PE MINISONIC

By D. SHAW

PART THREE

- Keyboard Controller
- Noise Generator
- Ring Modulator
- Power Amplifiers

THIS month the remainder of the electronic circuitry in the synthesiser is described which includes KEYBOARD CONTROLLER, RING MODULATOR, NOISE GENERATOR and POWER AMPLIFIERS.

THE KEYBOARD CONTROLLER

The KEYBOARD CONTROLLER as illustrated in Fig. 3.1 is a relatively simple means of providing a range of voltages which, when applied to the input of a VCO, cause it to oscillate over a range of pitches normally associated with a chromatic scale or, alternatively, over a range of pitches quite outside what might be termed normal musical acceptance.

IC1 and IC2 are inverting operational amplifiers whose outputs are linked by a chain of resistors the junctions between which are connected to the keyboard contacts. R5 and VR1 form a divider between the positive rail and ground such that the swing of the potentiometer covers a range of about 4·7 volts.

The wiper of VR1 is linked to both i.c.'s so that the output of these devices will track, in unison, the setting of VR1. R1 and VR2 form a second divider between the negative rail and ground with the wiper linked to IC1 only. Thus VR2 is able to provide an offset to IC1 which is variable over 4·5 volts.

The purpose of the voltage difference between the swings of the two potentiometers, is so that, under normal conditions, the key contact voltages can never go positive and thus drive the VCO's into saturation.

SPAN AND TUNE CONTROLS

The KEYBOARD CONTROLLER can be matched to a wide range of keyboard sizes and VCO control voltages.

If, for example, a two octave keyboard is to be used and the required control voltage for the VCO's is 600mV per octave, then VR2 (the "Span" control) will require to be offset by 1·2V with respect to the inverted value of VR1's setting. Once this has been used and the required control voltage for the VCO's are able to reproduce a chromatic octave by making a series of consecutive key contacts, then VR1 may be adjusted over a wide range without affecting the "tune" of the VCO's.

In simple terms the "position" of the two-octave keyboard may be varied over the audio frequency range and the "white" notes may be made to play in any required key signature. This latter feature will commend itself to those "play-it-by-ear" musicians who may sometimes find difficulty in translating a well known melody in the key of C into its correct signature.

For more serious applications, however, the ability to swing the keyboard "position" enables the Minisonic to play in tune with a number of conventional acoustic instruments which may, themselves, not be precisely "spot-on" as far as tuning is concerned.

KEYBOARD RESISTOR CHAIN

No setting-up is required for the KEYBOARD CONTROLLER other than to check that the outputs of both IC1 and IC2 respond correctly to the settings of VR1 and VR2. Fig. 3.1 gives a table of resistor values which may be used for the divider system on keyboards of various sizes.

It will be noted that the overall value of resistance in each case is approximately the same in order that the loading on the i.c.'s will vary by a minimum amount regardless of the size of keyboard employed.

THE "HOLD" OR ANALOGUE MEMORY

Although covered by the general heading of KEYBOARD CONTROLLER the HOLD circuit is a quite separate entity which fulfils an important function in the scheme of the synthesiser.

Last month it was indicated that the ENVELOPE SHAPER could give a decay characteristic lasting up to 16 seconds. In other words, from the instant the key contact is broken, the audio signal will continue —at a diminishing level—for the prescribed period. It is obvious therefore that, for the best effect to be achieved, the VCO frequency must remain constant for the period over which the decay is taking place.

With the key contact broken so too is the VCO programming voltage disconnected unless there is some means by which the VCO can continue to be programmed regardless of key contact condition. The HOLD circuit provides the means whereby the VCO can continue to oscillate at the frequency prescribed by the last programmed voltage either until the ENVELOPE SHAPER completes its cycle or until another voltage is programmed in.

HOLD CIRCUIT

The circuit of the HOLD facility is shown in Fig. 3.2a. IC3 is an operational amplifier in which the output signal is divided by means of VR4, R8 and R9 to provide balanced levels of positive and negative feedback.

When the balancing is carefully done the circuit is theoretically capable of presenting an infinite impedance to incoming signals. In practice, however, it is more usual to calculate the input impedance on the basis of the parallel value of the feedback resistors times the open loop gain of the amplifier. Thus the input impedance is of the order of 2,500 megohms.

The hold capacitor (C2) is, ideally, a low leakage type. A charge applied to C2 is reflected at the output of IC3 with any drift at the output due to a combination of capacitor leakage and minor thermal effects within the i.c.

COMPONENTS . . .

KEYBOARD CONTROLLER AND HOLD

Resistors
R1 10kΩ
R2–R4 47kΩ (3 off)
R5 9·1kΩ
R6, R7 47kΩ (2 off)
R8, R9 20kΩ (2 off)
R10 47kΩ
R11 et seq See text

Potentiometers
VR1, VR2 10kΩ linear carbon (2 off)
VR3 10kΩ sub-miniature horizontal skeleton preset
VR4 10kΩ 15-turn preset

Capacitors
C1 1,000pF
C2 1μF 63V polycarbonate

Integrated Circuits
IC1–IC3 Type 741 8-pin d.i.l. (3 off)

Miscellaneous
SK1 2mm socket

KEYBOARD CONTROLLER

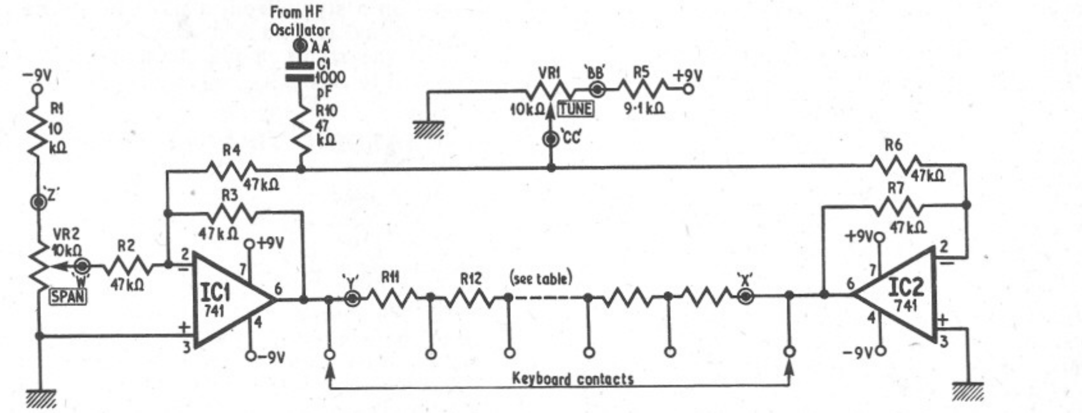


Fig. 3.1. Circuit of the KEYBOARD CONTROLLER (excluding the HOLD circuit). The table (below) shows values of resistors (R11 et seq) and numbers required for various length keyboards. This applies to both printed circuit and conventional keyboards

KBD DIVIDER RESISTORS

Size	Resistor	Number off
1 octave	150Ω	13
2 octave	82Ω	25
3 octave	51 or 56Ω	37
4 octave	39 or 43Ω	49
5 octave	33 or 36Ω	61

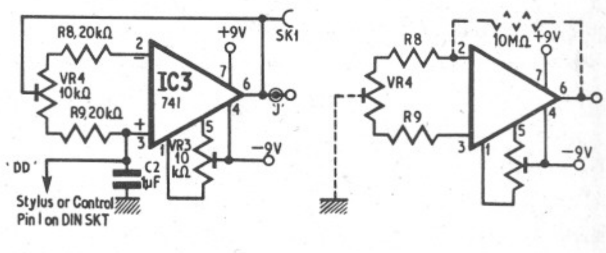


Fig. 3.2(a). The circuit of the HOLD section of the KEYBOARD CONTROLLER. (b) It is important that this circuit should be adopted when nulling the HOLD offset. Temporary links are shown dashed. The feedback resistor should be 10MΩ or more

It is possible to balance the circuit such that the output drift is better than 1mV/sec but to do so requires considerable patience and care, particularly when nulling the offset. The circuit for this latter procedure is shown in Fig. 3.2b. The component assembly should be as shown on the circuit board layout but the wiper of VR4, instead of being linked direct to the output of IC3, is temporarily connected to the 0V rail.

A second temporary feature is the inclusion of a high value feedback resistor (ideally 10MΩ or more) as shown hatched in Fig. 3.2b.

Adjust VR4 so that its wiper is close to the centre of travel and, with power on, adjust VR3 until the output of IC3 is *precisely* zero volts. The temporary links and feedback resistor may now be removed and the circuit completed as shown in Fig. 3.2a.

Minimising the drift in the HOLD circuit is best done by ear, i.e. using the Minisonic vco's rather than an oscilloscope as part of the test equipment. Details of this procedure will be included as part of the final setting up.

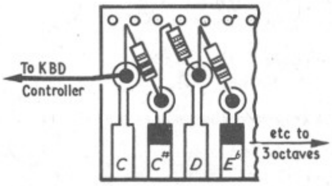


Fig. 3.3(a). Wiring of the edge connector strip as used on the prototype. Resistors are wired in from the conductor side of the board. Excess wire on the other side of the p.c.b. should be trimmed off and filed flush so that the board may be glued to the front panel

THE KEYBOARD

The Minisonic offers the possibility of being operated with a number of keyboard options, the cheapest being the edge-connector type. Other options will be discussed next month.

A printed circuit keyboard was adopted in order that the instrument could be both compact and fully self-contained. In the prototype a three-octave keyboard was made up using a standard edge-connector strip as shown in Fig. 3.3a but satisfactory operation could only be achieved after much practice due to the narrow conductors involved. Mounting of the divider resistors should be generally as shown in the diagram.

COMPONENTS . . .

HARDWARE

Control Knobs, 14mm—19 with skirt, 1 without skirt (ReAn Products—see *Market Place*)
On/off d.p.d.t. toggle
Battery connectors, PP9 2-off positive and negative
0·1in matrix Veroboard 45 × 34 holes
Keyboard 37-way edge connector strip (or see text)
Materials for stylus (see text)
5-pin 180° DIN socket

STYLUS

In the first prototype the stylus employed two contacts and was illustrated on the front cover of the November issue. The double contact, however, greatly added to the difficulties of playing the instrument and thus modifications were carried out so that a single contact stylus could be employed.

Perhaps the simplest stylus involves the adaptation of a ball-point pen (see Fig. 3.3b). If this method is chosen it is important that all traces of ink are removed from the ball end using an organic solvent before any attempt is made to solder in the wire lead.

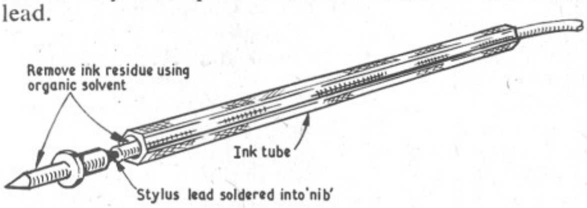


Fig. 3.3(b). A suggested construction method for the stylus using an old ball-point pen

Note that organic solvents should be treated with caution since most of them give off a vapour which can be harmful if inhaled continuously. The assembly when completed should be potted within the lower half of the pen by means of Araldite or Silicon Rubber Compound.

Those constructors having access to a lathe could make up a stylus from a piece of ¼in brass rod. If this method is used it is important that the extreme tip of the stylus should be rounded off and well polished to ensure a good contact.

ULTRASONIC TRIGGER SYSTEM

(The circuitry in this section is the subject of a Patent Application)

The changeover from a double-contact to a single-contact stylus presented a difficult problem simply because the signals required to set the HOLD circuit and to trigger the ENVELOPE SHAPERS are essentially incompatible. Direct coupling between the inputs of these two circuits was therefore not possible since, once the HOLD capacitor was charged, the d.c. level would remain on the stylus lead and the ENVELOPE SHAPER in the "on" condition, until the charge on the HOLD capacitor had leaked away.

This would occur quite rapidly in the circumstances thereby giving rise to an undesired portamento effect. Similarly it was not possible to decouple the ENVELOPE SHAPER from the stylus lead since so doing would restrict the "attack" phase to one rate only—and that very fast. The solution proved to be the application of a principle which is believed to be unique in electronic musical instruments.

HF OSCILLATOR

A HIGH FREQUENCY OSCILLATOR is coupled directly into the KBD CONTROLLER in such a way as to distribute the signal evenly across the divider. The stylus lead which now goes direct to the HOLD capacitor is also connected through a decoupling capacitor to an a.c. detector circuit which, through an integral switch, is used to trigger the ENVELOPE SHAPER.

Four components only go to make up the HF OSCILLATOR which is shown in Fig. 3.4.

VR1 controls the frequency of operation by prescribing the proportion of positive feedback and thereby varying the peak to peak value of the output signal. With the component values given the frequency range is from 2kHz at 18V peak-to-peak, to 250kHz at 80mV peak-to-peak. Output waveforms are also shown in Fig. 3.4.

OSCILLATOR FREQUENCY

The optimum setting of the HF OSCILLATOR is 40kHz at 6V p-p as measured at point "AA." The attenuating effect of C1, R10 and VR1 in the KBD CONTROLLER will combine to reduce the signal to 500mV p-p measured on the keyboard contacts.

It should be noted however that the setting of VR1 in the controller will affect the level of the h.f. signal—the lower the setting of VR1 the lower will be the level of the signal on the contacts. This is not really a problem since the detector sensitivity is around 50mV and also, for most applications, it will be found that VR1 will require to be at a relatively high setting.

HF DETECTOR

The circuit of the DETECTOR is shown in Fig. 3.5. IC2 is a high gain follower decoupled from the stylus lead by means of C2. C1 provides additional decoupling for the stylus lead thereby ensuring that hum signals which may be included in the lead do not cause triggering of the envelope shapers. C4 and C5 provide frequency compensation for IC2 which is a 709 operational amplifier to give the advantage of the higher gain bandwidth offered by this device.

The output of IC2 provides drive to TR1 the collector of which is coupled through R6 to the bases of TR1 and TR2 on both ENVELOPE SHAPERS. (Note that this latter coupling is via the DIN socket and JK1 on both ENVELOPE SHAPERS.) C6 blocks any d.c. appearing at the output of IC2 while R5 sets a current limit.

Under quiescent conditions the output of IC2 is nominally zero volts and TR1 is off. An a.c. signal of sufficient level on the stylus lead will cause IC2 to follow and each positive excursion of IC2 output will switch TR1 on causing the collector to go to about −8·5 volts. The ENVELOPE SHAPERS thus start to attack and C7 receives a negative charge.

H.F. OSCILLATOR AND DETECTOR

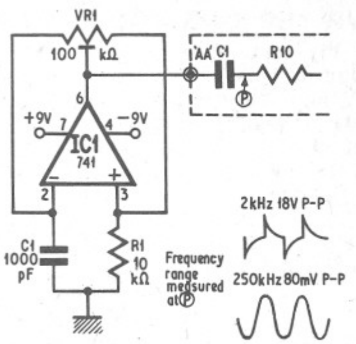


Fig. 3.4. Circuit of the HF OSCILLATOR. Components in the dotted box are on KBD CONTROLLER circuit and are mounted on main board. Typical waveforms at different settings of the VR1 are also shown

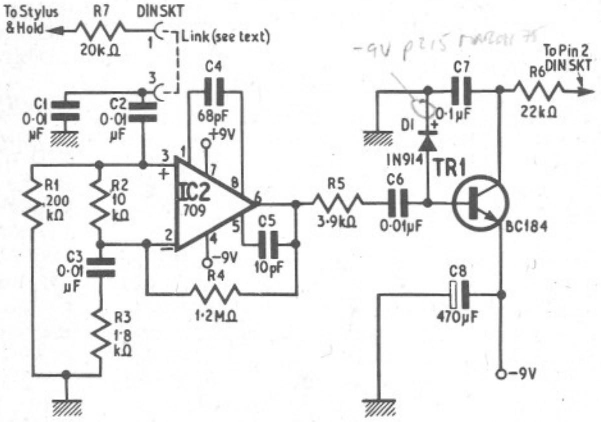


Fig. 3.5. Circuit of the HF DETECTOR. Resistor R7 is for isolation and was 20kΩ in the prototype. The DIN socket is for external keyboard attachment and wiring options will be described next month. C1 is mounted on the DIN socket

COMPONENTS . . .

HF OSCILLATOR

Resistors
R1 10kΩ
VR1 100kΩ subminiature horizontal skeleton preset

Capacitor
C1 1000pF

Integrated Circuit
IC1 Type 741 8-pin d.i.l.

HF DETECTOR

Resistors
R1 200kΩ
R2 10kΩ
R3 1·8kΩ
R4 1·2MΩ
R5 3·9kΩ
R6 22kΩ
R7 20kΩ (see text)

Capacitors
C1–C3 0·01μF (3 off)
C4 68pF
C5 10pF
C6 0·01μF
C7 0·1μF
C8 470μF 16V elect.

Semiconductors
D1 1N914
IC2 Type 709 8-pin d.i.l.

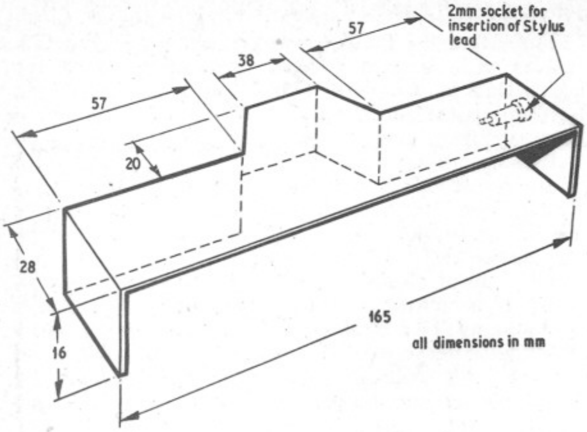


Fig. 3.6. Dimensions of the keyboard cover which was made from 3mm card

The time constant of C7 is such that it will lose only a small proportion of its charge during the negative half cycle of the h.f. signal. The result is that an effectively constant negative signal is presented to the ENVELOPE SHAPERS during the period that the stylus and/or key contacts are made.

ISOLATION RESISTOR

In addition to the components making up the DETECTOR Fig. 3.5 also shows a resistor, R7, in series with the stylus lead and HOLD circuit. The purpose of this resistor is to provide a degree of isolation for C2 in the HOLD circuit so that its relatively large capacity will not over-attenuate the signal on the stylus.

R7 (20kΩ in the prototype) also provides a delay in the d.c. charging rate of C2 with the result that there is a 20ms portamento effect. This effect is not really too noticeable unless consecutive KBD voltages are programmed from opposite ends of the KBD but it could perhaps be a source of irritation for the constructor wishing to use the Minisonic for serious musical purposes.

In these circumstances R7 could be replaced by an inductance which would provide the degree of a.c. isolation required whilst presenting only a nominal resistance to d.c. A suitable choke could be made up from a small ferrite ring toroidally wound with about 20 to 30 turns of 34 s.w.g. enamelled copper wire.

Some experimenting will possibly be required to get just the right value and it would be best to start with the greater number of turns and reduce these as necessary to get the best balance between a.c. isolation and d.c. resistance.

PORTAMENTO

As a modification to the prototype circuits some constructors may wish to incorporate a variable portamento control. In view of the lack of space on the front panel the best way to do this is to mount a miniature edgewise volume control—such as is used on some transistor radios—inside the upper edge of the printed circuit keyboard cover.

The cover is shown in Fig. 3.6. The wire from the stylus socket on the side of the KBD cover would then be routed to one end of the potentiometer while the slider would go via R7, or inductor as mentioned above, to pin 1 on the DIN socket.

RING MODULATOR

The Minisonic RING MODULATOR is an improved version of the circuit which originally appeared in the *P.E. Sound Synthesiser* (August 1973). The essential features of the circuit have been retained however and the circuit is shown in Fig. 3.7.

The RING MODULATOR produces a unique output waveform which comprises, at the same instant, the sum and difference between any two applied input frequencies. This function is carried out in a purpose-built integrated circuit, the SG3402N. With one of the input frequencies fixed, variation in the other will ring the changes in the output frequencies as shown in Table 3.1.

Referring to Fig. 3.7, R1 and R2 form an input attenuator on the so-called carrier input (pin 7) such that, when driven from a VCO, the input signal level at C1 will be about 40mV.

Similarly R3 and R4 attenuate the modulator or control input so that, when driven by a VCO, the input at C2 is about 200mV. This procedure results in an output signal of about 1·5 volts at pin 4 and the same signal in antiphase at pin 11. The antiphase signals are amplified differentially by IC2 to give a peak output signal of three volts which is then attenuated by R9 and R10 to a level compatible with the remainder of the Minisonic circuits.

SETTING UP THE RING MODULATOR

Setting up the RING MODULATOR is very simple. With the circuit completed link the modulator input to the 0V rail and connect the output to a suitable power amplifier. Apply a signal of about 1kHz to the carrier input (normally connected direct to VCO1) and adjust VR1 until the output signal reduces to the lowest possible level. This should, with a correctly wired circuit, be 50dB or more below the peak signal level. At this point the RING MODULATOR is correctly balanced with minimum carrier breakthrough.

NOISE GENERATOR

The NOISE GENERATOR is built round the highly successful Z1J noise diode manufactured by Semitron Ltd., and is shown in Fig. 3.8. Output from the Z1J

Table 3.1: OUTPUTS FROM THE RING MODULATOR

	Frequency						
Carrier	700	600	500	400	300	200	100
Modulator	400	400	400	400	400	400	400
Sum	1100	1000	900	800	700	600	500
Difference	300	200	100	0	100	200	300

RING MODULATOR

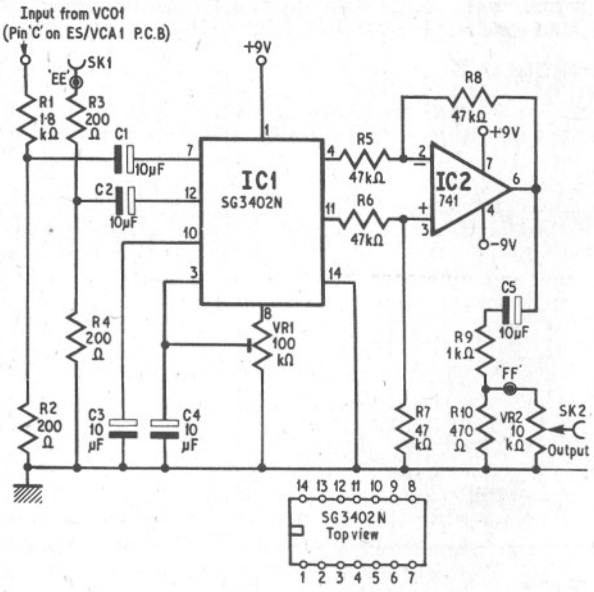


Fig. 3.7. Complete circuit of the RING MODULATOR

COMPONENTS . . .

RING MODULATOR

Resistors

R1	1·8kΩ
R2–R4	200Ω (3 off)
R5–R8	47kΩ (4 off)
R9	1kΩ
R10	470Ω

Potentiometers

VR1 100kΩ subminiature horizontal skeleton preset
VR2 10kΩ log carbon

Capacitors

C1–C4 10μF 6·3V tantalum (4 off)
C5 10μF 16V tantalum

Integrated Circuits

IC1 SG3402N
IC2 Type 741 8-pin d.i.l.

Miscellaneous

SK1, SK2 2mm sockets (2 off)

is amplified by the high gain follower IC1 and led, through decoupling capacitor C5, to the volume control VR1.

The NOISE GENERATOR is the only circuit in the Minisonic which does not operate completely successfully down to a battery voltage of ± 7·5 volts.

In the prototype the noise generator ceased to work when the battery voltage had reduced to ± 7·8V. This situation may be corrected to a certain extent by shorting out R2 and R3 and/or by reducing the value of R1 to, say, 82kΩ. No setting up is required for this circuit.

NOISE GENERATOR

COMPONENTS . . .

NOISE GENERATOR

Resistors

R1	91kΩ	R5	200kΩ
R2, R3	22Ω (2 off)	R6	56kΩ
R4	470kΩ	R7	1·2kΩ

Potentiometer

VR1 10kΩ linear carbon

Capacitors

C1 0·01μF
C2 100μF 25V elect.
C3 0·01μF
C4 100μF 25V elect.
C5 0·01μF

Integrated Circuit and Diode

IC1 Type 741 8-pin d.i.l.
D1 Z1J noise diode (Semitron)

Miscellaneous

SK1 2mm Socket

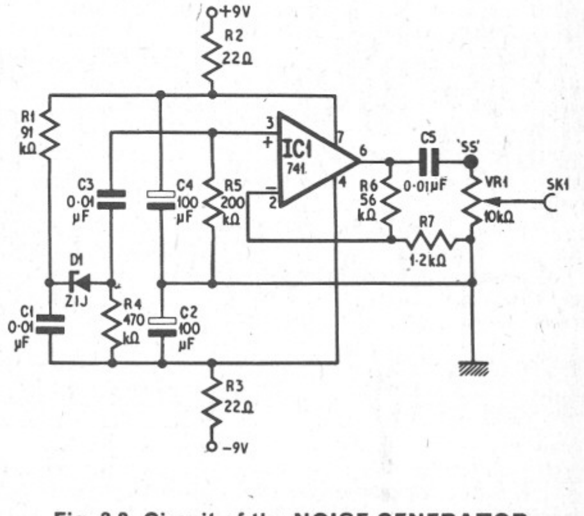


Fig. 3.8. Circuit of the NOISE GENERATOR

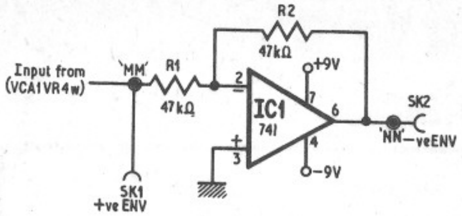


Fig. 3.9. Circuit of the **CONTROL ENVELOPE INVERTER**. This is fed with the output of **ES/VCA1** via **VR4** (see last month)

COMPONENTS . . .

R1, R2	47kΩ (2 off)
IC1	Type 741 8-pin d.i.l.
SK1, SK2	2mm sockets (2 off)

POWER AMPLIFIER

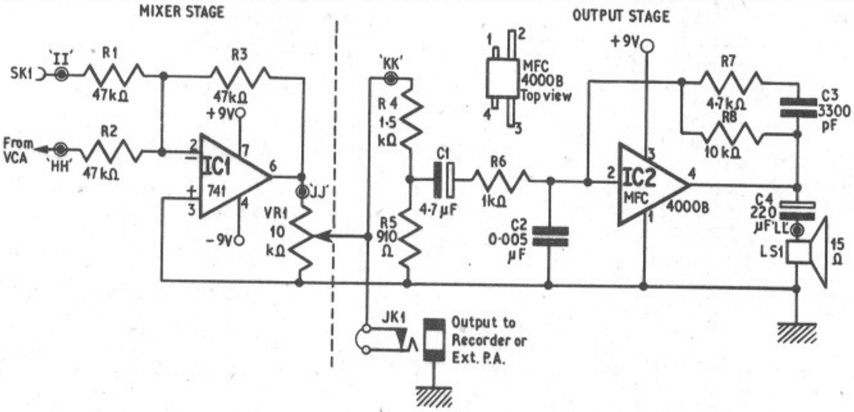


Fig. 3.10. Complete circuit diagram of one of the **POWER AMPLIFIERS** with integral two-input mixers. Note that the mixer stages are mounted on the main circuit board

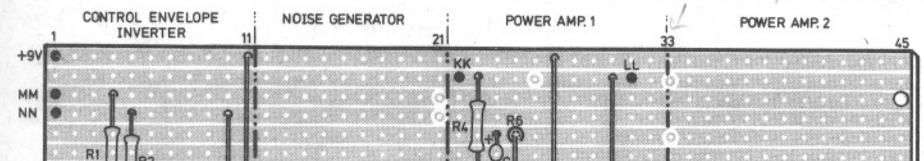


Fig. 3.11. The Veroboard panel which carries the NOISE GENERATOR, HF OSCILLATOR AND DETECTOR, CONTROL ENVELOPE INVERTER, AND POWER AMPLIFIERS

COMPONENTS . . .

POWER AMPLIFIERS AND MIXERS
(2 off)

Resistors

R1–R3	47kΩ (3 off)
R4	1·5kΩ
R5	910Ω
R6	1kΩ
R7	4·7kΩ
R8	10kΩ

Potentiometer

VR1 10kΩ log carbon

Capacitors

C1	4·7µF 35V tantalum
C2	0·005µF ceramic
C3	3300pF
C4	220µF 40V elect. (or 470µF 16V)

Integrated Circuits

IC1	Type 741 8-pin d.i.l.
IC2	MFC4000B

Miscellaneous

LS1	3in 15 speaker
SK1	2mm socket
JK1	3·5mm jack socket

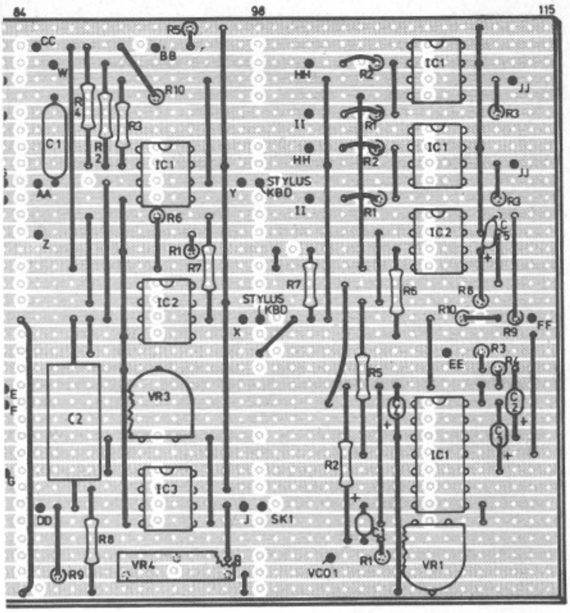


Fig. 3.12. The layout on the main Veroboard panel, the majority of which was shown last month

CONTROL ENVELOPE INVERTER

Shown in Fig. 3.9, the CONTROL ENVELOPE INVERTER represents a modification to the prototype instrument and has been included, principally, so that the VCF may be programmed automatically from ENVELOPE SHAPER 1. The inverter itself is a simple unity-gain inverting amplifier which requires no setting up procedure.

POWER AMPLIFIERS

The complete circuit of the power amplifiers, which includes a two-input inverting mixer, is shown in Fig. 3.10. As with all the virtual earth circuits in the Minisonic the mixer has the minimum number of inputs and almost any number of additional inputs may be applied by following the basic details given in Part 1 of the series.

The slider of the volume control (VR1) at the mixer output is wired directly to a jack socket from which may be taken a signal suitable for driving an external power amplifier, tape recorder, external mixer, etc.

CIRCUIT BOARD LAYOUT

The CONTROL ENVELOPE INVERTER, HF OSCILLATOR and DETECTOR, NOISE GENERATOR, and POWER AMPLIFIER stages are carried on a separate circuit board which is illustrated in Fig. 3.11.

The KEYBOARD CONTROLLER, RING MODULATOR and POWER AMPLIFIER/MIXER stages are all included on the main circuit board part of which was illustrated last month. The remainder of the board is shown in Fig. 3.12.

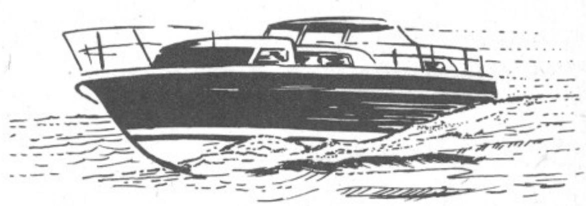
Next month: Final wiring-up and adjustments. Keyboard options, as well as circuit additions for more ambitious constructors will be discussed.

Stop Press: The author has developed a printed circuit board to carry all the Minisonic electronics. More details next month.

NEXT MONTH...

MARINE SPEEDOMETER

Solid-state electronics provide an easy-to-make solution to the measurement of boat speed—suited to both motor and sail environments and giving reasonable accuracy at sensible cost.



AC/DC MILLIVOLTMETER

A fully protected voltmeter which will read a.c. voltages down to 5mV r.m.s. but will withstand overloads of up to 250V. Operates at all audio frequencies.

PROBABILITY ANOMALY DETECTOR

Investigate your powers of extra-sensory perception with this specially designed unit. A meter registers your influence on the random noise in a Zener diode—the greater your power the higher the reading.

PRACTICAL
ELECTRONICS

FEBRUARY ISSUE ON SALE JANUARY 10, 1975