Designing a proper layout for the bus board was anything but easy. Unlike computer circuits, almost every connection of the three printed circuit boards (VCO, etc.) requires a line to the 'outside world'. Figure 1 shows the circuit diagram of the bus board and its inputs. Particular attention must be paid to the VCO board, because the numbers shown do *not* correspond to those indicated on the printed circuit board. This irregularity was brought into line after the other boards were numbered.

Figure 1 shows the new numbers which are printed on the bus board. In order to cross-refer to the old (original) connection numbers (on the VCO) table 1 should be used.

Let's look at the connections of the bus board from top to bottom to see exactly what their individual functions are (figure 2)!

All the printed circuit boards have the same supply voltage connection points (14 . . . 16). For this purpose, three tracks run the full length of the bus board. They lead to the connection points 40, 36 and 38 of board 1 (VCO), to 18, 20 and 22 of board 2 (DUAL ADSR) and to 6, 18 and 26 of the ... board (VCA-VCF).

The connections can be found ... easily in two ways:

- look at the number shown on the printed circuit boards;
- mount the analogue boards on the bus board. Now turn the bus board so that the copper side is facing you ... the component side of the analogue modules are towards the left. The ...

the 'poly bus'

this bus will save you a lot of time . . .

Constructors who intend to make a complete polyphonic synthesiser with the polyphonic keyboard by using the printed circuit boards described in previous articles will be confronted with a complex problem: wiring up the connections between up to 30 printed circuit boards! This will tax the patience of even the expert. For this reason a bus board has been designed to contain three analogue modules (VCO, DUAL-ADSR, VCA-VCF) at a time, helping to keep the amount of wiring to the bare necessities and avoid any errors. Also included in the article are a few suggestions for the construction of the complete synthesiser.

1

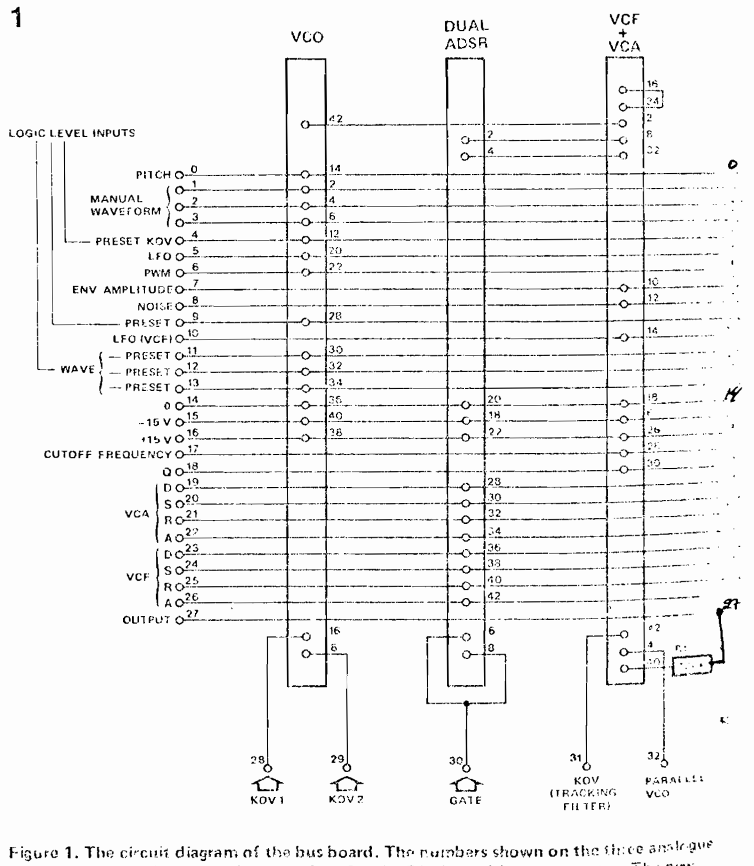

Figure 1. The circuit diagram of the bus board. The numbers shown on the three analogue modules indicate the order of connections for the 21-pin multiway connector. The new connections for the VCO can be found by numbering the pins (even numbers) as indicated in table 1. These inputs and outputs are described in detail in the text.

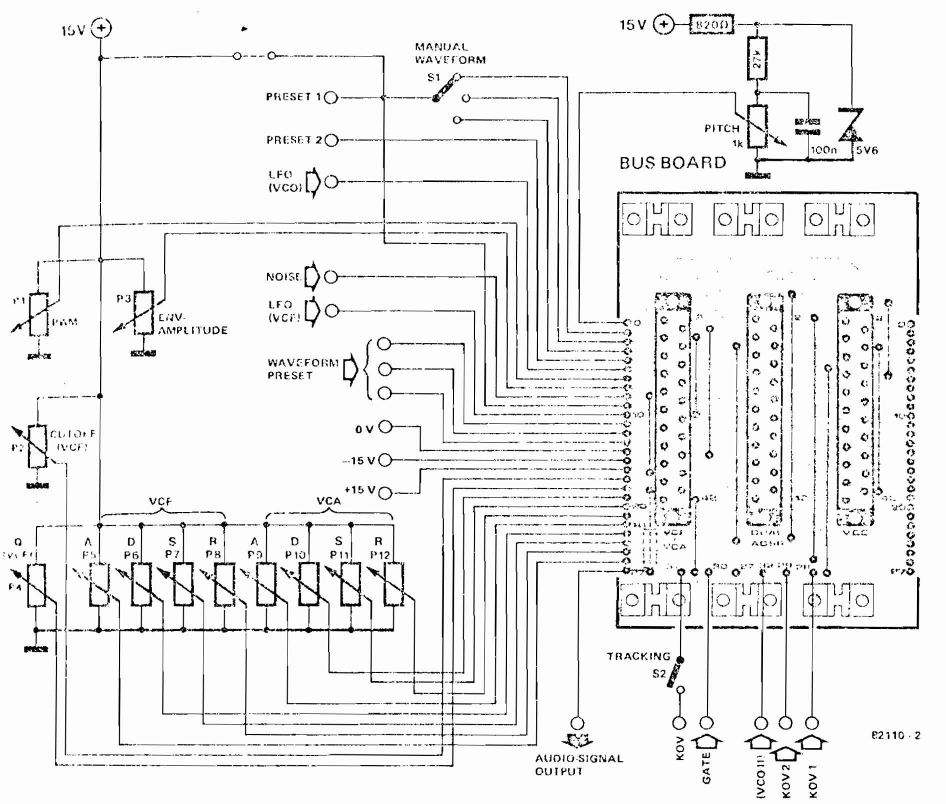

Figure 2. Only a single bus board must be connected to the controls on the front panel via connections 1 . . . 27. The other bus boards are interconnected by means of wire links. Connections 28 . . . 32 must be separately linked for each individual channel.

Table 1. Connections of the VCO multipoint connector.

[illegible] 1981	New: bus board
34	2
32	4
30	6
10	8
2	10
20	12
36	14
14	16
18	18
12	20
22	22
42	24
6	26
16	28
28	30
26	32
24	34
6	36
2	38
4	40
8	42

nections are numbered with even numbers (connector pin multiplied by 2), beginning from the top.

The circuit at the left side of figure 2 only has to be constructed once. All the other bus boards can be connected together by means of 27 wire links. Each channel receives specific information via connections 28 . . . 32. These are the control voltages and corresponding gate pulses supplied by the polyphonic keyboard.

Connection 0

The tuneshift board connected to the input unit makes it possible to change the pitch of the polyphonic synthesiser one semitone at a time, in either direction.

An infinite variation of the VCO frequency to simulate other instruments cannot be realised by the processor, due to the digitalisation of the KOV. For this task an adjustable DC voltage must be fed to the VCOs of all channels (pitch control). A 1 kΩ potentiometer, which is connected to the positive supply voltage via a series resistor, serves to shift all VCOs simultaneously by approximately one full tone.

A simple solution for mounting the zener diode, capacitor and series resistor is to solder them directly to the tags of the potentiometer. It is advisable to cover them with a 'tube' of insulation sleeving to prevent the possibility of 'shorts'.

Changes to the VCO board

The 'pitch' voltage mentioned earlier is fed to input 36 (new number: 14) of the VCO board via bus line 0. (This input is indicated as number 44 in the circuit diagram.) Those constructors who do not wish to make use of the switching facility between parallel and separate operation of the VCOs must fit 4 wire links to the socket of IC7 (1, 2/3, 4/8, 9/10, 11). In this case the track between pin 9 of IC7 and P5 will have to be

broken and pin 9 reconnected to the track that leads to pin 15 of IC1. Pins 8, 9 and 10, 11 must be interconnected, irrespective of whether parallel or separate operation is preferred.
Before coming to the switching facilities of the KOV it is advisable to mount wire links in order to short out all the switches in IC7. A wire link is also needed between pins 8 and 9 for the following reasons:
In the monophonic synthesiser the voltages at the tune potentiometer and the range stage switch reach the VCO control input via the KOV switch. Without these voltages the VCO frequency would be below 1 Hz at a control voltage of 0 V (from the D/A converter of the keyboard). However, as some readers may know, a suitable tone for musical purposes is only produced at a control voltage of approximately 5 V. Therefore a voltage of 5 V must be fed to range input 13 via a wire link to point 13 (output of A1). In this case, IC6 will not be used. But, pins 2 and 3 of this IC must be linked together.

3

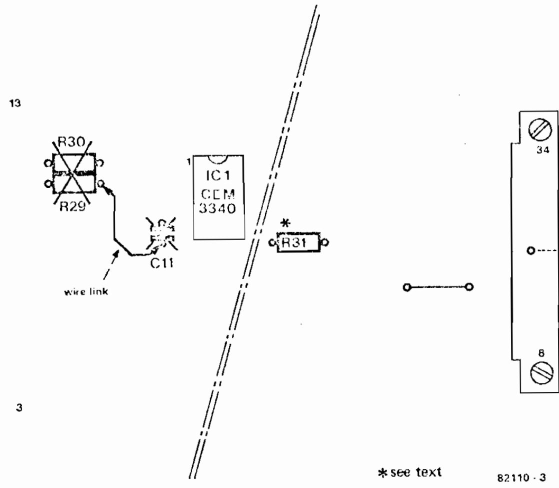

Figure 3. A wire link must be inserted and several components replaced in order to allow the pulse width of the squarewave VCO signal to be varied. Remove C11, R29 and R30 and insert a wire link as shown here. The value of R31 becomes 33 kΩ.

Calibration of the VCOs

After all wire links required have been inserted we can start with the calibration procedure. The following measures will simplify the procedure considerably:

- Remove P1! The VCO of a polyphonic synthesiser must be extremely stable. Despite the fact that P1 is a potentiometer the voltage range covered by one turn is too wide and therefore not stable enough for polyphonic purposes. So, out it goes!
- Presets P5 and P6 are replaced by a low tolerance precision resistor (metal film), because the polyphonic keyboard supplies exactly 1 V per octave. The critical adjustments of P5 and P6 during calibration are therefore dispensed with.
- Now P9 must be set so that an increase in control voltage (1 V) will double the frequency of the VCO.
- Despite the identical control voltages, not all of the VCOs will oscillate at the same frequency, due to component tolerances. As a result, some compensation for variations in the control voltages supplied to each VCO is required. This can be as much as 300 mV and a D/A converter circuit has been designed for this purpose. Due to lack of space in this issue this circuit will be described at a later date.

4

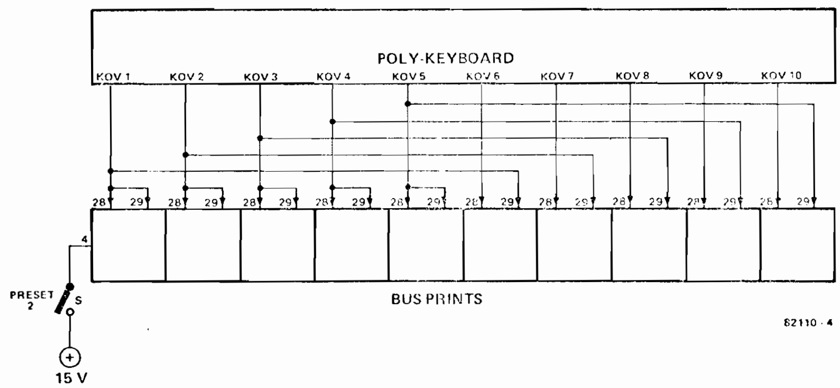

Figure 4. It is possible to connect two channels to one control output, thanks to the switch 'preset 2'. This means that only 5 keys can be played simultaneously (in the 10 channel version). Two channels having the same frequency will then be heard when depressing one key, which gives the well-known beat effect.

5

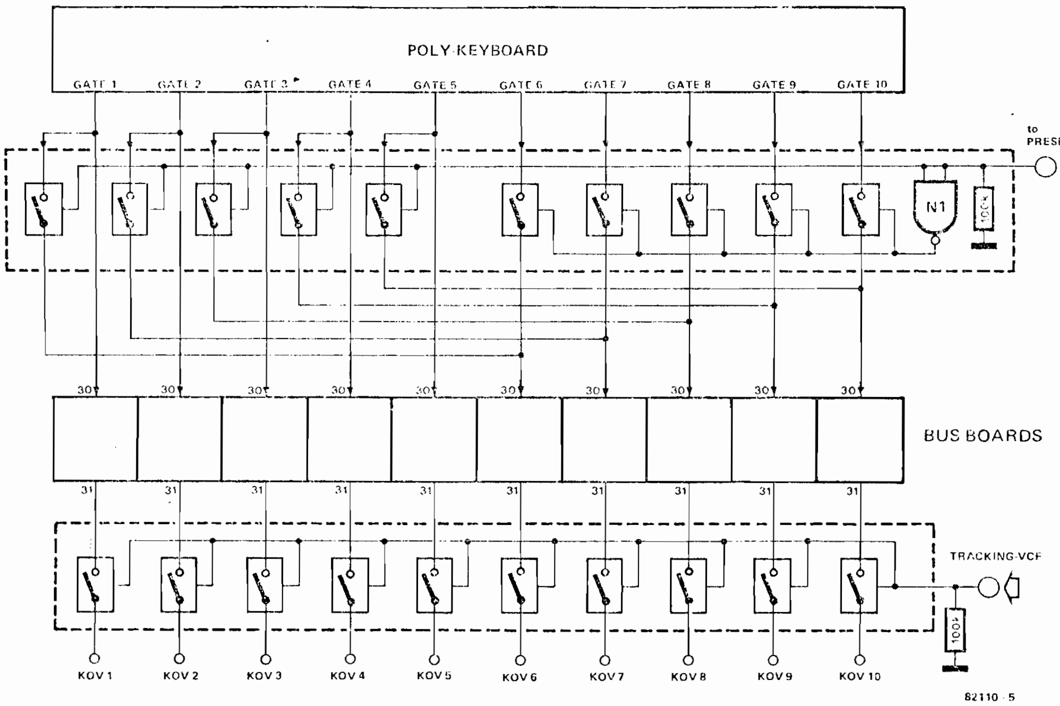

Figure 5. The gate pulses must be routed to perform the triggering, as shown here. This circuit must be constructed on a piece of Veroboard since there are no switches present on the analogue boards to take care of this task. The well known 4066 ICs are used as switches for this purpose. The 'tracking' inputs of all bus boards (connection 31) can also be simultaneously controlled by means of CMOS switches. The wiring of the ICs should not cause any problems. The positive supply voltage of the CMOS switches and the gate must be connected to pin 14 of each IC and pin 7 must be connected to ground.

Connections 1, 2, 3, 9, 11, 12 and 13

A logic level at 'preset 1' (+15 V or 0 V) determines whether the waveform of the VCO can be set by the front panel switch (S1) or by information stored in the preset memory. Without the preset facility, the input indicated as 'preset 1' must be connected to +15 V. This voltage is fed to inputs 1, 2 and 3 by S1.

A glance at the VCO circuit diagram (Elektor, December 1981 issue) shows that these inputs are connected to the control inputs of the waveform generator switch IC8. Pin 9 of the bus board leads to the inputs of N4. It should be noted that gate N4 is incorrectly drawn in figure 1 (December) as a NAND when it is in fact a NOR gate (4001). A 4011 can be used without difficulty because N1, N2 and N4 function purely as inverters, N3 is not needed. The logic '1' at N4 switches off IC9 so that information coming from the preset memory (pins 2, 4, 8, 9) will not affect the circuit. Connections 11 . . . 13 of the bus board, which lead to pins 2, 4 and 8 of IC9, do not have to be connected yet!

Figure 4 published in Elektor December 1981 clearly indicates that three additional wire links are required. The three soldering points next to IC8, nos 36, 38 and 40, must be connected to the three soldering points in the top right-hand corner. Although it is not the ideal approach, it certainly is much cheaper than a double-sided board. All other connections shown in this figure are irrelevant.

Input: preset 2

The VCO board contains an electronic switch for selecting two different control voltages: KOV 1 and KOV 2. The logic level at input 4 of the bus board determines which of the two voltages controls the VCO frequency (KOV 1 via connection 28 and KOV 2 via 29).

The KOV must be fed to connection 28, if input 4 is not connected.

Inputs 5 and 10: LFO

An LFO signal at input 5 modulates the frequency of all the VCOs. Input 10 is connected to all the VCFs: an LFO signal changes the cutoff frequency of all the filters.

Input 8: Noise

A noise signal connected to this input is filtered by each of the VCFs, thus producing chords.

Connection 31: Tracking filter

This connection must be fed to the KOV of the corresponding channel, during the tracking mode, using a single-pole switch. With several channels a central switching system using CMOS ICs is recommended. One possibility is shown in figure 5. This procedure is also followed when connecting the VCOs in parallel.

Connection 32: VCO II

We are dealing with the well known and often described beat effect that occurs when at least 2 VCOs oscillate at (almost) the same frequency. In the polyphonic synthesiser this effect can only be produced with 2 VCOs or more per signal. Due to the fact that the bus board can only contain one VCO at a time, a solution was sought. As a matter of fact, two alternatives were found:

The economical version. It is possible to connect the second half of all channels to the control voltages of the first half, thanks to the input 'preset KOV'. The number of keys that can then be de-

6

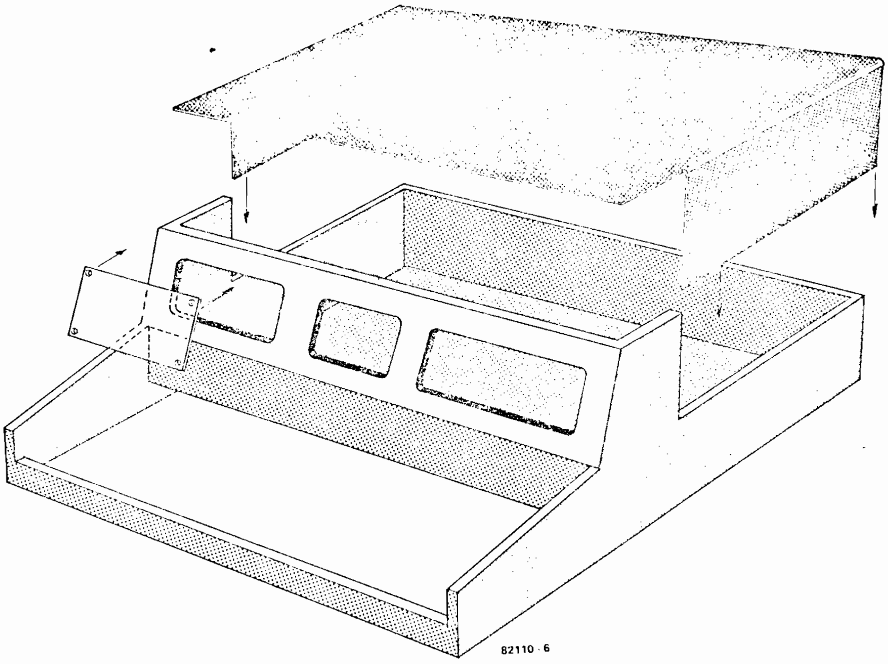

Figure 6. A suggestion for constructing the cabinet for the Polyformant is illustrated here. Readers may wish to base their design on other equipment already in their possession. The cabinet must be fairly strong as it may well be asked to take quite a few knocks in use.

pressed simultaneously is reduced by 50% (figure 4).
The expensive version: Each channel receives an additional VCO which is not mounted on the bus board and its signal output must be attached to bus connection 32.

Connection 27: audio signal output

Thanks to the resistors R1 (100 kΩ) on the bus boards it is possible to connect the audio signal output directly to the inverting input of the opamp mixing stage.

The remaining connections

All other bus connections must be linked to the 12 potentiometers on the front panel as indicated in figure 2. Their functions were already described in previous articles.

Further changes to the analogue boards

The external connection for the pulse width modulation (PWM) of the VCO is now via pin 22 on the connector of the VCO board (with the modifications as shown in figure 3).

VCF/VCA board

The signal inputs for the VCOs lead from the multiway connector (points 2 and 4) to the opposite side of the board (connections 1 and 3). As both potentiometers meant for the volume control may be left out, wire links must be soldered between 1/7 and 3/9.

Wire links in the CMOS IC sockets

1. VCO: see the changes in the previous sections.
2. VCA-VCF: Except for the two CMOS switches, all ICs must be mounted in their proper places. This calls for some minor changes to the wire links that already exist in the sockets:
   - IC3 socket: 1-2 and 10-11 instead of 8-9, 3-4.
   - IC4 socket: 1-2 instead of 3-4.
3. ADSR: 3-4 and 10-11 for all CMOS IC sockets.

Gate triggering

The small circuit shown in figure 5 is for gate triggering and can be constructed on a piece of Veroboard. This circuit allows a choice to be made between a fixed VCF frequency (tracking) and a VCF frequency controlled by the KOV.

General calibration

We cannot give an absolutely definite pitch indication, as this is, as mentioned earlier, a matter of taste. Constructors who wish to tune their instrument according to the official standards can find precise frequency indications in the corresponding technical literature.

Frequency drift

What with ten VCOs working independently, some readers may wonder what the frequency stability is like. As every pianist knows, the slightest shift in pitch will make his/her instrument sound awful. Unfortunately the same is true of all other polyphonic instruments. According to manufacturers, such problems cannot arise where VCOs are concerned. To be on the safe side, Elektor's designers tested them and came to the same conclusion. Nevertheless, the instrument must still be protected against large temperature fluctuations and a stable voltage supply helps avoid problems of this kind.

The power supply

Due to the large number of printed circuit boards the power supply must be able to deliver quite a lot of current. Remember that each analogue channel requires a current of approximately 190 mA (positive and negative supply).

7

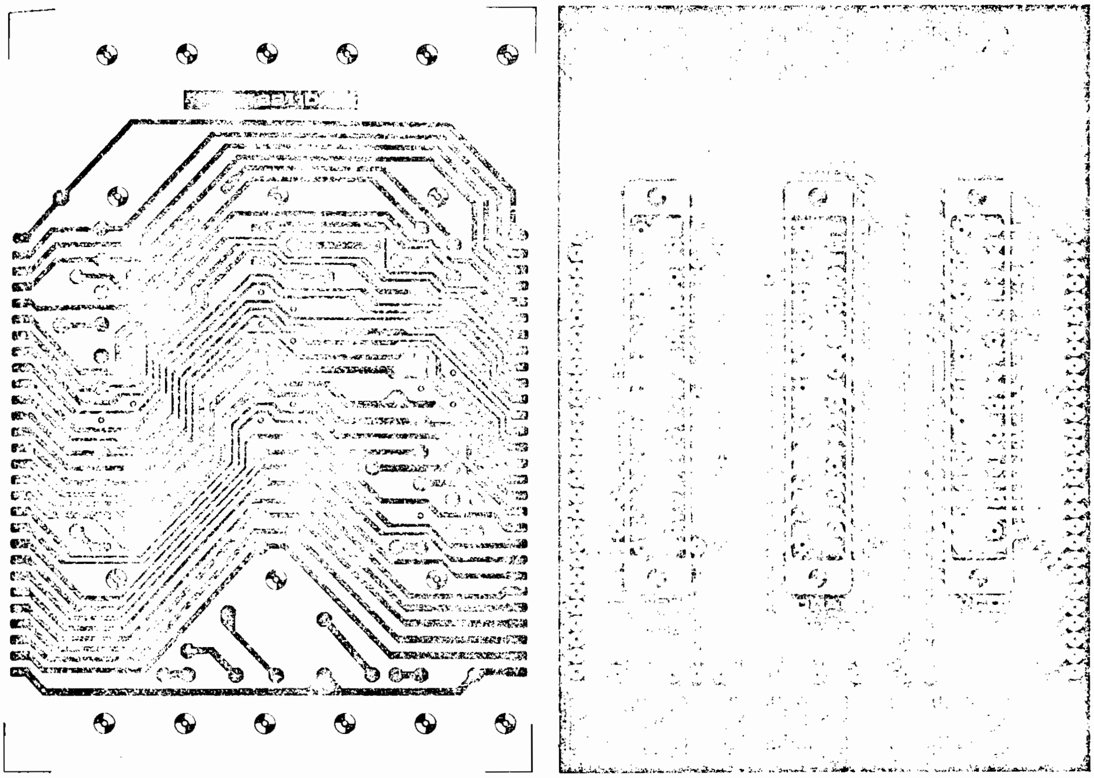

Figure 7. The track pattern and component overlay of the bus board.

Table 2

All changes of the VCO board when used for the polyphonic synthesiser.
Additional wire links and changes

1. Socket IC7: 3, 4/10, 11/1, 2/8, 9
   (If no KOV switching is desired)
2. Socket IC6: 2, 3
3. Connect soldering point 36 (next to IC8) to pin 2 of the multiway connector (new indication)
   Connect soldering point 38 to pin 4
   Connect soldering point 40 to pin 6
4. Link connection 13 to connection 15
5. Remove C11, R29 and R30. Mount a wire link as shown in figure 3. Replace R31 by a resistor having a value of 33 k.
6. Remove P1!
7. Replace P5 and P6 by a metal film precision 100 k resistor!
8. With KOV switching
   Socket IC7: Wire links between 8, 9 and 10, 11.
   Interrupt copper track from pin 9 to P5!
   Make a wire link from pin 9 to pin 2.
   Mount IC7!

Parts list

Resistor:
R31 see text

Miscellaneous:
three 21 pin multiway connectors
six card supports
for the printed circuit boards

These components are only sufficient for one complete bus board.

Practical hints for construction and wiring

The interconnection wiring of the polyphonic synthesiser has been reduced considerably by the use of the bus boards. Obviously, due to the large number of switches and potentiometers on the front panel, it has not been possible to eliminate all the connection wires completely.
We strongly recommend the use of card supports on the bus boards. They go a long way in helping avoid damage to the boards and connectors when fitting and removing cards and they are not that expensive.
The construction of a strong wooden housing is not too difficult. However, please remember that a wooden cabinet is bound to make the synthesiser rather heavy to carry around. It will also need a fairly substantial stand. One possible design for a suitable case is illustrated in figure 6. But readers are welcome to use their own ideas.
The bus boards can best be mounted with aluminium brackets, which in turn can be attached to the keyboard assembly.

Hints for calibrating the analogue boards

It is rather difficult to reach the presets during calibration once the boards have been inserted into the bus boards. It is therefore advisable to use an extension cable consisting of a 21-way ribbon cable together with a plug and socket. This will enable the board to be calibrated with ease.
This is not the end of the story. A further article will be appearing, covering the output unit, in the next issue of Elektor — if all goes well!