DRUM SYNTHESISER

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THE synthesiser was originally developed using a keyboard, as the key contact was the easiest method of implementing the switching function required. However, as time passed by, other methods of controlling the basic synthesiser circuits were investigated, and the drum synth was born.

This works on the principle of a pick-up or sensor of some kind picking up the vibrations of a drum or pad and then feeding these signals to the circuitry which controls the synth. Note that this signal is only a trigger signal and that the synth produces the actual sound.

The unit to be described here can use one of a variety of methods to pick up the drum signal and trigger the envelope shaper etc. in the synth which is contained in a separate case. It runs off a regulated mains power supply which could be used to power external equipment if desired.

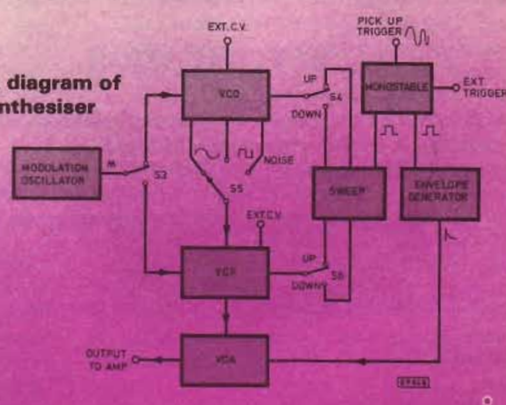
BLOCK DIAGRAM

Fig. 1 shows the basic arrangement of the circuits in the synth. The sweep generator circuit provides a rising or falling envelope (as selected) which is mixed with the triangle wave output from the modulation oscillator, and an external control voltage if desired, and fed to the voltage controlled oscillator (VCO) and voltage controlled filter (VCF) to control their frequencies. The output of the VCO (sinewave, squarewave or white noise as selected) is fed directly to the VCF and passes on to a voltage controlled amplifier (VCA) which is controlled by an envelope generator, triggered by the drum pick-up. This gives the sound its percussive envelope, essential in imitating drums etc. From here the sound is fed to the external amplifier or tape recorder as required via the output socket.

MODULATION OSCILLATOR

The circuit for this is shown in Fig. 2. It is a standard integrator/comparator oscillator circuit and its purpose is to generate a linear triangle wave, frequency variable over the low frequency range cycling the pitch of the VCO or cut-off frequency of the VCF as described earlier. IC1, R2, and C2 form an integrating network. C2 charges up linearly via R2 until it triggers IC2, which forms a comparator. On triggering, the output switches polarity and so charges C2 in the opposite direction at a rate dependent on the setting of VR1. When S1 is in the l.f. (low frequency) position, C1 is placed in parallel with C2, increasing its capacitance and thus decreasing the frequency. The range is about 0·5Hz to 200Hz on a.f. (audio frequency) and 1 cycle in 30 secs. to 10Hz on l.f. S3 routes the modulation voltage to the VCO or VCF in the proportion set by VR2, the oscillator being disconnected when not required by S2.

Fig. 1. Block diagram of the Drum Synthesiser



VOLTAGE CONTROLLED OSCILLATOR

This generates the actual signal which will form the final sound. It has two waveshapes, sine and square, and a white noise output which will be discussed later. The circuit for the VCO and noise generator is shown in Fig. 3. It is based on a custom i.c., the SSM2044. This is a completely integrated voltage controlled low-pass filter system in one package requiring very few external components. The system comprises an exponential converter for controlling the cut-off frequency exponentially from a linear control voltage which is fed in at pin 13, a four-pole low-pass filter block based on transconductance amplifiers which has a −24dB/octave cut-off slope and minimum control range of 10,000:1, and a circuit for controlling Q (or resonance) from an input control current fed into pin 2. If the Q current is increased beyond a certain value, the filter is forced to oscillate at the cut-off frequency producing a pure sinewave at the output. This is the principle used to generate the sinewave in the VCO, the range being approximately 25Hz to 2·5kHz. The output appears at pin 3 of the i.c. and is a current. This is converted into a voltage and buffered by IC3, so producing a sinewave of around 8V peak to peak depending on the setting of VR3. VR3 sets the voltage which is converted into a current by R7 and controls the Q. This allows accurate setting of the Q for maximum stability over the oscillation range, and greatest purity in the sinewave.

The control voltages for the VCO from the modulation oscillator, the sweep circuit via S4 and VR5, the manual frequency potentiometer, and external input, are summed by IC6 and the resulting voltage is attenuated to around 80mV

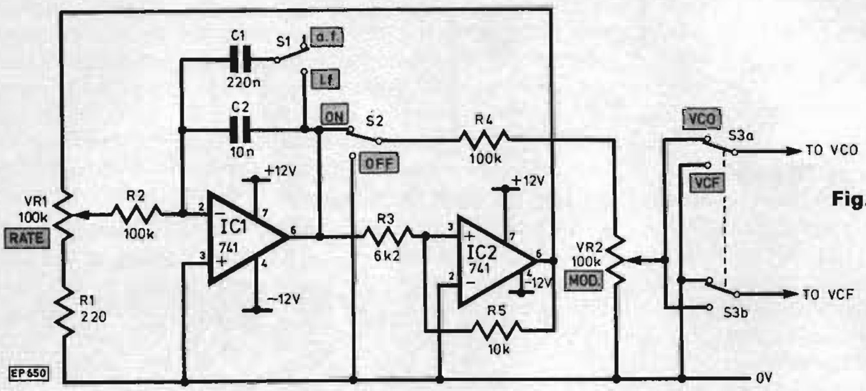


Fig. 2. Circuit of the modulation oscillator

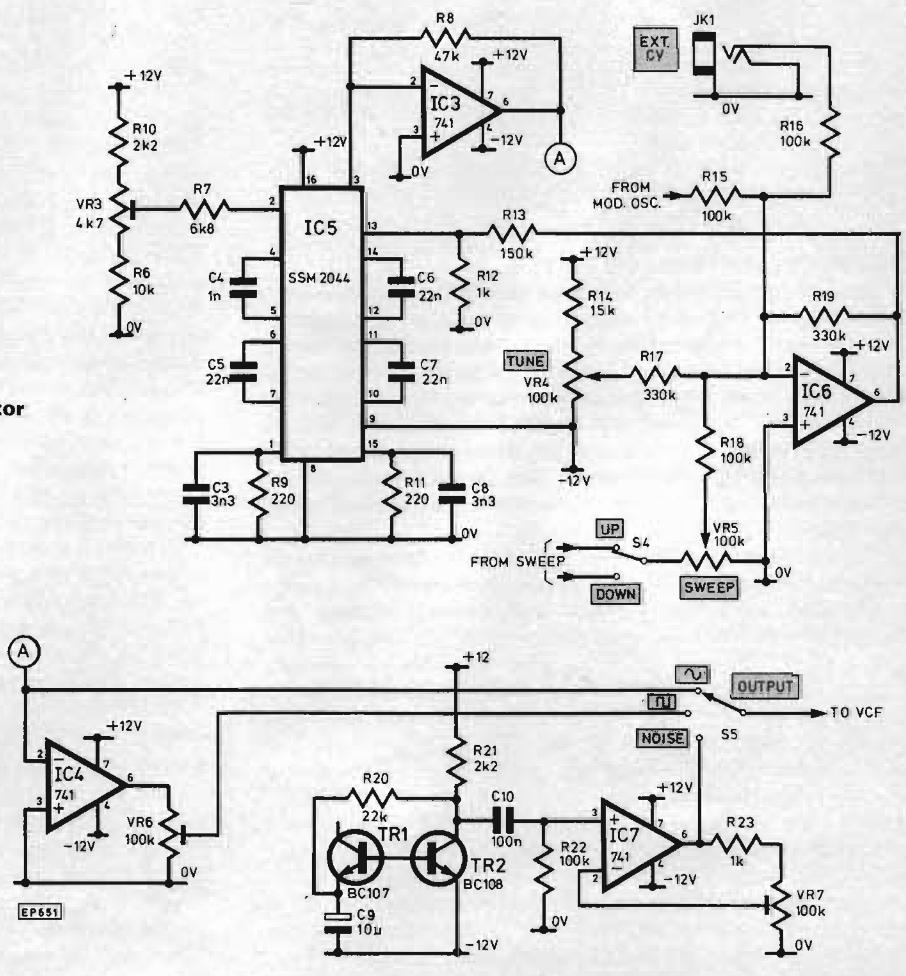


Fig. 3. Circuit of the VCO and noise generator

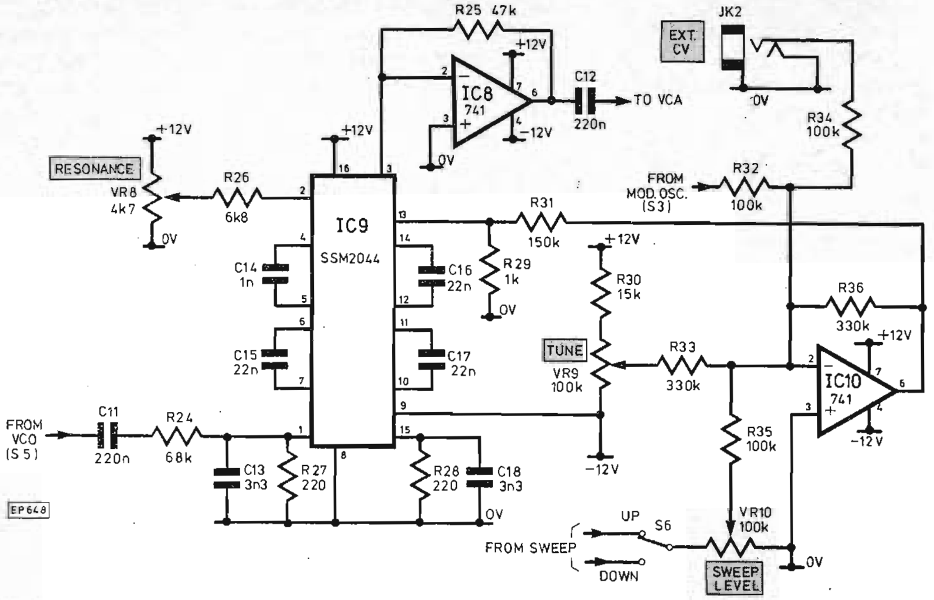


Fig. 4. Circuit of the voltage controlled low pass filter

by R13 and R12, and fed to pin 13 of IC5. Although some exponential oscillators using discrete components suffer from temperature drift problems in the exponential generating transistor, the on-chip exponential generator in the SSM2044 has circuitry which keeps this drift to a minimum and the prototype was found to be thermally stable, the oscillator settling down a few seconds after switch on.

The sinewave is fed to a simple comparator formed around IC4. This produces a squarewave of adjustable amplitude by VR6.

The noise generator uses a reverse biased transistor emitter/base junction (TR1) to produce white noise which is amplified by TR2 and further amplified by IC7, the gain of which can be set by VR7.

Switch S5 selects the desired output waveform: sine, square, or noise. The presets VR6 and VR7 are adjusted so that all waveforms are at the same level.

VOLTAGE CONTROLLED FILTER

Once the basic signal has been generated, some way of controlling its timbre or tonal quality must be provided to give variation in the sound, since raw squarewave or white noise becomes boring very quickly. This quality is affected by the voltage controlled filter which is a low-pass type. This filter has an exponentially voltage controllable cut-off frequency, variable over roughly the same range as the VCO, a cut-off slope of −24dB/octave, and resonance variable up to oscillation. It uses the same chip as the VCO, the SSM2044.

The circuit is shown in Fig. 4. The same combination of control voltages as in the VCO is used in the VCF, i.e. sweep, modulation oscillator, manual, and external. These are summed in the required proportions by IC10. This provides the control voltage for IC9. VR8 provides a variable voltage which is converted to a current by R26 and controls the filter's Q. The input signal is taken directly from the waveform selector switch of the VCO. IC8 converts the output current into a voltage and buffers it, this signal going directly to the next stage.

Since the VCF's cut-off frequency is exponentially related to control voltage, as in the VCO, the VCF and VCO will track each other with fair accuracy if controlled by the same voltages. Better tracking accuracy could have been achieved using close tolerance resistors, but in this application the added expense was felt to be unnecessary.

TRIGGER INPUT CIRCUIT

Each time a sound is required in any instrument, it must be initiated in some way, i.e. plucking a string, or pressing a key. In a drum synth the sounds are initiated by the signals from a transducer placed near to or on a drum, as mentioned earlier. These signals are of no use to the synth, since a sharp, high level pulse is required. For this reason an amplifier and pulse generator are used.

The circuit is shown in Fig. 5 and is very simple. The incoming low level signals are first attenuated to the desired amplitude by the sensitivity control VR11, and then amplified by a non-inverting, variable gain, op-amp circuit using IC11. The gain can be set by VR12 to any value between 1 and the op-amp's open loop gain (typically around 100,000). Thus by setting the gain high, when a low level signal is presented to the input, a high level, squared-up signal will appear at the output, due to the clipping action of the circuit.

To provide a stable voltage representing an on or off condition, a capacitor C20 is charged via D1 by this squared waveform so rectifying it. D1 allows only positive pulses to charge the capacitor and prevents it from instantly discharging when the op-amp output falls to zero. R38 controls the decay time of the capacitor and allows it to discharge quickly on removal of the input waveform. The voltage across this capacitor is used to trigger the monostable pulse generator formed around two gates from IC12. This triggers on the positive excursion of the voltage across C20, producing a positive pulse of around 0·01s long. This is what is fed to the circuits requiring a trigger signal.

A manual switch is included so that sounds can be set up without the unit being connected to a microphone or pick-up. Also included is an external trigger input which requires a positive d.c. pulse of about 8V or above (absolute maximum 12V). When a jack plug is inserted into the external trigger socket the drum input circuit is automatically disconnected. R39 ensures that the input to IC12a is never left floating, otherwise instability could occur, causing false triggering.

SWEEP MODULATION

This circuit, as explained earlier, provides a rising or falling voltage each time the synth is triggered. The speed of the change of voltage is controllable via the decay pot. The circuit is shown in Fig. 6. CMOS switches IC13a and IC13b, together with IC14, C22, R41, and VR13 form a simple envelope generator. IC12c is connected as an inverter so that when one of the CMOS switches is on, the other is off.

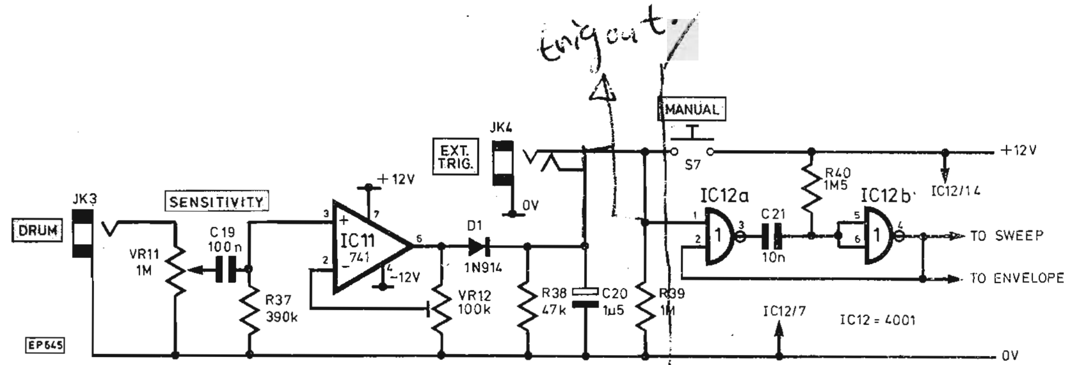


Fig. 5. Circuit of the trigger input

When the trigger input is low the input to switch IC13b is high and it is on, so holding C22 at ground potential via VR13. When the trigger input becomes high IC12c is switched, IC13a switches on, and C22 charges via R41 to approx. +10V. When the trigger pulse is removed IC13b switches back on again and C22 discharges to ground at a rate determined by the resistance of VR13. Thus a falling envelope as in Fig. 7a is produced. The voltage on C22 is buffered by IC14 to provide a usable output. This output is inverted by IC15 to provide the rising envelope as shown in Fig. 7b. The VCO and VCF each contain a switch which selects the direction of the sweep envelope, and a potentiometer to control the amount of sweep modulation. The decay control can vary the decay time from approximately 0·1s to 10s.

VOLTAGE CONTROLLED AMPLIFIER

So far, since the VCO and noise generator are on all the time, the output of the drum synth would be a continuous sound, hence some method of switching on the output and controlling its decay time is required. The circuit which does this is the voltage controlled amplifier together with the envelope generator. For simulating percussive sounds, which is what the drum synth does, an envelope with fast attack time and slower decay time is necessary. This means that the sound, when initiated by the trigger pulse, must increase in volume to its maximum almost instantly, and then die away to zero at a preselected rate. To produce this effect an envelope generator produces a positive-going envelope voltage with the above characteristics which is fed to the VCA, a device which gives an output signal proportional to its control voltage, so shaping the output signal.

The circuit can be seen in Fig. 8. The voltage envelope is generated in the same manner as in the sweep generator, C23 charging via R44 to give a fast attack, and discharging via VR14 giving variable decay. Since only a positive envelope is required no inverter is included.

The VCA is based on the CA3080 transconductance op-amp i.c. This functions similarly to an ordinary op-amp but its output is multiplied by a current injected into pin 5, called I_{abc}. Thus by feeding a signal into the inputs the gain and hence amplitude of the signal can be linearly controlled by varying I_{abc}. IC17 together with TR3 and R45 convert the envelope voltage into a current suitable for controlling IC18. When IC16's output is 0V then there is no output from the VCA since I_{abc}=0. VR15 converts the current output of IC18 into a voltage, and also sets the volume to the output socket via C24.

POWER SUPPLY

The synth is powered from a mains ±12V stabilised power supply. This uses two integrated circuit regulators, the 78M12 and 79M12, to provide positive and negative voltage rails as can be seen from Fig. 9. Each rail can provide a maximum of 500mA before the regulator's current limit acts. Since the drum synth draws only around 40mA from each rail, external equipment could be driven from the PSU. For instance if two drum synths were built only one power supply could supply both via a socket on the back of the case for example. Note that if the maximum current is required to be drawn then the regulators will require heatsinks. D3 shows that the power is on.

CONSTRUCTION

Construction should begin with the preparation of the case. The prototype was housed in a rexine covered case size 13in × 8in × 4½in. The drilling dimensions are shown in Fig. 10. The diameters of the mounting holes for the switches and l.e.d. will depend on the particular components

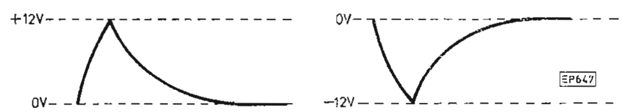


Fig. 7(a). Falling envelope **Fig. 7(b). Rising envelope**

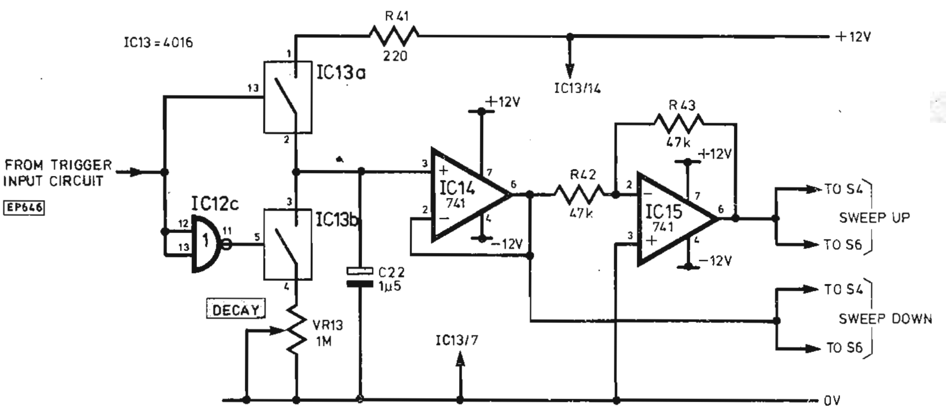


Fig. 6. Circuit of the sweep modulation generator

used by the constructor. Once all the case drilling has been completed, the front panel can be covered in Con-Tact or similar, or painted if desired. It can now be lettered with white rub-down lettering, and then sprayed with clear varnish to protect it. The transformer should be mounted to the back panel with 8BA bolts, and connected to the mains lead and mains switch as shown in Fig. 10.

damaged by leakage from a soldering iron tip. IC12 and IC13 should be left in their protective foam until all other circuit board construction is complete. Then they should be put into the sockets, keeping handling to a minimum.

Begin preparing the circuit board by drilling the mounting holes and making the breaks in the copper strips. Now the PSU can be constructed. When building the power supply,

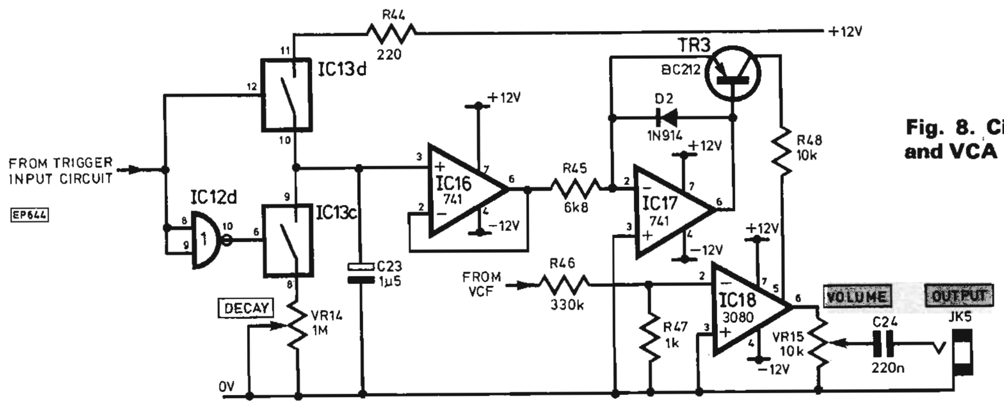


Fig. 8. Circuit of the envelope generator and VCA

All potentiometer spindles should be cut to length and the potentiometers, switches, sockets, and l.e.d. mounted to the panel. These should be wired up as shown, the panel mounted components being connected too. Uninsulated, single-core wire is used to link all the common connections at the back of the panel. Otherwise lightweight, stranded wire should be used for interconnection.

The use of coloured wire greatly helps in the identification of wires and their functions. A source of suitable wire is a metre of 25 or 36 core multicore cable. The wires to the circuit board need not be connected yet. Attention can now be turned to this circuit board.

Most of the components are contained on a 115 holes × 36 strips piece of Veroboard, excepting those soldered directly to the potentiometers and switches on the front panel so as to minimise the number of wires running to and from the circuit board. It is recommended that the power supply section be built and tested first. Once working this will provide power for testing the other sections. Circuit layout is shown in Fig. 11.

To make building, testing, and setting up easier, each circuit is laid out on the board so as to be completely isolated and independent from all the other circuits, apart from sharing power supply connections. This allows each one to be built and tested without having built any others onto the board. A convenient procedure is to build the circuit board up from left to right. It is recommended that i.c. sockets or Soldercon pins be used for all i.c.s particularly IC5 and IC9 to prevent them being overheated during soldering, and IC12 and IC13 since these are CMOS chips and could be

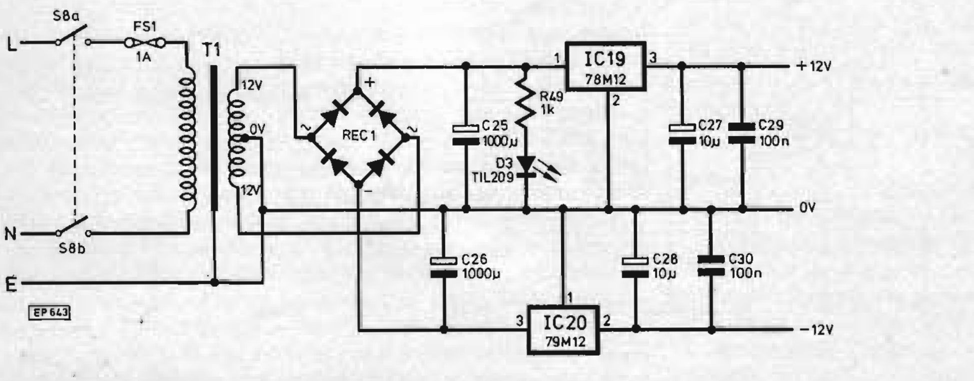
double check the polarity and positioning of all the components. Check carefully that the regulators have been inserted facing the right way round. The power supply constructed, the transformer should be connected (mains to the primary) and with a voltmeter across +12V and −12V the mains should be switched on. If there is no reading on the voltmeter then switch off immediately and check for any breaks missed out on the circuit board underside, and wiring errors. If a reading is obtained, then measure the voltage of the positive and negative rails with respect to ground. These should be approximately 12V. This being successful, the construction of the rest of the sections can begin.

The i.c. sockets should be soldered in place first since the presence of these will aid the positioning of the other components. Resistors and capacitors should be soldered in next, attention being paid to the polarity of the electrolytics and tantalums. The transistors and diodes should now be soldered, preferably using a heatshunt. Ensure that the diodes have been inserted the correct way around, the end with the red band is the end with the bar on the diagram (the cathode). Veropins are recommended to be used for all leads entering and leaving the board, as these allow wires to be connected and disconnected easily when testing etc.

TESTING

Preliminary testing of each section as it is built can be performed as follows.

Mod. Osc. Connect VR1 temporarily to the circuit board. Connect an amplifier, with its volume set very low, to pin K8



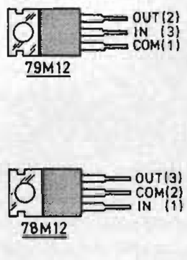


Fig. 9. Power supply unit

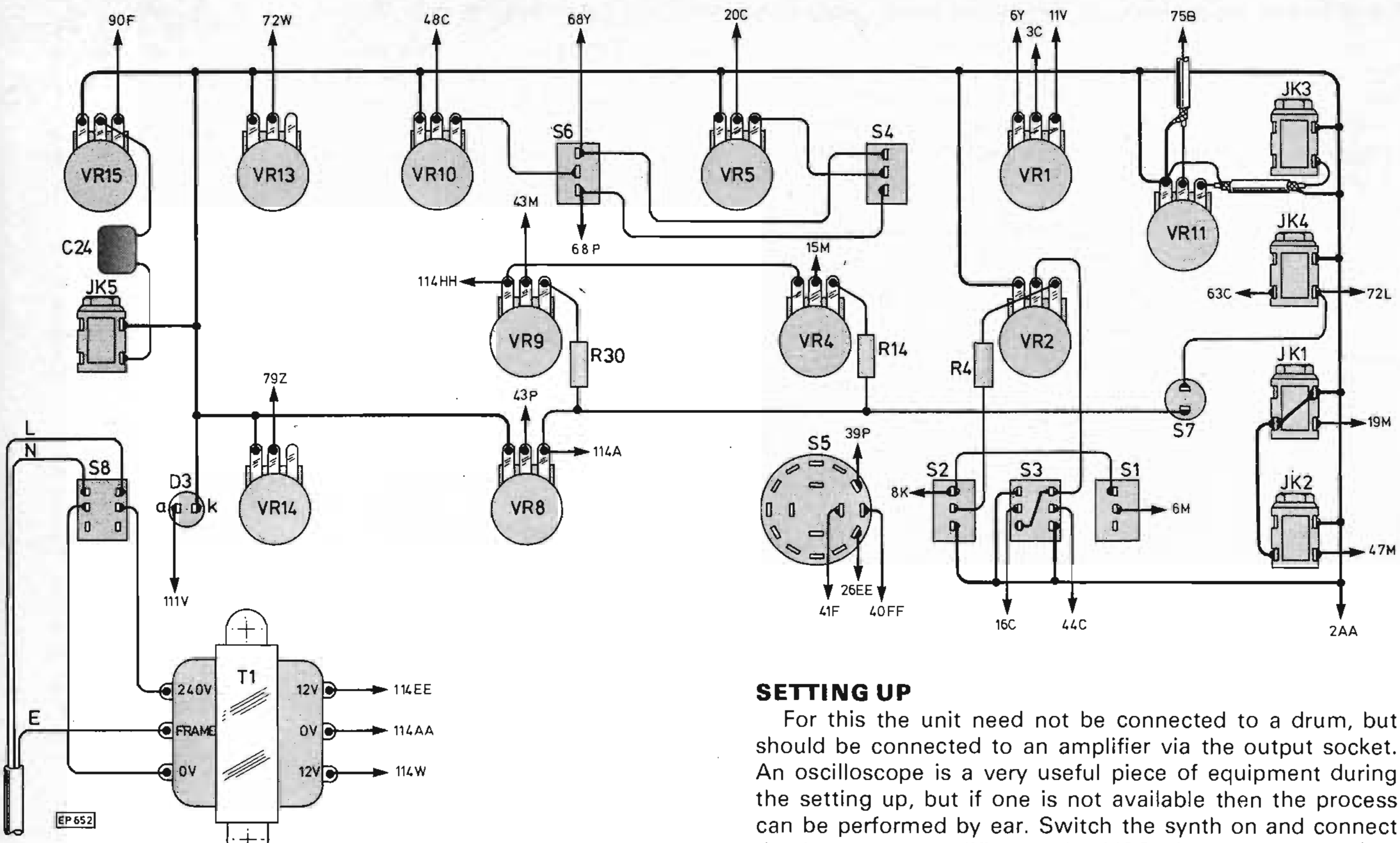


Fig. 10. Front panel layout

and check that a tone can be heard, VR1 altering the frequency. Short pins K8 and M6 together and the pitch should become a series of clicks.

VCO Adjust VR3 to max. (slider at +ve end). Connect an amplifier to pin EE26 and then pin FF40. Both should produce an audio tone.

Noise Generator Connect an amplifier to pin P39. The characteristic rushing sound of white noise should be heard.

VCF Connect pin P44 to the +12V rail and check that a tone can be heard at pin Y54.

Sweep Connect VR13 temporarily to the board and connect a voltmeter (25V d.c. range) with positive to pin Y68. Short pin L72 to +12V briefly and the voltage should rise on the voltmeter and then decay to zero at a rate adjustable by VR13. Also make sure that an inverted output is available at pin P68 (remember to reverse the voltmeter connections).

VCA Connect pin C82 to noise gen. pin P39 and solder VR14 and VR15 temporarily to the board. Connect an amplifier to pin F90 and short pin to +12V as before. The sound should be heard and then decay in volume to zero at a rate adjustable by VR14.

Trigger Input Adjust VR12 to nearly max. (slider near 0V). Connect a voltmeter to pin C63. The voltage should rise from zero in a positive direction when a finger is placed on pin B75 (the hum induced in a finger should be sufficient to trigger the circuit). The reading should return to zero when the finger is removed.

These tests having been successfully completed, then the circuit board can be mounted in the case using 1in 8BA bolts and $\frac{1}{2}$in 8BA spacers. The wires to the front panel can now be connected too, as shown in Fig. 10. Note that screened lead should be used on all board/front panel connections on the drum input circuitry. This completes the construction of the drum synth although the circuits are still to be set up.

SETTING UP

For this the unit need not be connected to a drum, but should be connected to an amplifier via the output socket. An oscilloscope is a very useful piece of equipment during the setting up, but if one is not available then the process can be performed by ear. Switch the synth on and connect the 'scope or amplifier to the VCO sinewave output (pin EE26). Adjust VR3 for as pure a sinewave as possible. Make sure of the full range by observing the waveform whilst rotating VR4 between its extremes. If the waveform deteriorates or disappears then adjust VR3 until this is stopped. Note the sinewave amplitude, and now connect the 'scope or amp to the squarewave output (pin FF40). If this is impure then adjust VR3 once more slightly, rechecking the sine output. Adjust VR6 until the squarewave is at the same amplitude as the sinewave. Now check the noise output (pin P39) and adjust its level (via VR7) to that of the others. This done, if using a 'scope observe the output of the modulation oscillator (pin K8) which should be a triangle wave. All waveforms should be symmetrical about zero. The gain in the input section of the trigger circuitry should be set so that the wiper of VR12 is almost at the end connected to ground. If it is found that sensitivity is too high, or low, then this setting can be altered to correct this. Moving the wiper towards IC11 output reduces the gain. It now remains to check out each section of the synth, using the "Manual" front panel push switch to trigger it.

USING IT

The unit will normally be triggered by a conventional drum, and several methods are possible. A contact microphone can be constructed using a small crystal microphone insert. A length of screened lead should be connected to this to allow it to be plugged into the synth. This insert can be taped onto the side of a drum so picking up the drum vibrations and triggering the unit. Low impedance transducers such as loudspeakers and earphones also will provide a trigger signal. A special drum can be constructed for use with the synth. This would include a pad for the drum stick to strike, and a miniature loudspeaker beneath this to collect the sound and provide a triggering signal. A cassette recorder microphone could be used, or virtually any other type of microphone. This would be mounted on a

COMPONENTS

Resistors

R1,R9,R11,R27,R28,R41, R44	220
R2,R4,R15,R16,R18,R22, R32,R34,R35	100k
R3	6k2
R5,R6,R48	10k
R7,R26,R45	6k8
R8,R25,R38,R42,R43	47k
R10,R21	2k2
R12,R23,R29,R47,R49	1k
R13,R31	150k
R14,R30	15k
R17,R19,R33,R46,R36	330k
R20	22k
R24	68k
R37	390k
R39	1M
R40	1M5

All $\frac{1}{4}$W ±5% carbon

Potentiometers

VR1,VR2,VR4,VR5,VR9, VR10	100k lin.
VR3	4k7 vertical preset
VR6,VR7,VR12	100k vertical preset
VR8	4k7 lin.
VR11,VR13,VR14	1M log.
VR15	10k log.

Capacitors

C1,C11,C12,C24	0·22µF polyester C280
C2,C21	10nF mylar
C3,C8,C13,C18	3n3 ceramic
C4,C14	1nF ceramic
C5,C6,C7,C15,C16,C17	22nF mylar
C10,C19,C29,C30	0·1µF polyester C280
C20,C22,C23	1·5µF 25V elect.
C25,C26	1000µF 25V elect.
C9,C27,C28	10µF 25V elect.

Switches

S1,S2,S4,S6	miniature SPDT toggle
S3	miniature DPDT toggle
S5	4-pole 3-way rotary
S7	push-button momentary action
S8	miniature DPDT mains toggle

(All switches available from Maplin)

Semiconductors

D1,D2	1N914
D3	TIL209
TR1	BC107
TR2	BC108
TR3	BC212
IC1–4,IC6–8,IC10,IC11, IC14–17	741 8-pin IC
IC5,IC9	SSM2044 (Digisound)
IC12	CD4001
IC13	CD4016
IC18	CA3080
IC19	78M12 +12V 500mA voltage regulator (Maplin)
IC20	79M12 −12V 500mA voltage regulator (Maplin)
REC1	W005 50V 1A bridge rectifier

Miscellaneous

T1	12–0–12V 1A mains transformer,
JK1–5	$\frac{1}{4}$in. mono switched jack socket,
FS1	1A fuse and holder

Veroboard 115 holes × 34 strips,

I.c. sockets	8-pin	14 off
	14-pin	2 off
	16-pin	2 off

Case: 13in. × 8in. × 4$\frac{1}{2}$in.,
8 BA nuts, bolts, and spacers,
screened cable, mains cable, stranded wire, knobs etc.

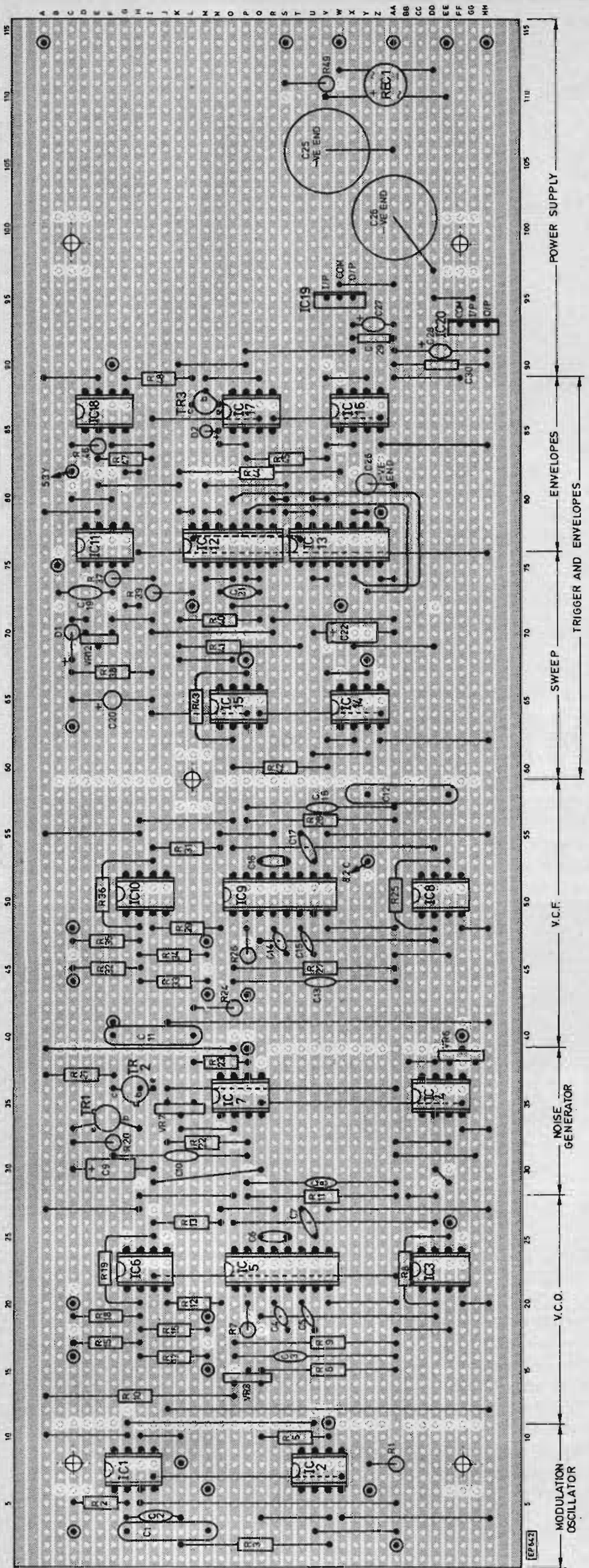
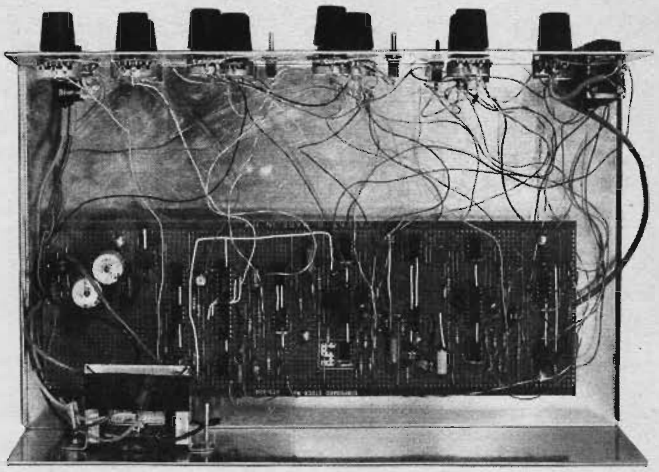


Fig. 11. Veroboard component layout



Internal layout

microphone stand and placed beneath a drum with the bottom skin removed. A Shure Unidyne B was found to trigger the synth reliably. The choice of triggering arrangement is really up to the constructor who can use a method best suited to the way he will be using the unit. It should also be borne in mind that when used with a microphone, a clap or even a shout can be used, so extending the versatility even further.

VCO/VCF CONTROL INPUTS

The external control voltage inputs for the VCO and the VCF are included so as to extend the usefulness of the synth. These may be used with any device which produces a control voltage (absolute maximum 12V) such as a foot pedal or another synthesiser. These sockets were primarily designed to allow the synthesiser to be connected to a sequencer, the ext. trig. input also being used, requiring a positive pulse. The control voltage law is around 3 volts/octave, but it should be noted that the VCO and VCF may not be accurately exponential over their full range since component tolerances, the lack of temperature compensation, and the use of 741 op-amps may cause inaccuracies. Nevertheless, they are fairly exponential over the central part of their range. The use of even a simple sequencer allows a wide range of rhythms to be generated.

With the VCA "Decay" control adjusted for a short, slight decay and the sine output of the VCO being used, an ordinary drum sound is produced, from a bass drum through to bongos and woodblocks as the VCO "Tune" control is adjusted. Increasing "Decay" and adding "Down Sweep" to the VCO produces the well-known "pew-pew" disco Syndrum sound. Using the square output of the VCO, synthesiser "waa-waa" sounds can be obtained by increasing "Sweep" on the VCF. Adding low frequency modulation to the VCF in large amounts produces a burbling noise. Using "Noise" and "Sweep" on the VCF, noises varying from sea and thunder to jet-plane whooshes can be achieved by varying the VCF "Tune" and "Resonance" controls. With a short, punchy VCA decay, and a suitably set VCF, snare drum sounds can be obtained using "Noise". Obviously these are just a few of the sounds which can be produced, and the limit is really the user's ingenuity. ★