PROGRAMMABLE SOUND GENERATOR

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THE GENERAL INSTRUMENT AY-3-8912 Programmable Sound Generator was designed to produce a variety of complex sounds under software control. By using a register stack the processor can load values into the sound chip and then carry on with other tasks while the sound is being generated.

It is easy to interface the i.c. with the UK101 and to add sound to your BASIC programs by means of the POKE command.

BLOCK DIAGRAM

Fig. 1 is a block diagram of the 8912 i.c. There are three tone generators and a noise generator. The three tones can be fed out to outputs A, B and C. The noise can be added to any or all of the tones, or it can be output instead of a tone. The amplitudes of the noise and tones can be set to one of sixteen fixed values, or they can be varied by means of an envelope generator. The envelope generator amplitude modulates the outputs and can be set for various options of fast or slow attack and decay, single shot or repeat, etc. allowing a wide variation of sounds. The three outputs are logarithmic.

PSG REGISTER ARRAY

Fig. 2 shows the register array in detail. Register Ø and register 1 are cascaded to give a 12-bit word which sets the period of tone A, the top 4 bits of register 1 not being used and the bottom 4 bits forming bits 8, 9, 10 and 11 of the 12-bit word. The register can be set to any value between 1 and 4095 decimal. As the clock is divided by 16 before being fed to the tone generator, the output frequency is:

$$f = \frac{Fclock}{16 \times R}$$

where R lies between 1 and 4095. Registers 2, 3 and 4, 5 similarly control tone generators B and C. Register 6 is used to control a pseudo random noise generator. Only the bottom 5 bits are used, and again, the clock is divided by 16 before being fed to the noise generator.

Register 7 is the output control register. Bits 6 and 7 should always be set to one as we are outputting data to the PSG (Programmable Sound Generator). Setting bit Ø low will enable tone A to be output to channel A. If at the same time bit 3 is set low the noise generator will be mixed with tone A. If bit Ø is now set high only noise will be output on channel A. Likewise bits 1 and 4 control tone B and noise to channel B, and bits 2 and 5 control tone C and noise to channel C. Remember it requires a low or Ø to select a tone or noise, for example, writing 254 decimal to register 7 selects tone A.

Register 8 is used to set the amplitude of channel A in the fixed output level mode. Bits 5, 6 and 7 are not used. If bit 4 is set to Ø then the output amplitude is set at one of sixteen fixed levels by means of bits Ø to 3. If bit 4 is set to a '1', however, bits Ø to 3 have no effect and the output amplitude is set by the envelope generator. Registers 9 and 1Ø are used similarly for channels B and C. Registers 11 and 12 are cascaded to give a 16-bit word to set the envelope period. The clock is divided by 256 before being fed to the envelope control, so with a 2MHz clock we can get a period range of about 0·1Hz to 7800Hz.

Register 13 determines the shape/cycle of the output as follows.

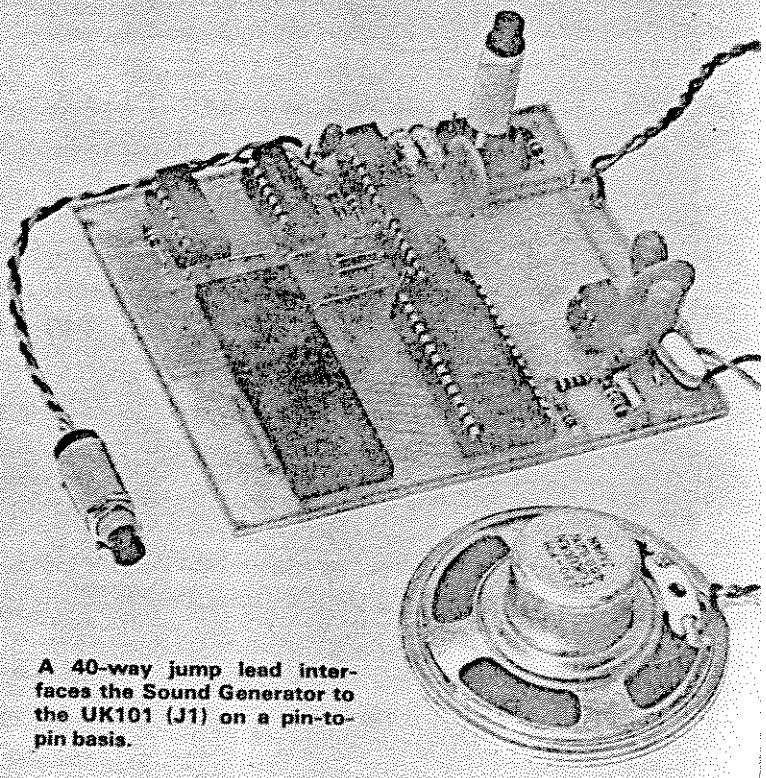
The envelope generator further counts down the envelope frequency by 16, producing a 16-state per cycle envelope pattern as defined by its 4-bit counter output, E3, E2, E1, EØ. The particular shape and cycle pattern of any desired envelope is accomplished by controlling the count pattern (count up/count down) of the 4-bit counter and by defining a single-cycle or repeat-cycle pattern.

This envelope shape/cycle control is contained in the lower 4 bits (B3–BØ) of register 13. Each of these 4 bits controls a function in the envelope generator, as illustrated in the following:

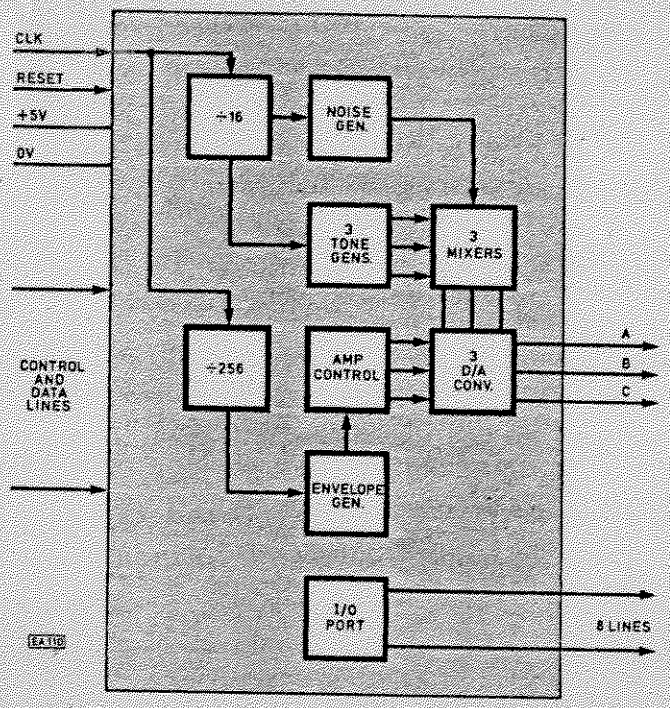
Envelope Shape/Cycle Control Register (R13)

B7	B6	B5	B4	B3	B2	B1	B0	FUNCTION
Not Used								Hold
								Alternate
								Attack
								Continue

To Envelope Generator



A 40-way jump lead interfaces the Sound Generator to the UK101 (J1) on a pin-to-pin basis.



The definition of each function is as follows:

Hold When set to logic 1, limits the envelope to one cycle, holding the last count of the envelope counter (E3–E0 = ØØØØ or 1111, depending on whether the envelope counter was in a count-down or count-up mode, respectively).

Alternate When set to logic 1, the envelope counter reverses count direction (up-down) after each cycle.

NOTE: When both the Hold bit and the Alternate bit are ones, the envelope counter is reset to its initial count before holding.

Attack When set to logic 1, the envelope counter will count up (attack) from E3, E2, E1, EØ = ØØØØ to E3, E2, E1, EØ = 1111: when set to logic Ø, the envelope counter will count down (decay) from 1111 to ØØØØ.

Continue When set to logic 1, the cycle pattern will be as defined by the Hold bit. When set to logic Ø, the envelope generator will reset to ØØØØ after one cycle and hold at that count.

To further describe the above functions could be accomplished by numerous charts of the binary count sequence of E3, E2, E1, EØ for each combination of Hold, Alternate, Attack and Continue. However, since these outputs are used (when selected by the Amplitude Control registers) to amplitude modulate the output of the Mixers, a better understanding of their effect can be accomplished via a graphic representation of their value for each condition selected, as illustrated in Fig. 3.

Register		BIT B7	B6	B5	B4	B3	B2	B1	B0
R0	Channel A Tone Period	8-BIT Fine Tune A							
R1						4-BIT Coarse Tune A			
R2	Channel B Tone Period	8-BIT Fine Tune B							
R3						4-BIT Coarse Tune B			
R4	Channel C tone Period	8-BIT Fine Tune C							
R5						4-BIT Coarse Tune C			
R6	Noise Period				5-BIT Period Control				
R7	Enable	IN/OUT IOB	IOA	C	Noise B	A	C	Tone B	A
B8	Channel A Amplitude				M	L3	L2	L1	L0
R9	Channel B Amplitude				M	L3	L2	L1	L0
R10	Channel C Amplitude				M	L3	L2	L1	L0
R11	Envelope Period	8-BIT Fine Tune E							
R12		8-BIT Coarse Tune E							
R13	Envelope Shape/Cycle					CONT.	ATT.	ALT.	HOLD.
R14	I/O Port A Data Store	8-BIT PARALLEL I/O on Port A							

Fig. 2. Register array of AY-3-8912

```
10  R=61680:V=61681
20  FORT=0 TO 14:X=INT (RND(5)*255)+1
25  IF RND(9)<.5 THEN POKER,7:POKEV,248
26  IFRND(4)<.5 THEN POKER,1:POKEV,0
30  GOSUB 1000
40  NEXT
50  FORT=1 TO 5000:NEXT
60  Y = INT (RND(7)—15):FOR T = 1 TO 255:POKER,Y POKEV,T
70  NEXT
75  FORT=255 TO 1 STEP —1:POKER,Y:POKEV,T
76  NEXT
80  GOTO 20
1000 POKER,T: POKEV,X:RETURN
```

Let the Sound Generator create its own sounds with this random program. Push it through a power amplifier for maximum effect.

Register 14 is the output port. Writing data to this register outputs it on pins 7 to 14 of the AY–3–8912.

CIRCUIT DIAGRAM

Fig. 5 shows the circuit diagram of the unit. IC3a and b provide a 1 to 2MHz clock to the PSG. IC3c and IC4a provide a reset to the chip, R2 and C3 providing power on reset. The three output channels of the 8912 are mixed together and are amplified by IC6. The UK101 data lines DØ to D7 are fed to pins 28 to 21 of IC5. Pins 7 to 14 of IC5 are the output port lines from register 14.

Two addresses are used to load the PSG, FØFØH and FØF1H. IC1 decodes when address bits 2^4 to 2^7 and 2^{12} to 2^{15} are high. IC2 decodes when address bits 2^1 to 2^3 and 2^8 to 2^{11} are low and R/$\overline{W}$ is low. Address bit 2^0 goes to IC4C. When you write to address FØFØH pins 18 and 20 of IC5 go high and the data on the data lines is written into an address latch in the PSG, i.e. if you write Ø to FØFØH the address latch in the PSG points to register Ø. If you now write to address FØF1H then the data on the data lines will be written into the register pointed to by the address latch, i.e. if you write 128 to FØF1H then 128 will be written into the register pointed to by the address latch, in this case register zero.

CONSTRUCTION

Construction is straightforward using the circuit diagram, Fig. 5 and component layout, Fig. 7. Fit the wire links followed by the sockets (it is advisable to use sockets with CMOS and MOS devices). Fit the resistors and capacitors then fit the coil former L1 and wind on 60 turns of 30 SWG enamelled wire. fit two cores into L1. A Molex plug can be fitted to the output port if it is needed. Fit wires for reset switch S1 and for the speaker. Add wires for 0V and +5 volts. If preferred the +5 volts could be brought in from the UK101 via the spare pin on J1 (pin 11). The p.c.b. is connected to the UK101 via a 40 to 40 pin jumper cable.

If IC6 and IC7 are not fitted in the UK101 it will be necessary to fit two dil plugs in place of them, wired as shown in Fig. 8.

TESTING THE UNIT

Check the p.c.b. very carefully for any solder splashes causing shorts. Fit the i.c.s, connect the unit to the UK101 via a 40-way jumper cable and power up.

As stated previously, writing a number between 0 and 14 to address FØFØH (DECIMAL 61680) will set up an address latch in the i.c. to point to one of the registers RØ to R14. If you then write to address FØF1H (61681 DECIMAL) you can write data into the appropriate register.

Load the following program:

```
1Ø    POKE  61680, Ø     (POINT TO REGISTER Ø)
2Ø    POKE  61681, 255   (LOAD 255 INTO REG. Ø
                          (TONE))
3Ø    POKE  61680, 7     (POINT TO REG. 7)
4Ø    POKE  61681, 254   (SELECT REG. Ø TO O/P)
5Ø    POKE  61680, 8     (POINT TO REG. 8)
6Ø    POKE  61681, 15    (SELECT O/P AMPLITUDE)
1ØØ   END
```

and run.

This outputs a single tone. To add noise change line 40 and ADD 70 and 80:

```
4Ø    POKE  61681, 246   (SELECTS TONE AND
                          NOISE ON A)
7Ø    POKE  61680, 6     (SELECTS REG. 6)
8Ø    POKE  61681, 1     (ENTERS NOISE VALUE)
```

and run.

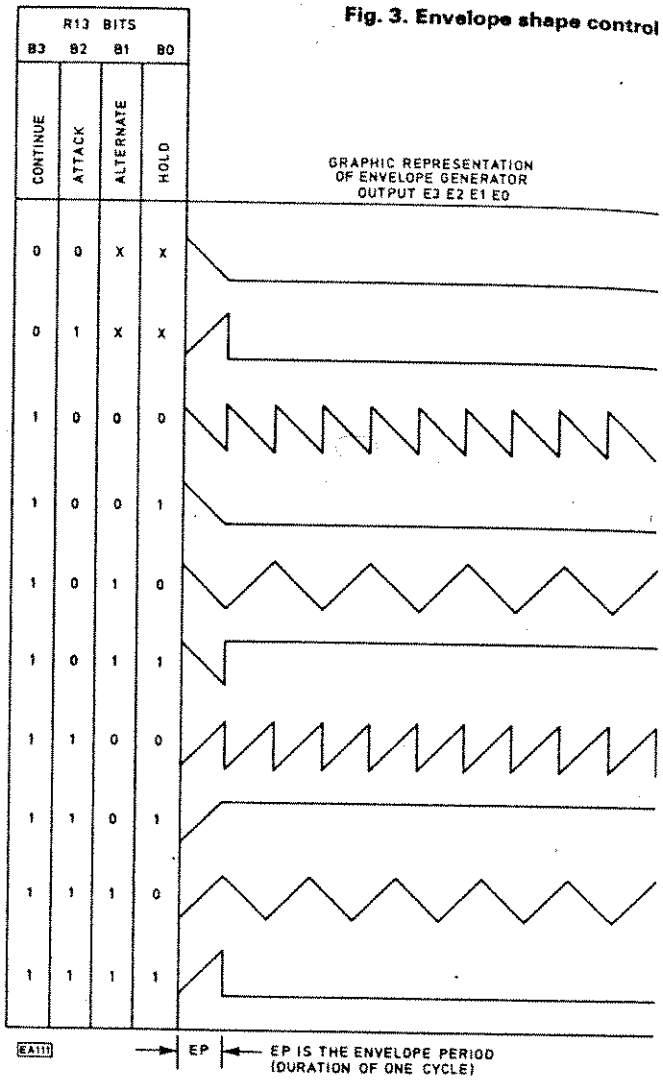


Fig. 3. Envelope shape control

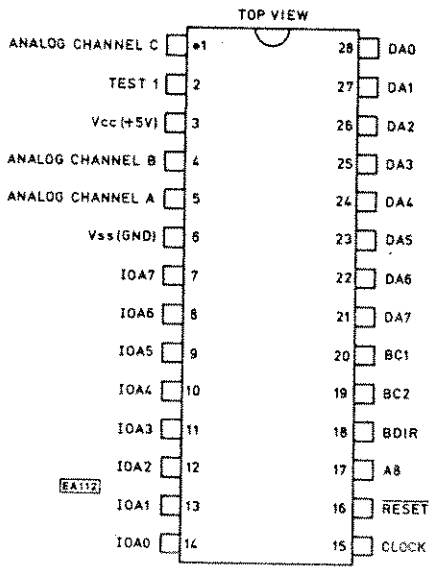


Fig. 4. AY-3-8912 pin-outs

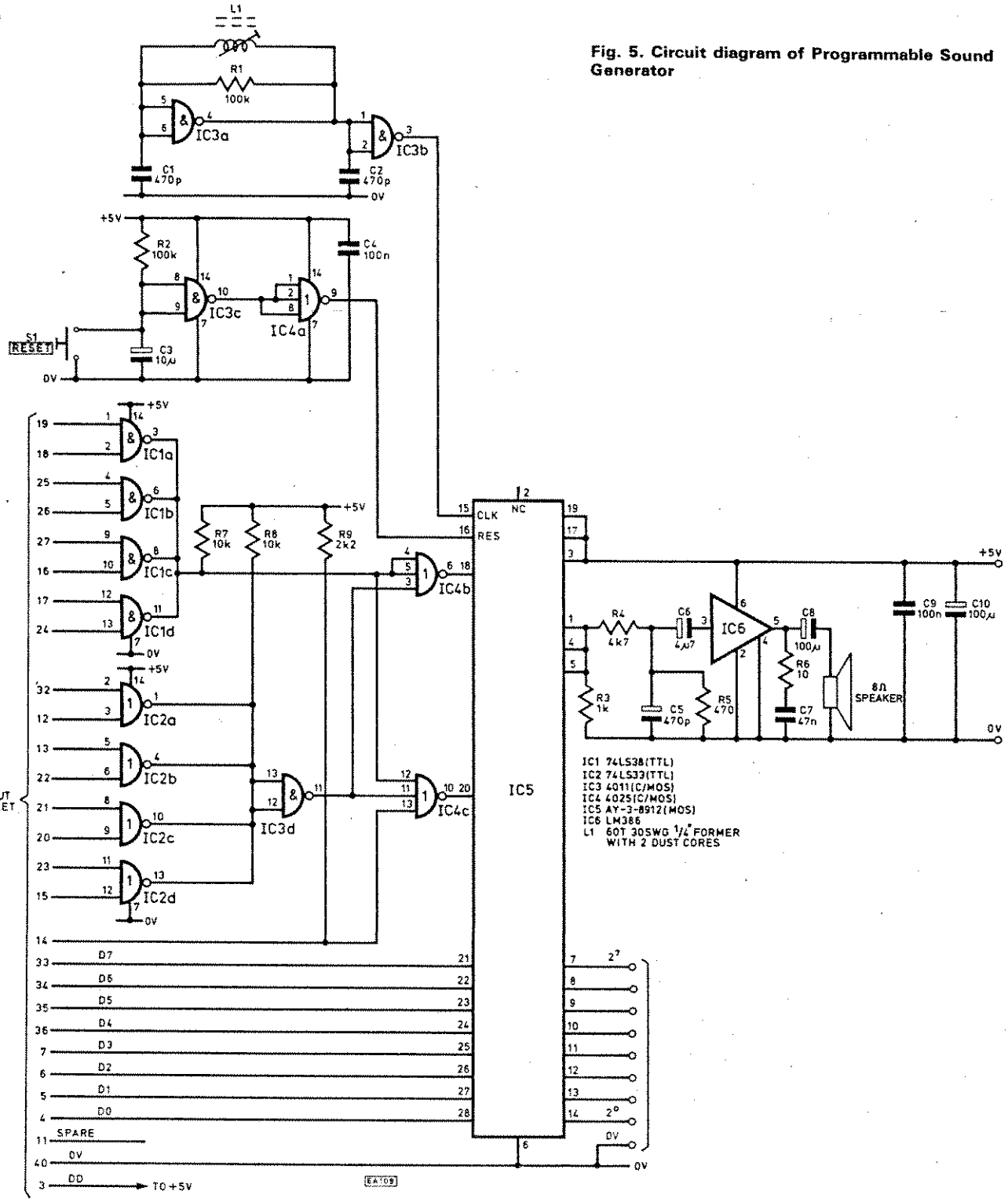


Fig. 5. Circuit diagram of Programmable Sound Generator

IC1 74LS38(TTL)
IC2 74LS33(TTL)
IC3 4011(C/MOS)
IC4 4025(C/MOS)
IC5 AY-3-8912(MOS)
IC6 LM386
L1 60T 30SWG 1/4" FORMER WITH 2 DUST CORES

COMPONENTS . . .

Resistors

R1, R2	100k (2 off)
R3	1k
R4	4k7
R5	470
R6	10
R7, R8	10k (2 off)
R9	2k2

Capacitors

C1, C2, C5	470p (3 off)
C3	10µ tant., 10V
C4, C9	100n (2 off)
C6	4µ7 tant. 10V
C7	47n
C8, C10	100µ tant. 10V (2 off)

Integrated Circuits

IC1	74LS38
IC2	74LS33
IC3	4011
IC4	4025
IC5	AY-3-8912
IC6	LM386

Miscellaneous

L1	RS coil former: 228-090 + 2 cores: 228-107
S1	SPST push button
Speaker	8Ω

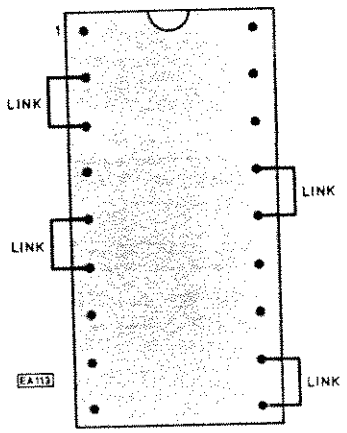


Fig. 8. Blanking plugs for IC6 and IC7 sockets on the 101

To check envelope shapes clear above program by typing NEW.

Enter the following:

```
10    POKE  61680,1
20    POKE  61681,2
30    POKE  61680,7
40    POKE  61681,254
50    POKE  61680,8
60    POKE  61681,31
70    POKE  61680,12
80    POKE  61681,64
90    POKE  61680,13
100   POKE  61681,0
110   END
```

and run.

Change line 100

```
100   POKE  61681,4
```

and run.

Change line 100

```
100   POKE  61681,8
```

and run.

By referring to Fig. 3 you can check out all the waveforms by altering line 100.

Sweep frequency effects. Enter the following program:

```
10    LET   A=100       (INITIALISE A)
20    POKE  61680,2
30    POKE  61681,A     (LOAD A INTO REG. 2)
40    POKE  61680,7
50    POKE  61681,253   (SELECT CHAN. B O/P)
60    POKE  61680,9
70    POKE  61681,15    (SELECT FULL AMP. O/P)
80    LET A=A+2
90    IF A<200 GO TO 20
100   GO TO 10
```

and run. You get a decreasing sweep frequency.

Change the following lines:

```
10    LET A=200
80    LET A=A-2
90    IF A>100 GO TO 20
```

and run. You get an increasing sweep frequency.

That checks out the unit. As you can see there is plenty of scope to add sound effects to your program. Short bursts of noise sound like gun shots, larger bursts sound like explosions. Tones can be played and the 3 channels allow chords to be output. All it takes is practice.

The unit may be fitted in a small case on its own or it may be mounted inside the computer case, as it is quite small.

```
10 INPUT "REGISTER"; R
20 INPUT "CONTENT"; C
30 POKE 61860, R: POKE 61681, C
40 GOTO 10
```

Learning to drive the sound generator will be much assisted by using the above program. You can load any register with any value directly, and discover how various control signals translate into actual sound. If you get in a pickle, push the reset button and start again.