CHAPTER 2

SINGLE-CHIP SYNTHESISER

If you take a VCO, a low frequency oscillator, an envelope shaper and VCA, a noise generator and a mixer, plus various other bits and pieces, you have got a simple synthesiser. What may be surprising is that all of this is now available in a little black package with 28 pins protruding therefrom.

The SN76477N chip is now available for two or three pounds. It is primarily intended for use in games and alarms. However, due to the versatility of the device it is possible to program an extremely wide variety of audio waveforms.

Programming is by four methods, namely resistors, capacitors, logic and analogue signals, operating in various combinations.

Figure 2.1 shows a block diagram of the chip. Essentially there are three sound generators – the LFO, VCO and noise generator, which are mixed, given an envelope, amplified and finally outputted. Most parameters can be controlled externally and any combination of the three generators can be selected in the mixer.

We shall look at each block in the system in turn, concentrating on how it is controlled and what it controls after it.

Low Frequency Oscillator (LFO)

The LFO has a working frequency range from 0.1 Hz to 30 Hz, which is controlled by a resistor on pin 20 and a capacitor on pin 21. The frequency is given by:

$$f = 0.64/RC \text{ Hz}$$

The LFO produces two outputs – the first is a square wave which is fed to the mixer, and the second is a triangular wave which is fed to the VCO via a switching system. This second waveform can be changed to an exponential one by putting a resistor across the timing capacitor on pin 21.

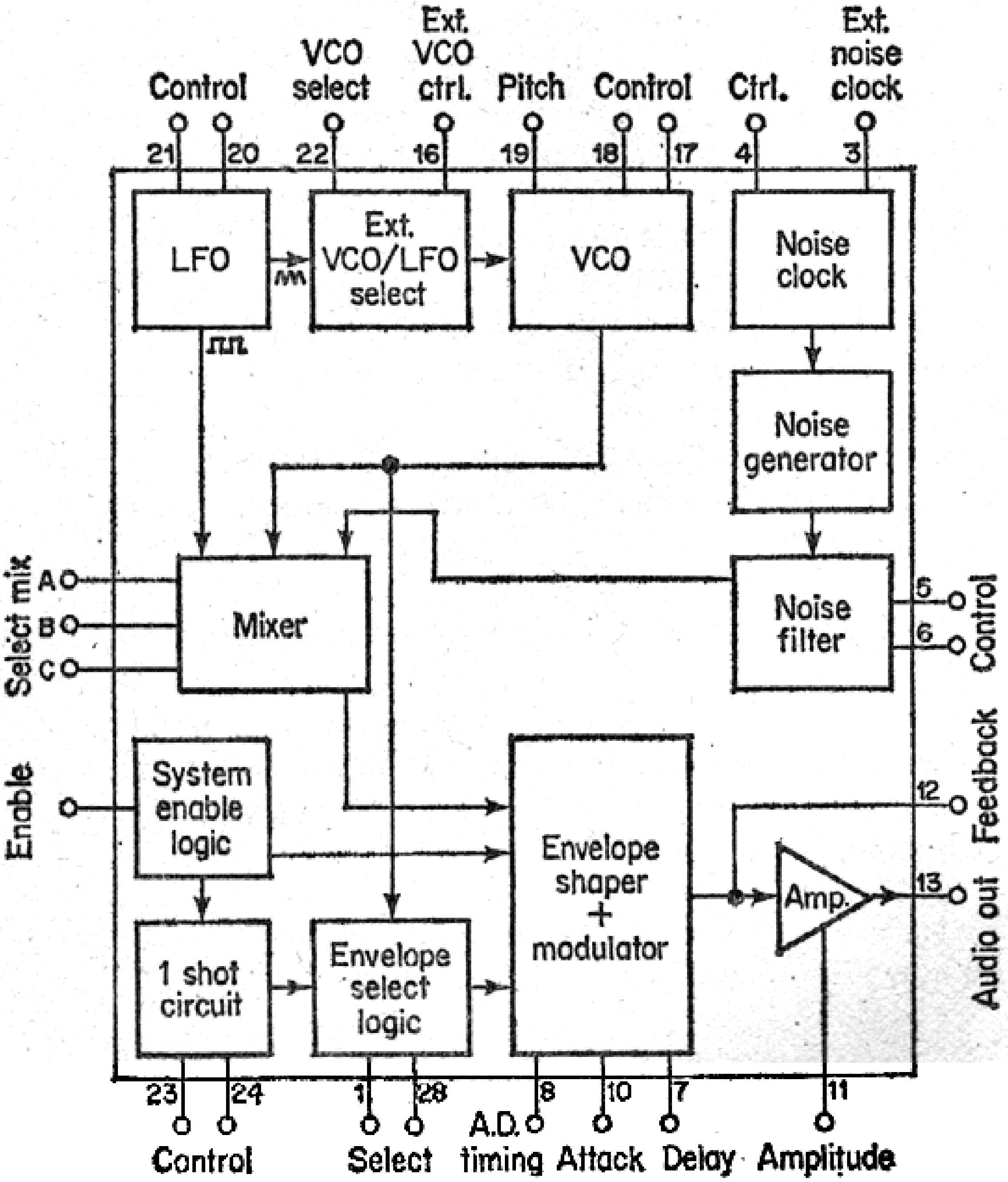


Fig. 2.1 Block diagram of 76477

Voltage Controlled Oscillator (VCO)

The VCO has a working frequency range from 1 Hz to 20 kHz, and this is controlled by

a) an external voltage (pin 16)

or

b) the triangular output from the LFO

and/or

c) a resistor and capacitor on pins 18 and 17 respectively.

In fact the resistor and capacitor set the minimum frequency of the VCO, and is given by:

$$f = 0.64/RC \text{ Hz}$$

Between the LFO and VCO is a switching circuit which selects either the LFO triangle output or an external control voltage as a control input to the VCO. The switching function is controlled by logic signals on pin 22. Therefore a logic 0 on pin 22 connects the VCO control input to an external control voltage on pin 16, while a logic 1 connects the LFO triangle output to the VCO input. The external control voltage must lie between 0 and 2.5V. Frequency increases with decreasing voltage.

A voltage on pin 19 adjusts pitch, or mark-space ratio. This facility permits a change in the quality and tone colour of the sound produced. This voltage should be between 0 and 2.5V., and the mark-space ratio increases with increasing voltage.

The output of the VCO, which is a square wave, is fed to the mixer and to the envelope select logic.

Noise Generator

Something that hi-fi buffs are forever trying to eliminate is that which puts a lot of life into electronic music. In the 76477, white noise is generated by a shift register, clocked by a ring oscillator (noise clock). It is then passed through a low-pass filter whose bandwidth can be varied externally by a capacitor at pin 6 and a resistor at pin 5. The cutoff frequency is given by:

$$f = 1.28/RC\ Hz$$

It is possible to omit filtering by removing the capacitor and leaving a resistor at pin 5.

The noise clock's frequency can also be varied with an external resistor on pin 4. Alternatively an external clock can be connected via pin 3.

Mixer

The three outputs from the LFO, VCO and noise generator are fed to the mixer. This is not an analogue mixer in the normal sense because instead of summing the input signals it multiplexes them. No problems are caused for us however, since the mixer output is taken internally to the envelope shaper and modulator.

The contents of the mix are determined by the three control lines A, B, C on pins 26, 25, 27 respectively. Logic signals are presented to these lines according to the truth table in Figure 2.2 in order to achieve the respective mix required. Note the control situation with logic 1 on all inputs – the output from the mixer is inhibited.

C (27)	B (25)	A (26)	Output
0	0	0	VCO
0	0	1	LFO
0	1	0	Noise
0	1	1	VCO/noise
1	0	0	LFO/noise
1	0	1	LFO/VCO/noise
1	1	0	LFO/VCO
1	1	1	Inhibit (zero output)

Fig. 2.2 Mixer truth table

System Enable Logic/One Shot Circuit/Envelope Select Logic/Envelope Shaper and Modulator

The first three circuits are all basically logic circuits which provide control for the envelope shaper and modulator.

The system enable logic switches the signal output of the chip on or off depending on whether a logic 1 or 0 respectively are applied to pin 9. This circuit also operates in conjunction with the one-shot circuit, which is a monostable whose time constant is determined by a resitor and capacitor on pins 24 and 23 respectively. This time constant can be found from:

$$t = RC \text{ seconds}$$

The one-shot circuit enables many sounds like explosions or percussive effects to be made. The monostable is activated when pin 9 goes from logic 1 to logic 0. In practice this is easily carried out with a push-button arrangement.

The envelope select logic is a circuit which decides which signal will be fed to the envelope shaper and modulator. The selection is controlled by logic signals on pins 1 and 28, and the truth table for this is shown in Figure 2.3. This circuit works in conjunction with the envelope shaper and modulator, which generates and applies an attack-decay envelope to the selected input. How this works with the envelope select logic is also set out in Figure 2.3

Logic input pin 1	Logic input pin 28	Envelope selected	Attack ramp starts on....
0	0	VCO	Positive edge from VCO
0	1	Mixer only	System enable (pin 9) to logic 0
1	0	One-shot	System enable (pin 9) to logic 0
1	1	VCO with alternating cycles	Every other positive edge from VCO

Fig. 2.3 Envelope select table

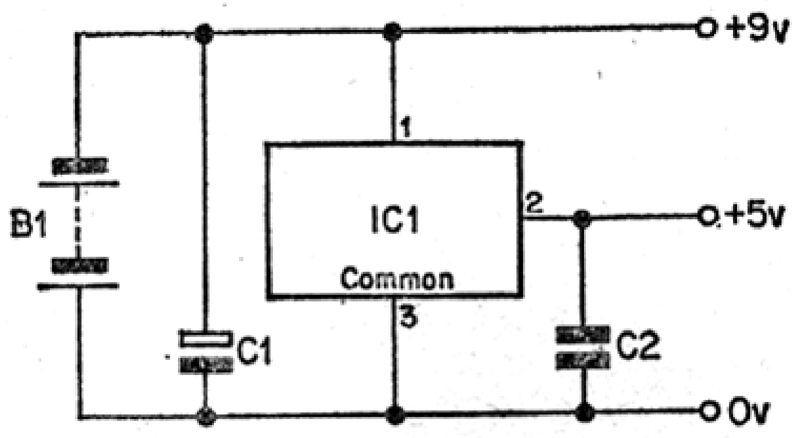
The envelope shaper is a simple attack-decay type whose attack and decay functions are controlled by resistors on pins 10 and 7 respectively, and also a capacitor on pin 8. The resistors set the relative attack and decay times, while the capacitor sets the overall timing.

Output Amplifier

The envelope shaper and modulator feeds directly into the output amplifying stage. The gain can be varied externally, and the output voltage peak-to-peak will be 3.4 R_V/R_G where R_V is the resistor at pin 12 and R_G is the resistor at pin 11.

Since R_G at pin 11 controls the gain directly, it can be usefully employed for amplitude modulation. The recommended limits to its value are 22 kΩ to 220 kΩ.

There also exists, via pin 12, the possibility of providing an external input. This can be in the form of a voice signal, via a microphone and pre-amplifier, or an electric musical instrument such as a guitar or organ. Feeding such a signal in here has the effect of mixing the internal signal with external before being amplified and outputted.



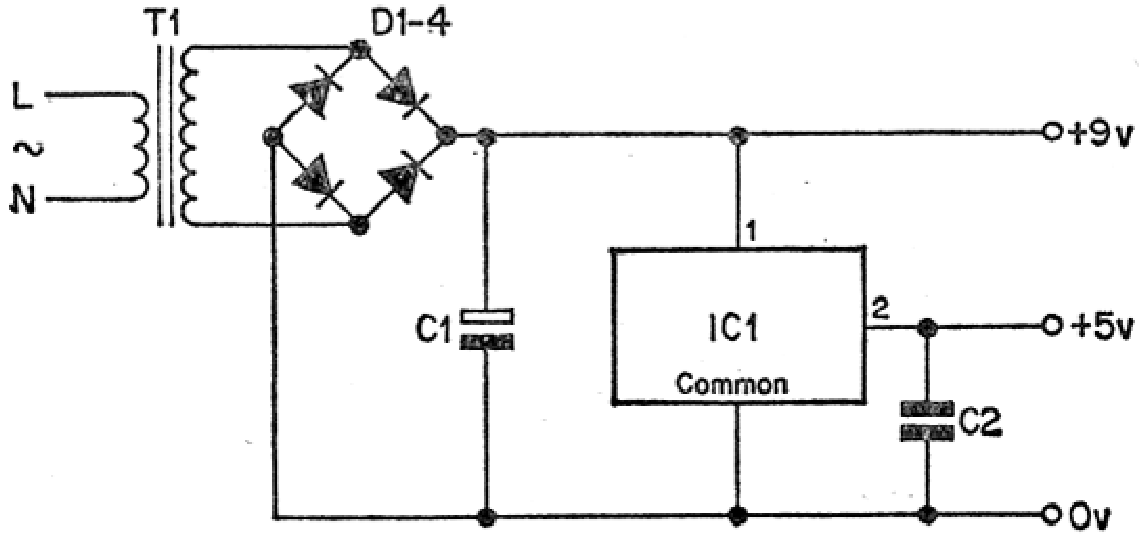
Components:
C1 100μF 16v elect.
C2 0·1μF polyester
IC1 μA78L05AWC 5v regulator at 100mA
B1 9v battery PP6 or similar

Fig. 2.4 Battery power supply

Regulator

This is the power supply of the chip. Externally, it requires a regulated 5 volts, an unregulated, but smoothed, 9 volts, and a ground. The current drawn by the chip is around 15 mA. This can easily be supplied by a battery, and a circuit to be used with one is shown in Figure 2.4. This circuit is required to give the regulated 5V. supply.

Figure 2.5 shows a mains power supply which will do the same job.



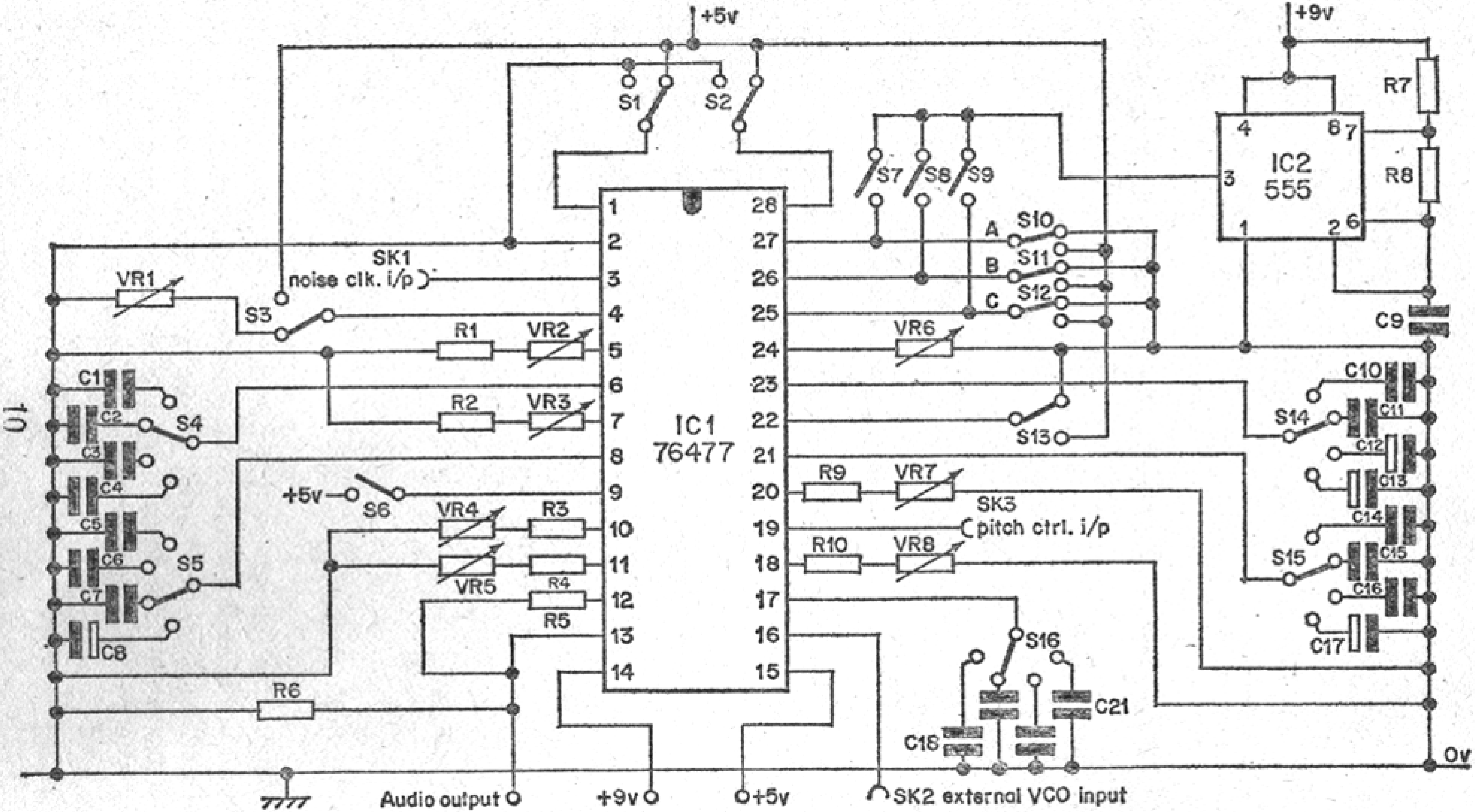
Components:

CI	470μF 16v elect.
C2	0·1μF polyester
IC1	μA78L05AWC 5v regulator at 100mA
D1–4	W01 bridge rectifier
T1	Mains transformer 6v at 6VA

Fig. 2.5 Mains P.S.U.

A Practical Circuit

To enable the full potential of this chip to be realised, the circuit in Figure 2.6 has been designed so that all of the various functions of the chip can be varied. In most cases this means potentiometers or switched resistors/capacitors, but where logic signals are required simple on/off switches are used.


+5v
+9v
S1
S2
R7
R8
IC2
555
S7
S8
S9
S10
S11
S12
S13
A
B
C
IC1
76477
SK1
noise clk. i/p
VR1
S3
R1
VR2
R2
VR3
VR6
C9
C1
C2
C3
C4
C5
C6
C7
C8
S4
S5
+5v
S6
VR4
R3
VR5
R4
R5
R6
R9
VR7
SK3
pitch ctrl. i/p
R10
VR8
S14
S15
C10
C11
C12
C13
C14
C15
C16
C17
S16
C18
C21
0v
Audio output
+9v
+5v
SK2 external VCO input

Components:

R1	4·7k
R2	4·7k
R3	4·7k
R4	22k
R5	33k
R6	4·7k
R7	10k
R8	10k
R9	4·7k
R10	4·7k
all ¼W	10% carbon
VR1	100k lin.
VR2–4	1M lin.
VR5	470k lin.
VR6–8	1M lin.
C1	330pF polystyrene
C2	1000pF polystyrene
C3	2200pF polystyrene
C4	0·01μF polyester
C5	0·01μF polyester
C6	0·1μF polyester
C7	1μF polyester
C8	10μF 12v elect.
C9	4700pF polystyrene
C10	0·1μF polyester
C11	1μF polyester
C12	10μF 12v elect.
C13	22μF 12v elect.
C14	470pF polystyrene
C15	4700pF polystyrene
C16	0·47μF polyester
C17	4·7μF 12v elect.
C18	100pF polystyrene
C19	0·01μF polyester
C20	0·1μF polyester
C21	1μF polyester
IC1	SN76477
IC2	NE555V
S1–3	1 pole changeover
S4–5	1 pole 4 way rotary
S6–9	1 pole on/off
S10–13	1 pole changeover
S14–16	1 pole 4 way rotary
SK1–3	single sockets to suit (e.g. phono, jack, etc.)

Fig. 2.6 Practical circuit for 76477

It would be easy to provide switches and variable controls for every possible patching arrangement, but some of these have been dispensed with in the interests of economy and simplicity of the final layout.

In this circuit, a clock generator has been provided which can be used to switch the mixer control lines A, B or C so that two simultaneous signals can be passed to the envelope shaper. This has the effect of providing the components of a mix with different levels with respect to one another. The rate of switching is about 60 kHz, which is well above the audible range.

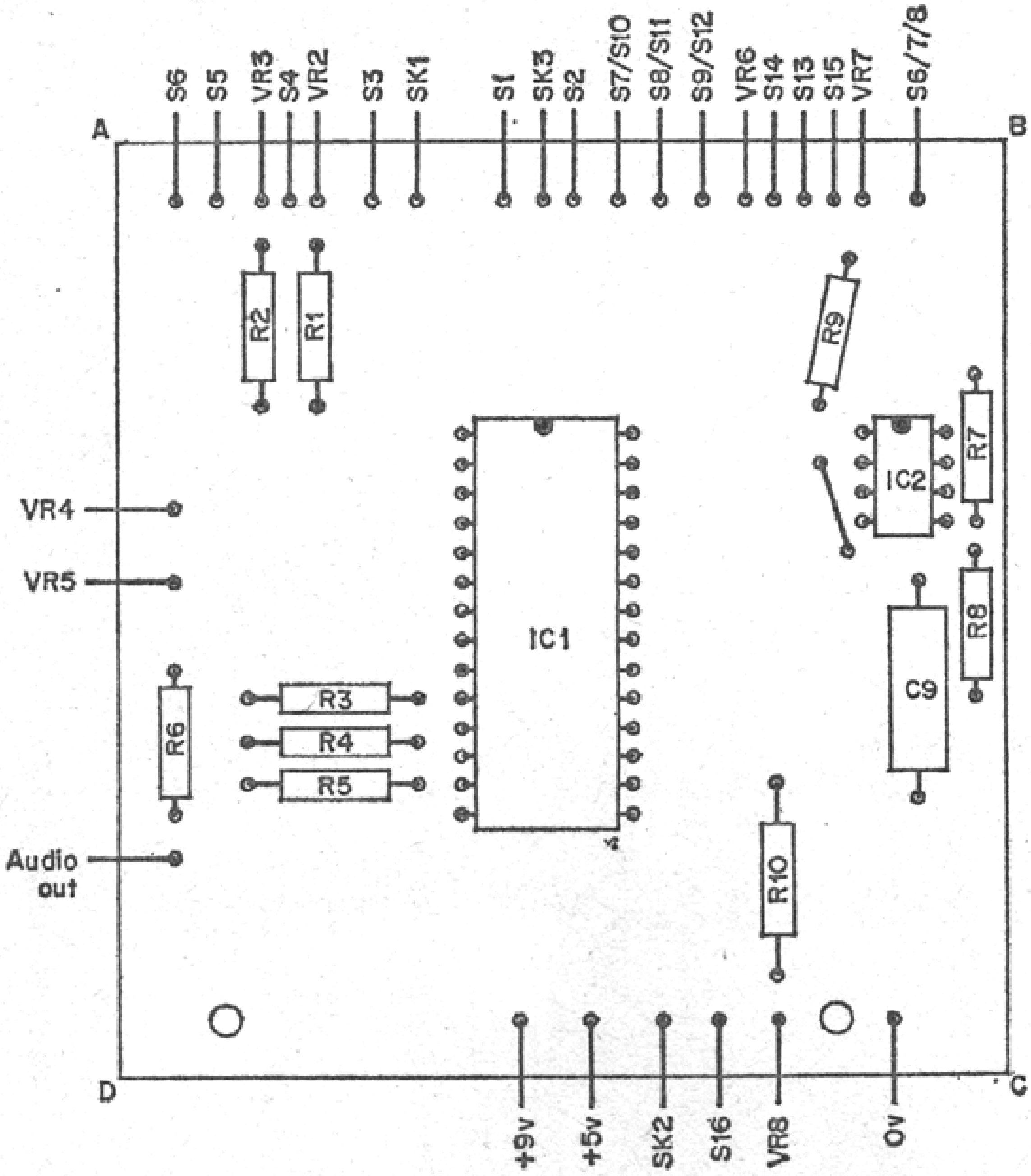


Fig. 2.7a Printed circuit layout for main circuit

There now follows full construction details.

Construction

The main chip and most of the associated components are mounted on a single printed circuit board. All potentiometers and switches are mounted on the case's front panel, connected to the p.c.b. by wiring. Figure 2.7 shows the layout and copper pattern for the main board, while Figures 2.8 and 2.9 show the boards for the battery p.s.u. and mains p.s.u. respectively. It is advisable to use a socket for the main chip – it will enable you to test the circuit before putting the I.C. in.

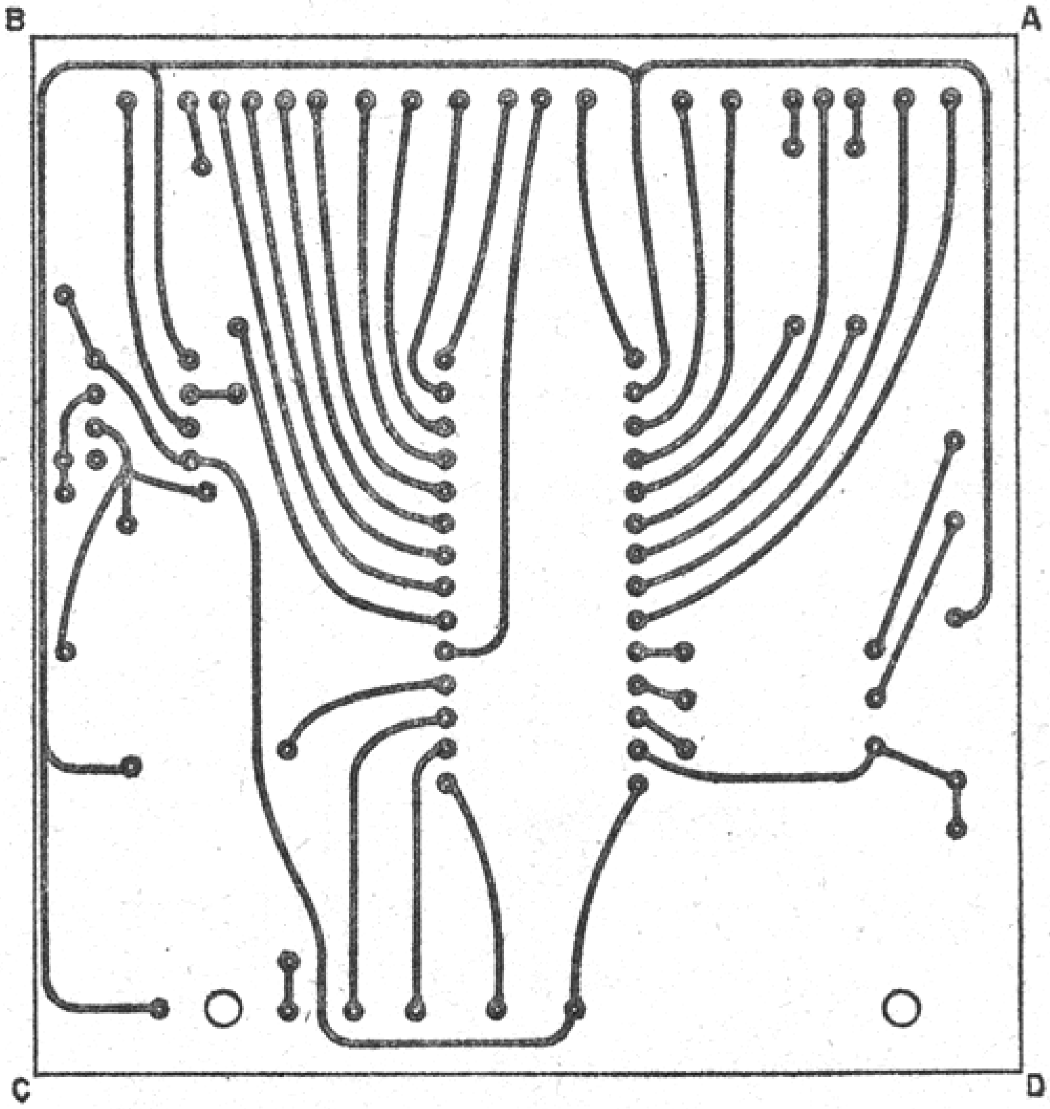


Fig. 2.7b Copper pattern for main circuit

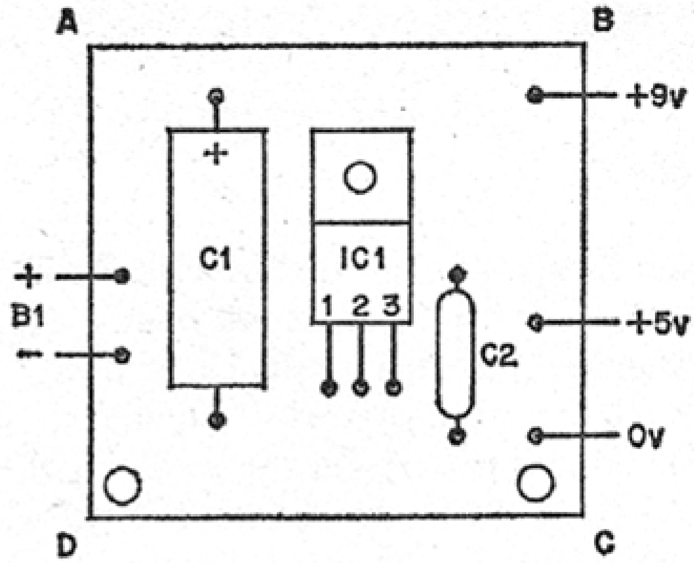


Fig. 2.8a Printed circuit layout for battery P.S.U.

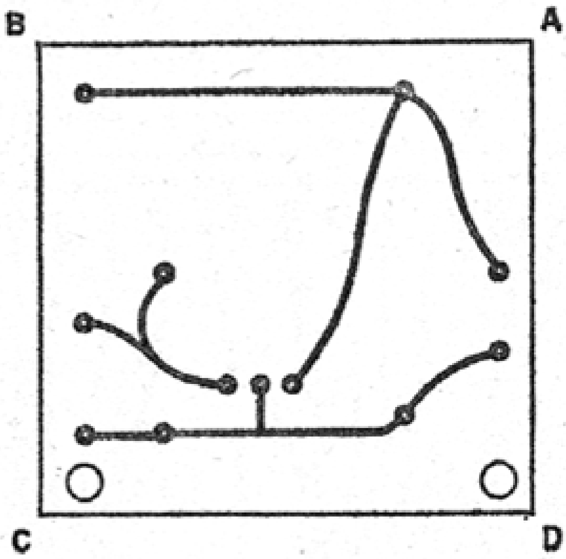


Fig. 2.8b Copper pattern for battery P.S.U.

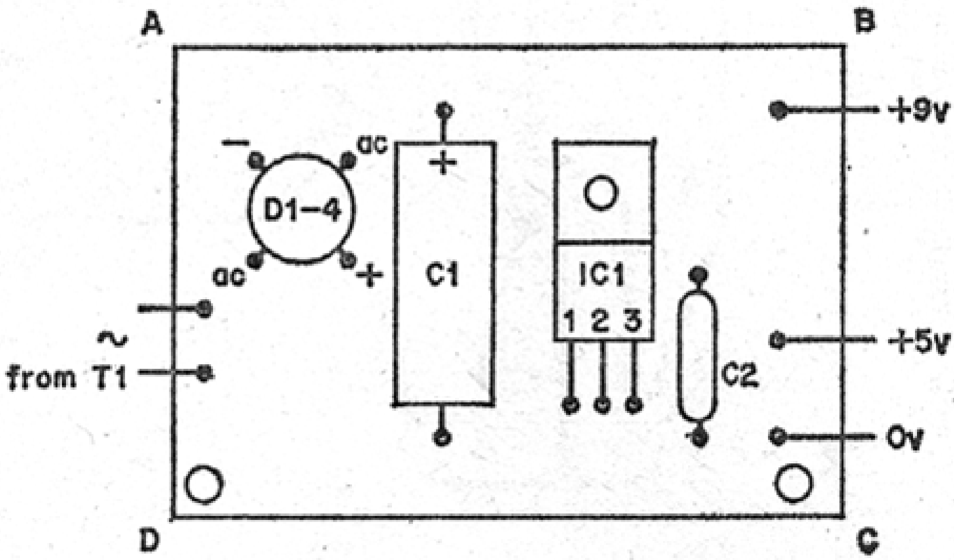


Fig. 2.9a Printed circuit layout for mains P.S.U.

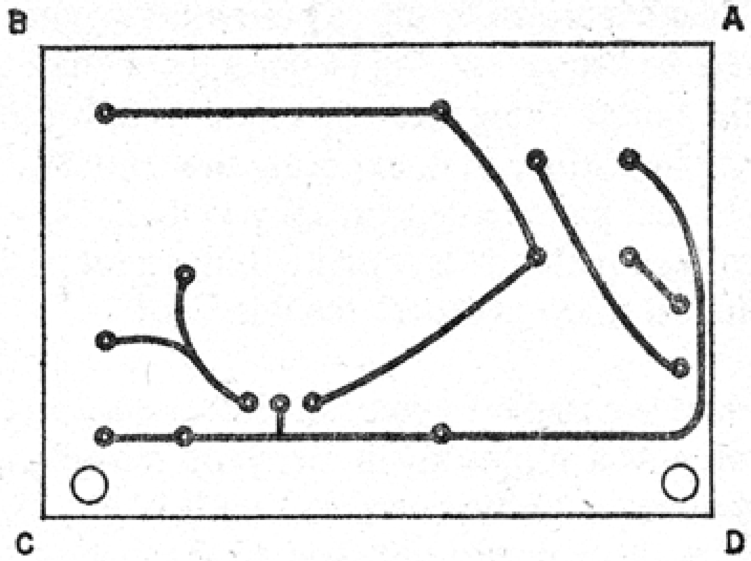


Fig. 2.9b Copper pattern for mains P.S.U.

The whole works can be housed in one case. The case should preferably be aluminium, to provide screening for the audio sections. One with a large removable front panel is ideal, because this panel will be able to carry all of the controls as well as the main board. This method of construction provides for a very neat layout and enables simple maintenance to be carried out. Figure 2.10 shows how the panel fits together. The sequence of construction is to build the main board first, and then mount the pots and switches onto the front panel. The panel, of course, should be pre-drilled, or punched, and lettered.

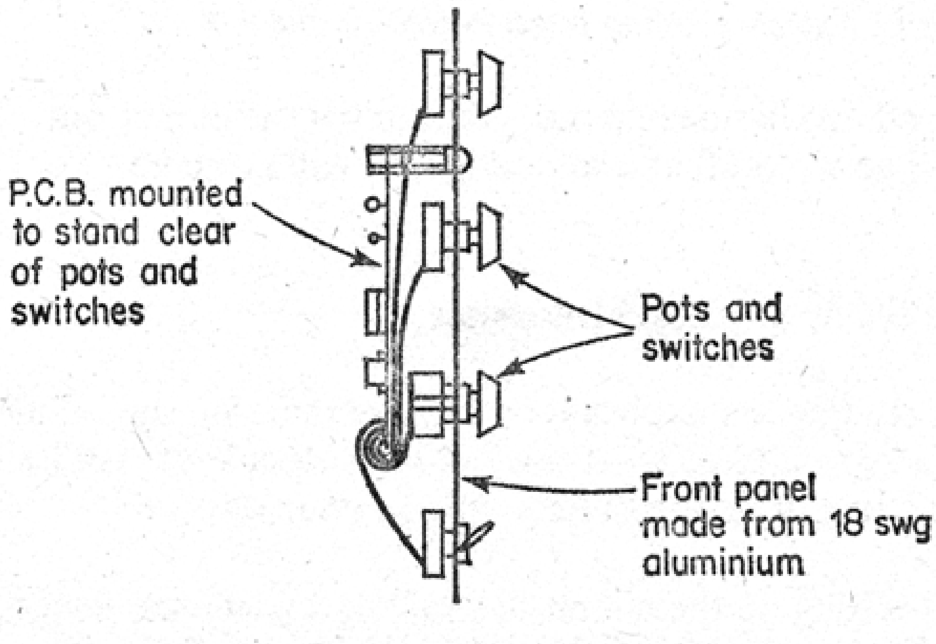


Fig. 2.10 Diagram showing method of panel assembly (not to scale)

Wiring can then begin, following the circuit diagram. The rule at this point is to keep all wiring to one side of the board, so that when the board fixing screws are removed, it can be 'hinged' away from the panel, exposing the controls. Use different coloured connecting wires if possible. Not only do they look professional but they make things a lot easier when you are trying to find out where the wires go!

When the panel is complete, you can start preparing the rest of the box. The power supply fits in here and fairly long wires should be connected to the board so that it is easy to lay the panel alongside the box without stretching the wires. The mains cable (if you are using a mains p.s.u.) is led into the box through a hole at the back. Make sure there is a grommet in this hole and it's a good idea to clamp the cable inside the box. Figure 2.11 gives details of the box assembly.

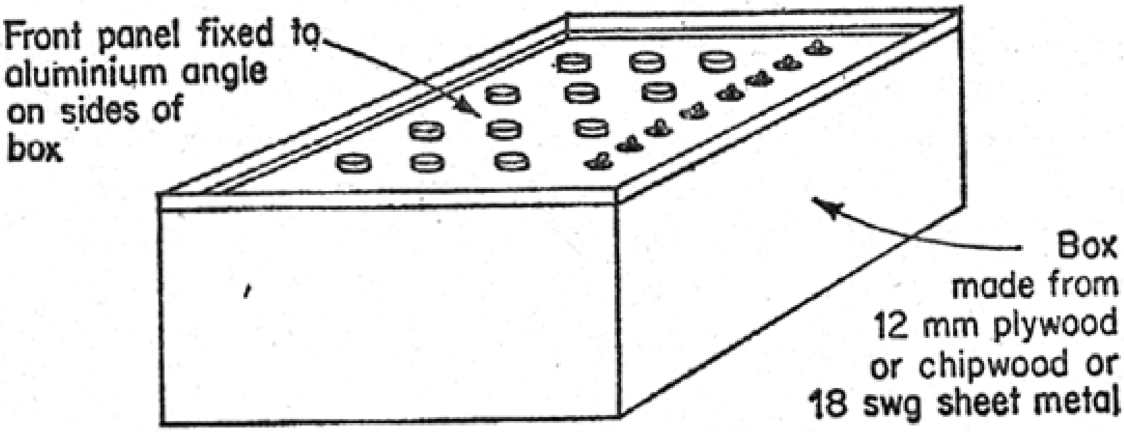


Fig. 2.11 Sketch showing panel in place in the box

After all this has been done, you can try the circuit out. Little should go wrong that a soldering iron will not cure.

Using the Single-Chip Synthesiser

After reading the explanatory notes earlier you should already have a good idea of what the 76477 is capable of, but here are just a few extra hints to help you on your way.

When setting up the circuit to produce a particular sound, it is best to adjust the controls in the following order:

1) Set all pots and rotary switches to their mid-values.

2) Select mixer combination.

3) Select envelope.

4) Adjust VCO, noise generator, and LFO.

5) Adjust attack and decay.

6) Adjust output amplitude.

A large variety of waveforms can be synthesised with this circuit, but further effects can be produced by bringing in the external circuits such as the clock on the mixer select lines or the the external noise clock. The VCO frequency also has provision for external control and this could be connected to a device such as the sequencer to be described later, or another voltage-generating device.