PE Sound Synthesiser 11

KEYBOARD

By G.D.SHAW

THE article this month deals with the remainder of the electronics sited within the keyboard unit and details the divider system, the analogue memory or hold circuits, modulation amplifiers, envelope shaper/v.c.a.s and mixer. The overall system has been extensively redesigned to take maximum advantage of the greater versatility of the logarithmic v.c.o.s and with the aim of improving the live performance capability of the instrument.

BLOCK SCHEMATIC

A block schematic arrangement of the keyboard unit is shown in Fig. 11.1 and the unit has been designed to accommodate a four-octave Kimber-Allen keyboard. The specified keyboard may be obtained through the Electronic Organ Constructors Society at 4 Lees Barn Road, Radcliffe-on-Trent, Nottingham NG12 2DS. The E.O.C.S are also able to supply the contact assemblies and mounting strips. The type of contact assembly required is the G.B.-2 paired contact unit, also by Kimber-Allen.

Although a four-octave keyboard is specified it should be made clear that smaller—or larger—units may be employed with no changes to the circuitry other than the adjustment to the number of divider resistors employed. With respect to the use of smaller keyboards, the E.O.C.S. have informed the author that they have a limited number of two-octave organ keyboards by Herrburger Brooks. These are full sized timber keys faced with plastic and mounted on a hardwood frame. The keys themselves are in reverse colours with black naturals and white sharps, and although they will require to be sprung by the constructor, the additional work required is reflected in the attractive pricing of £5 per keyboard.

Reverting again to Fig. 11.1 it will be seen that the keying system is divided into two channels each channel having its own electronic assemblies and signal path. Signals from both channels join together in the final circuit, a simple virtual-earth mixer. The purpose of this arrangement is to allow a rhythm accompaniment and melody line to be programmed at the same time, channel 1 programmed by the upper 31 keys and channel 2 by the remainder.

The tuning arrangement allows the transition between the two channels to be musically consecutive., Spread apart by one or more octaves or the channels juxtaposed in terms of frequency with the 31 note channel providing a bass line to a treble channel 2. Since the combined effect of the tuning controls is continuously variable there are a number of intermediate possibilities such as channel 2 dupli-

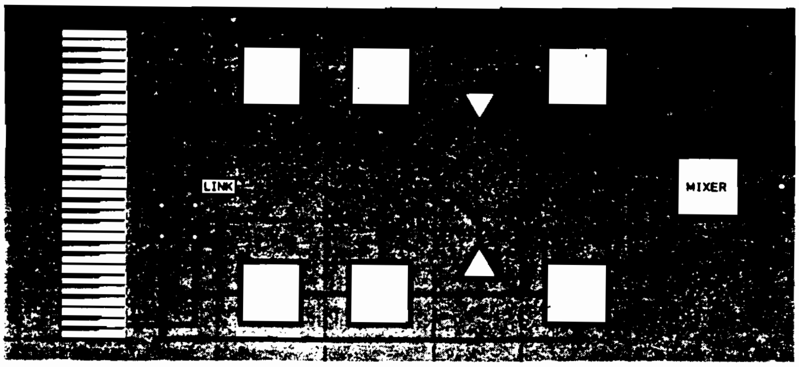

Fig. 11.1. Block schematic of keyboard unit

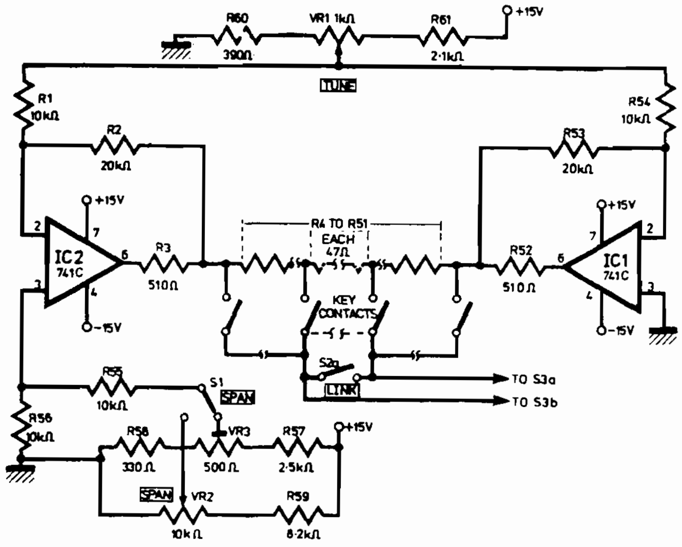

Fig. 11.2. Keyboard divider network

COMPONENTS . . .

DIVIDER

Resistors
R1 10kΩ
R2 20kΩ
R3 510Ω
R4–R51 47Ω (48 off)
R52 510Ω
R53 20kΩ
R54–R56 10kΩ (3 off)
R57 2·5kΩ
R58 330Ω
R59 8·2kΩ
R60 390Ω
R61 2·1kΩ
All 2% metal oxide

Integrated circuits
IC1–IC2 741C (2 off)

Potentiometers
VR1 1kΩ semi-precision wire-wound
VR2 10kΩ midget moulded linear carbon
VR3 500Ω cermet

Switches
S1 s.p.c.o. miniature toggle
S2 d.p.c.o. miniature toggle

cating sections of channel 1 or, in more bizarre terms, both channels programmed in different keys.

The programming voltage from the keyboard is led to a memory circuit which holds the last voltage entered until such time as a new voltage is programmed or until the hold circuits are grounded. The output voltage from the hold circuit is used to program its respective v.c.o. to the desired frequency which is then amplitude modulated in the envelope shaper/v.c.a. Triggering of the envelope shaper takes place each time a key is depressed in the appropriate channel and each envelope shaper is provided with separate attack and decay controls together with an additional percussive attack facility which may be switched in as desired.

Frequency modulation between oscillators may be achieved by means of the modulation amplifiers which have sufficient gain to swing the frequency of the v.c.o.s through the entire audio spectrum. Finally, a link switch is provided to enable both channels of the system to be programmed in parallel.

THE DIVIDER NETWORK

Fig. 11.2 shows the theoretical circuit of the keyboard divider network in which resistors R4–R51 inclusive form the actual divider which is "floated" between the outputs of two operational amplifiers. The output of IC1 is coupled to the high frequency end of the divider and IC2 to the low frequency end. R60, VR1 and R61 together form an adjustable divider which is coupled to the inverting inputs of both i.c.s. Thus, by means of VR1, the main tuning control, the voltage on output of the i.c.s may be swung through a range of rather more than 8 volts.

Since this latter effect will be equal at both ends of the keyboard it is necessary to apply an offset to one of the i.c.s in order that a voltage differential will exist across the divider chain. The offset is applied to the non-inverting input of IC2 through the medium of either one of two divider chains.

SPAN FACILITY

R57, VR3, R58 provide what has been termed the fixed span facility with the preset VR3 having sufficient swing to enable the V/Octave range to be adjusted between about 400mV/octave to rather more than 1V/octave. R59, VR2 provide the variable span facility which is adjustable over a range of about 8·0V. The setting of VR3 is normally adjusted so that one octave width on the keyboard spans precisely one frequency-octave. VR2 on the other hand enables the frequency spread of one keyboard-octave to be varied between a fraction of a semitone (micro-tones) to several tens of semitones (macro-tones). The actual effect, in terms of frequency range, resulting from the swing on both VR2 and VR3 will depend very much on the requirements demanded by the v.c.o. as a result of the "Law Adjust" setting.

The exact value of the divider resistors R4 to R51 is not too critical except that they should be of sufficiently low a value so that the combined loading of the v.c.o.s does not cause a measurable change in the voltage at any point on the divider. Values between 10 and 60 ohms should meet all the necessary criteria. For best results, however, it is important that, whatever the nominal value of divider resistor chosen, the individual resistors are

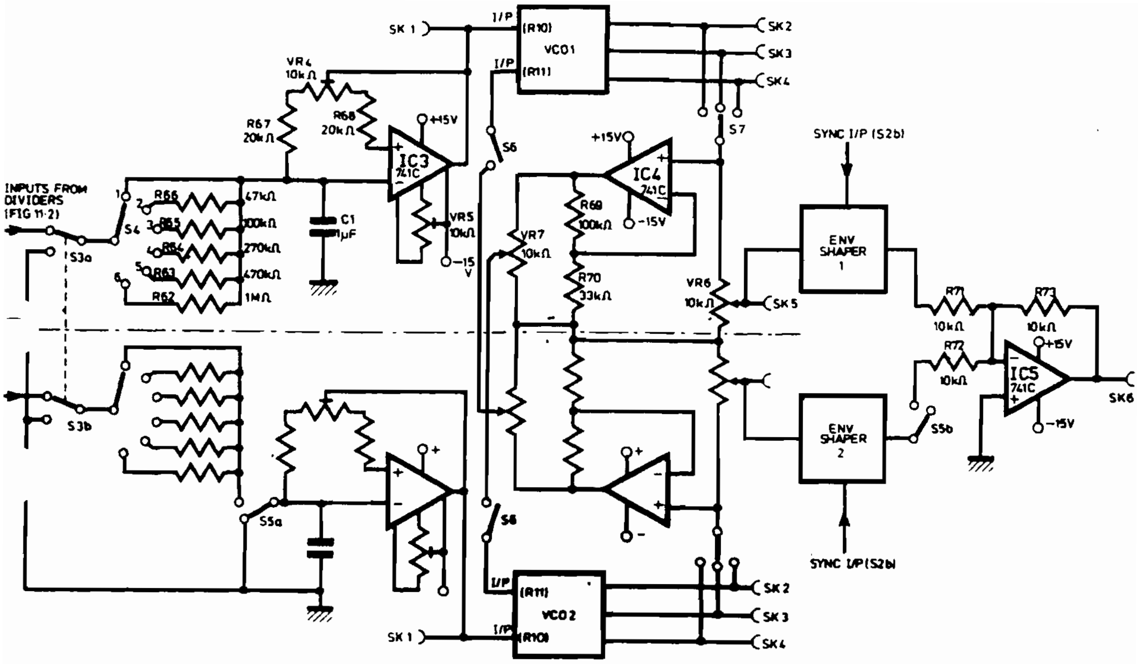

Fig. 11.3. Circuit of hold, modulation amplifier and mixer for both channels with v.c.o. interconnections. The component values for the mirrored hold and modulation amplifier circuits are identical

COMPONENTS...

HOLD CIRCUIT (2 off)

Resistors
R62 1MΩ 5% carbon
R63 470kΩ 5% carbon
R64 270kΩ 5% carbon
R65 100kΩ 5% carbon
R66 47kΩ 5% carbon
R67 20kΩ 2% metal oxide
R68 20kΩ 2% metal oxide

Potentiometers
VR4–VR6 10kΩ 15 turn cermet

Capacitor
C1 1μF 63V polyester

Integrated Circuits
IC3–IC4 741C

Switches
S3 2-pole 6-way
S4 d.p.c.o. toggle
S5 d.p.c.o. toggle

MODULATION AMPLIFIER (2 off)

Resistors
R69 100kΩ
R70 33kΩ

Integrated Circuit
IC4 741C

Potentiometer
VR7 10kΩ midget moulded linear carbon

Switches
S6 s.p.c.o. miniature toggle
S7 2-pole 3-way

MIXER

Resistors
R71–R73 10kΩ (3 off) 5% metal oxide

Integrated Circuit
IC5 741C

as closely matched to the nominal value as possible. It is particularly important that the ohmic value of any 12 consecutive resistors in the divider should be a close match with any other selection of 12 consecutive resistors.

The junctions between individual resistors in the divider are hard wired to the moving contact of their respective contact assemblies mounted below the keyboard, the fixed contacts being joined into two bus-bar units which can be joined by means of a link switch. A similar arrangement is employed for the second pair of contacts which serve to provide the sync pulse necessary for the envelope shapers.

ANALOGUE MEMORY

The divider voltage resulting from the depression of any particular key is routed into the analogue memory circuits via S3 and S4 as shown in Fig. 11.3. The purpose of the hold circuit is to retain the last programmed keyboard voltage for sufficient time to enable the desired tone processing to be completed. For example, with S4 in position 1, the depression of a key is sufficient to cause C1 to become charged to the value associated with that particular key. At the same time a sync-pulse is routed to the envelope shaper which, if it is set to provide a rapid attack, will turn on the v.c.a. and allow the oscillator tone to be heard. If the envelope shaper is also set to provide a long decay, the oscillator tone will immediately begin to die away.

In operation the hold circuit utilises the common-mode rejection of the 741 operational amplifier to provide a very high input impedance. Positive and negative feedback are applied by means of R67 and R68 with VR4 serving to provide a balance between the respective levels of feedback to the inverting and non-inverting inputs of the amplifier. C1 is the reservoir capacitor and is coupled directly to the non-inverting input.

The input impedance of the circuit is given by the paralleled value of R67 + part of VR4, and R68 + part of VR4 times the open loop gain of the amplifier. Thus depending on component tolerances the input impedance can be anywhere within the range 250 to 2,500 megohms and since a 1·0μF capacitor is specified the leakage time constant of the network will similarly vary between 250 and 2,500 seconds.

PORTAMENTO

When keyboard voltages are routed direct to C1 in the hold circuit the change in level of the charge on C1 is virtually instantaneous. However, if a resistance is interposed between the keyboard and C1 the rate of change of charge is inversely proportional to the value of the resistor. This provides a very convenient means of adding a portamento facility and R62–R66 are included for this purpose, being switched in as required by S4.

Portamento is the name given to the effect when the transition between two successive notes in a musical piece is accomplished in a gliding manner encompassing all the intermediate frequencies.

The nature of the hold circuit requires that the setting-up procedure be followed with great care since any output offset voltage present will inevitably cause the holding ability of the circuit to wander. With VR4 in its electrical mid position, and with the wiper grounded, a 10 megohm resistor is connected between the output and inverting input of the amplifier. With power on, VR5 is then adjusted so that the output is precisely zero when observed on the most sensitive setting of the oscilloscope. When satisfied that the initial setting up has been correctly accomplished the circuit connections may be made as generally shown in Fig. 11.3 but omitting the connections to the v.c.o. and portamento resistors. With power on again, and observing the output of IC3 on the oscilloscope, apply about −6V transiently to the junction of R67 and C1. Careful adjustment of VR4 will result in virtually negligible drift and, in the prototype, it was found that a drift of 6mV/20 minutes was quite easily attainable.

The −6V charge on C1 during the setting-up procedure is also quite an important value since it will be found that the circuit will have a much greater degree of drift if the applied voltage is significantly higher or lower than this value. For this reason S5 is provided to ground the input of the hold circuit during switch-on or when the keyboard is "idling" for any length of time thus ensuring that the v.c.o. is not over or under driven.

The output of the hold circuit is routed directly to the R10 input of the v.c.o. the three output waveforms of which are, in turn, routed to a selector switch, S7.

MODULATION AMPLIFIERS

The wiper of S7 is coupled to the v.c.o. level control VR6 and also directly to the non-inverting input of what has been termed the modulation amplifier. The output of the modulation amplifier driven by VCO1 is then routed to the R11 input of VCO2 through S6, a similar arrangement existing between VCO2 and the R11 input of VCO1.

The net result of this arrangement is that each oscillator can frequency modulate the other either separately or at the same time. Although simple in concept this system is capable of generating waveforms having very complex harmonic structures and is thus able to produce an enormously wide range of sounds and effects.

In the modulation amplifiers R69 and R70 set the gain at about 4·5 and VR7 provides a modulation depth control. S5a/b provide a means of turning VCO2 off in the sense that its input and output are isolated and its frequency controllable either by its own manual frequency control or by its associated modulation amplifier or both. The main purpose of this arrangement is to allow VCO2 to provide a vibrato modulation to VCO1.

ENVELOPE SHAPERS

From the wiper of VR6 the v.c.o. signal is routed into a v.c.a. based on the MFC6040 which is, in turn, controlled by an envelope shaper triggered by depression of any of the keys on the keyboard. The working of the circuit shown in Fig. 11.4 is as follows.

IC1–TR1 represent a current amplifier/follower with overall feedback. The output at the emitter normally is +4·5V under quiescent conditions thus

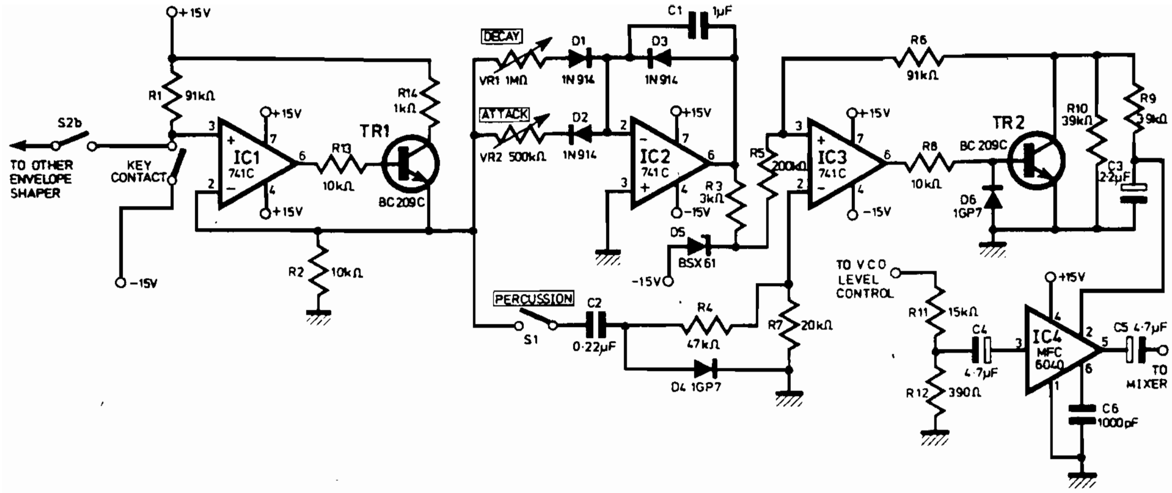

Fig. 11.4. Circuit of keyboard envelope shaper and voltage controlled amplifier

COMPONENTS . . .

ENVELOPE SHAPER (2 off)

Resistors

R1	91kΩ	R8	10kΩ
R2	10kΩ	R9	3·9kΩ
R3	3kΩ	R10	39kΩ
R4	47kΩ	R11	15kΩ
R5	200kΩ	R12	390Ω
R6	91kΩ	R13	10kΩ
R7	20kΩ	R14	1kΩ

All 5% ¼W carbon

Transistors

TR1–TR2 BC209C (2 off)

Integrated Circuits

IC1–IC3 741C (3 off)
IC4 MFC6040

Diodes

D1–D3 1N914 (3 off)
D4 1GP7
D5 BZX61 V Zener
D6 1GP7

Capacitors

C1 1μF polyester
C2 0·22μF polyester
C3 2·2μF 35V tantalum
C4 4·7μF 35V tantalum
C5 4·7μF 35V tantalum
C6 1,000pF polystyrene

Miscellaneous

S5 d.p.c.o. toggle, S7–4 pole 3 way rotary (2 required), VR6–10kΩ midget moulded carbon (2 off), 2mm miniature sockets (12 off), 1–4 octave keyboard, G.B-2 pair contacts (49 off) (see text), contact locating strip.

driving IC1 hard negative, or to −12·5V as determined by. the divider R3–R5. With a negative input signal to the non-inverting input of IC2 the output of this device is also negative and TR1 is turned off. With TR2 off the control input of the MFC6040 rises to +6V and thus attenuates the audio input signal by about 77dB.

The application of a negative trigger pulse to the input of IC1 causes TR1 to turn off and the output at R2 to go to −15V. C1 thus discharges via D2/VR2 and the output of IC2 rises from −12·5V to about −4V. Under these conditions the non-inverting input of IC3 becomes positively biased, its output goes positive turning on TR2 which thus effectively short circuits R10 and causes the control voltage to IC4 to fall to about +4·3V. When the trigger pulse is removed C1 charges to a level again via D1/VR1 and the original situation is positive restored.

A separate percussive attack can be obtained by differentiating the trigger pulse to the envelope shaper by means of C2. The negative differentiated trigger pulse is applied to the inverting input of IC3 with the effect previously described except that in this case the magnitude of the pulse causes the v.c.a. control voltage to fall to +3·7V corresponding to an audio signal amplification of about 12dB. The percussive attack may be used on its own by advancing the trapezoid attack control to the slowest rate and playing the keys in a staccato manner. Alternatively the percussive attack may be mixed with the normal trapezoid control waveform or it may be switched out altogether by means of S1.

The audio signal outputs of the envelope shapers are led to a simple unity gain, virtual earth mixer shown in Fig. 11.3. The level of signal from each channel is controlled directly from VR6 on each of the oscillators.

Next month: construction of the keyboard housing, wiring and tuning instructions. Details will also be given of a small p.s.u. which will enable the keyboard unit to be operated independently of the main synthesiser.