4001
IC5,IC6 = LM 741
IC7 . . . IC9 = 4066

Miscellaneous:
S1 = 6 pole rotary switch
S2 = dual ganged 3 pole rotary sv