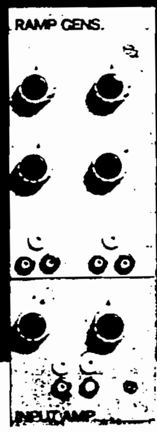
# PE Sound Synthesiser 4

# RAMP GENERATORS & INPUT AMPLIFIERS

By G.D. Shaw




THIS month, the operation and construction of the ramp generators and input amplifiers will be described together with guidelines on using the various modules, so far described, in combination.

## RAMP GENERATOR

The ramp generator to be described is effectively a sawtooth oscillator capable of working down to very low frequencies. At the low end of its working range the output of the device may be considered to be slowly changing d.c. and, unlike the v.c.o. which produces an output waveform swinging about zero, the output of the ramp generator is single-ended, that is, swinging from zero to about −3·5V.

The reason for this arrangement is that the ramp generator is considered essentially as a device for programming other voltage controlled modules all of which require control voltages of one polarity only. This requirement, incidentally, does not mean that alternating voltages cannot be used for programming and, as will be shown, many interesting effects can be obtained when the control voltages vary about zero.

As with the v.c.o. the principle of operation is that of the linear integrator although the circuit shown in Fig. 4.1 is very much simpler.

IC1 is the integrator which receives its positive control voltage either from VR1, an external source, or from both in combination. IC2 is a comparator which, since single ended operation is required, utilises a reference voltage set by R7-R8 and transistor TR1 to discharge the integrating capacitor C1. The reference voltage also determines the peak ramp output voltage of the circuit.

## CIRCUIT OPERATION

The operation of the circuit is as follows. The divider R7/R8 provides −3·5V at the non-inverting input of IC2 and effectively biases TR1 off. Assuming that the R1 input to IC1 is open circuit, a positive voltage derived from VR1 is applied to the inverting input of IC1 via R2 and the integrator begins to ramp negatively at a rate determined essentially by R2/C1.

When the ramp output voltage applied to the inverting input of IC2 is equal to or greater than the reference voltage the comparator switches to its positive saturation state, turns on TR1, and discharges C1 via R6 and R7.

The sawtooth output waveform is taken from the junction of R4 and R5 via VR4 while a pulse output is available from the emitter of TR1. Note that this requires to be a.c. coupled if it is to be used effectively.

## CONSTRUCTING THE RAMP GENERATORS

Construction of the ramp generators is perfectly straightforward, the recommended circuit board layout being shown in Fig. 4.2. Note that both ramp generators (RG1/RG2) are built on one circuit board and that power supply decoupling is not required.

The method of construction should generally follow that employed for the v.c.o. module. Components should be mounted to the front panel and prewired before the panel is secured to the circuit board support plate. Note, however, that in this case the main wiring harness from the ramp generators should leave the front panel at the top and pass over the top edge of the circuit boards while the wiring to the input amplifiers should be as short as possible and routed direct to the appropriate circuit board.

A detail of the panel component wiring and board layout is shown in Fig. 4.3. The McMurdo plug should now be prewired and mounted into the support plate.

## TESTING

When assembly of one of the ramp generators has been completed make temporary connections to power supply leads and front panel controls and connect a resistor of at least 10 megohms across the integrating capacitor C1. Set VR2 and VR1 to their minimum values, VR3 to its mid-position, and switch on the power supply. Observe the integrator output on the oscilloscope and adjust VR3 for zero offset. Switch off and remove the 10 megohm resistor.

Set VR2 to its mid-position and switch on again. A sawtooth waveform of about 7Hz should now be observed. Gradually reduce the setting of VR2 until the slope of the ramp begins to show slight rippling.

# RAMP GENERATORS

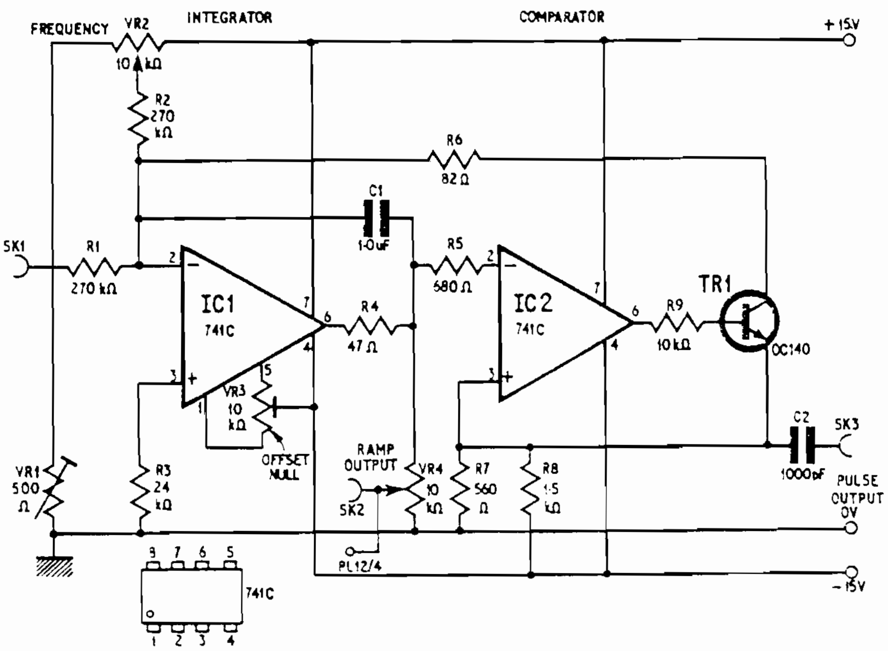



Fig. 4.1. Circuit of a ramp generator

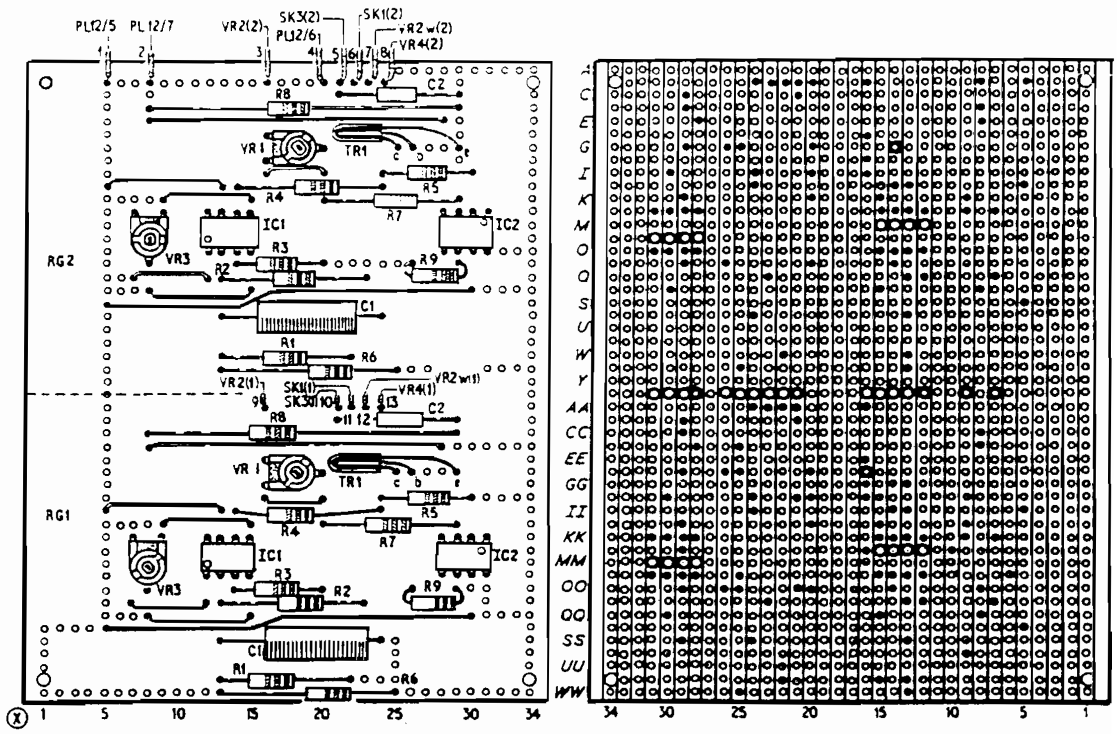



Fig. 4.2. Component layout and wiring of ramp generators

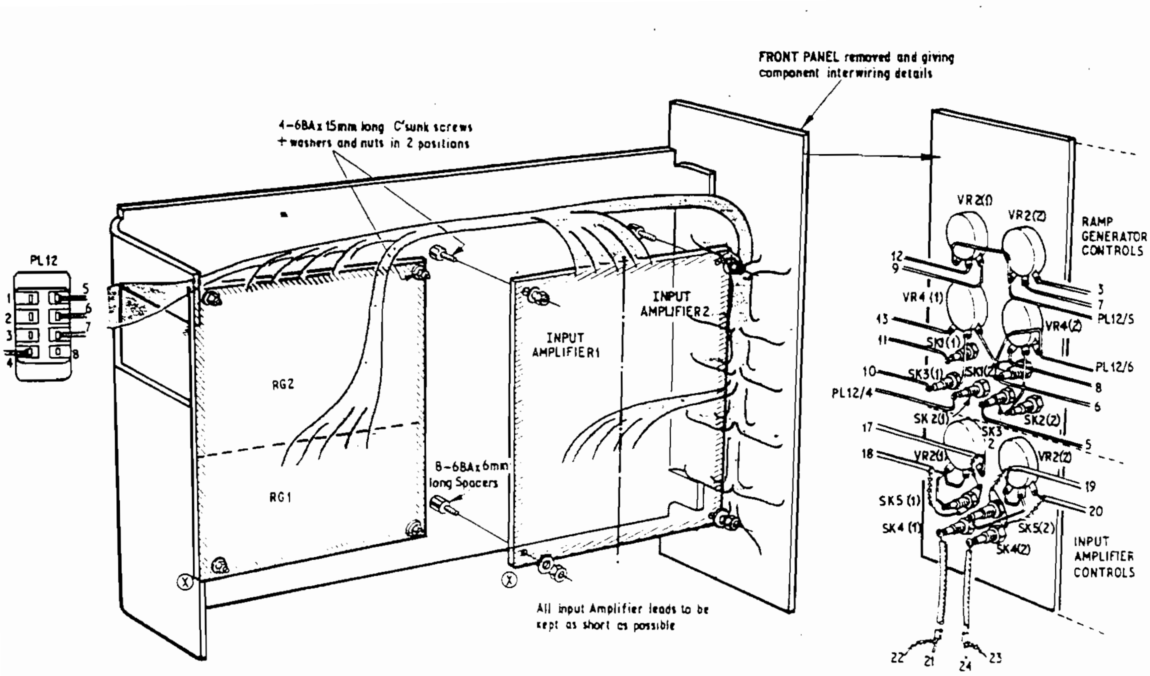



Fig. 4.3. Control panel wiring and board layout of ramp generator module. A lead should be taken from SK2(2) to PL12/8

## COMPONENTS . . .

### RAMP GENERATOR (2 OFF)

**Resistors**

| | |
|---|---|
| R1, R2 | 270kΩ (2 off) |
| R3 | 24kΩ |
| R4 | 47Ω |
| R5 | 680Ω |
| R6 | 82Ω |
| R7 | 560Ω |
| R8 | 1·5kΩ |
| R9 | 10kΩ |

All 2% $\frac{1}{2}$ watt metal oxide

**Capacitors**

C1 1µF polyester 25V
C2 1,000pF polystyrene

**Integrated Circuits**

IC1, IC2 741C 8 pin D.I.L. (2 off)

**Transistor**

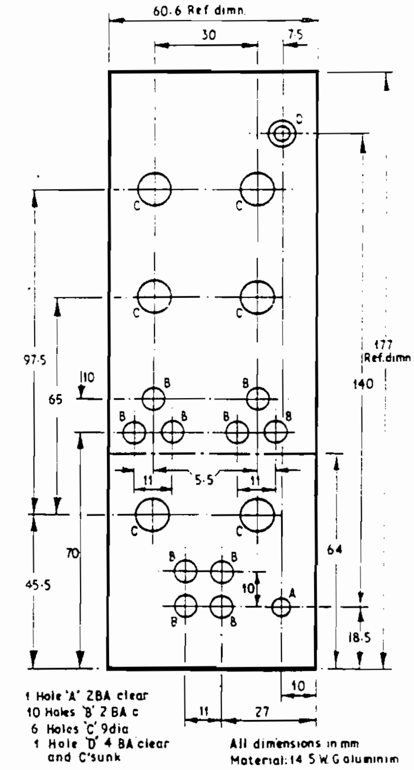
TR1 OC140

**Potentiometers**

| | |
|---|---|
| VR1 | 500Ω horizontal carbon preset |
| VR2 | 10kΩ miniature moulded carbon linear potentiometer |
| VR3 | 10kΩ horizontal carbon preset |
| VR4 | 10kΩ miniature moulded carbon linear potentiometer |

**Miscellaneous**

SK1–SK3 2mm miniature sockets (3 off), 2 Elma knobs, 34 × 17 way 0·1in matrix Veroboard



# INPUT AMPLIFIER

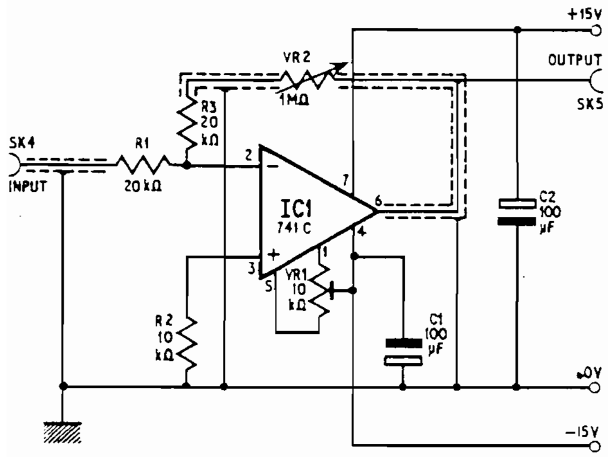



Fig. 4.4. Circuit of an input amplifier

## COMPONENTS . . .

**INPUT AMPLIFIERS (2 OFF)**

**Resistors**

R1 20k Ω
R2 10k Ω
R3 20k Ω
All 2% ½ watt metal oxide

**Capacitors**

C1, C2 100µF elect. 25V (2 off)

**Potentiometers**

VR1 10k Ω horizontal linear preset
VR2 1M Ω linear miniature moulded carbon

**Integrated Circuit**

IC1 741C 8 pin D.I.L.

**Miscellaneous**

SK4, SK5 2mm miniature sockets (2 off), 34 × 17 way 0·1in matrix Veroboard, 1 Elma type knob

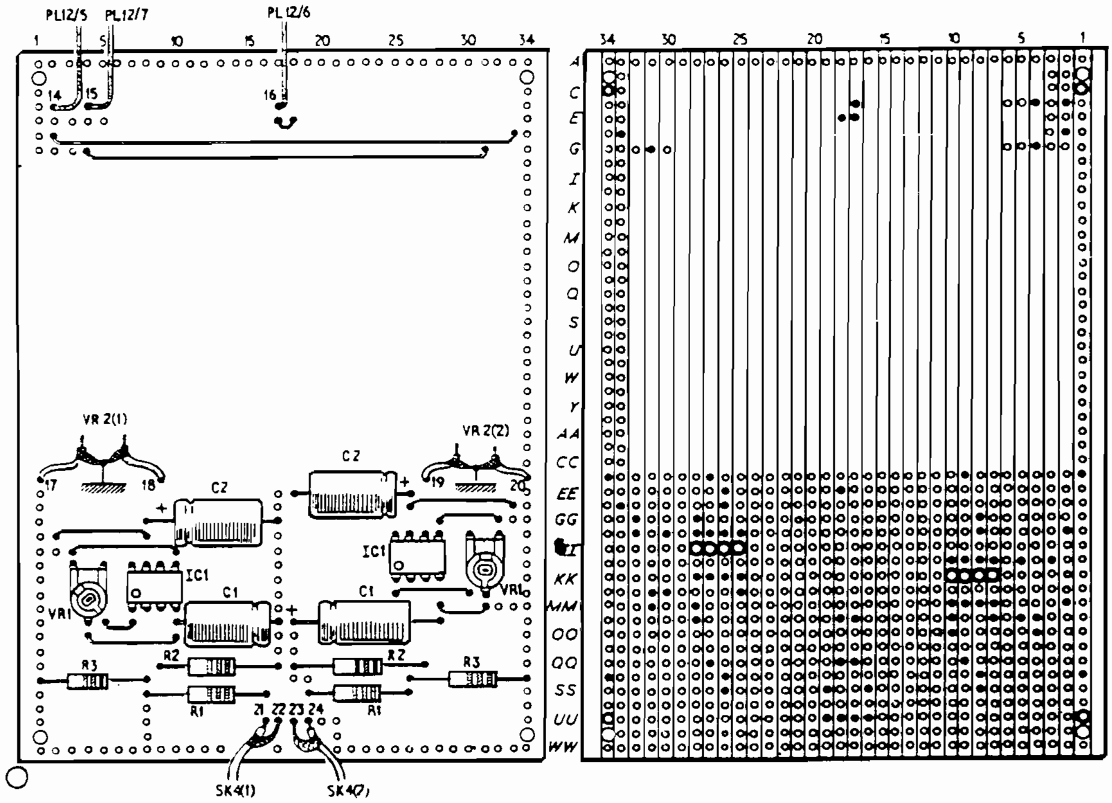



Fig. 4.5. Circuit board layout of input amplifiers

Increase the setting of VR1 until the rippling disappears and make further reductions in the setting of VR2, adjusting VR1 as necessary to keep the slope ripple free. Note that at the minimum setting of VR2 the ripple effect is at very low frequency and shows itself more as a hesitancy in the motion of the oscilloscope trace.

With careful adjustment, and the component values shown, it is possible to achieve a low frequency of 0·01Hz but it is almost impossible to remove ripple entirely at this frequency and generally it is best to set the low end of the range to 0·05Hz to ensure stability. The upper frequency limit with the 1·0μF integrating capacitor is about 15Hz.

In the prototype instrument one ramp generator was built as described and the second was built with an integrating capacitor of 0·47μF thus giving an upper frequency limit of about 30Hz with very little sacrifice to the v.l.f. end of the range. Such a procedure is recommended since the higher frequency is very useful in the production of rapidly changing, complex sound patterns.

When both ramp generators have been built and tested, mount the circuit board on the support plate in the position remote from the front panel (Fig. 4.3).

## INPUT AMPLIFIERS

The input amplifier theoretical circuit is shown in Fig. 4.4 and the circuit board layout in Fig. 4.5.

Although very simple in design rather more care is required in the component layout if hum pick-up is to be avoided, this latter problem tending to occur more when the gain control VR1 is at its maximum setting. Note that screened wire is used to connect the input sockets and gain controls to the circuit board. These wires should be trimmed as closely as possible to the required length and led directly to the circuit board without being formed into a harness.

The only setting up required is the adjustment of the offsets. VR2 should be set to maximum, the input grounded and, with the power supply on, adjusted to give an output level of precisely zero.

Reference to block diagram in Part One will show that Oscillator 1 is programmed directly by Ramp Generator 1 through the medium of a prewired interconnection. Accordingly tag 4 on the ramp generator McMurdo socket (SK12) should be connected to tag 1 on the v.c.o. socket (SK8). This direct connection may be over-ridden by inserting either an open circuit or grounded jack plug into the external programming socket of the v.c.o. Alternatively a jack plug coupled to a patch cord may be used to provide programming from another source.

It is recommended that grounded jack plugs are used if precise manual control of v.c.o. frequency is required.

## PROGRAMME DATA SHEET

The completion of this module provides the constructor with greater facilities for the production of programming waveforms and some quite complex sound structures. With the addition of the v.c.o. module there are now seven separate circuits and 12 controls to manipulate. There is thus a need for a method of logging control settings and interconnections so that any given sound structure may be repeated at a later date.

Details of a data sheet which will prove ideal for the purpose are given in Fig. 4.6. Control settings would normally be recorded in the circles on the front panel representation while module interconnections would be indicated by a dot in the appropriate square on the grid matrix. Data recorded in the figure relates to the production of a type of bird song which will be described in detail in a later article.

## USING THE CONSTRUCTED MODULES

The provision of the input amplifiers allows waveforms from the oscillators and/or ramp generators to be mixed either additively or subtractively when used in combination with the voltage inverter. The permutation of all the possible settings of amplitude and frequency controls implies that an enormous range of sound structures may be produced and, whereas it is beyond the scope of this article to cover all the possibilities, a number of simple experiments are suggested for guidance.

Starting with the ramp generators, Fig. 4.7a shows the type of relationship which may be observed on the oscilloscope when one ramp generator is running at ten times the frequency of the other. With the output of a v.c.o. coupled to a suitable power amplifier and its frequency control at zero, application of either of the waveforms shown will cause the v.c.o. frequency to be swung from the lowermost end of the range to an upper frequency determined by the amplitude of the ramp generator waveform.

Since the upper frequency limit of the v.c.o. is dictated by the saturation level of the differential stage and since the gain of this stage is 10 then a programming waveform amplitude of about 1·4V will drive the v.c.o. to its maximum frequency.

Fig. 4.7b shows the effect of mixing the waveforms shown in Fig. 4.7a additively. To achieve this, route the outputs of the ramp generators to separate input amplifiers which have their gain controls set to zero, i.e. unity gain, and then to the inputs of the voltage inverter. Observation of the output of this latter device reveals the composite waveform.

With the ramp generator output levels adjusted so that the maximum combined level is about 1·4V route the voltage inverter to the input of the v.c.o. The result is an undulating sound the lowermost frequency of which is continuously rising at a rate set by the frequency of the slowest running ramp generator.

## SUBTRACTIVE MIXING

Fig. 4.7c shows the effect of subtractive mixing of the ramp generator waveforms. Achievement of the staircase form is as follows.

Set the amplitude of the slowest ramp generator output to 1·4V and route this to the voltage inverter via an input amplifier set to unity gain. Route the second ramp generator to the voltage inverter direct. Since this now sees the inputs from the ramp generators at opposite polarities the result is subtractive mixing which, when the amplitudes are at the correct levels, produces a staircase as shown.

Application of this waveform to the v.c.o. produces a rising, arpeggio-like sound. A falling arpeggio may be produced by reversing the routing of the ramp generators with the slowest direct to the voltage inverter, and fastest to the voltage inverter via the input amplifier. In this latter case the frequency control of the v.c.o. has to be set to its maximum level since the waveform from the voltage inverter is now positive going.

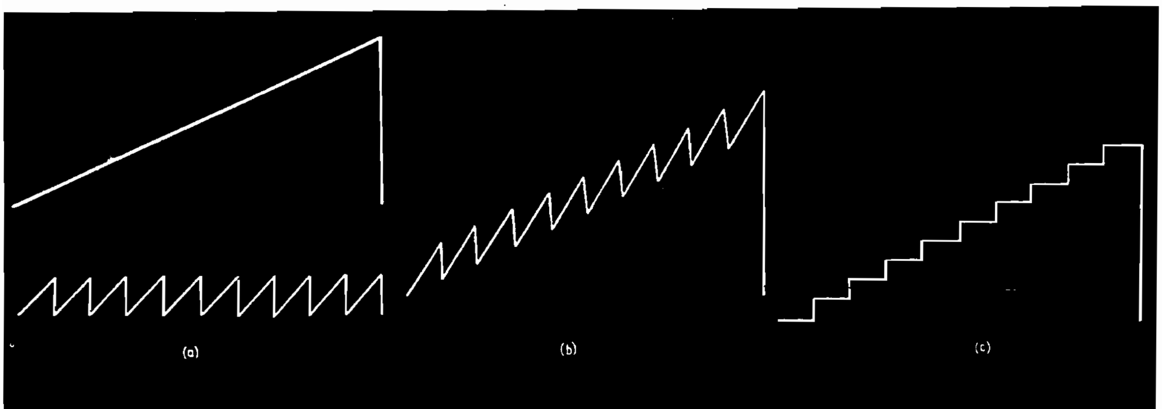



Fig. 4.7. (a) Components for additive mixing; (b) resultant through addition of components; (c) subtractive mixing produces staircase waveform

## FIXING THE V.C.O. LIMITS

In these examples the v.c.o. has been programmed through its maximum working range but it is, of course, possible to achieve the same effect within very precise frequency limits. For example, suppose it is wished to provide an arpeggio rising from 130Hz to 520Hz, the frequency control of the v.c.o. is set to give the voltage required to produce 130Hz. The fact that the ramp output will, at times, be zero volts will not affect the l.f. performance limit since the v.c.o.s were originally set up with a link simulating a zero-volt programming input. Thus from Fig. 3.4 in last month's article it will be seen that the initial setting of the v.c.o. will require an input of about 24mV. Also it will be seen that a frequency of 520Hz requires an input of about 42mV and thus the output amplitude of the combined ramp generator signal will have to be (42–24)mV. In a similar manner the manipulation and adjustment of the manual and automatic voltage sources can set the programmed sequence almost anywhere in the working range of the v.c.o.

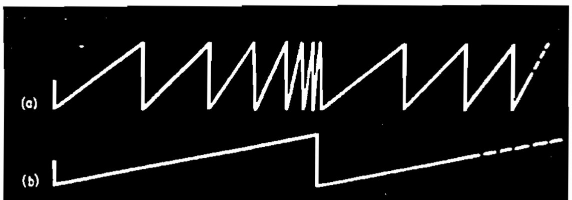



Fig. 4.8(a). Programmed ramp generator output (b) programming waveform

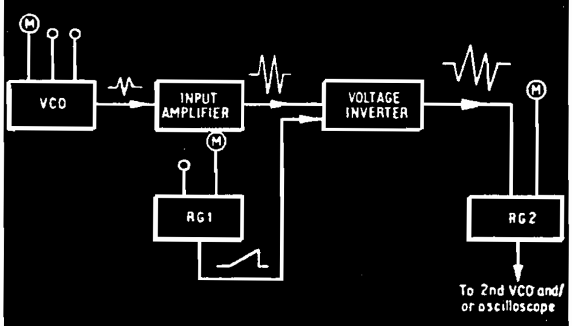



Fig. 4.9. Block diagram for ramp generator programming

## PROGRAMMING THE RAMP GENERATORS

The monotonous repetition of the ramp generator output can be considerably varied by application of programming voltages to its own external control input. Fig. 4.8 illustrates the effect of applying a steadily rising voltage to the control input.

The voltage has been derived from the output of the other ramp generator running at a fairly low frequency and routed via one of the input amplifiers set to provide a peak ramp output of positive 14V. The resultant output of the programmed ramp generator consists of a series of ramps gradually increasing in frequency as the programming voltage rises to its peak, the aural effect when used to programme a v.c.o. being a kind of bounce.

For the best effect the programmed ramp generator should be running at about twenty times the frequency of the other.

An extension of the above system is shown in the block diagram Fig. 4.9. In this case one of the v.c.o.s is also providing a programming waveform which is first amplified to provide an output swing of ±7V. This is then combined, in the voltage inverter, with the output of the programming ramp generator set to its maximum output level. The voltage inverter is then routed to the programmed generator which has been set to run at about 7Hz, the overall result being a bounce which is changing its rate in a pattern depending on the relative frequencies of the programming sources.

### EXPERIMENTAL COMBINATION

There are many other combinations of the programming devices all of which result in the production of characteristic sounds. The constructor is encouraged to investigate these as widely as possible noting the control settings and interconnections which produce sounds of particular interest.

It should be noted that even quite small adjustments to amplitude and frequency of programming waveforms can cause relatively great changes in the sound structure. This is particularly the case when amplitudes are adjusted in complex programming waveforms such that the waveform changes potential, i.e. crosses zero. In these cases the v.c.o. will cease to oscillate for as long as the programming waveform remains positive and thus, for a fairly rapidly changing waveform, the long term output of the v.c.o. will resemble a series of tone bursts of varying frequency.

The use of positive going programming waveforms to the v.c.o. should be investigated with care, particularly when the manual frequency control is at or near zero. The sudden application of a large positive input will cause an unpleasant click due to the increase in v.c.o. output voltage as it goes into saturation. Similarly a low potential positive input applied for a prolonged period will, on its removal, give rise to a click when the v.c.o. comes out of saturation.

### USING A RECORDER

It is perhaps prudent, at this stage, to mention that a tape recorder is a most necessary adjunct to the Synthesiser if the full potential of the instrument is to be realised. This is essential because, although live performance is possible, it is somewhat limited due to the design of the keyboard which is monophonic. In order to produce complex realisations, it is necessary to employ a recorder in order that multitracking of one form or another may be used to blend or superimpose consecutive series of sound structures into a comprehensive whole.

In a similar manner many sound effects may be enhanced by the addition or superimposition of secondary sounds. This procedure can be particularly useful when complex effects such as storms, battles or woodland birdsong are being synthesised.

Quite apart from the creative aspects of using the tape recorder another important reason for its application with the Synthesiser lies in the establishment of a taped library of sounds.

Many excellent books and articles have been written on this subject but, in the field of creative recording, T. Dwyer's "Composing with Tape Recorders" (Oxford University Press 1971) contains much useful information.

*NOTE:*
*The power supply transformer in Part 2 has 0–30, 0–30V separate secondaries. R1 and R6 should be 5·6kΩ 2% ½ watt metal oxide resistor. IC2 should be insulated from chassis with a mica washer. In Part 3, VR2 is 100kΩ.*

**Next month: Sample Hold and Noise Generator.**



# BOOK REVIEWS

**ELECTRONIC MUSIC PRODUCTION**
**By Alan Douglas**
**Published by Sir Isaac Pitman & Sons Ltd**
**148 pages 5½in × 8½in. Price £2·75**

ELECTRONIC MUSIC PRODUCTION presents a very much "up to the minute" look at the use of electronics in the production of music with special reference to the synthesiser and the applications of voltage control. The book is divided into four main sections. 1—Properties of conventional musical instruments. 2—Musical scales, temperament and tuning; concord and discord. 3—Electronic music generators. 4—Electronic music and the composer. Additionally there are two appendices which provide, in the first, a detailed specification of the Synthi 100, a highly advanced synthesiser designed for interfacing with a computer and, in the second, details of MUSYS documentation standards together with an example drawn from part of a composition programmed on the Synthi 100. Finally there is a comprehensive bibliography and index.

*Electronic Music Production* is a lucidly written book packed with data much of which will be new to the reader. There are plenty of clear line illustrations and circuit diagrams and there is little doubt that this book will be "required" reading for all students of electronic music—amateur and professional alike.

G.D.S.