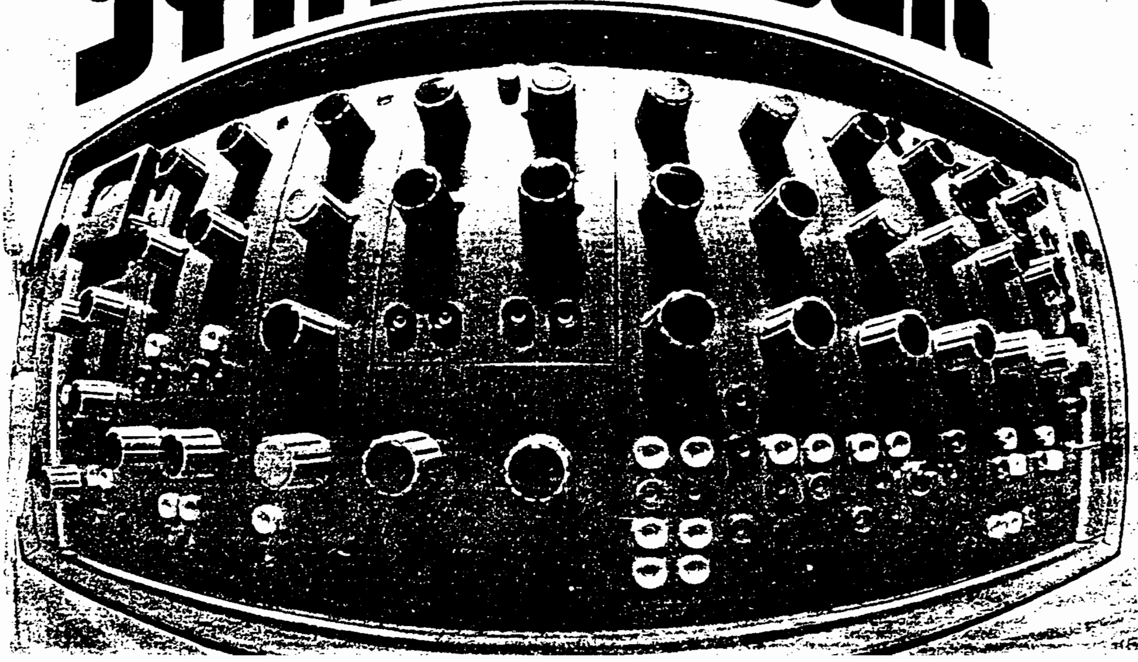
A VERSATILE INSTRUMENT FOR THE COMPOSER, MUSICIAN OR KEEN EXPERIMENTER IN THE CREATION OF SOUNDS IMITATIVE OR UNIQUE

By G.D.SHAW

SOUND SYNTHESISER



THE realisation of music and allied effects by means of a variety of electronic devices has been possible for a good many years. The electronic organ, for example, was becoming rapidly accepted a decade before World War II. Of the vast range of electronic instruments now available, however, there are a few which are not aligned to operate around a conventional chromatic scale. Thus, for the performer, the appeal of such instruments would be based primarily on the effect of tone quality, ease of playing and novelty in design.

For the composer, however, the abundance of electronic instruments does little more than provide a range of alternatives to supplement or replace standard instruments of the orchestra. Out of such a situation the idea of *musique concrete* was born. This technique enabled composers to create and experiment with sound forms generated naturally or unnaturally by such unlikely sources as dustbins, rattling teacups, conversation or malplayed musical instruments. Some workers incorporated a system of manually operated oscillators, both groups linking their sound sources to one or more disc cutters or, later, tape recorders.

The task of creating and blending discrete tones into a coherent and recognisable musical work involved so much laborious effort that *musique concrete* established the reputation of being more of a technical exercise than a creative art form. Thus the publication of Moog's designs for voltage controlled amplifiers and oscillators about eight years ago was hailed with enthusiasm in many quarters of the musical world.

Moog's designs crystallised the ideas and requirements expressed by a number of serious composers whose creativity was hammered and frustrated by the confines of the accepted musical disciplines. The possibilities of and extensions to Moog's original circuits have led with great rapidity to the inception of a series of variably complex devices having the generic label of synthesiser.

THE SYNTHESISER DEFINED

What exactly is a synthesiser? The word "synthesis" is defined as the building up of separate elements into a connected whole and this, very succinctly, describes the function of the synthesiser with respect to the formation of sound structures.

Essentially the instrument consists of a number of sound sources and sound treatments which may be combined together in an enormous diversity of ways to produce an equally varied range of sounds in a number of applications.

1. As a live performance instrument. A considerable company of popular artists and groups use a synthesiser, in one form or another, as a standard item of equipment either to supplement their normal methods of sound treatment or to play as an instrument in its own right.

2. As a sound effects unit. The use of the synthesiser is by no means restricted to musical circles and it is equally at home "producing" creaking doors, artillery fire, explosions, dripping water, birdsong and a virtually unlimited range of sounds similar to those featured in and popularised (for some) by the "Dr Who" series. Thus the tape recording enthusiast, amateur dramatic society, cine club and so on could easily find the synthesiser becoming a useful and indispensible tool.

3. As an audio-visual teaching aid (in conjunction with a good oscilloscope) the synthesiser can provide an invaluable insight into the fundamentals of electronic and acoustic waveform phenomena. In this respect there is a large potential field of application.

IMITATIVE OR UNIQUE

The term synthesiser carries the implication, for some, that the instrument is of an essentially imitative nature and/or that the sounds produced by it are ersatz. With regard to the former criticism, the degree of control which may be exercised in a well designed synthesiser is such as to allow it to imitate a wide range of musical instruments very effectively.

For the sound effects man, the ability of the instrument to produce imitations of a wide range of naturally occurring sounds is a feature which cannot be lightly set aside.

In answer to the second criticism which implies that the sound forms produced by the synthesiser are in a sense unreal—nothing could be further from the truth. The nuance and timbre imparted by the synthesiser to a fundamental tone is no less real than the nuance and timbre imparted to the same tone by say a trumpet or a violin. In practice the purity and exactitude of the tonal permutations made available by the synthesiser are frequently inspiring and possess a beauty which is peculiarly their own.

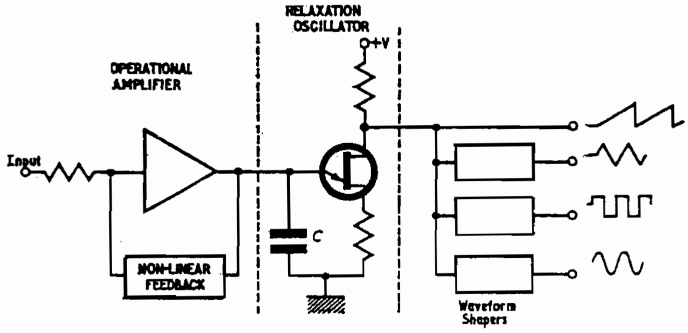


Fig. 1. Block diagram of a voltage controlled oscillator

VOLTAGE CONTROL

Various forms of voltage control have been known and exploited for a number of years but the application of the principle to the control of synthesiser circuits results in the appearance of a number of unique features. By way of illustration one could scarcely choose better than a form of voltage controlled oscillator based on the design published by Dr Moog. Fig. 1 shows such a device in block form.

The relaxation oscillator is driven by an operational amplifier the output current of which is proportional to the exponential of the input. As the output current increases so also will the rate at which the charge on capacitor "C" reaches the unijunction breakdown voltage. Thus the frequency is increased.

The unijunction sawtooth is fed to a series of waveform shaping circuits which provide a useful number of "in phase" outputs. By means of this system relatively wide frequency ranges may be obtained without the necessity of switched RC or inductively tuned networks.

The general principle of voltage control may similarly be applied to almost any parameter in any of the devices built into the synthesiser, e.g. amplifier gain, filter bandpass or band reject characteristics, degree of reverberation and so on. There are a number of distinct advantages in so doing, these are:

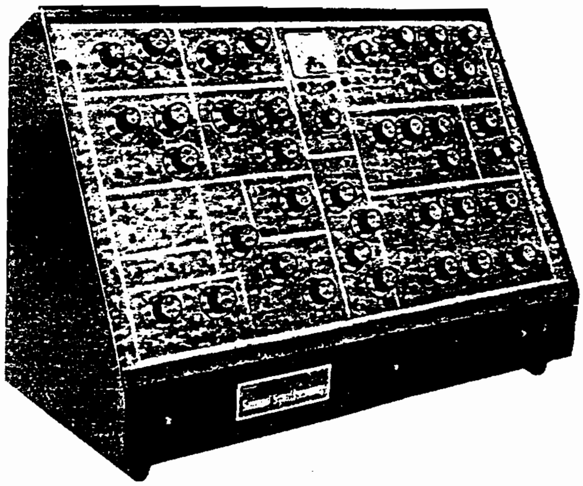
1. Signal and control paths are quite separate from one another. Thus a device may be remotely controlled without compromising the signal in any way.
2. Devices can control one another in a continuously variable manner without the necessity of complicated, expensive and limited-range switching circuits. In certain circumstances a device may control or limit its own output by using part of the signal output as feedback to the control input.
3. By provision of high input impedance to the control circuits each controlling device has a potentially large "fan-out" capability thus making multiple parameter control a possibility.

A specific example of voltage control is given later in this article and will serve to underline the flexibility and versatility of the system.

SYNTHESISER DESIGN

designing a synthesiser care has to be taken ensure that the system does not become so comzx',that it is impossible to operate effectively. Consequently it is necessary to define the requirements of the instrument and to specify the means by which these requirements may be met. In this respect a form of modular construction offers the distinct advantage that one may start with a simple system and increase the size and complexity as and when required.

As a general rule most sounds have a fairly complex structure comprising a fundamental tone, one or more overtones or harmonics and, in some cases, an element of noise. It is usually the fundamental tone which dominates the sound structure and which provides the primary means by which the sound is observed.



The author's prototype synthesiser is shown above. Below is the final version built in modular form and housed in a Vero metal case

Another important feature concerns the way in which the sound structure is presented. The rapidity with which the sound becomes audible, the maximum volume attained and the rate at which the sound dies away together constitute a pattern, known generally as an envelope, which contributes very largely to the recognition of the sound. Variation in the rapidity of attack and the rate of decay of an otherwise unchanging sound structure can make an enormous difference to the auditory effect of the sound on an observer.

Two other factors play an important part with respect to the recognition of sound. These are timbre and nuance. Timbre is defined as the characteristic quality of sounds produced by each particular instrument or voice, depending upon the number and character of the overtones while nuance relates to the delicacy, or shade of meaning, of a sound.

ACHIEVING THE REQUIREMENTS

It is a relatively straightforward matter to provide hardware to meet three of the above requirements, i.e. fundamental tones may be provided by one or more oscillators; variation in sound presentation is achieved by means of an envelope shaper while timbre may be varied by selective filtering and additive mixing, either separately or in combination, together with a degree of reverberation.

Control of nuance cannot, however, be achieved by the application of a discrete piece of hardware but is controlled by the inter-adjustment of practically all the parameters involved in any particular sound structure.

PROGRAMMED MODULES

The hardware so far considered covers the basic necessities of sound formation but offers nothing that cannot be obtained from a selection of signal generators, reverberation amplifier and integrator, all of which are easily obtainable as discrete units and in a variety of forms. The next stage, therefore, is to devise a means whereby the principal function of the modules may be voltage controlled and to provide the means by which they may be programmed to produce a range of tone patterns or rhythms. Automatic programming may be achieved by provision of one or more ramp or random voltage generators.

If these latter devices are, themselves, made programmable then the possible control signal permutations, with only a small number of modules, becomes

SPECIFICATION

Stabilised Power Supply
+15V/O/−15V at 750mA per rail. Max. ripple at 12 per cent overload is less than 15mV.

Two Input Amplifiers
Gain variable from unity to × 50.

Two Ramp and Pulse Generators
Frequency range (a) 0·01Hz to 15Hz.
(b) 0·05Hz to 30Hz.
Manual and voltage control. Output voltage is 4V nominal ramp and −4V nominal pulse.

Two Triangular/Square Wave Oscillators
Frequency range (voltage control) less than 1Hz to 16·5kHz. Frequency range (manual control) 5Hz to 10kHz. Output voltage: Triangular 350mV p-p. Square 1V p-p.

Two Output Amplifiers
Variable gain with manual and voltage control. Panning facility between channels. Input level 500mV. Maximum voltage gain +13dB.

Reverberation Amplifier
Variable gain manually controlled. Voltage control of reverberation. Unity gain with reverberation out. Frequency range of spring line −3dB at 80Hz and 4kHz. Input level 500mV.

Ring Modulator
Four quadrant multiplier based on integrated circuit. Frequency response effectively flat from d.c. to greater than 150kHz. Input levels 2 × 500mV max. Output level 800mV max.

Tone Control
Tuneable active filter. Effective slope 7dB/octave. Overlapping bass and treble ranges allow extreme effects to be obtained.

Envelope Shaper
Produces an envelope of variable shape and period derived from internal constant voltage source and external trigger. May be triggered manually. Output waveforms variable from pulse, sawtooth, trapezoid, and triangular.

Noise Generator
Provides up to 3·5V white noise. Control of colouration by means of tuneable low pass filter.

Sample and Hold
Random voltage generator which can double as an additional ramp generator. Produces staircase waveforms of formal or random nature. Clock output is provided for synchronisation purposes. Output level −6V max.

Differential Amplifier
Provides additive and/or subtractive mixing facilities. Output level proportional to sum and/or difference of the four inputs provided, maximum 26V p-p.

Inverter
Similar to above but with only two inverting inputs.

Meter Unit
A meter with precision rectifier circuit to read a.c./d.c. signals in two ranges: 0·5V and 1V

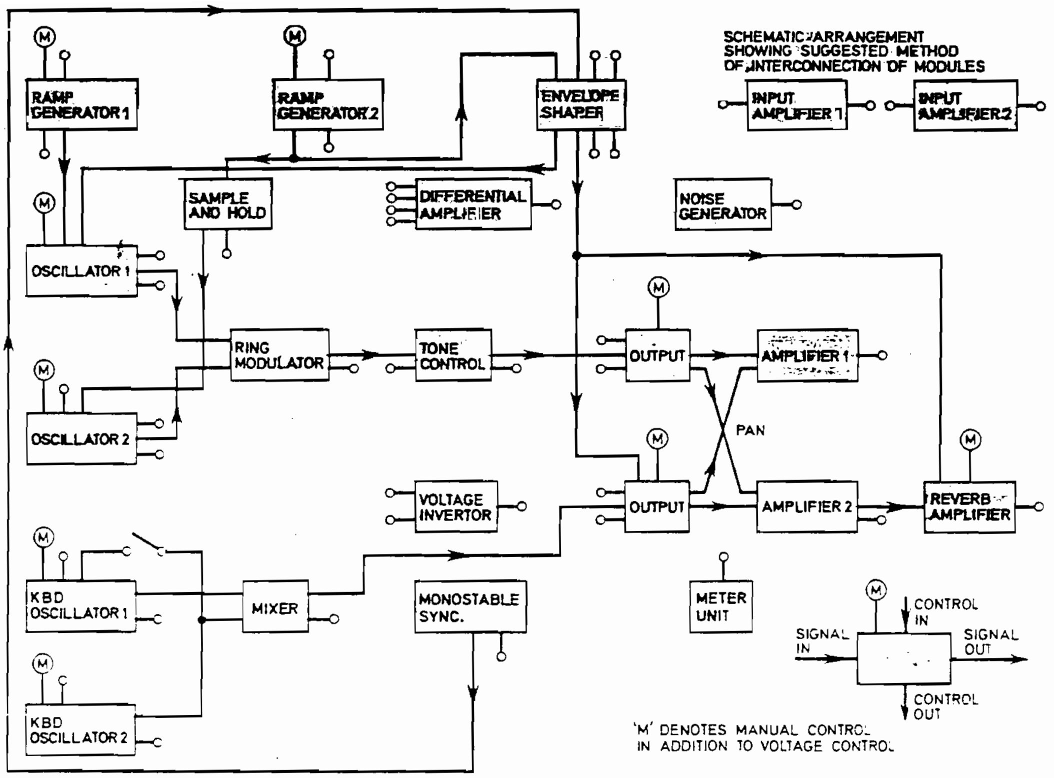


Fig. 2. Block diagram of the synthesiser

very wide indeed. If the frequency range of the ramp generators is sufficiently wide they may themselves be considered as sound sources and used for the direct provision of rhythms.

Similarly, with the control signal suitably attenuated and running at a frequency of between 6–8Hz, a single ramp generator may be used to provide a vibrato modulation to an oscillator thus adding greatly to the interest content of discrete tones.

Synthesiser keyboard with separate sustain, vibrato and oscillator units mounted on the left

ADDING A KEYBOARD

Perhaps the simplest method of programming the oscillators is by the addition of a keyboard. Since keying provides a range of control voltages to the oscillator the keyboard itself may be considered to be a manually operated staircase generator.

The keyboard may also be used to provide gating and synchronising pulses to initiate treatment or shaping sequences each time a key is depressed.

SOUND TREATMENTS

The only sound treatment so far given any degree of consideration is that of reverberation. There are, however, a number of others which can provide very useful extensions to the facilities offered by the synthesiser. Up to now the accent has been on synthesis by addition, but, equally, one can synthesise by subtraction.

In this latter case the starting point is a complex sound, such as white noise, from which the required elements are obtained by filtration. There is thus a place for one or more notch and/or band-pass filters the actual characteristics of which may be varied by means of voltage control.

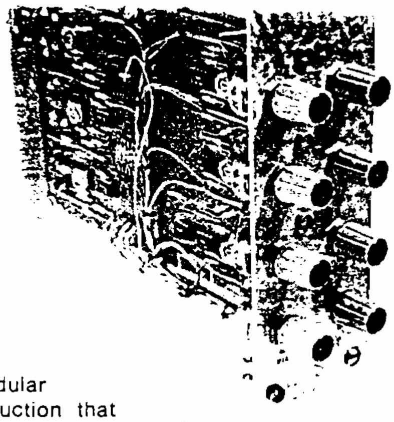
On the simpler side there is also a place for a form of tone control of sufficient range to enable extreme effects to be investigated.

INTERFACING

Finally, it is necessary to consider the best means of interfacing the synthesiser with external equipment so that it may accept as wide a range of inputs as possible without distortion and, on the output side, provide a similar widely compatible drive.

A block diagram of the synthesiser to be described is given in Fig. 2.

The idea of external connection compatibility for all modules was believed to be a prime requirement in view of the possibility that many constructors may wish to build only a limited number of the


The basic modular form of construction that will be used throughout the series

modules to be described as additions to existing synthesiser projects. In view of this situation it may seem somewhat paradoxical to provide modules labelled input and output amplifiers.

In point of fact these can be connected in virtually any position in a chain of modules the main limitation being due to the possible saturation of the amplifiers due to the input levels being exceeded.

The final stages of the output amplifiers are cross-coupled by "panning" controls thus enabling stereo and "floodsound" effects to be investigated.

INTERCONNECTIONS

Referring again to Fig. 2, it will be noted that many of the modules are shown with interconnections made between them.

Of the three most widely used systems of module interconnection the one most suited to the modular concept is that in which individual devices are coupled by means of patch cords. The great disadvantage of this system is that a complicated patch can render the front panel controls almost inaccessible.

With a view to relieving this situation modules may be connected internally in the manner in which they are most likely to be used. The actual method of internal connection is really a matter of the individual constructor's preference, those connections shown in Fig. 2 being intended as a guide rather than a mandatory requirement.

BUILDING THE SYNTHESISER

Full constructional details will be given on building the synthesiser shown and an outline specification of the instrument appears in this article.

Extensive use has been made of the 741 operational amplifier since the use of these devices invariably simplifies design and construction in comparison with circuits in which discrete semiconductors are employed. Furthermore, the 741 offers the feature of unconditional stability under almost any operating condition and is protected internally against "latch-up" and output short circuit and is readily available at economic prices from a variety of sources.

The only test equipment requirement is for a good oscilloscope, particularly during the setting up stages. Ideally the scope should be d.c. coupled but, failing this, a high resistance voltmeter will suffice to monitor the v.l.f. performance of the various modules.

Next month, constructional details for the stabilised p.s.u. will be given.