

ELECTRONICS TODAY INTERNATIONAL 4600 SYNTHESISER

Full Construction Details

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4600 INTERNATIONAL MUSIC SYNTHESIZER

In this booklet we describe the construction of a music synthesiser—the International 4600. This synthesiser is a full scale unit with a programming patchboard making it suitable for studio use. It is constructed in a modular form which gives a high degree of flexibility allowing constructors to tailor the instrument to their own requirements.

Another booklet is available* giving details of the International 3600 Synthesiser, a relatively inexpensive model that is basically designed as a portable, limited capability instrument for stage work.

*Publication date tentatively February 1976.

EXPERIMENTATION in electronic music has been carried out since the earliest days of vacuum tube technology. One of the earliest pioneers in the field was B.F. Meisner who published the article "Design Considerations for a Versatile and simple Electronic Musical Instrument" in 1935. By the late 40's the electric piano and organ had become well established, but very few real advances were made. Even in the early 60's, the electronic-music studio consisted simply of a variety of tape recorders, filters and other devices which were used to modify the sounds of conventional instruments.

The first real breakthrough came in 1965 with the introduction of the first commercial Voltage Controlled Electronic Music Synthesizer designed by Robert Moog. Since then development has been rapid indeed, and in just eight years synthesizers have become one of the most versatile and flexible of electronic musical

instruments. Today they are used extensively by both popular and classical musicians to create new and exciting sounds.

Very soon after Moogs' revolutionary voltage-control concepts were introduced, the use of a digital computer was proposed as a means of extending the basic system and providing real time control of synthesizer operation. During recent years much work has been pioneered on digitally generated "computer music". This concept however, despite its incredible potential, is still in its infancy, and dependent for advancement on further technological developments.

The basic genius of voltage control is its conceptual simplicity, and although the method of implementation has changed much since 1965, the concept itself has not. Moog proposed that the basic sound sources, such as electronic oscillators and random noise generators, be electronically generated and that these sources be modified in amplitude and frequency by other electronic devices. The resultant signals would then be processed conventionally with reverberation and multi-track tape techniques. This in itself was not revolutionary but Moog proposed that all these generation and modification functions be VOLTAGE CONTROLLED. He then designed such circuitry — and the Voltage Controlled Music era had begun.

Voltage control implies that the oscillator frequencies (and/or harmonic structure), the gains of mixer/amplifiers and the cut-off frequencies of timbral-determining filters could all be changed by a control voltage. It need not be a constant voltage, indeed one oscillator could control another's frequency which in turn could control another, and so on. The complexity of sounds thus generated defy classical description, some of them are subjectively very pleasant, some are not, but they *all* are creative. Conventional sounds that can be specified in terms of amplitude, frequency and timbre can now be

artificially produced and, if desirable, the specifications can be changed to "improve" the basic effect.

It was indeed fortunate that much research had been previously conducted into the structure of conventional instrumental sounds and consequently musicians such as Walter Carlos (responsible for the recording "Switched on Bach") were able to speedily demonstrate the versatility of the voltage controlled synthesizer and thus ensure its widespread acceptance.

The Commonwealth Copyright Act (1968) vests in the 'maker of a work' the exclusive right to reproduce, publish and adapt that work for a specified period of time, (generally the life of the 'maker' plus fifty years).

Commercial manufacturing organisations should clearly understand that such copyright extends to all plans, drawings, circuit diagrams, photographs etc. in this book.

Commercial organisations are also asked to note that certain aspects of this design are the subject of provisional patents. These are:—

Provisional Patent 3650, — method of generating sawtooth waveforms.

Provisional Patent 3651, — method of switching resistors in voltage controlled filters.

DESIGN PHILOSOPHY

The International Voltage Controlled Synthesizer has been developed as a "state of the art" system. Extensive use has been made of digital techniques and CMOS has been used as the primary logic family.

No compromises have been made that would hinder expansion of the system to keep pace with the ingenuity or finances of its owner. The basic modules have been selected so that the unit will be just as suited to studio use as it is for a live "on-stage environment."

In this unit, a 484 point patchboard system is used to facilitate the rapid selection of various equipment configurations.

Separate headphone and main output level controls and switches are provided to ease on-stage cueing of the device.

All control voltages and generated waveforms have the same limits (zero and +5 volts), so that control and signal voltages are directly interchangeable.

The unit requires only a 240 volt ac supply (the synthesizer is not critically dependent on either the voltage or frequency of this supply), and an external power amplifier and speaker for normal operation. The headphone output will supply in excess of one watt. This is adequate to drive a small monitor speaker if an external amplifier is not available. Any dc offset voltages inherent in the circuitry are nulled in the initial construction. The keyboard intervals are also tuned during initial construction and will not require readjustment unless the unit is unusually roughly handled.

VOLTAGE CONTROLLED OSCILLATORS (VCO)

Four VCO's are provided in this unit. Each VCO is switchable to the output waveforms listed below:-

Sine, Triangular, Sawtooth, Reverse sawtooth, Pulse wave (including square-wave with variable mark-space ratio).

The fourth oscillator can provide two simultaneous outputs. In all oscillators, great care has been taken in the design to ensure purity of waveform.

Each oscillator covers the frequency spectrum 0.1 Hz to 10 kHz in eight ranges. There are LO, 32ft, 16ft, 8ft, 4ft, 2ft, 1ft and ½ft. The seven top ranges are tuned exactly one octave apart and the "LO" range is provided to generate sub-audio frequencies for special effects.

The oscillators are completely linear over the upper 10 octaves of their

range and several fed from the one control voltage will "track" accurately over the entire keyboard.

CONTROLLER

The model 4600 has a Controller unit which provides an adjustable dc voltage and an ac coupled modulation level control.

THE KEYBOARD CONTROLLER

The keyboard is fully digital. Forty-eight separate voltages are generated as a four octave x 12 semitone matrix. These are normally adjusted to produce an equal tempered scale. The output voltages (and hence oscillator pitch) have negligible temperature dependence nor will they change significantly as the unit ages.

This method used for voltage generation is completely different from, and its performance superior to, all other keyboard controllers details of which have been previously published. Most other keyboard controllers generate a linear pattern of voltages which are then converted to the required semitone values in an exponential converter, or by using an exponentially controlled oscillator. These exponential converters usually rely upon the characteristics of a transistor emitter base junction in which the temperature drift is substantial, resulting in the semitone interval having to be retuned every time the unit is played.

A fully variable "glide" (or "portamento") facility is provided, with a companion on/off switch. An "Absolute Pitch" control allows continuous transposition over several semitones.

The keyboard also generates a trigger output which goes from -7 to +7 volts whenever a key is pressed and returns to -7 volts when the key is released. A sample and hold circuit acts as a "memory" to maintain the control output voltage at the value of the last key pressed. (This enables the oscillators to maintain the last pitch selected until another key is pressed).

VOLTAGE CONTROLLED FILTERS

Two VCF's are provided giving three separate filter characteristics: lowpass, bandpass and highpass. The cut-off slopes in all modes are 40 dB/decade, using easily reproduced two-pole active filters. The cutoff frequencies are a linear function of control voltage over a minimum range of 50 Hz to 5 kHz. Thus a filter and an oscillator fed from the keyboard (or, of course, any other control source) will track each other automatically. This also, is a feature not usually available in commercial equipment.

The filter characteristics do not change with a change in control voltage, that is, the Q factor is independent of frequency.

NOISE SOURCE

This generator produces an almost purely Gaussian white noise. A digital shift register with feedback is used to generate a pseudo-random binary sequence 218 bits long (262 144 random points). Every second, about 30 000 are generated and these are integrated (filtered) to provide a random noise signal.

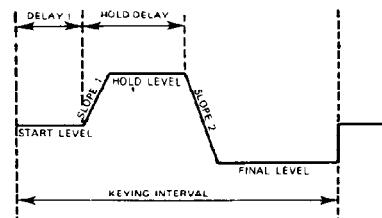
The spectral purity of this white noise is much better than those methods which use a Zener diode or noisy transistor as the source. In addition no component selection or tuning procedure is required.

THE ENVELOPE GENERATOR

This module modifies the amplitude-time characteristic of a continuous input tone to give it "attack" and "decay" characteristics. A unique envelope is generated as shown in Fig. 1A.

All slopes are variable over a minimum range of five milliseconds to five seconds and the delay is adjustable from "off" — in which mode slope 3 is initiated only when the keyboard trigger goes to zero — to a maximum of approximately three seconds. This unique feature allows simulation of very fast attack-decay instruments (vibraphones, for example). The envelope generator contains a voltage controlled amplifier that is switchable to either linear or square-law control characteristics. Provision is also made for an external trigger (other than that from the keyboard) to initiate the envelope.

Fig. 1A. Characteristics of envelope generator.



THE TRANSIENT GENERATOR

Two types of transient generator are used, type A and type B. Type A is primarily used to modulate the keyboard output voltage, such that transients can be generated on oscillator and filter outputs during the formation of a single note. The 4600 has two generators, one type A known as TRANSIENT 2, and one type B known as TRANSIENT 1.

The type B generator is basically similar to the envelope controller but does not include a voltage controlled amplifier. Hence its output is a dc waveform and not a modulated envelope as in the envelope generator. This unit may be used as an envelope control if required in conjunction with one of the ring modulators.

The type A transient generator is a unique feature, as an infinite variety of output functions are available.

When a trigger is received, nothing happens until a preset delay (delay) has elapsed. Slope is then initiated until the hold level is reached. Delay 2 is initiated on the completion of delay 1 after which Slope 2 begins and continues until the final preset level is reached.

For example if the following settings are made:-

START LEVEL	0
DELAY 1	2
SLOPE 1	2
HOLD LEVEL	+5
HOLD DELAY	2
SLOPE 2	2
FINAL LEVEL	-2

then the keyboard output voltage when a key is pressed would be modified as shown in Fig. 2A.

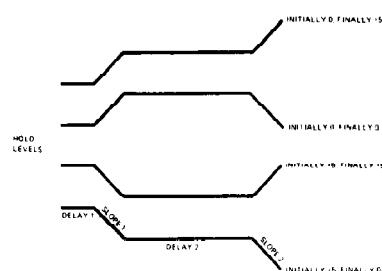


Fig. 2A.

Such an output would, when applied to an oscillator, cause it to commence the note in tune, raise it say one octave higher and then drop one octave lower. This frequency modulation of the oscillator can create some very interesting and pleasing sounds. The number of semitones or octaves shifted up or down is uniform over the entire keyboard range, the design range is plus or minus two octaves. Usually however this signal would be used to control a VCF (in the bandpass mode) being fed from a complex waveform (considerable harmonic content). Upon pressing a key the above waveform would cause the filter to commence at the timbre as selected by the VCF "tune" control, sweep up to the higher overtones and finish on the lower components.

Although this diagram may be typical, the start hold and final levels may be varied as required.

This timbral change allows the simulation of instruments such as the piano as well as the generation of new sounds which are quite different to those from basic instruments.

AMPLIFIERS 1 AND 2

These units are fitted to the International 4600 only and are in effect voltage controlled amplifiers which serve a dual function as selected by a mode switch.

When the "Ring modulator" mode is selected the unit effectively multiplies the two input functions. Thus if either is zero, the output is zero. If one input is a dc control voltage varying between zero and +5 volts then the output will consist of the other input function with an amplitude linearly controlled by the dc control voltage.

The other mode merely ac couples the input and in this mode the unit may be used as a general purpose amplifier.

MIXERS

Five mixers are used in the 4600, all are direct coupled and hence may be used for control voltages or signals.

Mixers 1 to 3 are used solely for mixing the outputs of oscillators 1 to 4 and there is no access to their inputs. Mixers 4 and 5 have two inputs each, their outputs however may be paralleled to provide one four-input mixer.

OUTPUT EQUALIZER AND VOLUME CONTROL

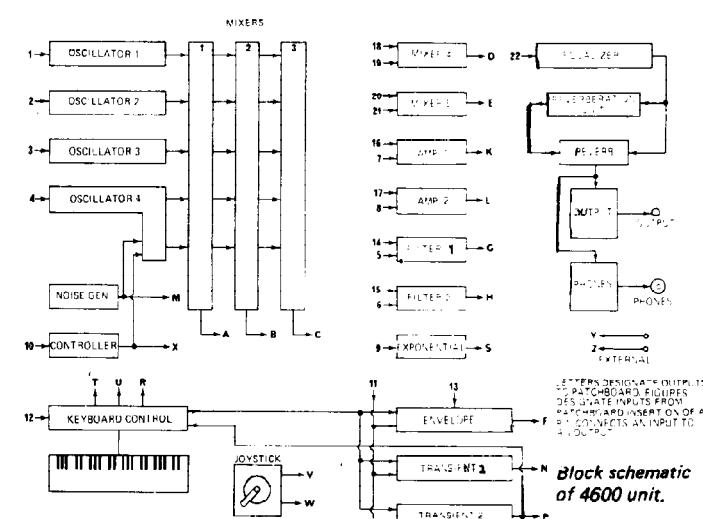
All signals are passed through a five section equalizer. This signal is then mixed with the same signal after passing through a spring reverberation unit. The reverberation control acts like a crossfader allowing the proportions of direct signal and reverberation to be controlled. The combined signal is then passed to an output amplifier and to a headphone amplifier each of which has an independent level control. A switch is provided to switch off output if required.

JOYSTICK CONTROL

A joystick is fitted to the model 4600. It is accessible via the patch board and may be used to control, for example, two oscillators simultaneously, but differentially.

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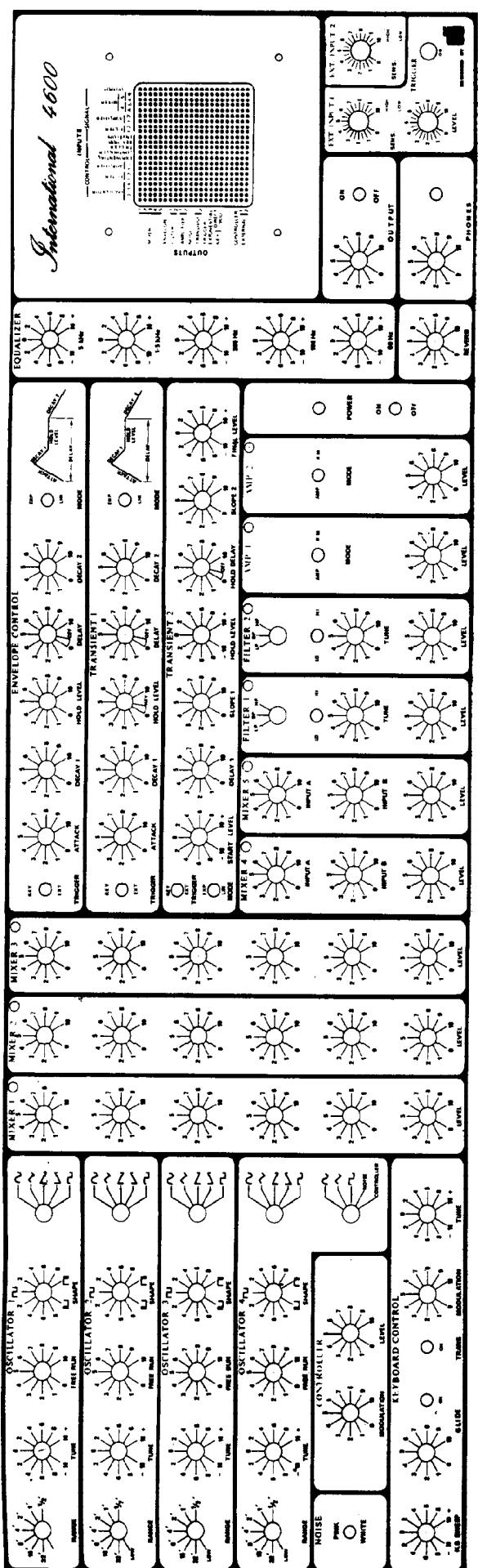
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SPECIFICATION INTERNATIONAL 4600 SYNTHESIZER

KEYBOARD	48 (F to E monophonic)	MIXERS 1, 2 and 3 Inputs	5 (one from each oscillator output) each with independent level controls.
Number of Keys Outputs to Patchboard Trigger	-7 V to + 7 transition at each key press. Trigger is inhibited if more than one key is pressed. 0 to + 5 volt 9 to + 15 volts transient generator No. 2 patchboard.	Level control	adjusts output level from each mixer.
Analogue (direct) Analogue (modulated) Inputs		Overload Output	Indicated by LED lamp. to patchboard.
Controls: Sweep	allows manual sweep, up or down from the keyed note over any selected span. adjustable rate 0.10 seconds switchable.	MIXERS 4 and 5 Inputs	two each from patchboard individually adjustable adjustable with overload indication to patchboard.
Glide		Input levels	
Transient	selects direct modulation of keyboard by transient generator No. 2.	Output level	
Modulation	allows patchboard input to modulate keyboard to maximum of ± 2 octaves.	Controls.	
Tune	tunes keyboard ± 2 semitones.	Type	active, voltage controlled 0.5 volt signal from patchboard 0.5 volt control from patchboard
Oscillators		Inputs	
Number Controls: Range	4 (oscillator 4 has dual output) provides seven ranges from $\frac{1}{2}''$ to 32 plus low frequency (0.01 Hz) special effects source. tuning range of $\pm \frac{1}{2}$ octave internal voltage source manually adjusts oscillator over full range. varies mark/space ratio of square wave output. selects sine, triangular sawtooth, inverted sawtooth or square wave as output second output of oscillator 4 provides noise or controller output.	Cutoff Rate Control Range	selects high pass, bandpass or lowpass filter characteristics selects tuning range tunes filter to control source. controls output level with overload indication. 24 dB/octave 2 decades
Tune Free Run		Type	voltage controlled, ac or dc coupled via patchboard (0 to + 5 volts) via patchboard (0 to + 5 volts)
Shape		Input Signal Input Control Mode Mod	dc coupled functions as voltage controlled amp ac coupled function as ring modulator to patchboard level controlled and with overload indication.
Waveform		Amp	
		Output	
NOISE	provides pink or white noise direct to the patchboard. Noise is also selectable by oscillator 4, second output.	from patchboard or keyboard direct.	
CONTROLLER		Attack Decay 1 and Decay 2. Hold Level Delay	all adjustable from 5 msec to 5 sec. adjustable 0-5 volts. adjustable 5 msec to 5 sec, or duration of key contact closure as selected. linear or exponential voltage controlled amplifier with a range of 60 dB. to patchboard.
Input Output		Control Mode	
Controls: Level	sets dc level, that is, centre frequency of controlled oscillator. controls level of modulation source selected via patchboard.	Modulation	0 to 1 volt RMS 1 k ohm level control provided together with on/off switch.
		Output	

TRANSIENT 1	BASICALLY similar to Envelope Generator but voltage controlled amplifier is omitted. Hold level may be adjusted to match keyboard output.
TRANSIENT 2	from keyboard or patchboard start hold and final adjustable 0 to + 5 volts. adjustable 5 msec to 5 sec adjustable 5 msec to 5 sec or for duration of key contact closure. to patchboard and to keyboard control.
EXPONENTIAL CONVERTER	0 to + 5 volt from patchboard. Input Output converts linear input to exponential output.
JOY STICK	2-axis control of any two functions linear or exponential output as required 0 to + 5 V.
EXTERNAL SIGNALS	2 signals 50 mV to 2 V Number of Inputs Input Impedance
OUTPUT EQUALIZER	5 Number of Stages Centre Frequencies kHz Active filter $> \pm 10$ dB.
REVERBERATION UNIT	Type Range of Adjustment Type Output
PHONE OUTPUT	Power Output Load Impedance Output Level
SIGNAL OUTPUT	Level Load Impedance Level



THE PERCEPTION OF SOUND

Loudness

The most basic characteristic of a sound is its loudness. The apparent loudness of a sound is a function of its intensity, or level, but there are three main factors which affect our perception of that intensity.

The first factor is that of the response characteristics of the ear. Our hearing can accommodate a huge range of sound intensity, but our perception of that intensity is not linear but logarithmic. To double the apparent loudness of a source, its intensity must be increased at least eight times. This is the reason for the use of exponential converters in the synthesizer, they are there to change a *linear* signal change to a *subjectively linear* (logarithmic) signal change.

The second factor is the *frequency – dependent sensitivity* of our hearing mechanism. This is expressed graphically in the well-known Fletcher-Munson equal loudness level contours (Fig. 3.)

These show that as the intensity of a sound is reduced there is a considerable reduction in hearing sensitivity in the bass region relative to that in the midrange.

This phenomenon accounts for the difference in apparent loudness between (say) a 200 Hz sine wave and a 200 Hz sawtooth wave. The sawtooth wave contains high harmonic content and although its overtones are not the same intensity as the fundamental, our hearing is more sensitive to them. As the effective loudness of a complex sound is dependent on the algebraic sum of the loudnesses of each component of that sound, we hear the sawtooth as being much "louder" than the sine wave, although their amplitudes may be identical.

The third factor affecting perceived loudness is the *duration* of the sound. It takes a finite time for our hearing to react to the presence of a sound and to analyse its characteristics.

Sounds which are very short in duration (.01 seconds, or 10 milliseconds) are perceived as being of lower loudness than they actually are (in addition very little pitch information is gathered from such a short burst of sound). Further, when the ears have become conditioned to the presence of a sound there is a gradual drop in apparent loudness.

When we synthesize very short attack transients we must allow for this lack of sensitivity and this means a much larger overshoot is required than would otherwise seem necessary.

Absolute Pitch Although perception of pitch is not precisely logarithmic, an exponential characteristic comes fairly close to producing equal subjective pitch change from a linear input. (Fig. 5.)

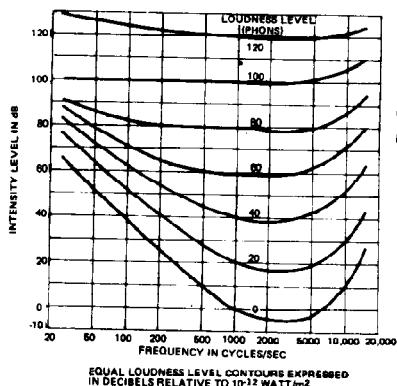


Fig. 3. Equal loudness contours (Fletcher-Munson)

Musical Pitch Two tones whose frequencies differ by a factor of 2 are said to be *one octave apart*. This octave is usually divided into twelve increments, known as semitones which differ from each other by

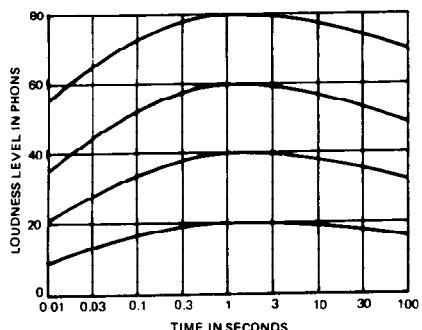


Fig. 4. Relation between loudness level and duration time.

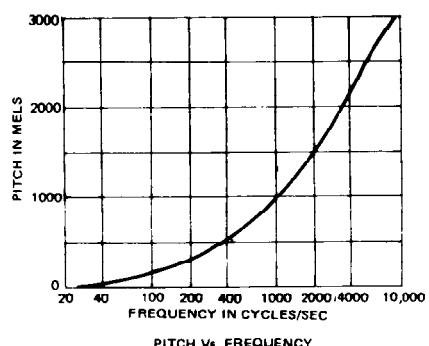


Fig. 5.

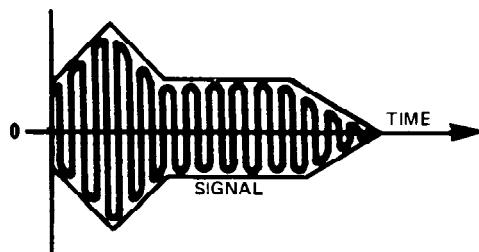


Fig. 6. The 'envelope' of a sound is the variation of its intensity with time.

a factor of the twelfth root of 2 ($12\sqrt[12]{2} \approx 1.059463$).

Such a musical scale is termed "equal-tempered" and is used for all keyboard instruments. There are also several so called "just" or "true" scales that are based on harmonic structure. A musical textbook should be consulted if further information on these scales is required.

All previous voltage controlled synthesizer designs have been able to obtain "equal tempered" intervals only. The digital keyboard incorporated in both the synthesizers described in this series can be adjusted to these "just" scales, this should only be considered by a competent musician and is generally unnecessary. Frequencies of the fundamental tones of each semitone in the effective musical scale are shown in Table 1.

Envelope The envelope of a sound is the variation of its intensity with time as shown in Fig. 6. The rate of variation of the envelope is very slow compared with the time variation of the sound itself (sine wave shown in Fig. 6. is the base sound.) Although the envelope is symmetrical about zero it is usually referred to in terms of the modulus.

TABLE 1 THE TEMPERED SCALE

	OCT 1	OCT 2	OCT 3	OCT 4	OCT 5	OCT 6	OCT 7	OCT 8	OCT 9	OCT 10
F	21.8	43.7	87.3	174.6	349.2	698.5	1396.9	2793.8	5587.7	11175.3
F#	23.1	46.2	92.5	185	370	740	1480	2960	5920	11839.8
G	24.5	49	98	196	392	784	1568	3136	6272	12543.9
G#	26.0	51.9	103.8	207.7	415.3	830.6	1661.2	3322.4	6645	13289.8
A	27.5	55	110	220	440	880	1760	3520	7040	14080
A#	29.1	58.3	116.5	233.1	466.2	932.3	1864.7	3729.3	7458.6	14917.2
B	30.9	61.7	123.5	246.9	493.9	987.8	1975.5	3951.1	7902.1	15604.3
C	32.7	65.4	130.8	261.6	523.3	1046.5	2093	4186	8372	16744
C#	34.6	69.3	138.6	277.2	554.4	1108.7	2217.5	4435	8869.8	17739.7
D	36.7	73.4	146.8	293.7	587.3	1174.7	2349.3	4698.6	9397.3	18794.5
D#	38.9	77.8	155.6	311.1	622.3	1244.5	2489.7	4978	9956.1	19912.1
E	41.2	82.4	164.8	329.6	659.3	1318.5	2637	5274	10548.1	21096.2
32 ¹										
16 ¹										
8 ¹										
4 ¹										
2 ¹										
1 ¹										
1/2 ¹										
KEYBOARD COVERAGE OF SYNTHESIZER										

Half tone factor is 12th root of 2
approximately 1.05946309
scale is based on A - 440 Hz

Timbre The timbre of a musical sound is the characteristic that makes it possible to distinguish between two tones having the same intensity and fundamental frequency, but different waveforms. It expresses our ability to recognize the sound of a violin as different from that of a trumpet, even though the two instruments may be playing with the same pitch and loudness.

To describe analytically the timbre of a sound we must specify the frequencies of all the constituent components (termed "Partials") of that sound and their respective envelopes. (This group of envelopes is

referred to as the 'Complex Envelope' of a sound).

The partials may not necessarily be harmonic, indeed many natural sounds have partials which are inharmonic. For example, the frequency of the fifteenth overtone of middle C on a piano, is greater than sixteen times the fundamental frequency (middle C).

With an electronically generated waveform, however, the overtones are direct multiples of the fundamental, and so a miscellany of different oscillators must often be used when attempting to simulate the sound of a "natural instrument". ●

INTERNATIONAL MUSIC SYNTHESIZER

For ease of construction and greater reliability and stability of the synthesizer, extensive use has been made of integrated circuits of both analogue (operational amplifiers) and digital (CMOS). Hence this is not a recommended project for the beginner unless he has available the help of someone with experience.

Although the synthesizer can be built without the aid of test equipment, correct operation can only be assured

by the use of some equipment.

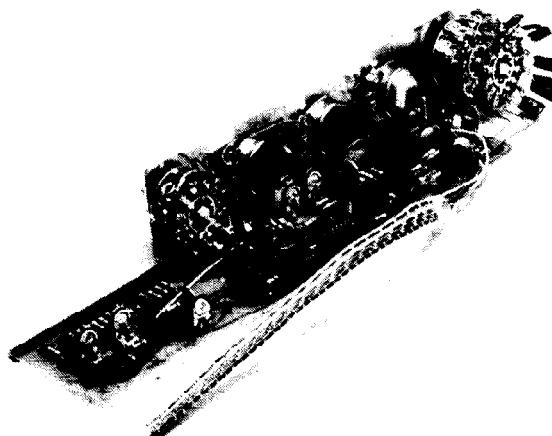
The most important instrument is most certainly an oscilloscope together with an organ tuner or digital frequency meter and an accurate dc voltmeter (preferably digital).

Components have been selected for use in the synthesizer on the basis of

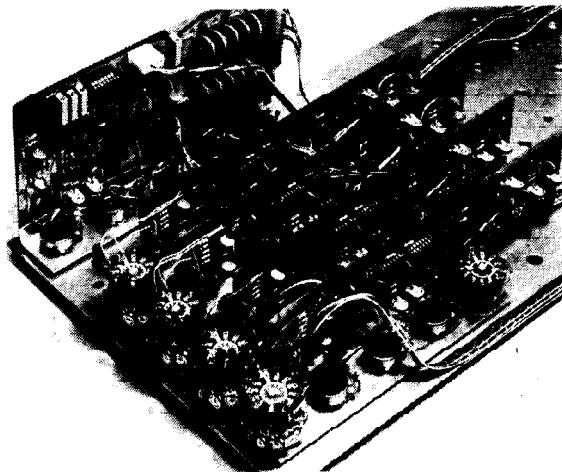
availability, price and performance. Many people do not understand that this is a monophonic (one note at a time) instrument. That is, only one voltage at a time can be generated from the keyboard. Although a polyphonic instrument could be designed it would be considerably more complex and would virtually require a complete synthesizer for each note to be played simultaneously.

Constructional details of the voltage controlled oscillators and the keyboard controller

The voltage controlled oscillator, showing the assembly of board potentiometers and switches to the sub panel.



The four oscillators and the keyboard controller shown assembled to the front panel.



CONSTRUCTION

General

Each separate synthesizer module is constructed as an individual subassembly, and these subassemblies are mounted onto a common front panel. It is recommended that plugs

and sockets are used for all inter-wiring between modules, as this enables individual modules to be completely aligned and tested before installation on the front panel. It also, of course, facilitates later servicing.

With circuitry as complex as that in

the synthesizer it is normal to use double-sided PC board. However, since this doubles the price of the boards we have elected to use single sided board with wire links where necessary. These have been kept as short, and as straight, as possible.

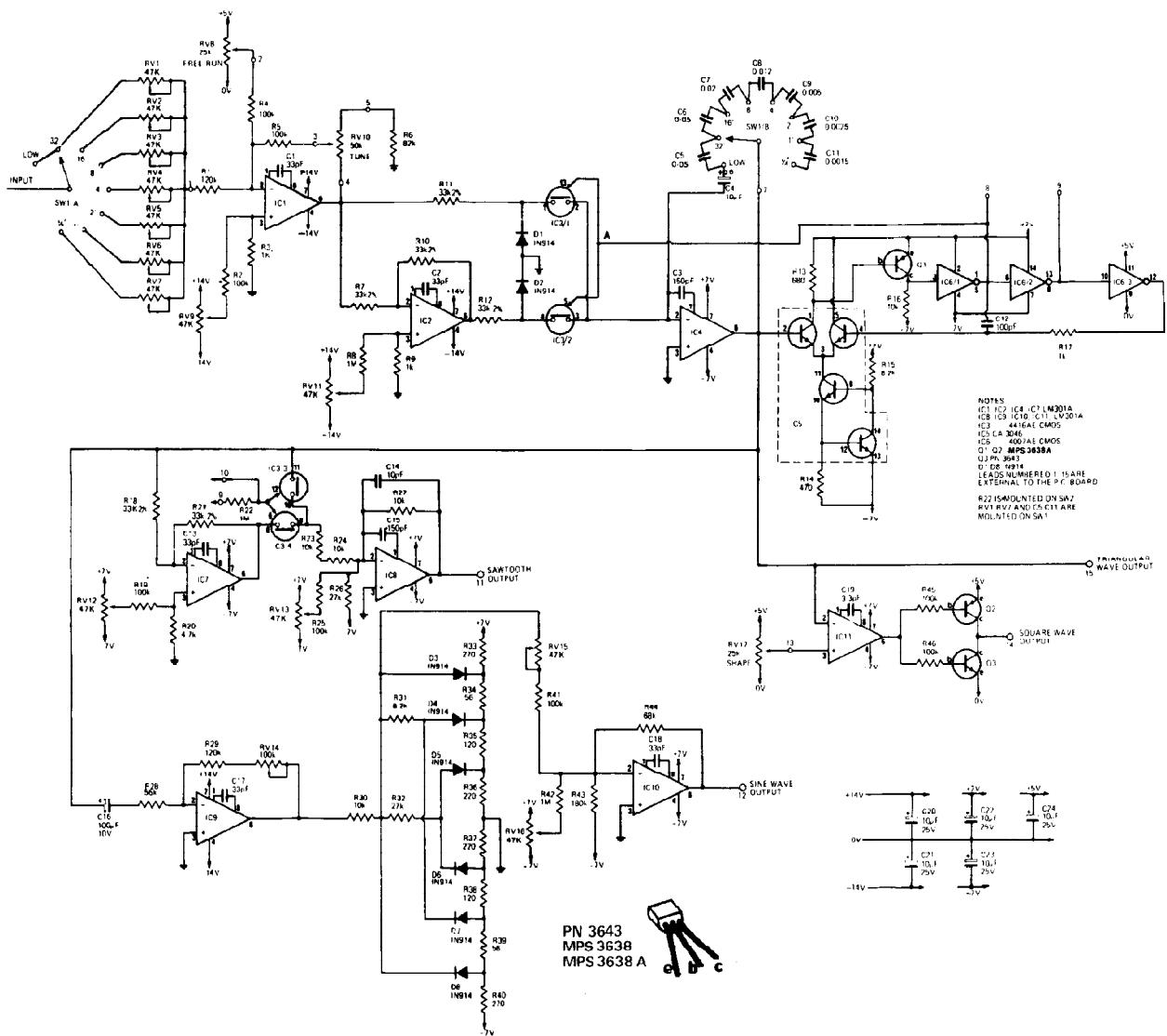


Fig. 7. The voltage-controlled oscillator.

Oscillators

Before mounting any components on the PC board install the links as shown in Fig.8. Note that some of the links, due to the proximity of other components, must be insulated. Make sure when mounting the components that the orientation of IC's, transistors, capacitors and diodes is correct. It is recommended that IC sockets be used for IC3 and IC6. These ICs should not be fitted until ready for testing and should not be handled excessively. Leads leaving the PC board are numbered on the overlay and these numbers correspond to leads on the circuit diagram and Fig. 13.

The external potentiometers and switches are mounted on a small aluminium bracket (Fig.15) which also holds the PC board (see photo). The metal bracket is fitted to the PC board on the component side and not the copper side.

Except for the power supply which has 6 wires (+14V, +7V, +5V, OV -7V, -14V) only two other wires leave the board. These are the input and the

output.

It is recommended that a plug and socket be used to connect the power supply from each module to the power supply board. Provision is made for this on the power supply board and the parts list contains the necessary order codes.

Before switching on double check all soldering, component selection and orientation, and power supply connections.

Keyboard Controller

Construction of this module follows the same line as specified for the oscillator. Provided the links are kept straight no insulated links need be used. It is recommended that IC sockets be used on IC1, 3, 4, 5, 7, 16 which are the CMOS devices.

It is recommended that a plug and socket be used to connect the keyboard to this module as it allows easy removal of the front panel. The layout of the PC board allows for the use of a plug.

ALIGNMENT Oscillator

This procedure will require the use of an oscilloscope and a digital frequency meter or organ tuner.

Procedure:

1. Connect all power rails to the power supply and, without any input connected to SW1, switch on.

2. Select the 8 foot range and turn free run control fully clockwise.

3. Select triangular waveform and observe the output waveform. This should be as per Fig.10a and go from 0 to +5 volts.

4. Select sawtooth waveform and observe the output. It will probably be similar to either Fig. 10b or Fig. 10c. Adjust RV12 to obtain a straight line as in Fig.10d.

NOTE: ADJUST RV13 SUCH THAT THE LOWEST EDGE OF THE WAVEFORM IS AT 2.60 VOLTS.

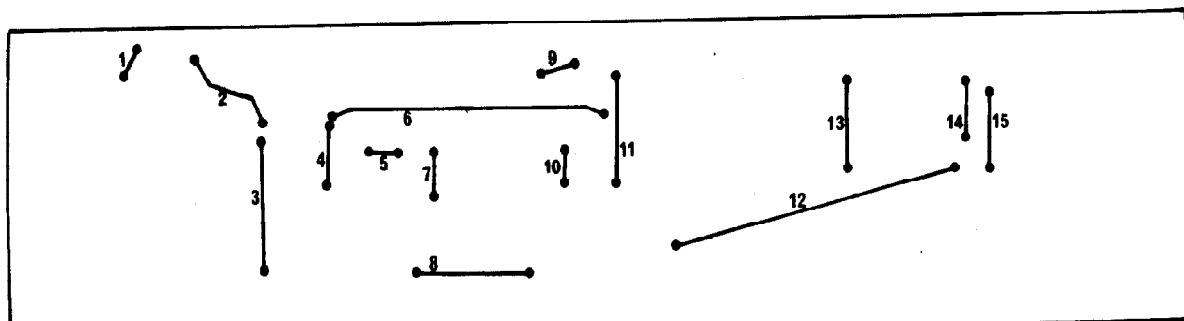


Fig. 8 Linking required on the oscillator board. This should be installed before components are fitted.

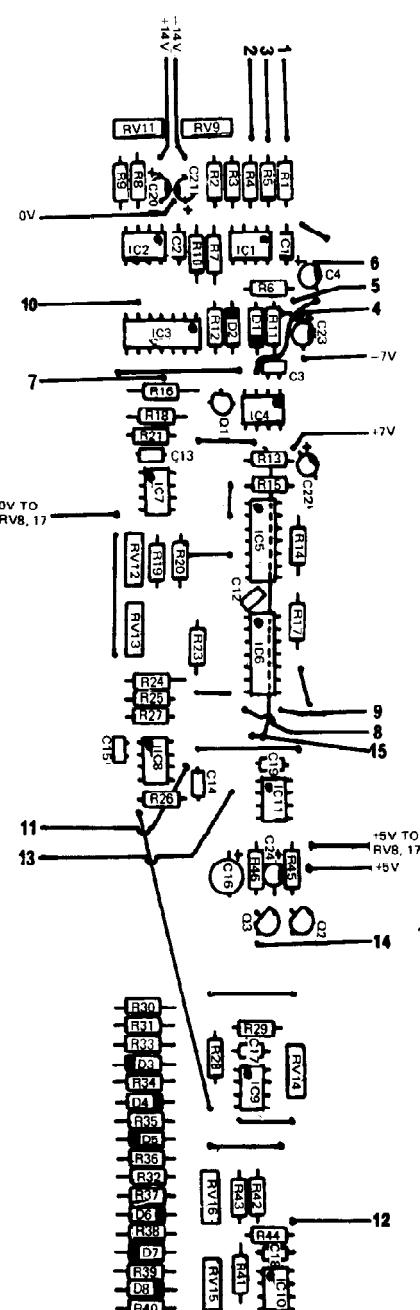


Fig. 9 Component overlay for the oscillator.

5. Select the ½ foot range and turn the free run anti clockwise until the oscillator is just running. The waveform will appear as in Fig.10e or Fig.10f. Adjust RV11 to obtain a straight line as in Fig.10d.

6. Adjust RV9 such that the oscillator is just running when "Freerun" is at zero.

7. Select 8 foot, maximum free run and sine-wave output. Adjust RV14 for best waveform as per Fig.10h. Incorrect waveforms are shown in Fig.10g and Fig.10j.

8. Adjust RV15 such that the waveform is 5 volts peak-to-peak.

9. Adjust RV16 such that the

lowest edge of the waveform is at zero volts.

10. Check that all waveforms are selectable by SW2 and that the square wave output is correct as per Fig.10k.

The calibration of each range is best performed in conjunction with the keyboard controller. With the keyboard controller connected, select the top note of the keyboard, or if no keyboard is available, link pins 21 and 33 on the keyboard controller. Hold this connection closed to eliminate drift and set keyboard tune, oscillator tune and free run controls all to zero. Adjust potentiometers RV1-RV7 to obtain the frequencies appropriate to the range as per table 2.

That completes the oscillator alignment.

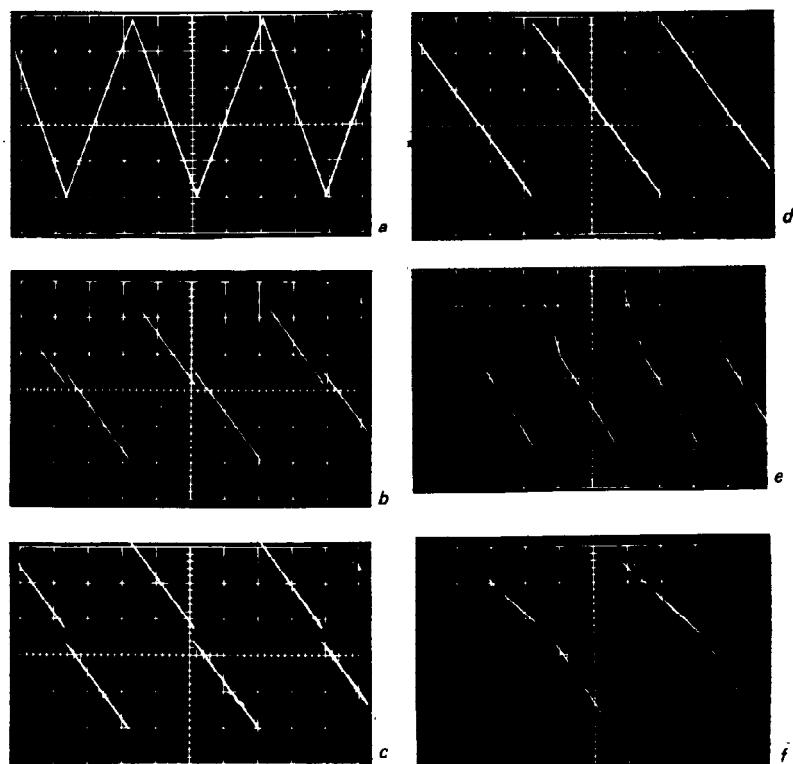


Fig. 10.

PARTS LIST OSCILLATOR

OSCILLATOR - HOW IT WORKS

The basic waveform generated by the oscillator is triangular. All other waveforms are generated by modification of this basic waveform.

The input voltage, normally between zero and +5 volts, is amplified in IC1. The tune control, RV10, controls the gain and can vary the output by a 2 to 1 ratio. With this control set at mid position, the output of IC1 is approximately equal to, but in antiphase with, the input voltage. That is, the stage has a gain of -1. Individual potentiometers on each switch position allow the ranges to be adjusted an exact number of octaves apart. Control RV9 adjusts the offset of IC7 and RV8 is the free run control. The output of IC1 is therefore normally in the range zero to +5 volts, but can range up to -12 volts if the modulated output from the keyboard is being used. (See keyboard controller).

The output of IC1 is inverted by IC2 to provide an identical voltage of opposite polarity, the offset of IC2 being adjusted by RV11.

Integrated circuit IC3 is a solid state, dual, double-throw switch. If the input at A is high (+2 volts) IC3/1 will be on and IC3/2 will be off, and vice versa if the input at A is low (-2 volts). The on resistance is between 200 and 500 ohms and the off resistance is of the order of 10^{12} ohms. Diodes D1 and D2 protect the input of the switch against the application of excessive voltage.

An integrator is constructed with IC4 and an integrating capacitor selected by SW1. If IC3/1 is on, the output of the integrator will be a linearly increasing voltage. Hence if IC3/1, 2 are switched alternately on and off,

the output of IC4 will be a triangular wave. Transistor array IC5 when connected to Q1 and IC6 acts as Schmitt trigger; where IC6 is simply a CMOS inverter with IC6/1 and IC6/2 connected to +7 and -7 volts and IC6/3 connected to zero and +5 volts. The output of IC6/3 provides feedback to the comparator section of the Schmitt trigger, and being a 0 to +5 volt level, makes the Schmitt points 0 and +5 volts. The output of IC6/1 controls the CMOS switches IC3/1 and IC3/2 which hence derive triangular wave from the integrator of 0 to +5 volt amplitude.

To generate a square wave of variable mark/space ratio, the triangular wave is simply compared to a dc level as set by the shape potentiometer (RV17) by IC11, the output of which is buffered by Q2 and Q3 which ensure that the output has the correct levels of '0' and +5 volts.

The sawtooth waveform is generated by inverting the triangular waveform in IC7 and level shifting to produce a waveform 180° out of phase having 0 to -5 volts levels. The output of these two waveforms is selected in turn by CMOS switches IC3/3 and IC3/4. These switches are controlled by either IC6/1 or IC6/2 dependant on the position of SW2 (reverse or normal sawtooth). The correct amplitude and level of the sawtooth is maintained by IC8.

The sinewave output is generated by amplifying the triangular wave in IC9 to about 15 volts peak-to-peak, symmetrical about zero. This signal is then clipped by the diode-resistor matrix to approximate a sinewave. This is then level shifted and amplitude controlled by IC10.

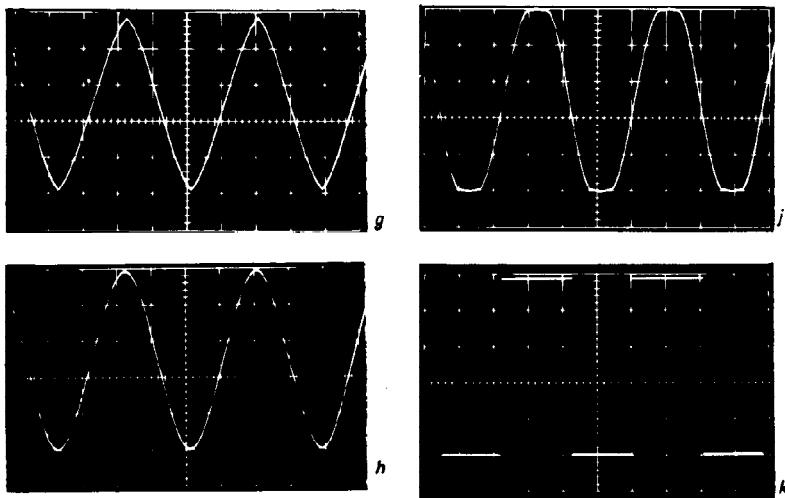


Fig. 10.

TABLE 2

Adjust	RV1	RV2	RV3	RV4	RV5	RV6	RV7
Range	32'	16'	8'	4'	2'	1'	½'
Frequency	329.6	659.3	1318.5	2637	5274	10548	21096

Keyboard Controller

The equipment required is an oscilloscope, organ tuner or digital frequency meter and an oscillator module.

Procedure:

1. Connect power supply, oscillator (to key output) and a keyboard if

available.

2. Set keyboard tune and sweep controls to centre, glide to 'off', modulation to zero and oscillator free run to zero.

3. Switch on and press the top note of keyboard, or link pin 33 to pin 21 in the keyboard controller.

R1,29	Min Res 120k
R2,4,5,19,25,41,45,46	Min Res 100k
R3,9,17	Min Res 1k
R6	Min Res 82k
R7,10,11,12,18,21	Oxide 33k
R8,22,42	Min Res 1M
R13	Min Res 680
R14	Min Res 470
R15,31	Min Res 8k
R16,23,24,27,30	Min Res 10k
R20	Min Res 4k
R26,32	Min Res 27k
R28	Min Res 56k
R33,40	Min Res 270
R34,39	Min Res 56
R35,38	Min Res 120
R36,37	Min Res 220
R43	Min Res 150k
R44	Min Res 68k
RV1,2,3,4,5,6,7,9,11, 12,13,15,16	Vert S-Min Preset 47k
RV8	Pot Log 25k
RV10	Pot Lin 50k
RV14	Vert S-Min Preset 100k
RV17	Pot Lin 25k
C1,2,13,17,18	Ceramic 33pF
C3,15	Ceramic 150pF
C4,20,21,22,23,24	Tant 10μF 25V
C5,6	Mylar 0.05μF
C7	Mylar 0.02μF
C8	Mylar 0.01μF and 0.002μF in parallel
C9	Mylar 0.005μF
C10	Mylar 0.005μF and 0.005μF in series
C11	Mylar 0.002μF and 0.005μF in series
C12	Ceramic 100pF
C14	Ceramic 10pF
C16	P.C. Elect 100nF 10V
C19	Ceramic 3.3pF
Q1,2	MPS 3638A
Q3	PN 3643
IC1,2,4,7,8,9,10,11	LM301A
IC3	4416AE
IC5	CA3046
IC6	4007AE
D1-D8	1N914
SW1	Maka Shaft, 2 off Maka Wafer 1p 11W and 1 pk Maka Spacer
SW2	Maka Shaft and Maka Wafer 2p 5W

Other Parts Required

1	Oscillator PCB
1	Oscillator Mtg Bracket
5	15mm Collet Knob Black
2	15mm Collet Indicator
3	15mm Collet Nut Cover
2	Bolt 6BA 1/4in.
2	Nut 6BA
2	Shakeproof Washer 6BA
2	DIL Socket 14-pin (for IC3 and IC6)
1	Wafercon Socket 8-way
8	Wafercon Terminals

The above components are required for each oscillator; the following components are also required:

- For oscillator 1 -
5 15mm Collet Cap Red
For oscillator 2 -
5 15mm Collet Cap Yellow
For oscillator 3 -
5 15mm Collet Cap Green
For oscillator 4 -
1 15mm Collet Knob Black
1 15mm Collet Indicator
5 15mm Collet Cap Blue
1 Rotary Sw 6

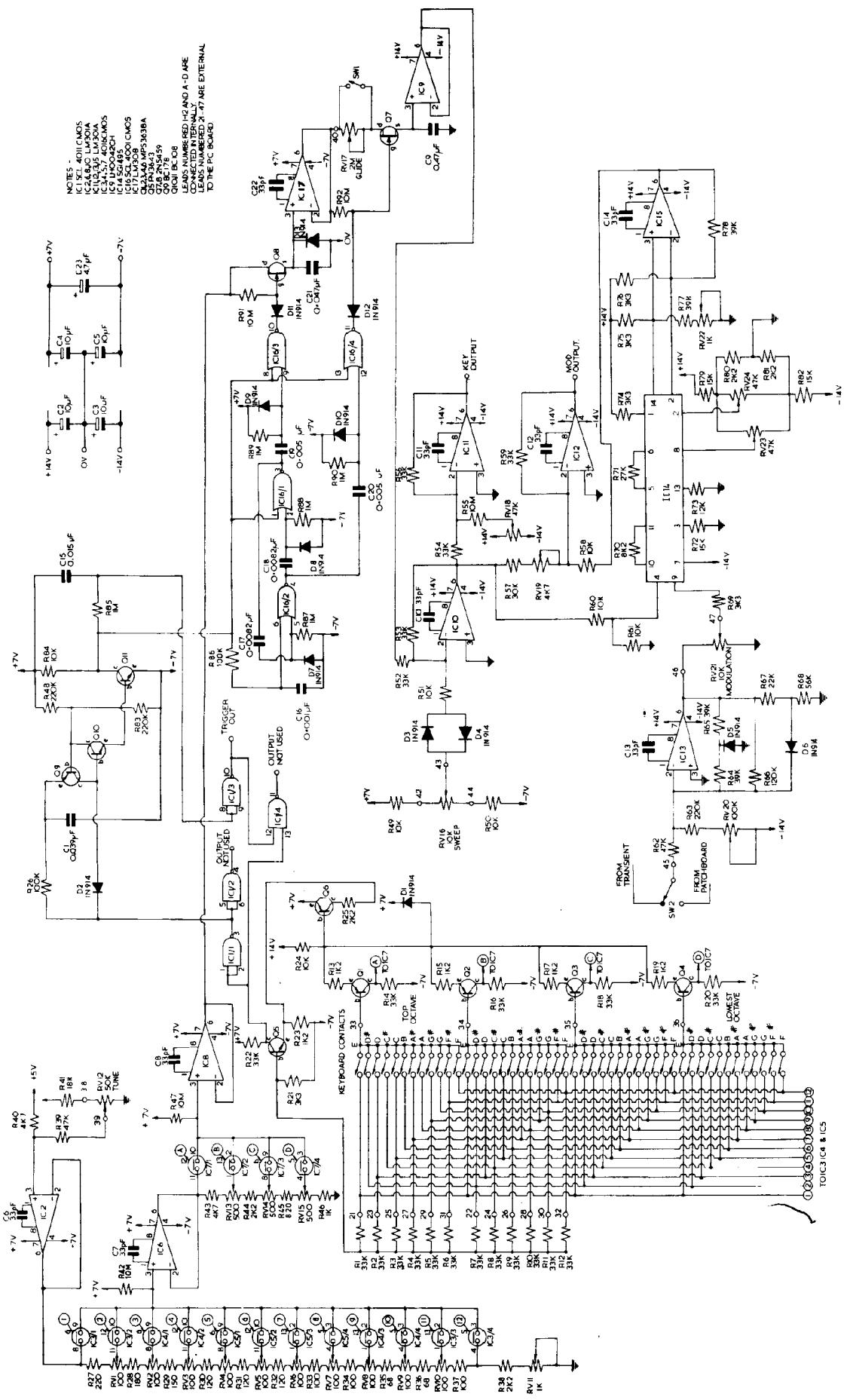
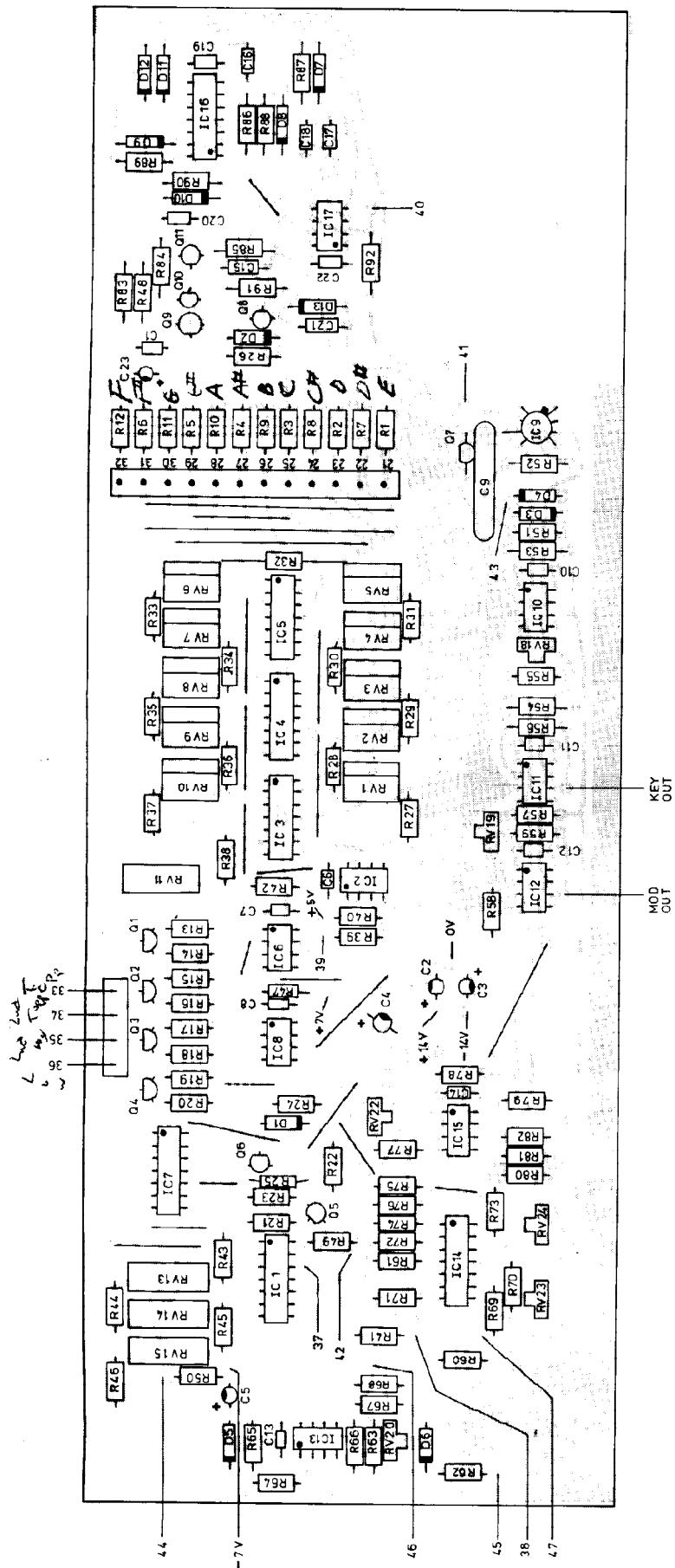


Fig. 11. Keyboard controller circuit.



4. Select $\frac{1}{2}$ foot on the oscillator and check that it is running.

5. Turn the sweep control and check that it varies the output frequency. It will be found that there is a dead region in approximately the centre of rotation where the oscillator frequency does not change. Set the knob such that zero on the scale occurs in the centre of this band.

6. Release the key (or link) and short capacitor C9 to ground. Turn the sweep control to zero and then adjust RV18 until the oscillator is just running. This compensates for offsets in the ICs.

7. Remove the short on C9, select the 4 foot range and depress the top note again.

8. Adjust the output frequency by use of the oscillator tune control to 2637 Hz. Calibration of the rest of the notes is then carried out in accordance with the order given in table 3.

9. Check that if a second note is pressed, whilst the first is still pressed, that the frequency does not change. If it does check if Q6 is turned on in the two note condition. If it is, increase R24 to 12k. If Q6 turns on with a single note pressed decrease R24 to 8.2k.

10. Release all keys, short C9 to ground, set modulation control to zero and free run control of the oscillator to obtain approximately 1 kHz.

11. Connect the output of the oscillator via a series 0.1 microfarad capacitor and piece of wire to pin 4 of IC14.

12. Observe the output at IC15 pin 6 and adjust RV24 to eliminate the 1 kHz from the output. Now inject the signal into pin 9 of IC14 and adjust RV23 to remove the 1 kHz.

13. Remove the signal input and adjust RV22 to provide zero volts output.

14. Remove the shorting link on C9.

15. Take a wire from the key out to pin 45 and press the second top E (connect pin 21 to pin 34). This will provide 2.5 volts into the exponential converter. Adjust RV20 to obtain zero volts at the output of IC13 pin 6.

16. Turn the free run control of the oscillator to zero and measure the frequency when the 'key out' is used as the voltage source. Now use the 'modulation out' as the signal and adjust RV19 for the same frequency.

TABLE 3
CALIBRATION ORDER

NOTE	OCTAVE	RANGE	FREQ (Hz)	ADJUST	NOTES
E	TOP	4'	2637	osc/tune	
F	TOP	4'	1396.9	RV11	
D#	TOP	4'	2489.7	RV1	RV1-RV10 may
D	TOP	4'	2349.3	RV2	be adjusted in
C#	TOP	4'	2217.5	RV3	any order as
C	TOP	4'	2093	RV4	there is no
B	TOP	4'	1975.5	RV5	interaction.
A#	TOP	4'	1865.7	RV6	
A	TOP	4'	1760	RV7	
G#	TOP	4'	1661.2	RV8	
G	TOP	4'	1568	RV9	
F#	TOP	4'	1480	RV10	
E	2nd TOP	4'	1318.5	RV13	RV13 - RV15 do
E	2nd Lowest	4'	659.3	RV14	not interact and
E	Lowest	4'	329.6	RV15	can be adjusted
					in any order.

KEYBOARD CONTROLLER - HOW IT WORKS

A voltage representing the selected note on the keyboard is derived from a resistive divider chain. The keyboard is divided into 4 octaves each of 12 notes. The divider chain R27-R38 provides a voltage dependant only on the note itself regardless of the octave, that is, the same voltage represents all As etc. Integrated circuits IC3, 4 and 5 are CMOS switches which are 'ON' if the control input is greater than +6 volts and 'OFF' if the control input is at -7 volts. These switches are used to select the required voltage which is buffered by IC6 to prevent loading the divider.

To select the required octave a second divider chain, R43-R46, is used the output being selected by IC7 and buffered by IC8. Therefore, by selecting one switch of IC3, 4 or 5 and one switch of IC7, a total of 48 discrete voltages may be generated.

The four-octave keyboard is provided with single-make contacts. On one side of the contacts every twelfth one is joined, that is all the As, all the A#s etc. so that twelve wires come out (see Fig.1). On the other side of the contacts all 12 contacts of an octave are joined so that 4 wires come out. Thus we have a 12 by 4 matrix.

If a single note is selected, for example A on the second top octave, a connection will be made between pins 28 and 34. The current produced in R10 turns on Q2 causing point (8) to go high. Similarly point 8 will go high turning on IC8/4 and IC7/2. This selects a discrete voltage which represents note A on the second highest octave. The process is similar for any other note on the keyboard.

When a single note is pressed the current in R1-R12 turns on Q5 causing its collector to go low. If two or more notes are pressed simultaneously the additional current through R24 forward biases Q6 turning it on. This hits the emitter of Q8 turning it off. Thus Q8 collector is low only when one single note is pressed.

Contact bounce on the trigger input is prevented by IC1. Transistors Q9, 10 and 11 form a 6 millisecond time delay for the trigger control signal. When a key is pressed Q5 turns on and switches IC1/1 which turns on Q9, 10 and 11. These then switch IC1/3 which squares up the signal to give the trigger output. The total time lag between pressing the key and the production of the trigger signal is around 20 milliseconds and the trigger signal continues for about 15 milliseconds after the key is released.

Q8 and IC17 form a sample and hold circuit which is capable of holding the required analogue voltage for a 10 millisecond period. Q7 and IC9 form the main sample and hold circuit and the voltage in the temporary store is transferred to the main memory after 5 milliseconds. Q7 and Q8 are controlled by IC16/4 and

IC16/3 respectively which are controlled in turn by IC16/1 and IC16/2. These latter gates form a monostable which produces a 4 millisecond pulse every 5 milliseconds. Potentiometer RV17 acts as a glide control by placing resistance in series with C9.

To provide sweep control (that is a voltage which can vary the frequency up and down smoothly over a large range), a voltage is derived from RV16 and mixed with the output of IC9 in IC10. Two diodes are fitted back to back, and in series with R51, to provide a dead band which facilitates setting of the zero position. Since IC10 inverts the output of IC9, IC11 is used to reinvert to the required polarity, and RV18 is used to cancel all offset voltages due to the characteristics of the linear ICs.

A second output is provided (mod output) which is normally the same as the key output but which may be modulated up or down. The keyboard output voltage is not linear per note but exponential. Hence the voltage change required to shift up 1 octave will depend on where the start point is. Therefore we must multiply the voltage by a factor to obtain the correct shift. This is done in IC14 and IC15, which form a linear multiplier, where the output is the product of the inputs (pin 4 and pin 8 of IC14). Pin 8 comes from the modulation potentiometer and pin 4 is the keyboard voltage. The output of the multiplier is then added to the keyboard voltage in IC12. With zero volts into pin 8 the output of the multiplier will also be zero and hence the modulation output will be the same as the keyboard voltage. If there is a voltage at pin 8 the keyboard output will be shifted so many semitones irrespective of the keyboard voltage.

Integrated circuit IC13 and its associated components form a linear to exponential converter which is used to control the input of the multiplier. The use of an exponential converter provides a subjectively linear frequency change for a linear input voltage change. The accuracy required is not great but the stability required is. This is the reason for synthesizing an exponential instead of the more commonly used voltage current relationship of a transistor or diode method. With this system an input of 2.5 volts will give zero voltage out due to the biasing current of R63-RV20.

The gain of IC13 is determined by R64, R65 and R66 when the input voltage is around 2.5 volts. At about 1.9 volts diode D5 becomes forward biased and the gain is reduced. At the other extreme, around 3.7 volts, D5 becomes forward biased increasing the gain. This results in a reasonable approximation of an exponential function.

PARTS LIST KEYBOARD CONTROLLER

R1-12, 14, 16, 18, 20, 22, 59	Min Res 33k
R13, 15, 17, 19, 23	Min Res 1k2
R21, 69, 74, 75, 76	Min Res 3k3
R24, 49, 50, 51, 58, 60, 61, 84	Min Res 10k
R25, 38, 44, 80, 81	Min Res 2k2
R26, 86	Min Res 100k
R27	Min Res 220k
R28	Min Res 180k
R29	Min Res 150k
R30, 31, 32	Min Res 120k
R33, 34, 37	Min Res 100k
R35, 36	Min Res 68k
R39, 62	Min Res 47k
R40, 43	Min Res 4k7
R41	Min Res 18k
R42, 47, 55, 91, 92	Min Res 10k
R45	Min Res 820k
R46	Min Res 1k
R48, 63, 83	Min Res 220k
R52, 53, 54, 56	Oxide 33k
R57	Std Res 30k
R64, 65, 77, 78	Min Res 39k
R66	Min Res 120k
R67	Min Res 22k
R68	Min Res 56k
R70	Min Res 8k2
R71	Min Res 27k
R72, 79, 82	Min Res 15k
R73	Min Res 12k
R85, 87, 88, 89, 90	Min Res 1M
RV1-10	Edge Preset 1000
RV11	15-Turn Cermet 1k
RV12	Pot Lin 50k
RV13, 14, 15	15-Turn Cermet 5000
RV16, 21	Pot Lin 10k
RV17	Pot Log 2M
RV18, 23, 24	Vert S-Min Preset 47k
RV19	Vert S-Min Preset 4k7
RV20	Vert S-Min Preset 100k
RV22	Vert S-Min Preset 1k
C1	Carbonate 0.039F
C2, 3, 4, 5	Tant 10nF 25V
C6, 7, 8, 10, 11, 12, 13, 14, 22	Ceramic 33pF
C9	Polyester 0.47uF
C15	Polyester 0.015F
C16	Carbonate 0.001F
C17, 18	Carbonate 0.0082uF
C19, 20	Mylar 0.005uF
C21	Polyester 0.047LF
C23	Tant 4.7uF 35V
Q1, 2, 3, 4, 6	MPS 3638A
Q5	PN 3643
Q7, 8	2N 5459
Q9	BC 178
Q10, 11	BC108
IC1	SCL4011AE
IC2, 6, 8, 10, 11, 12, 13, 15	LM301A
IC3, 4, 5, 7	4016AE
IC9	LH0042CH
IC14	SG1495
IC16	SCL4001AE
IC17	LM308
DI-13	IN914
SW1, 2	Sub-Min Toggle A
Other Parts Required	
1	Keyboard Controller PCB
1	Keyboard Controller Mtg Bracket
4	15mm Collet Knob Black
4	15mm Collet Cap Yellow
4	15mm Collet Nut Cover
2	Bolt 6BA 1/4in.
2	Nut 6BA
2	Shakeproof Washer 6BA
6	DIL Socket 14-pin
1	Wafercon Plug 4-way
1	Wafercon Plug 12-way
1	Wafercon Socket 4-way
1	Wafercon Socket 8-way
1	Wafercon Socket 12-way
24	Wafercon Terminals
1	Keyboard 48-note F-E
20	6BA Spacer 1/4in.
20	Self-Tapper No. 4 1/4in.
1	SRBP 0.1in.
6m	Gold Wire

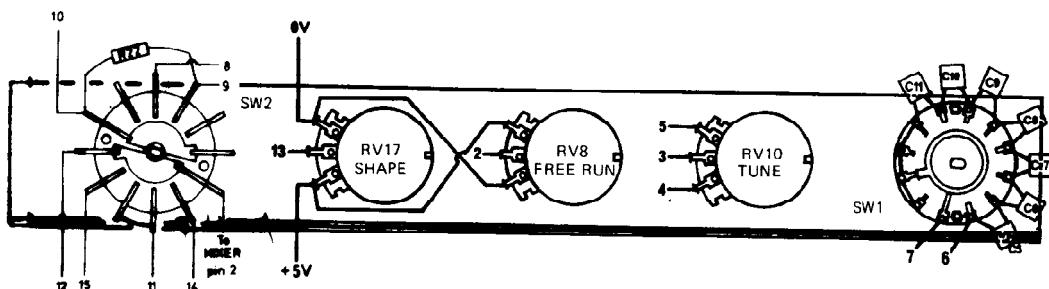


Fig. 13. Wiring to switches and potentiometers of oscillator – top wafer of SW1 only shown refer to Fig. 14.

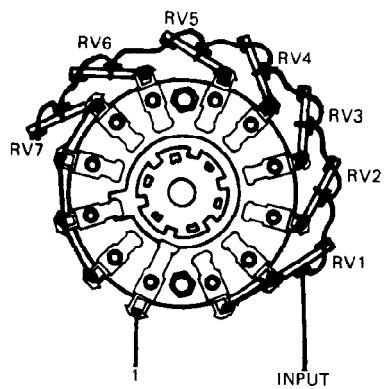


Fig. 14. Method of wiring up oscillator switch

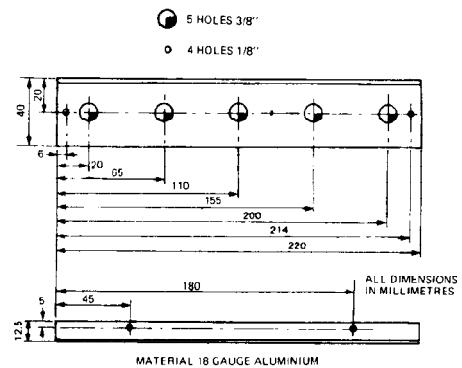


Fig. 15. Mounting bracket - oscillator.

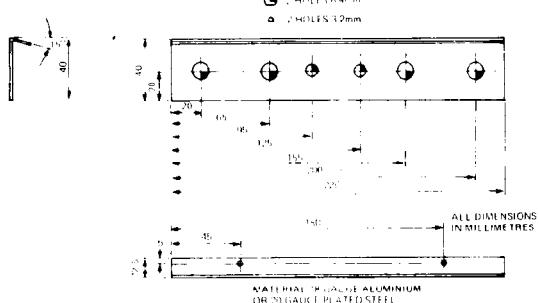
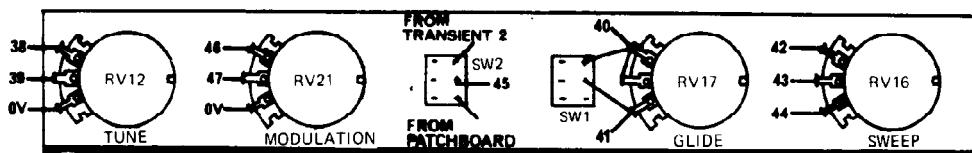


Fig. 16. Mounting bracket – keyboard controller.

Fig. 17. Wiring to switches and potentiometers of keyboard controller.



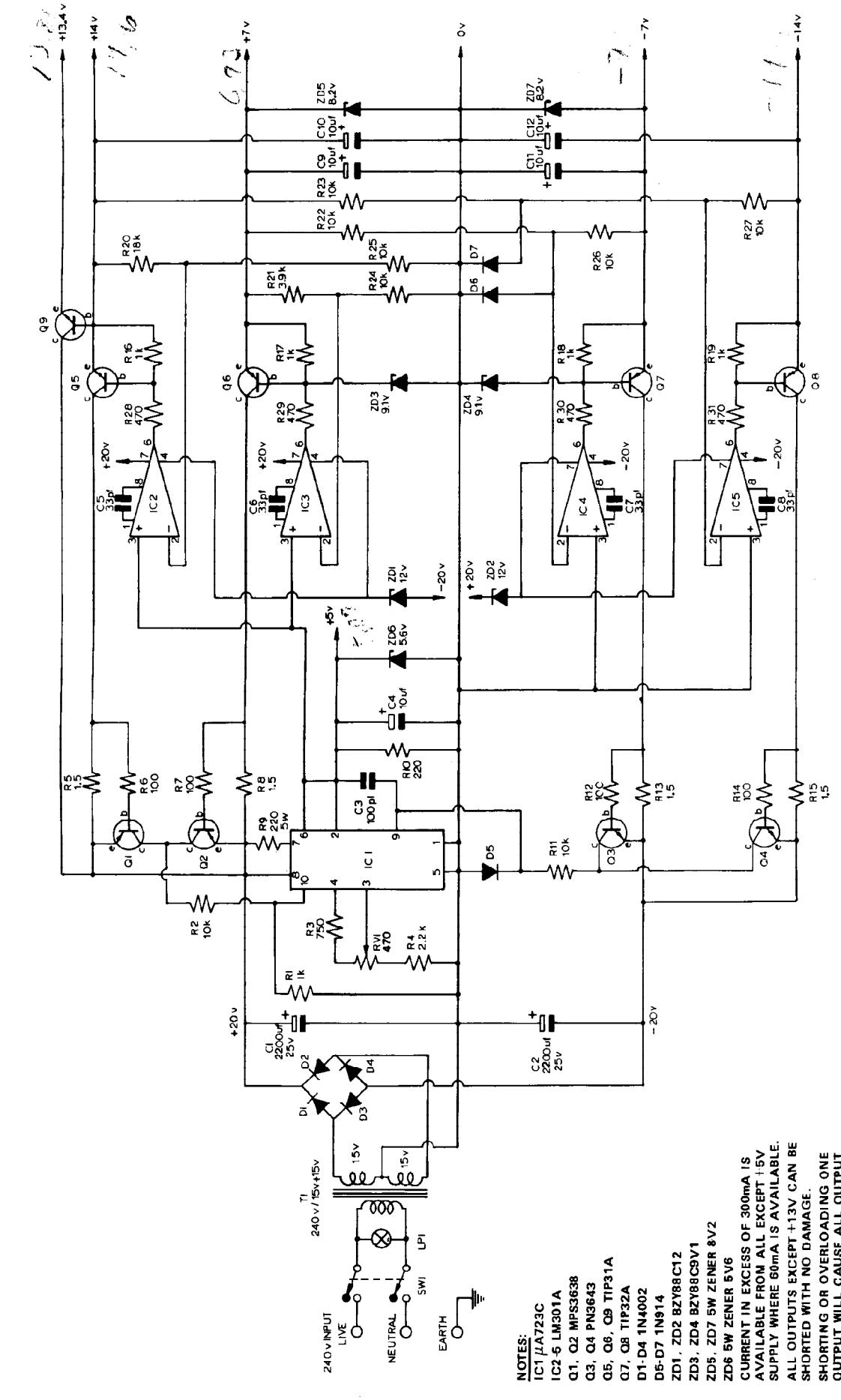


Fig. 18. Circuit diagram of the power supply.

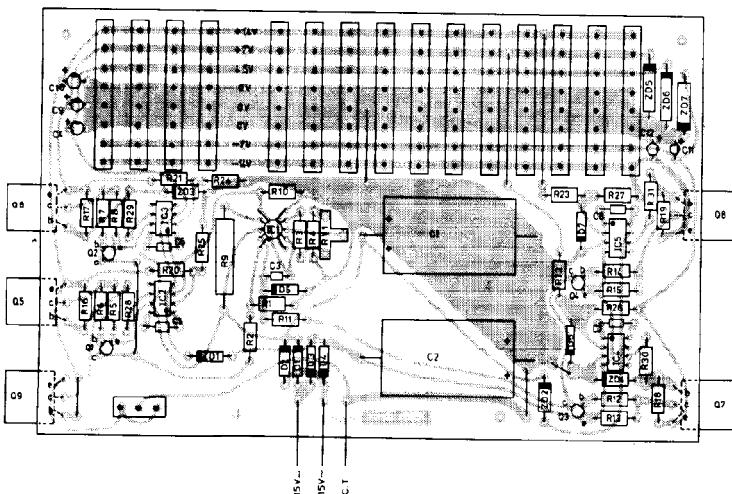
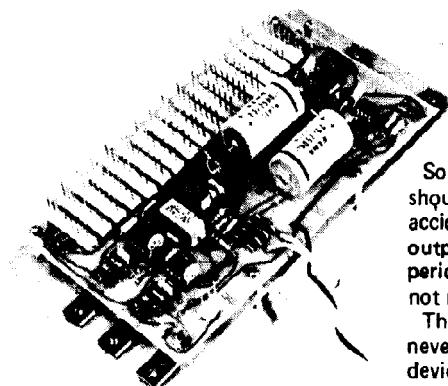
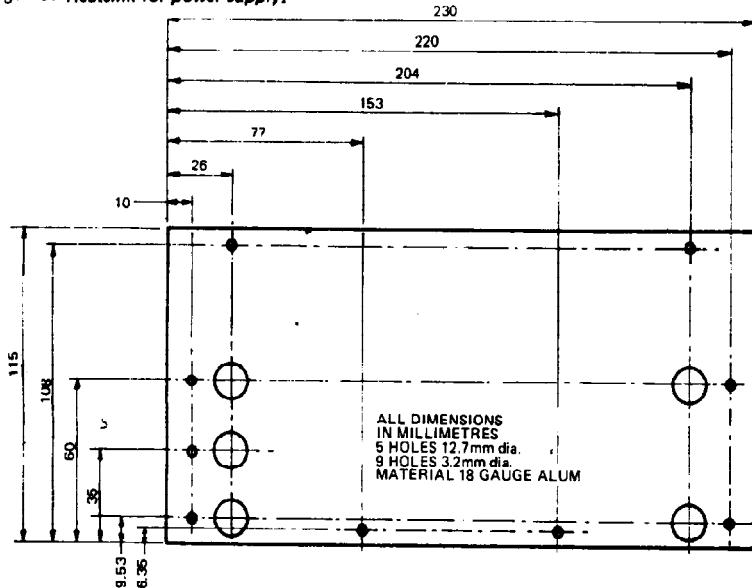


Fig. 19. Component overlay for power supply.



The method of construction of the power supply. Note particularly the mounting of the power transistors.

Fig. 20. Heatsink for power supply.



Power Supply

Assemble the PC board with the aid of the component overlay Fig.18. The power transistors should not be mounted at this time. Check the orientation of all the components especially checking the 723 regulator, the tag on the IC being next to pin 10.

The PC board is mounted by $\frac{1}{4}$ inch spacers onto an aluminium panel, Fig.20, which is also the heatsink for the power transistors. The power transistor leads must be bent apart and up at right angles to pass through the PC board from the underside.

The heatsink should be used as a guide to determine the bending points. Since the transistors are on the under side of the PC board there must be no strain on the joints, otherwise the PC board track may be broken. Mount the transistors, using mica insulators, in position on the heatsink. The transistors may then be soldered to the PC board through the access holes provided. If required the heatsink may then be removed for other work to be carried out.

PARTS LIST POWER SUPPLY

R1,16,17,18,19	Min Res 1k
R2,11,22,23,24,25, 26,27	Min Res 10k
R3	Std Res 750Ω
R4	Min Res 2k2
R5,8,13,15	Std Res 1.5Ω
R6,7,12,14	Min Res 100Ω
R9	5W W/W 220Ω
R10	Min Res 220Ω
R20	Min Res 18k
R21	Min Res 3k9
R28,29,30,31	Min Res 470Ω
RV1	Vert Skeleton 470Ω
C1,2	Axial 2,200μF 25V
C3	Ceramic 100pF
C4,9,10,11,12	Tant 10.5F 25V
C5,6,7,8	Ceramic 33pF
Q1,2	MPS3638
Q3,4	PN3643 2N
Q5,6,9	TIP31A
Q7,8	TIP32A
IC1	μA723C TO99
IC2,3,4,5	LM301A
D1-4	1N4002
D5,6,7	IN914
ZD1,2	BZY88C12
ZD3,4	BZY88C9V1
ZD5,7	5W Zener 8V2
ZD6	5W Zener 5V6
T1	MT206AT
SW1	Sub-Min Toggle E
LP1	Pan Neon Amber

Other Parts Required

- 1 Power Supply PCB
- 1 Power Supply Heatsink
- 1 Heatsink Clip-On
- 5 Bolt 6BA 1/4in.
- 4 Bolt 6BA $\frac{1}{4}$ in.
- 9 Nut 6BA
- 9 Shakeproof Washer 6BA
- 4 6BA Spacer 1/4in.
- 1 Wafercon Plug 3-way
- 16 Wafercon Plug 8-way
- 5 Kit (P) Plas
- 1 Fuseholder 20
- 1 Fuse 20 1A
- 1 Mains Conn P360
- 2m Min Mains

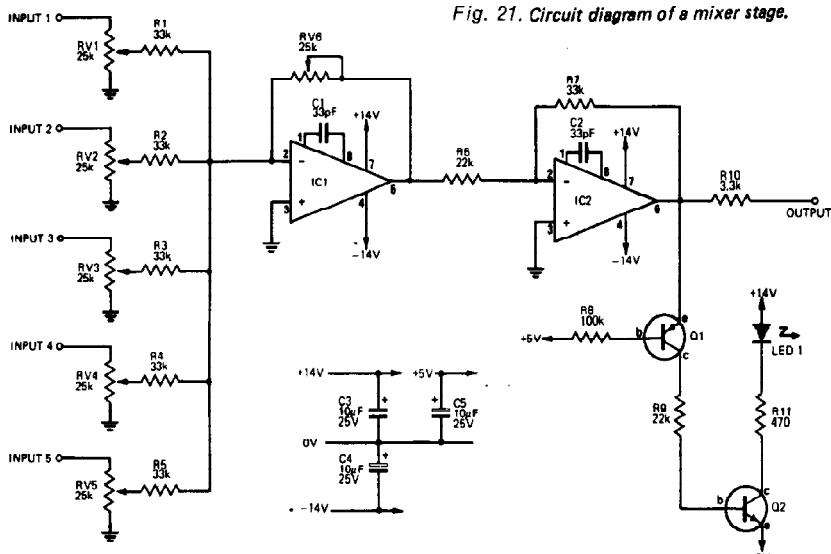
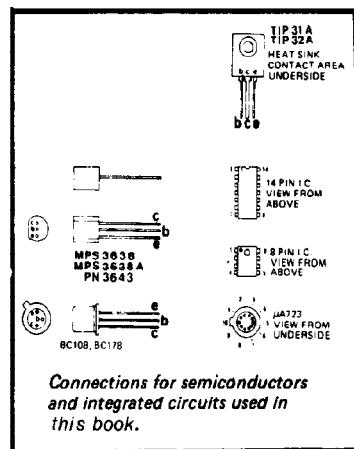


Fig. 21. Circuit diagram of a mixer stage.



Connections for semiconductors and integrated circuits used in this book.

NOTES

MIXER: ONLY SHOWN MIXERS 2-5 ARE SIMILAR
MIXER 1 AND 6 HAVE 3 INPUTS
IC1 AND IC2 LM301A
Q1 BC178
Q2 BC108

COMPONENT NUMBERS FOR MIXERS ARE AS FOLLOWS:
MIXER 1: ADD 40 TO ALL NUMBERS i.e. R5 BECOMES R25
MIXER 2: ADD 40 TO ALL NUMBERS i.e. R5 BECOMES R45
MIXER 3: ADD 60 TO ALL NUMBERS i.e. R5 BECOMES R65
MIXER 4: ADD 60 TO ALL NUMBERS i.e. R5 BECOMES R85
MIXER 5: ADD 80 TO ALL NUMBERS i.e. R5 BECOMES R85

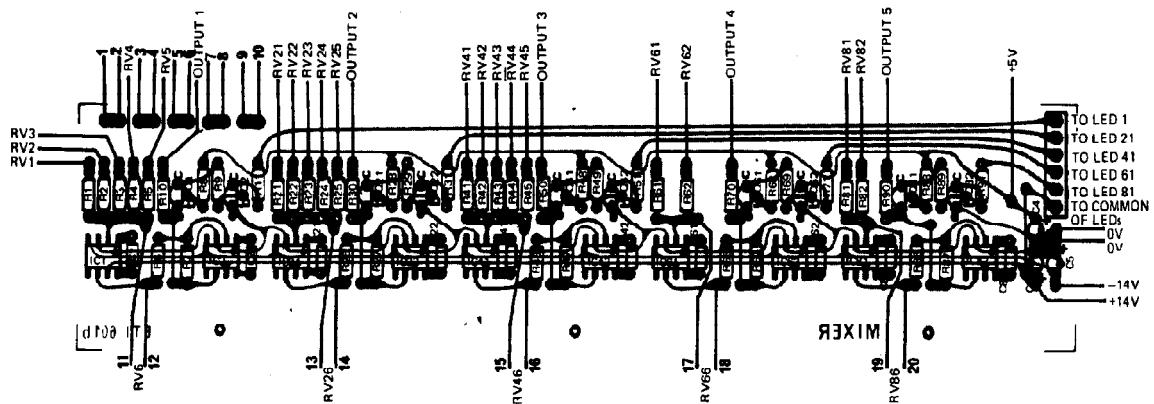


Fig. 22. Component overlay for mixer board.

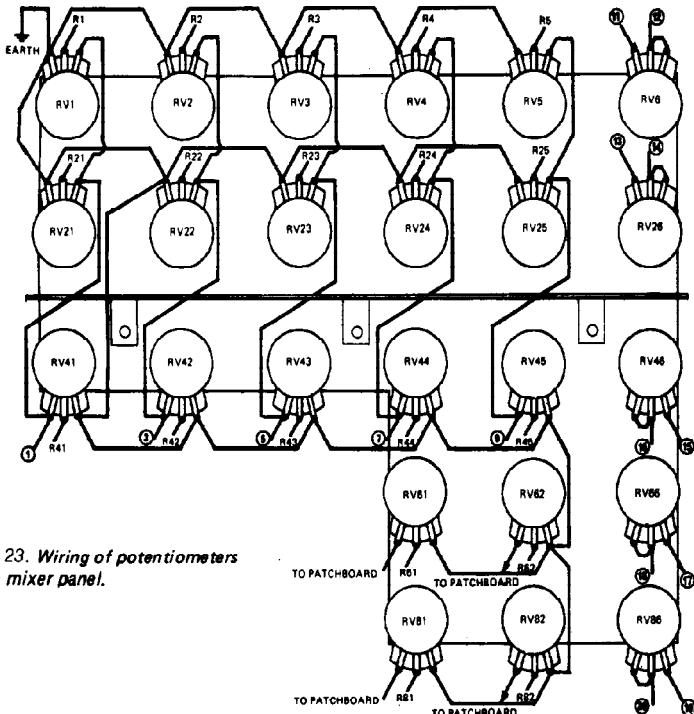


Fig. 23. Wiring of potentiometers on mixer panel.

Mixer

Assemble the PC board with the aid of the component overlay Fig. 22. Check the orientation of ICs and transistors.

The mechanical assembly is slightly different for this module than that for the oscillators. A metal plate is used to hold all the potentiometers (24) and three small brackets hold the PC board. The LED indicators are mounted on the front panel itself and are connected to the PC board either by soldering, or as recommended, by a plug and socket.

Each oscillator output is fed to three potentiometers on the mixer board. Five pads are provided on the PC board for connecting the common connection of each set of three potentiometers. A pin may also be fitted to each pad so that the oscillator connection may be disconnected if required.

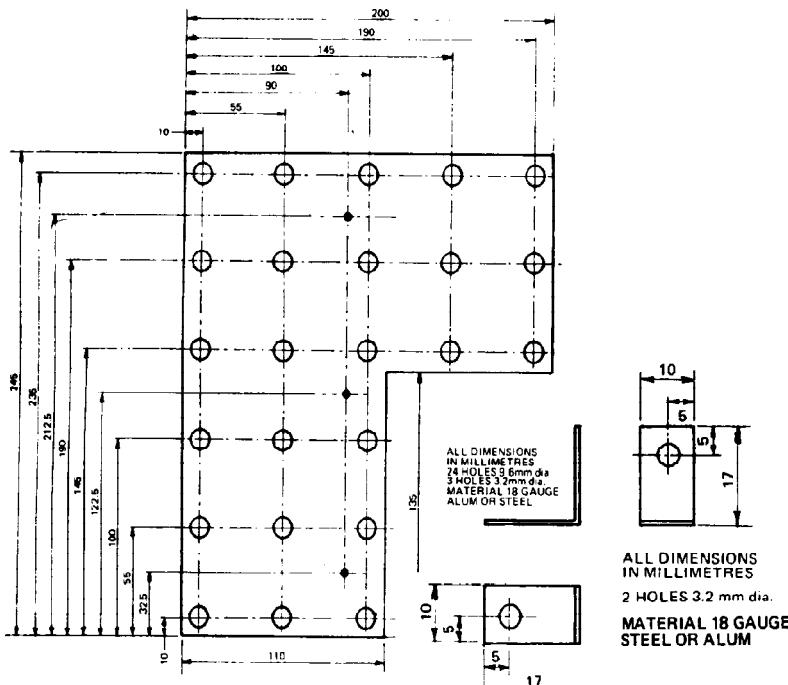


Fig. 24. Main mixer chassis.

Fig. 25. Mixer board support bracket (three required).

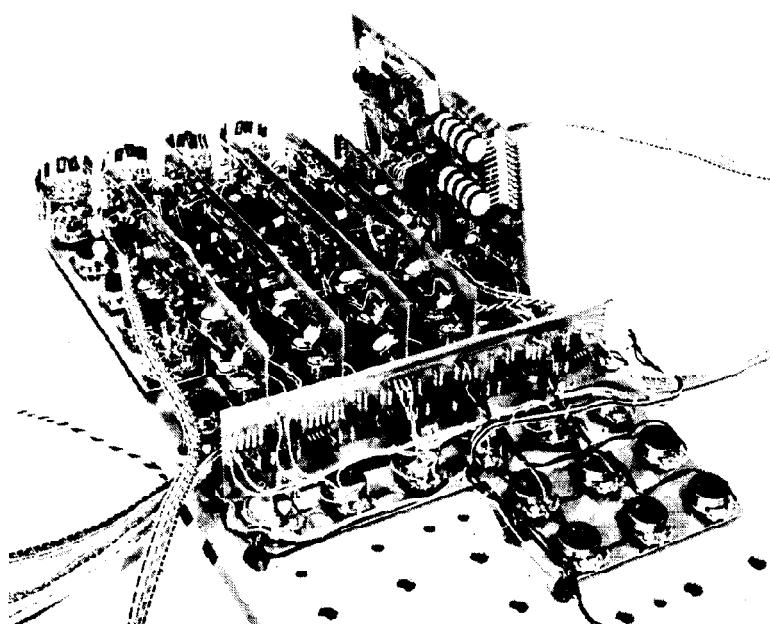
Noise generator and controller

The construction of the module is very similar to that of the oscillator.

Assemble the PC board with the aid of the component overlay, Fig. 27. It is recommended, that IC sockets are used for the CMOS. Make sure the integrated circuits and electrolytic capacitors are orientated correctly before soldering in place.

The PC board is then mounted on the metal bracket shown in Fig. 29.

The bracket goes on the component side of the PC board to prevent any possibility of shorting the copper tracks. The two potentiometers and the switch may now be mounted and wired up. This bracket also holds the additional switch related to oscillator 4 which is wired up as shown in Fig. 28. The interconnection between this switch and that in oscillator 4 can be either by soldered leads or a plug and socket can be used.



The mixer and noise generator modules shown mounted in position.

PARTS LIST MIXER

R1,2,3,4,5,7, 21,22,23,24,25,27, 41,42,43,44,45,47, 61,62,67, 81,82,87	Min Res 33k
R6,9,26,29,46,49,66, 69,86,89	Min Res 22k
R8,28,48,68,88	Min Res 100k
R10,30,50,70,90	Min Res 3k3
R11,31,51,71,91	Min Res 470k
RV1-6,21-26,41-46, 61,62,66,81,82,86	Pot Lin 25k
C1,2,21,22,41,42, 61,62,51,82	Ceramic 33pF
C3,4,5	Tant 10nF 25V
Q1,21,41,61,81	BC178
Q2,22,42,62,82	BC108
IC1,2,21,22,41,42, 61,62,81,82	LM301A
LED1,21,41,61,81	Led Red and Led Clip

Other Parts Required

1	Mixer PCB
1	Mixer Chassis
3	Mixer Mfg Brackets
24	15mm Collet Knob Black
3	15mm Collet Cap Red
3	15mm Collet Cap Yellow
7	15mm Collet Cap Green
6	15mm Collet Cap Blue
5	15mm Collet Cap Grey
24	15mm Collet Nut Cover
3	Bolt 6BA 1/4in.
3	C/S Screw 6BA 1/4in.
6	Nut 6BA
6	Shakeproof Washer 6BA
1	Wafercon Plug 6-way
1	Wafercon Socket 6-way
1	Wafercon Socket 8-way
14	Wafercon Terminals

PARTS LIST NOISE CONTROLLER

R1	Min Res 1M
R2	Min Res 150k
R3	Min Res 33k
R4	Min Res 18k
R5,6,7	Min Res 10k
R8,14	Min Res 3k3
R9,10,11,12,13	Min Res 100k
RV1,2	Pot Lin 25k
C1	Tant 0.47F 35V
C2	Ceramic 100pF
C3	Mylar 0.002F
C4	Mylar 0.001F
C5	Polyester 0.015μF
C6,7,8	Ceramic 33pF
C9,10	Tant 10nF 25V
IC1	4006AE
IC2	4030AE
IC3	SCL4001AE
IC4,5,6	LM301A
SW1	Sub-Min Toggle E

Other Parts Required

1	Noise Controller PCB
1	Noise Controller Mfg Bracket
2	15mm Collet Knob Black
2	15mm Collet Cap Grey
2	15mm Collet Nut Cover
2	Bolt 6BA 1/4in.
2	Nut 6BA
2	Shakeproof Washer 6BA
3	DIL Socket 14-pin
1	Wafercon Socket 8-way
8	Wafercon Terminals

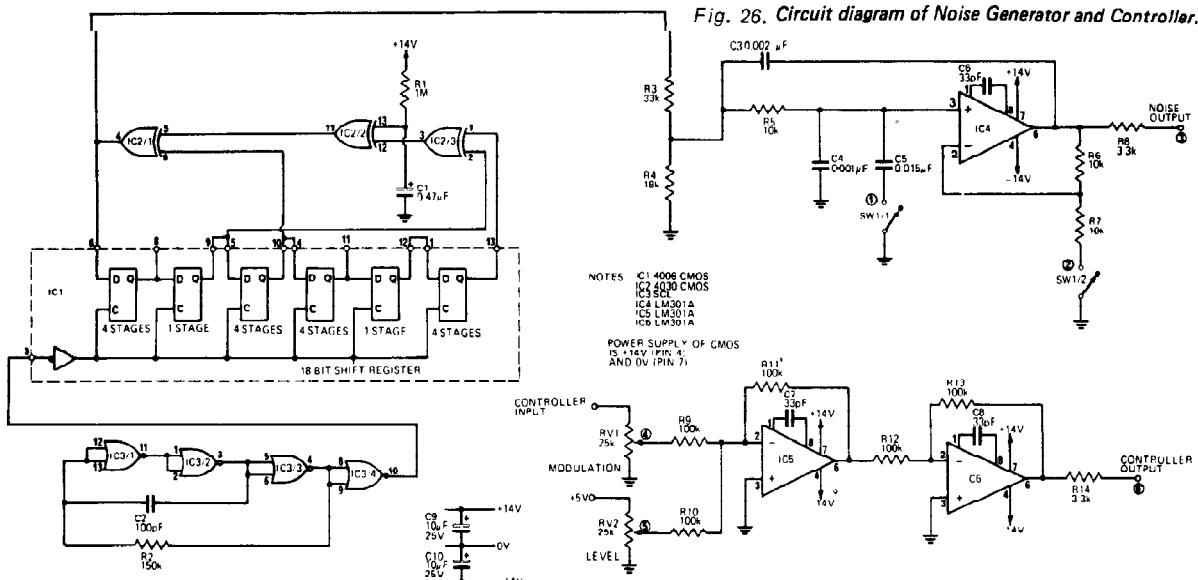


Fig. 27. Component overlay of Noise Generator and Controller.

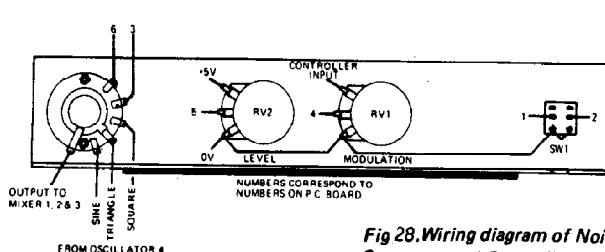


Fig 28. Wiring diagram of Noise Generator and Controller.

POWER SUPPLY – How it works

The power supply provides regulated outputs of +14V, +7V, +5V, -7V and -14V. The 5V supply can deliver 60 mA and all other outputs 300 mA. An additional output of +13.4V is provided to supply the high current requirement of the headphone output amplifier.

The rectifier and filter is conventional system supplying ± 1 . The 5V output is derived from a **μA723C**, voltage regulator (IC1) which has very good temperature and load regulation. The +5 volts is used as the main reference for the other supplies. Current limitation is provided for by R9 which limits the current to about 85 mA. The output

is adjustable by RV1 such that exactly 5V can be obtained.

The output of ICI can be shut down in either of two modes. A positive current into pin 10 or a negative current out of pin 9 will cause the output voltage to drop to zero. Use of this is made in the overload network of the other supply outputs.

The +7V output is via a series pass transistor, Q6, which is controlled by IC3, a high gain differential amplifier which is used as a comparator. The non-inverting input (positive) of IC3 is connected to the +5V output where, in addition, the inverting (negative) input, is connected via a 5/7 divider R21/24. The result of this connection is that the output will stabilize at +7V. The high gain of IC3

will keep this voltage constant with nominal load and supply voltage changes.

A current sensing resistor, R8, is in series with the collector of Q6. If the voltage across this resistor exceeds 0.6V, the base emitter of Q2 will become forward biased, turning it on. This causes a positive current to flow into pin 10 of IC1 shutting it down. Since the output of the +7V regulator is referred to the +5V output, the +7V supply will also shut down and the output current will be limited to about 400 mA. To prevent over voltage from the +7V supply on switch on, the output is limited by ZD3 to about 8.5 volts.

The -7V supply is similar to the +7V supply, except that the

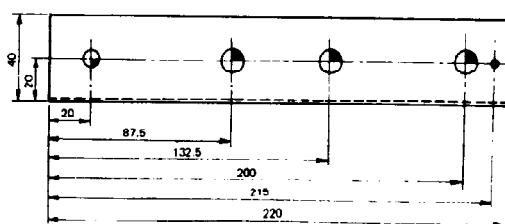


Fig. 29. Noise generator and controller support bracket.

reference voltage is now zero volts, (pin 3) and this is compared to a voltage at the junction of R26 and R22. The voltage will be zero when the output of the -7V is identical to the +7V but of opposite polarity. Diode D6 is used to protect the input of IC4. Overload on this output turns on Q3 which removes current from pin 9 of IC1 shutting it down. This shuts down the +7V supply and since the -7V "tracks" the +7V output, it also will shut down.

The $\pm 14\text{V}$ supplies are identical to the $\pm 7\text{V}$ supplies except for the sensing resistors R20/25 on the $+14\text{V}$ supply.

The $+13.4\text{V}$ output is simply an emitter follower on the $+14\text{V}$ rail. This supply should not however be shorted since no protection is provided.

Zeners ZDS, 6, 7, protect the $+5\text{V}$, $+7\text{V}$, and -7V rails against accidental short circuit with a 14V rail.

MIXER – How it works

The mixer used is quite conventional, using an IC (IC1) to sum the input currents. Individual gain control is provided by RV1-5 and overall gain by RV6. Since the output of this type of mixer is inverted an additional IC is used to reinvert the signal.

Overload indication is provided by

Q1, Q2 and LED1. If the output voltage exceeds 5.6V , Q1 becomes forward biased and Q1 and Q2 turn on, illuminating the LED indicator. The base resistor R8 prevents damage to Q1 should the output swing negative. The overload point as indicated by the LED is chosen to protect the inputs of following stages from being overloaded. The mixer itself has an overload point of about 12V .

Mixers 1,2, and 3 are identical whereas mixers 4 and 5, although otherwise identical, have only 2 inputs. The inputs of mixers 1,2, and 3 are wired directly to the outputs of the individual oscillators.

NOISE GENERATOR AND CONTROLLER – How it works

White noise is generated digitally by an 18 bit shift register which is clocked at about 35 kHz . Several feed-back loops around the shift register cause it to generate a pseudo-random bit pattern which closely approximates white noise.

The oscillator uses a quad, dual-input NOR CMOS gate (IC3), and although a NAND or inverter could be used in the circuit, it would not necessarily be a pin for pin replacement. Feedback is taken from the 5th, 9th and 18th stage in the shift register and these outputs are

"mixed" by IC2 which is an exclusive OR gate, (see table) the output of which controls the 'D' input of the shift register. Resistor R1 and capacitor C1 are used to ensure that the system will start.

INPUTS		OUTPUTS
A	B	
0	0	0
0	1	1
1	0	1
1	1	0

1 = HIGH LEVEL

0 = LOW LEVEL

The output of IC2/1, as well as being the control for the shift register, is the white noise we require. However, due to some unwanted components above 15 kHz , a low pass filter is used with a 15 kHz cutoff. To give an alternate "PINK" noise output, the filter is changed to cut frequencies above 500Hz with a 6 dB/octave slope. Since the output voltage will fall if some of the spectrum is removed, additional gain is also provided when 'PINK' noise is selected.

The controller is a completely separate function which is used to add a dc component to another signal or control voltage. This is done by mixing, in IC5, a percentage of the input signal and a percentage of a dc voltage. The output of IC5 is negative however, and must be inverted by IC6.

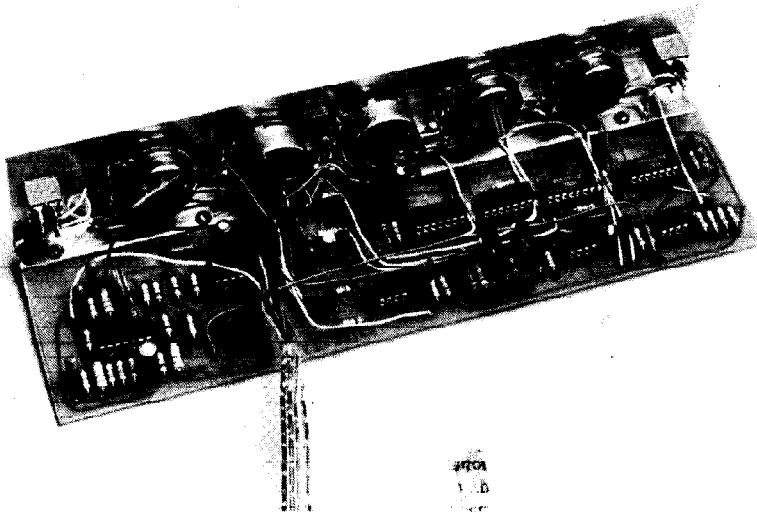
Transient Generator I

Assemble components to the printed circuit board, as shown with the component overlay (Fig. 31), paying particular attention to the orientation of integrated circuits, transistors, diodes and electrolytic capacitors. We recommend that sockets be used for the CMOS ICs at least. These CMOS ICs should also be the last components to be fitted to the board.

The mechanical assembly is similar to that for the oscillators (previously described). All rotary potentiometers and switches are mounted on a bracket as shown in Fig. 32. The bracket, in turn, is mounted onto the component side of the printed circuit board. The wiring between the potentiometer and the switches is as shown in Fig. 33.

The only section of this circuit that needs calibration is the exponential generator. The procedure is as follows:-

With the module switched to the linear mode check that normal output is obtained. Now with the trigger input disconnected, and the output voltage at 0V , adjust RV5 such that the output of IC3 is also 0V . Set attack



The Envelope Control module. The Transient Generator I module is similar except that the VCA board on the left is not fitted.

time to minimum and delay and hold level to maximum. If the module is now triggered the output voltage will go to $+5\text{V}$ and stay there for about 10 seconds.

Whilst the output is at $+5\text{V}$, adjust RV4 so that $+5\text{V}$ is also obtained at

the output of IC3. Recheck the 0V level and readjust if required. Repeat the procedure until both levels are correct.

When the module is returned to exponential mode check that the output of IC3 never goes negative.

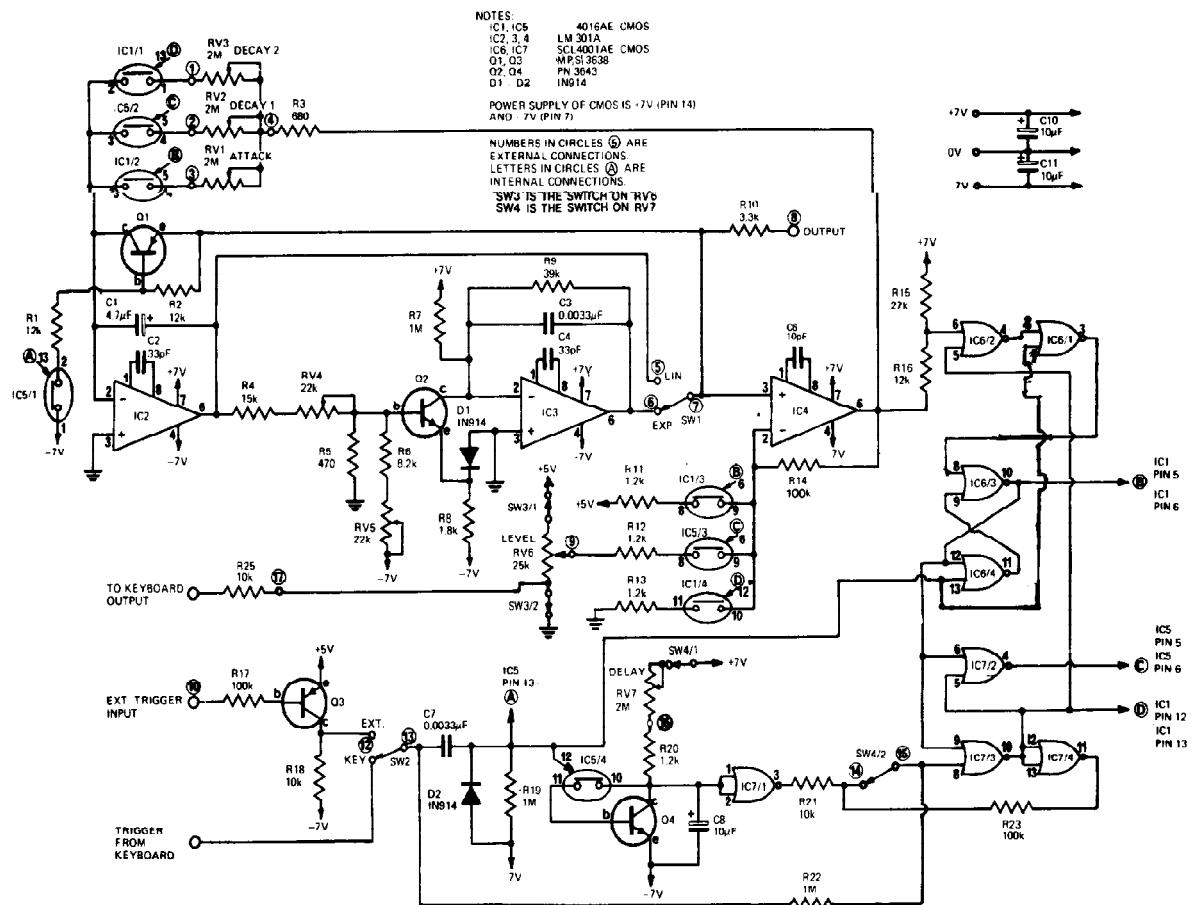


Fig. 30. Circuit diagram of Transient Generator 1. Envelope Control module also includes a modified VCA.

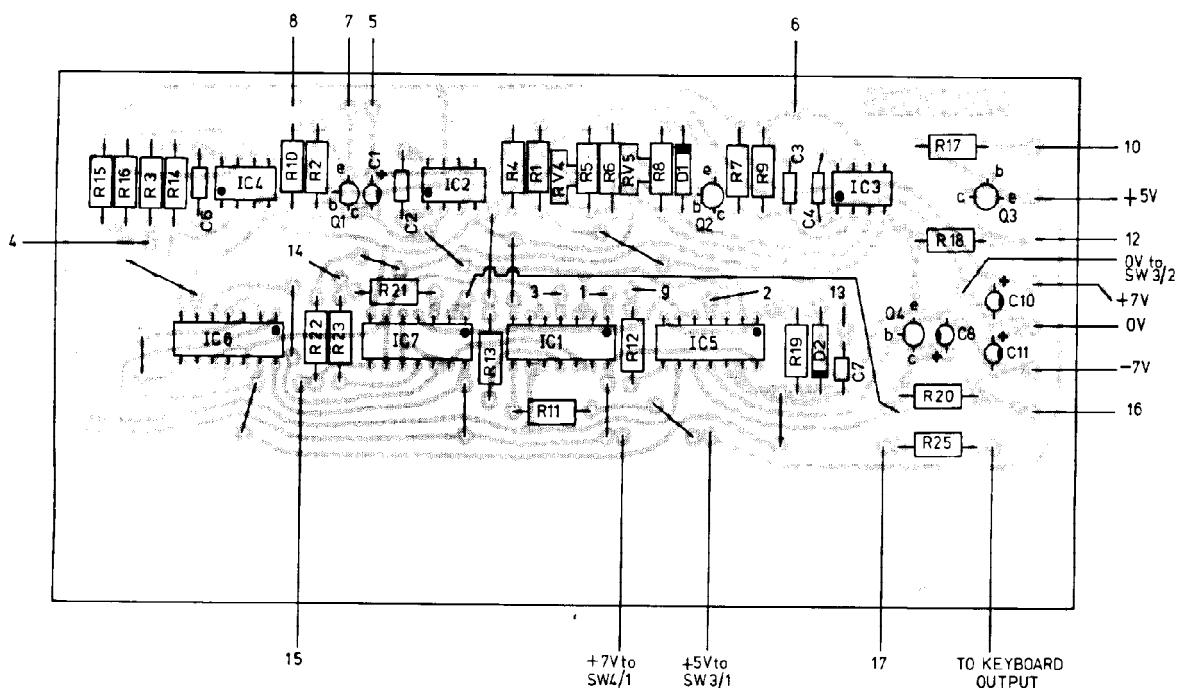


Fig. 31. Component overlay for Transient Generator 1.

HOW IT WORKS

Transient Generator I

The transient generator consists, basically, of two sections.
 (a) the wave-shaping circuitry (analogue).
 (b) Control circuitry (digital).

The analogue section consists of integrator (IC2), exponential converter (Q2, IC3) and comparator (IC4). The comparator is a high gain differential amplifier whose output is normally either at +6 volts or at -6 volts. There is a small input region where the amplifier operates in the linear mode and the output voltage will then be somewhere between these two extremes. Negative feedback is applied by R14 so that this linear input region is approximately 30 mV wide.

Solid state switches select one of three voltage sources as input to the comparator. ICI/3 selects +5 volts, ICI/4 selects 0V and ICI/3 selects the output of level potentiometer RV6 or the output of the keyboard.

The switch potentiometer RV6, when in the off position, allows the keyboard voltage to be the third voltage.

The output of the comparator is connected back to the input of IC2 by R3 and a slope potentiometer as selected by ICI/1, ICS/2 and ICI/2. If the output of the comparator goes to -6 volts, the output of the integrator, IC2, will be a voltage, linearly increasing at a rate set by the selected potentiometer (RV1, 2 or 3). Conversely if the comparator output is at +6 volts the integrator will produce a linearly decreasing voltage.

When the two inputs are within 30 mV of each other the slope of the integrator will decrease, and when they are equal, (comparator output at zero) the system output will be stationary at the voltage selected by ICI/3, ICS/3 or ICI/4. This point will be stable as the comparator output is applied back to its input in a negative feedback loop, either directly, or via an exponential generator.

Generation of the exponential function is based on the collector current to base-emitter-voltage relationship of a transistor, in this case Q2. The output of the integrator, after attenuation by R4, RV4 and R5, and level shifting by R6 and RV5, is applied to the base of Q2. Diode D1 biases the emitter of Q2 about 0.6 volts below zero and also provides temperature compensation for Q2. Resistor R7 applies a small bias and helps compensate different offset voltages in IC3. Integrated circuit IC3 produces an output voltage proportional to the collector current of Q2. Hence a linearly changing voltage, at the output of integrator IC2, will result in an exponential output from IC3. The range of the exponential generator is adjusted by RV4 and RV5.

When a key is pressed, the keyboard controller provides a -7 V to +7 V change. The positive edge of this transition is differentiated by C7 and R19, (the negative edge pulse is clipped by D2) to provide an approximately 3 msec wide pulse which turns on ICS/4 and Q4 thus discharging C8. In addition this pulse sets the flip flop formed by IC6/3 and IC6/4 so that the output at B is +7 V, and turns on ICS/1 and Q1 thus clamping the output line at 0V.

At the end of the 3 msec pulse, C8 begins to charge from -7 volts at a rate determined by RV7. When it reaches 0V, approximately, the output of IC7 changes from +7 V to -7 V and thus an internal delay is generated which is adjustable by RV7. Also immediately following the 3 msec period, the output B is at +7 V and hence ICI/2 is turned on selecting the attack potentiometer RV1, and ICI/3 is turned on, selecting +5 V as an input to the comparator. Thus, as pin 2 of the comparator is higher than pin 3, the

output will be low (-6 V) and the integrator will start to rise. The voltage divider formed by R15 and R16 will apply -2 V to the input of IC6/2.

At this point we pause to briefly explain the operation of digital logic NOR gates. The digital ICs used in this circuit contain four, 2 input NOR gates. In a NOR gate, if either one or both of the inputs are high, the output will be low. Only when both inputs are low can the output be high. This is illustrated below.

Input A	Input B	Output
0	0	1
0	1	0
1	0	0
1	1	0

Note for +7 V and -7 V supplies as used, 'O' means less than -1 V and '1' means greater than +1 V when applied to inputs, and 'O' means close to -7 V '1' means close to +7 V in the case of outputs.

Thus to return to our circuit the -2 V input at IC6/2 is a '0' input and the output of IC6/2 will be high at +7 V.

When the output of the integrator (or exponential generator) reaches +5 V the comparator output will drop to zero volts causing an input of +2 V to be applied to IC6/2. This is a '1' level and thus the output of IC6/2 will go to -7 volts. The output swing of IC6/2 is inverted by IC6/1 and resets the flip flop (IC6/3 IC6/4).

When the flip flop is reset its output goes to -7 V turning off ICI/2 and ICI/3 and a '0' is presented to IC7/2 and IC7/3 (pins 6 & 9).

If at this time the delay period has not expired (that generated by C8 & RV7) a '1' will still exist at the output of IC7/1. Thus IC7/3 has a '0' on pin 9 and '1' on pin 8 and its output will be a '0'. Hence both inputs of IC7/2 are '0' and its output will be a '1'. This turns on ICS/2 which selects DECAY 1 slope and ICS/3 which selects the output level set by RV6. The comparator now sees an error and drives the integrator to correct it. The output will stabilize again when the level set by RV6 has been reached. This output level will now be held until the 'C' control is removed.

When the delay period is completed the pin 8 input to IC7/3 goes to '0', and since the other input is '0', the output will be '1' and the output at 'C' will be turned off.

We now have the 'D' output at '1' and this selects the DECAY 2 potentiometer and 0V reference to the comparator. Again the integrator drives to correct the error. Positive feedback is provided around IC7/3 by IC7/4 so that the input may change much quicker.

When the delay potentiometer is switched off (SW4/1 and 2) trigger input will now be direct to IC7/3 pin 8 and the delay will be determined by the key-hold time only, and not by the internal generator.

If the DELAY time setting (either internal or external) is shorter than the time to complete DECAY 1, DECAY 2 will be initiated, provided the attack time is completed, immediately the delay expires.

If the DELAY setting is less than the ATTACK time setting the ATTACK will be completed, DECAY 1 eliminated and DECAY 2 initiated.

The trigger input from the patchboard is buffered by Q3 to ensure correct operating levels for the logic. It also provides an inversion which means that the trigger will occur on the negative edge of the input trigger pulse.

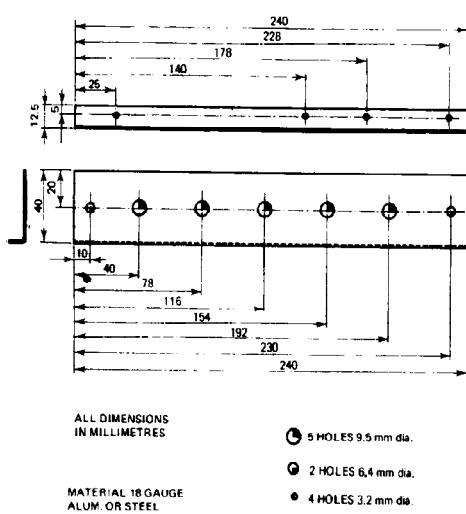


Fig.32. Mounting bracket for Envelope control and Transient 1 modules.

PARTS LIST

Transient Generator 1

R1,2,16	Min Res 12k	Q1,3	MPS3638
R3	Min Res 680Ω	Q2,4	PN3643
R4	Min Res 15k		
R5	Min Res 470Ω	IC1,5	4016AE
R6	Min Res 8k2	IC2,3,4	LM301A
R7,19,22	Min Res 1M	IC6,7	SCL4001AE
R8	Min Res 1k8	D1,2	1N914
R9	Min Res 39k		
R10	Min Res 3k3	SW1,2	Sub-Min Toggle A
R11,12,13,20	Min Res 1k2		
R14,17,23	Min Res 100k		Other Parts Required
RV6	Min Res 27k		
RV7	Min Res 10k		
C1	Pot Log 2M	1	Trans Gen 1 PCB
C2,4	Vert S-Min Preset	1	Trans 1/Env Mtg Bracket
C6	22k	5	15mm Collet Knob Black
C3,7	Sw Pot Lin 25k	1	15mm Collet Cap Red
C8,10,11	Sw Pot Log 2M	1	15mm Collet Cap Blue
	Tant 4.7μF 35V	3	15mm Collet Cap Yellow
	Ceramic 33pF	5	15mm Collet Nut Cover
	Ceramic 10pF	2	Bolt 6BA 1/4in.
	Carbonate 0.0033μF	2	Nut 6BA
	Tant 10μF 25V	2	Shakproof Washer 6BA
		4	DIL Socket 14-pin
		1	Wafercon Socket 8-way
		8	Wafercon Terminals

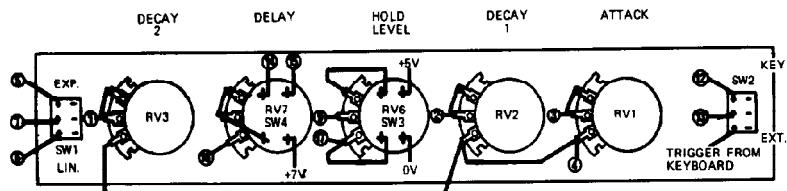


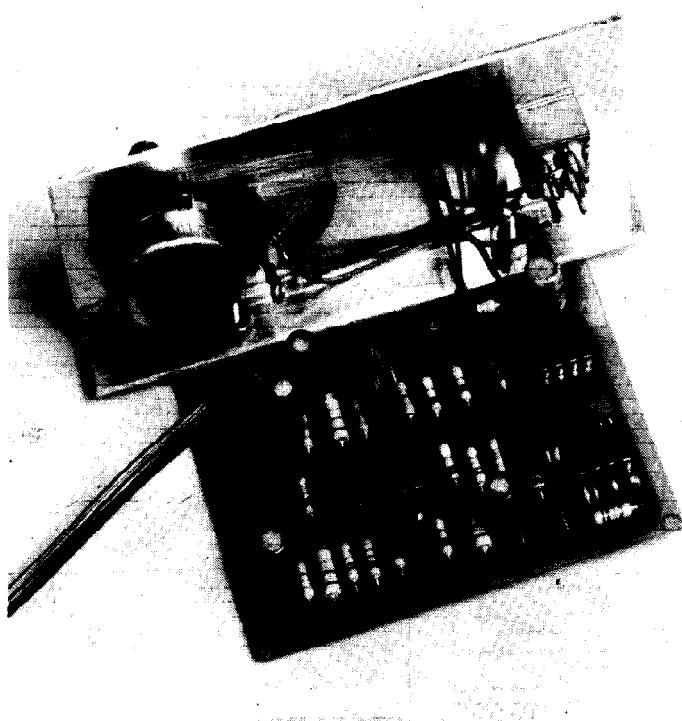
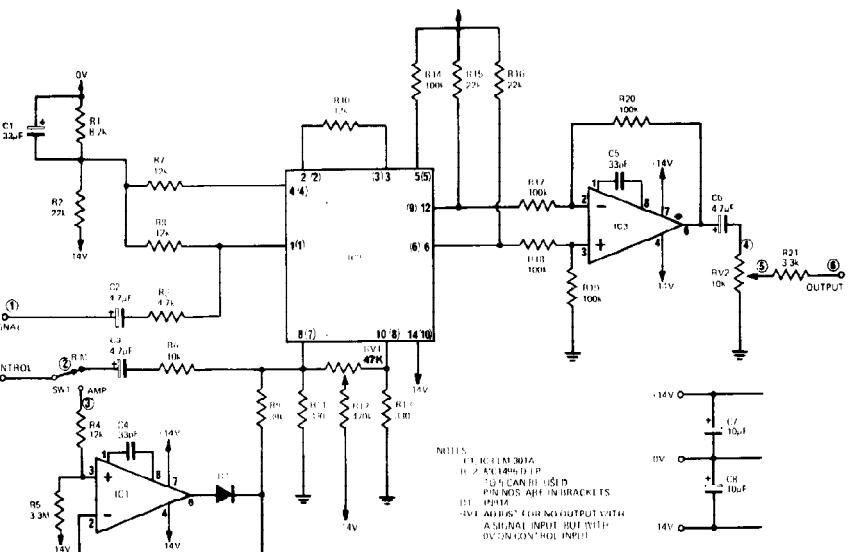
Fig.33.Wiring to switches and potentiometer for Transient Generator 1.

VOLTAGE CONTROLLED AMPLIFIER

This is a very simple module and should not cause any difficulty. The component overlay is given in Fig.35. and the potentiometer and switch wiring diagram in Fig.39. The MC1496 may be either a dual-in-line package or TO5. If the TO5 version is used it may be connected as shown in Fig. 34. The tag on the TO5 version is adjacent to pin 10 and this pin goes to what would otherwise be DIL pin 14 on the printed circuit board. Pin position 7, 9, 11 and 13 on the printed circuit board are not used with the TO5 IC.

The only adjustment required on this module is to null the output by adjusting RV1. With a signal applied to the input, and with 0V on the control input, set the switch to amp and adjust RV1 for minimum output.

Fig.34.Full circuit diagram of Voltage Controlled Amplifier. For use with Envelope Control module, IC1 and its associated components are omitted. See overlay, parts lists and text.



The voltage controlled amplifier

PARTS LIST

Voltage Controlled Amplifier

R1	Min Res 8k2
R2,15,16	Min Res 22k
R3	Min Res 4k7
R4,7,8,10	Min Res 12k
R5	Min Res 3M3
R6	Min Res 10k
R9	Min Res 39k
R11,13	Min Res 330Ω
R12	Min Res 470k
R14,17,18,19,20	Min Res 100k
R21	Min Res 3k3
RV1	Vert S-Min Preset 47k
RV2	Pot Lin 10k
C1	Tant 33μF 10V
C2,3,6	Tant 4.7μF 35V
C4,5	Ceramic 33pF
C7,8	Tant 10μF 25V
IC1,3	LM301A
IC2	MC1496
D1	1N914
SW1	Sub-Min Toggle A
Other Parts Required	
1	VCA PCB
1	VCA Mtg Bracket
1	15mm Collet Knob Black
1	15mm Collet Cap Grey
1	15mm Collet Nut Cover
2	Bolt 6BA 1/4in.
2	Nut 6BA
2	Shakeproof Washer 6BA
1	Wafercon Socket 8-way
8	Wafercon Terminals

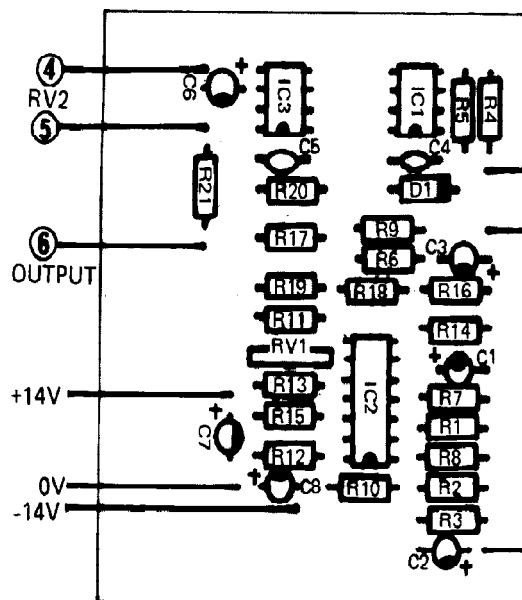


Fig.35. Component overlay for the Voltage Controlled Amplifier when used as a separate unit.

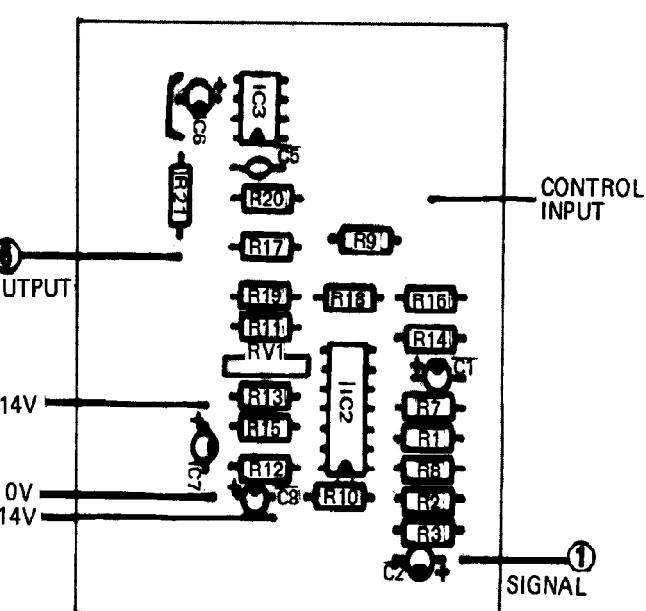


Fig.36. Component overlay for the Voltage Controlled Amplifier as used in the Envelope Control module.

ENVELOPE CONTROL

The envelope control is constructed by assembling a transient 1 module and a voltage controlled amplifier (VCA) to the same bracket. The VCA module is modified by omitting the rectifier IC1 (see 'How it Works' and overlay Fig.36) and the control input is taken from the transient 1 board output.

PARTS LIST

Envelope Control

- 1 TRANSIENT 1 GENERATOR
except R25 is not required and
RV6 becomes a Pot Lin 25k
- 1 VCA
except the following parts which
are not required:
R4, 5, 6, RV2, C3, 4, IC1, D1, SW1,
VCA Mtg Bracket, 15mm Collet Knob
Black, 15mm Collet Cap Grey, 15mm
Collet Nut Cover, Wafercon Socket
8-way, and 8 Wafercon Terminals

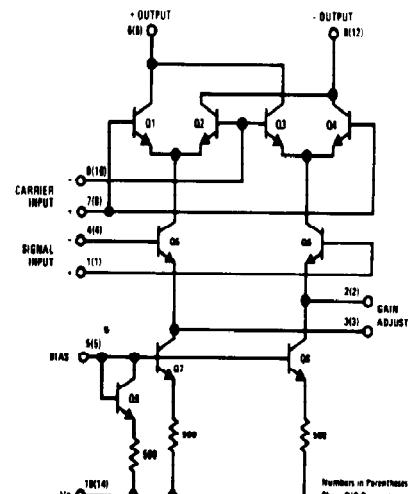


Fig. 37. Circuit diagram of the MC1496 balanced modulator-demodulator IC.

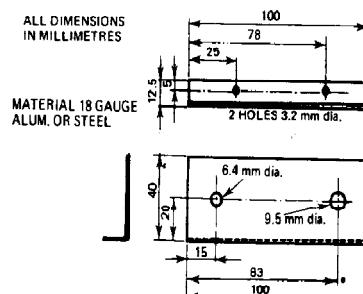


Fig.38. Mounting bracket for the voltage controlled amplifier.

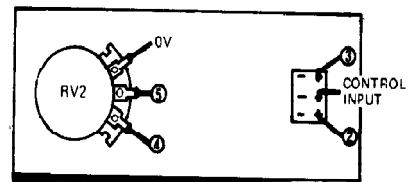
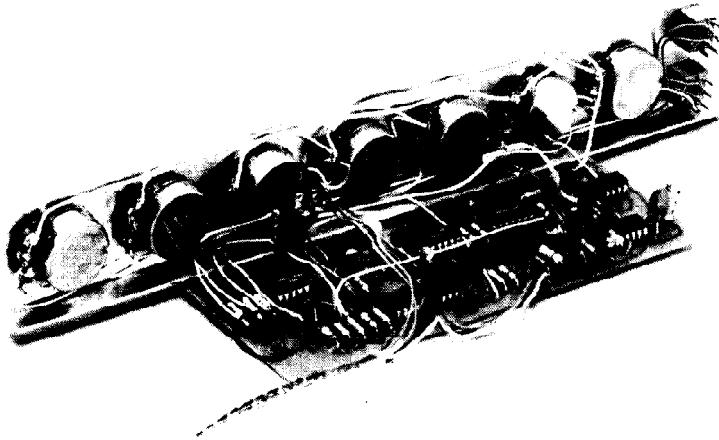


Fig.39. Wiring to front panel of Voltage Controlled Amplifier.



Transient Generator 2

TRANSIENT Generator 2 module provides an almost infinite variety of output shapes.

It may for example be used to modify the keyboard output voltage. Such a keyboard output would, when applied to an oscillator for example,

PARTS LIST

Transient Generator 2

R1,19,21,22	Min Res 100k
R2,13,18	Min Res 10k
R3	Min Res 15k
R4	Min Res 6800
R5	Min Res 470k
R6	Min Res 8k2
R7,9,11	Min Res 1M
R8,12,15,16,17	Min Res 1k2
R10	Min Res 1k8
R14	Min Res 39k
R20	Min Res 3k3
RV1,2,6	Pot Log 2M
RV3,4	Vert S-Min Preset 22k
RV5	SW Pot Log 2M
RV7,8,9	Pot Lin 25k
C1	Tant 4.7μF 35V
C2,6	Ceramic 33pF
C3,5	Carbonate 0.0033μF
C4,7	Tant 2.2μF 35V
C8	Ceramic 10pF
C9,10	Tant 10μF 25V
Q1	MPS3638
Q2,3,4	PN3643
IC1,2,3	LM301A
IC4,5	4016AE
IC6,7	SCL4011AE
D1,2	1N914
SW1,3	Sub-Min Toggle A
Other Parts Required	
1	Trans Gen 2 PCB
1	Trans 2 Mtg Bracket
7	15mm Collet Knob Black
3	15mm Collet Cap Red
2	15mm Collet Cap Blue
2	15mm Collet Cap Yellow
7	15mm Collet Nut Cover
2	Bolt 6BA 1/4in.
2	Nut 6BA
2	Shakeproof Washer 6BA
4	DIL Socket 14-pin
1	Wafercon Socket 8-way
8	Wafercon Terminals

cause it to commence the note in tune, raise to say one octave higher, hold the note for a preset period and then drop the note to one octave lower than the basic frequency.

The number of semitones or octaves, shifted up or down, is uniform over the entire keyboard range. The maximum design range of control is of the order of plus or minus two octaves.

Usually this module will be used to control a Voltage Controlled Filter (VCF), in the bandpass mode, being fed from a complex waveform (considerable harmonic content). Upon pressing a keyboard key the Transient 2 waveform could for example, cause the filter to commence at the timbre as selected the VCF "TUNE" control, sweep up to the higher overtones and finish on the lower fundamentals.

CONSTRUCTION

With the aid of the component

overlay (Fig 42), assemble components to the printed circuit board paying particular attention to the orientation of integrated circuits, transistors, diodes and electrolytic capacitors.

It is recommended that sockets be used — for the CMOS ICs at least. These CMOS ICs should also be the last components to be fitted to the board.

The mechanical assembly is similar to that for Transient 1. All rotary potentiometers and switches are mounted onto the bracket, drilling details for which are shown in Fig. 40. The bracket, in turn, is mounted onto the component side of the printed circuit board.

Wiring between the potentiometers and switches, and the connection points to the printed board is illustrated in Fig. 43.

CALIBRATION

As with Transient Generator 1, the exponential converter section has to be calibrated. Begin by setting SW3 to the LINEAR position and SLOPE 2 to maximum rate.

Measure the output voltage and check that it is variable between '0' volts and +5 volts by means of the FINAL LEVEL control.

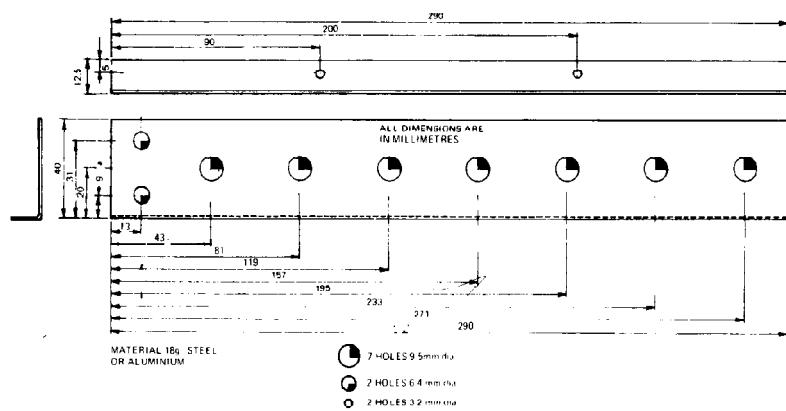
Adjust the output to '0' volts by means of the LEVEL CONTROL and adjust RV4 so that the output of IC2 is exactly zero.

Adjust the output to +5 volts with the level control and then adjust RV3 for +5 volts at the output of IC2.

Repeat the previous two adjustments until the settings remain correct when the level control is varied from one end to the other.

Switch to EXPONENTIAL and check that the output of IC1 does not go negative at any setting.

Fig.40. Mounting bracket for Transient Generator 2.



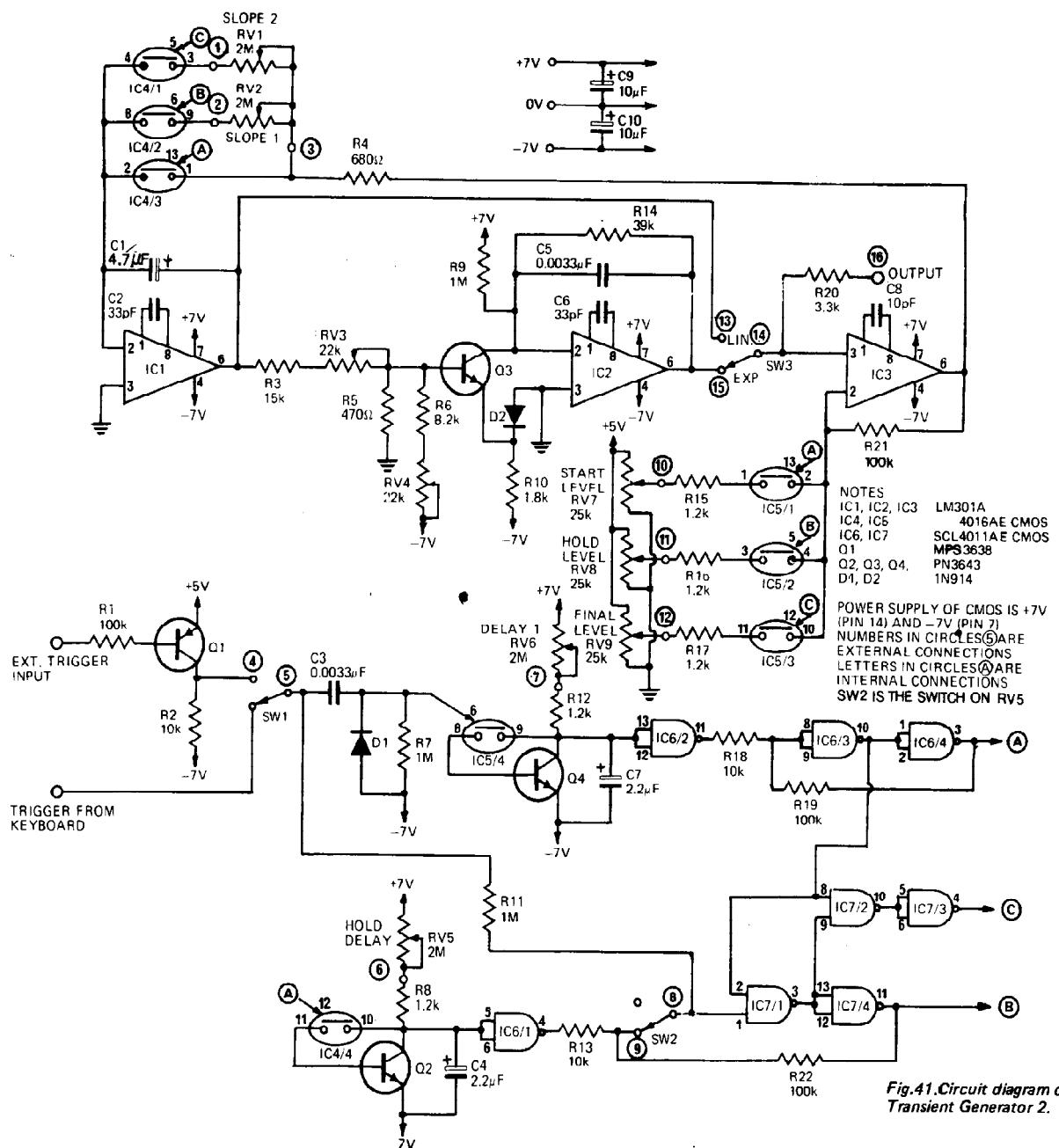


Fig.41.Circuit diagram of Transient Generator 2.

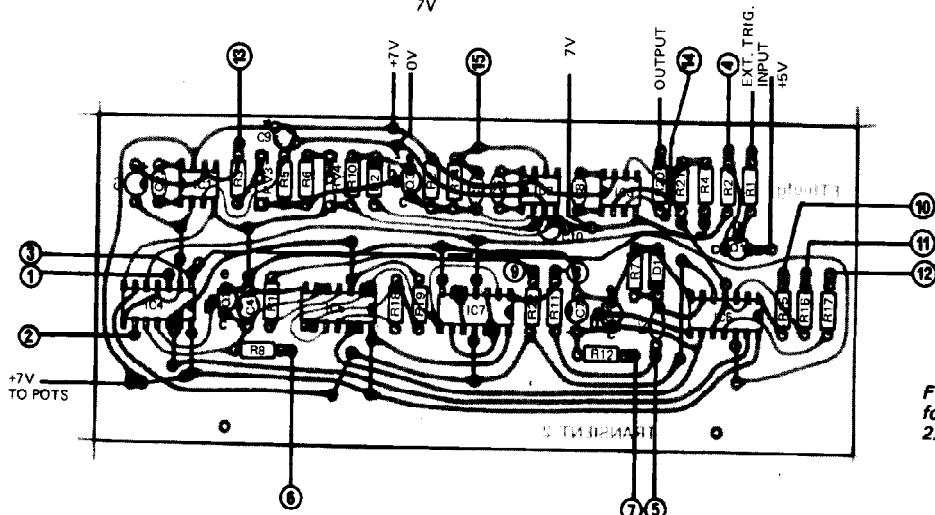


Fig.42.Component overlay for the Transient Generator 2.

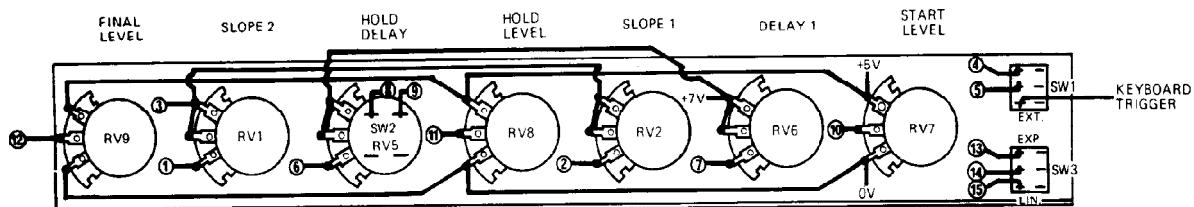


Fig. 43. Wiring diagram to switches and potentiometers on the mounting bracket.

Transient Generator 2

This module is very similar to the Transient 1 generator. It consists of two main sections.

1) The wave shaping circuitry (analogue).

2) The control circuitry (digital).

The analogue section is almost identical to that of Transient 1, and reference should be made to that. The main exception is the omission of the reset-transistor across the integrator IC. Additionally the three inputs to the comparator are all adjustable, the 'ATTACK' potentiometer has been deleted and the 'attack time' is thus always at its maximum rate.

Transient 1 "How it works", in conjunction with both circuit diagrams should readily explain the operation of this section.

The digital section of the two modules is different. That for Transient 2 works as follows:-

When a trigger pulse is presented to gate ICS/4, it turns on for about 3 millisecs. This discharges C7 via Q4. The resulting low level at the input of IC6/2 gives 'high' output at (A)

(IC6/4). Whilst (A) is high C4 will remain discharged.

The digital ICs used in this module are 2-input NAND gates (four per package), the truth table for which is shown below:-

INPUT 1	INPUT 2	OUTPUT
0	0	1
0	1	1
1	0	1
1	1	0

Note that for the ± 7 volt supplies as used, '0' means less than -4 V and '1' means greater than $+1$ V at the inputs. In the case of outputs, '0' means close to -7 V and '1' means close to $+7$ V.

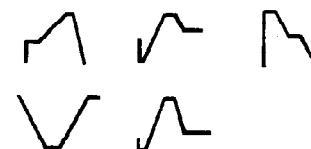
A high output at (A) will select the maximum slope rate and the START LEVEL potentiometer RV7. The output will go rapidly (within 5m-secs) to the level set by RV7.

After the initial 3 m-sec period C7 begins to charge at a rate selected by 'DELAY 1' control, RV6. When C7 charges to approximately 0V the output at (A) will go low allowing output (B) to go high selecting 'SLOPE 1' and the HOLD LEVEL as set by RV8. The output will now charge towards this new level at the

SLOPE 1 selected rate. At the same time capacitor C4 is also released and begins to charge. When about half charged (around 0V) the output (B) will go low and output (C) high. Thus 'SLOPE 2' is selected and the 'FINAL LEVEL' set by RV9. The output cycle is thus complete and the final level will be maintained until the unit is retriggered.

Note that the slopes can be in either direction depending only on the settings of the level potentiometers.

Below are examples of output waveforms available.



If the 'HOLD DELAY' potentiometer (RV5) is switched off, the key hold time replaces the hold delay, and, if the key hold time is less than DELAY 1, then at the completion of DELAY 1, SLOPE 2 and FINAL LEVEL will be selected - thus eliminating SLOPE 1 AND HOLD LEVEL.

The Voltage Controlled Filter module has a 100:1 control range.

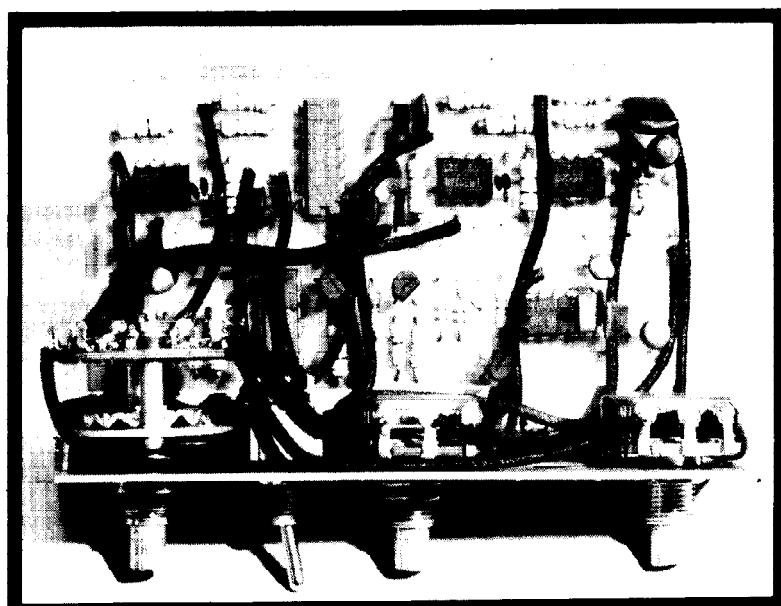
The following describes the operation and construction of the Voltage Controlled Filters (VCF). These filters have more than a two decade range and provide switchable lowpass, highpass and bandpass modes of operation, all with a 12 dB per octave slope.

Alternatively the filter designed for the 3600 may be used.

CONSTRUCTION

The method of assembly is similar to that used for most of the other modules. A small aluminium bracket is used to hold the printed circuit board and associated switches and potentiometers.

When assembling the components to the printed circuit board the usual care must be taken with the orientation of



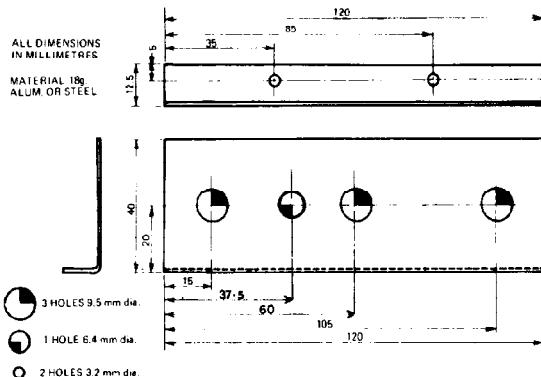


Fig.44. VCF mounting bracket.

HOW IT WORKS

The voltage Controlled Filter consists of four main sections:

1. The Buffer Amplifier.
2. A High Pass Filter.
3. A Low Pass Filter.
4. A Voltage/Frequency Converter.

The buffer amplifier, IC3, is used to provide a high input impedance (greater than 200 k) and a level shift. In the low pass and high pass modes the gain is approximately -6 dB and in the bandpass mode -11 dB. The reason for this will become obvious as we proceed. Note, that although we have called this circuit an amplifier, the output is in fact less than the input.

If, for the moment, the CMOS ICs (which are analogue switches) are considered to be ON (IC6, 4016), it may be seen that the highpass (IC4) and lowpass (IC5) filters are normal 2-pole active types. They have a gain of 6 dB (which accounts for the 6 dB loss in the buffer) and have a 1 dB rise just before cutoff frequency is reached.

In the bandpass mode the two filters are connected in series and the resultant overall gain is 11 dB, hence the 11 dB cut in the buffer-amp in this mode.

Thus it can be seen that by selecting buffer gains the overall gain is held at unity in all modes.

Note that the supply rails are +14 volts and zero. Thus the 'common' line, as used internally in the unit, is +7 volts.

To vary cutoff frequency, either the resistive or capacitive arms of the filter must be altered. To select the HIGH or LOW range (10 kHz or 2 kHz nominal upper limit) we change the capacitive arms. For voltage control we use special circuitry to change the resistive arms as follows:

If a resistor is switched in and out of circuit at a variable rate, and for a fixed duration, the effective resistance will be equal to $R_x \cdot \text{TOTAL TIME/ON TIME}$. A voltage-controlled oscillator is used to switch the resistive arms of the

filter on for a period of 200 nanoseconds and off for a time which is made variable. Take for example R12 (1.2 k) which is switched by IC6/1 (CMOS IC has a resistance of about 300Ω when on). If IC6/1 is switched at 1 MHz the effective resistance will be

$$\frac{(1200 + 300) \times 10^{-6}}{200 \times 10^{-9}} = 7500\Omega$$

If the oscillator frequency is reduced to 100 kHz the effective resistance will be 75 k, since the cutoff frequency of the filter is proportional to resistance, and the resistance is proportional to chopping frequency. If now the chopping frequency is made proportional to input voltage, it can be seen that cutoff frequency will be proportional to input voltage.

The voltage-to-frequency converter used does in fact have a linear relationship from about 10 kHz to 3.5 MHz. Frequencies below 20 kHz however should not be used, as the chopping frequency will become audible.

A variable constant-current source is provided by IC1 and Q2, where the base-emitter voltage of Q2 is compensated by taking feedback from the emitter of Q2 to IC1. A further constant current source is provided by Q1. The current from Q1 can flow either via Q3 to ground (output of IC2/2), or through Q2 as well as into C2. The current provided by Q1 is higher than the maximum available through Q2 and thus C2 will be charged by a constant current

polarized components. Assemble the components to the board in accordance with the overlay Fig.47, using sockets for the CMOS ICs at least. Note that IC2 MUST be a SCL4001AE as made by Solid State Scientific. Although this component is made under the same number by other companies, the Solid State Scientific version is much faster and has a much narrower linear region. If another brand is substituted the oscillator may work over a restricted range, or worse still may not work at all.

Wiring from the printed circuit board to switches and potentiometers is as shown in Fig.45.

(when IC2/2 is high) the value of which is determined by the input voltage.

The voltage on C2 is passed to the input of IC2/1 such that if this voltage is above approximately 7 volts the output of IC2/1 will be low (0V) whereas if the input voltage is less than 7 volts the output will be high (+14V).

A monostable having a pulse duration of 200 nanoseconds is formed by IC2/3 and IC2/4. If the input at pin 13 of IC2/4 goes high a negative going 200 nanoseconds wide, pulse occurs at pin 11 and is inverted by IC2/2. This positive pulse will turn off Q3 allowing the current from Q1 to charge C2. The voltage across C2 will rise about 3V in the 200 nanoseconds, and will go above the 7V level causing IC2/1 output to go low. Capacitor C2 will now be discharged by the current through Q2 until C2 voltage falls below the 7V level, retriggering the monostable, thus generating another 200 nanosecond pulse.

The repetition rate of the pulse is determined by the current through Q2 and hence is proportional to the input voltage. The 200 nanosecond pulse thus derived is used to turn on the CMOS switches in the active filters.

The input voltage to IC1 is variable by means of RV1 which thus acts as a 'tune' control. Resistor R1 provides a static voltage across RV1 which allows the filter to be tuned to a fixed frequency in the absence of a control input.

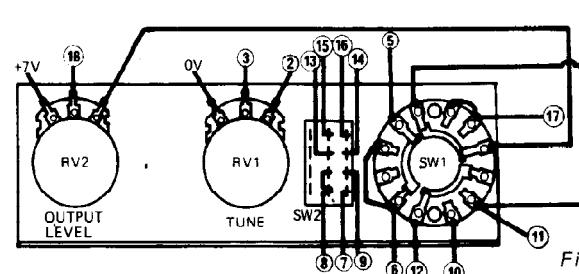


Fig. 45. Wiring diagram for switches potentiometers.

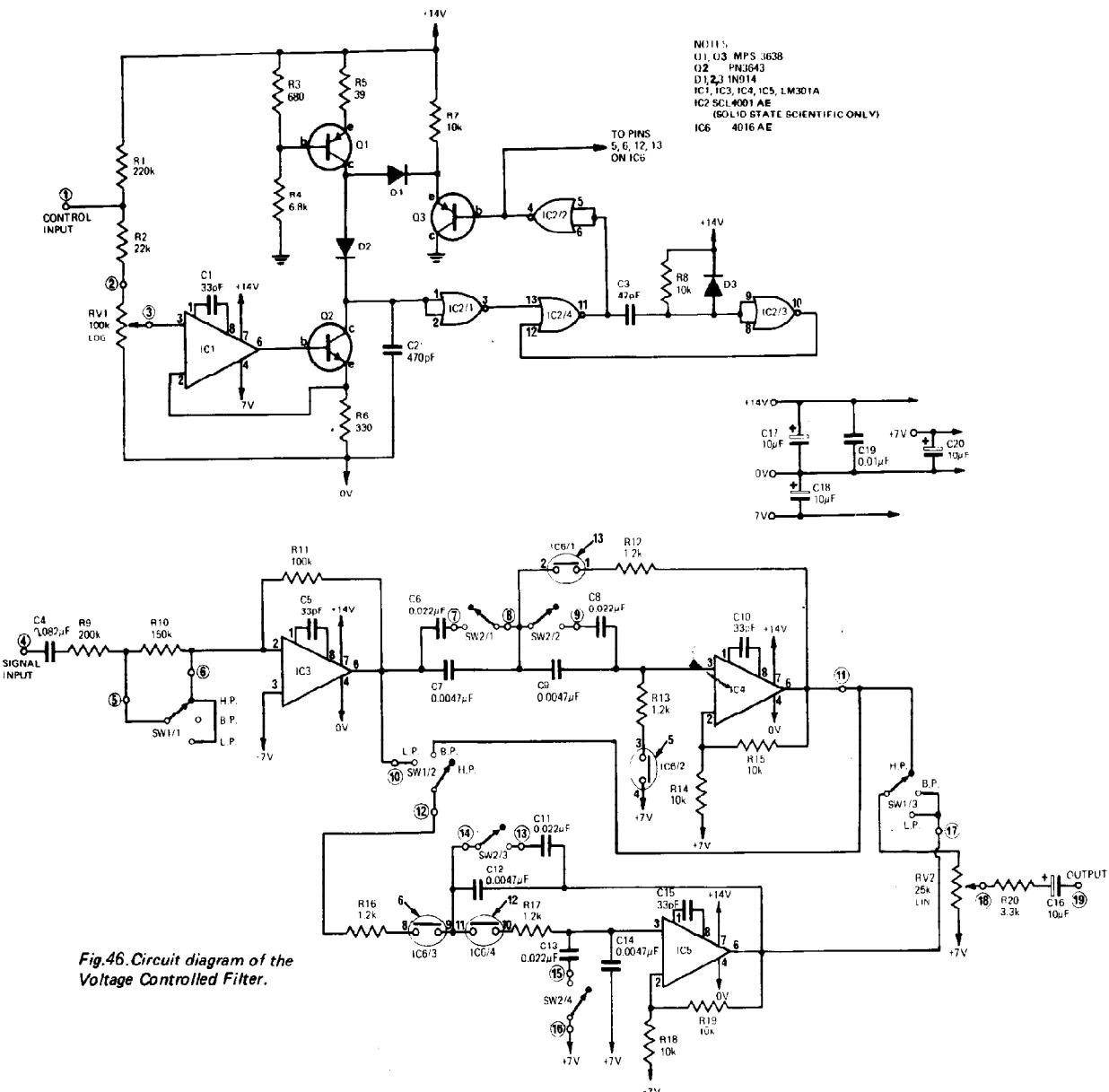
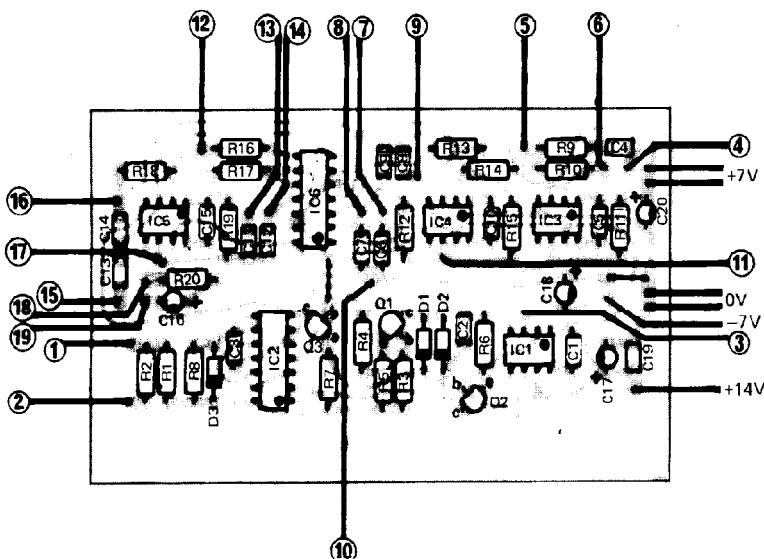


Fig.46. Circuit diagram of the Voltage Controlled Filter.



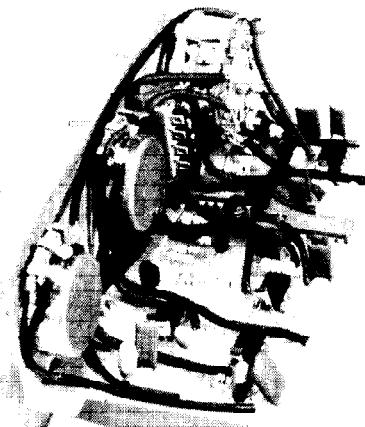
◀ Fig.47.Component overlay of VCF.

SPECIFICATION

MODES	low pass high pass band pass
SLOPES	12 dB/octave
Q	bandpass 1.5
CONTROL RANGE	> 100 : 1
FREQUENCY RANGE (Nominal)	
Low range	20 Hz – 2 kHz
High range	100 Hz – 10 kHz
INPUT VOLTAGE RANGE	
Time control at maximum.	30 mV – 5 V
NOTE:	Low end of range is limited by the chopping frequency dropping below 20 kHz thus becoming audible. High end of range is limited by the maximum obtainable oscillator frequency. (> 2MHz).

PARTS LIST V.C.F.

R1	Min Res 220k	Q1,3	MPS3038
R2	Min Res 22k	Q2	PM3643
R3	Min Res 680Ω	IC1,3,4,5	LM301A
R4	Min Res 6k8	IC2	SCL4001AE
R5	Min Res 39Ω	IC6	4016AE
R6	Min Res 330Ω	D1,2,3	1N914
R7,8,14,15,18,19	Min Res 10k	SW1	Rotary SW 4
R9	Std Res 200k	SW2	4P SM Toggle
R10	Min Res 150k		
R11	Min Res 100k		
R12,13,16,17	Min Res 1k2		
R20	Min Res 3k3		
			Other Parts Required
RV1	Pot Log 100k	1	VCF PCB
RV2	Pot Lin 25k	1	VCF Mtg Bracket
C1,5,10,15	Ceramic 33pF	3	15mm Collet Knob Black
C2	Polystyrene 470pF	2	15mm Collet Cap Red
C3	Ceramic 47pF	1	15mm Collet Cap Grey
C4	Carbonate 0.082μF	2	15mm Collet Nut Cover
C6,8,11,13	Polyester 0.022μF	1	15mm Collet Indicator
C7,9,12,14	Carbonate 0.0047μF	2	Bolt 6BA 1/4in.
C16,17,18,20	Tant 10μF 25V	2	Nut 6BA
C19	Polyester 0.01μF	2	Shakeproof Washer 6BA
		2	DIL Socket 14-pin
		1	Wafercon Socket 8-way
		8	Wafercon Terminals



OUTPUT STAGE

The following describes the output module which contains the equalizer, reverberation and output amplifiers as well as the joystick control buffers and an exponential converter.

CONSTRUCTION

The same procedure should be followed as previously described for other modules. Assemble the printed circuit board in accordance with the component overlay, Fig. 50., taking care with the orientation of polarized components. Wire the potentiometers and switches in accordance with Fig. 51.

SETTING-UP THE JOYSTICK POTENTIOMETER

All electrical adjustments must be carried out with RV7 at max. (+5V end of track).

These must be carried out before any wires are connected.

Screw self-tapping screws into holes f, g and h and tighten up on spindles, then slacken off screws by turning them twice anticlockwise. From above, centre the four zero adjusters (toothed knobs).

Hold the joystick so that it appears as shown in the sketch. Slacken clamp screws k, m and n. Twist pot. B clockwise two or three times allowing gimbal P to move freely towards pot. A ending up with the pot. tags as shown in the sketch. Tighten screw k. Move stick to bring gimbal P as close as possible to pot. C and hold gimbal in this position. Tighten screw f.

Twist pot. D clockwise two or three times (gimbal P will remain close to pot. C) ending up with the pot. tags as shown in the sketch.

Tighten screw n. Move stick to bring gimbal P as close as possible to pot. A and hold gimbal in this position. Tighten screw h.

Twist pot. C clockwise two or three times allowing gimbal Q to move freely towards pot. B ending up with the pot. tags as shown in the sketch. Tighten screw m. Move stick to bring gimbal Q as close as possible to pot. D and hold gimbal in this position. Tighten screw g.

Wire up the joystick as shown in Fig. 49. When the joystick is mounted pot. C will be the pot. nearest the keyboard.

Connect a voltmeter between OV and the joystick horizontal axis output wire (Output Stage pin 18). Operate SW2 so that pot. JB varies the voltage. Adjust RV11 to approx. centre position then slacken screw k. Move stick so that gimbal P is as close as possible to pot. C. Hold gimbal in this position and turn pot. B so that meter just starts to move from zero. Tighten screw k. Now move gimbal P as close as possible to pot. A. Adjust RV11 until meter reads 5V.

Operate SW2 so that pot. JD varies the voltage, then adjust pot. D and RV12 as above to obtain a 0-5V swing.

Finally connect the meter between OV and the joystick vertical axis output wire (Output Stage pin 20), and adjust JC and RV10 as above to obtain a 0-5V swing.

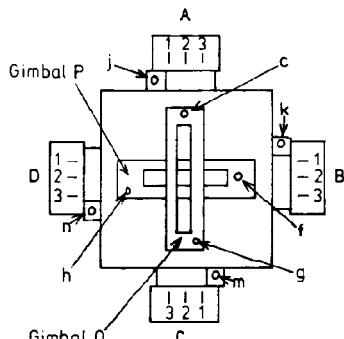
CALIBRATION

The exponential converter is the only section of the circuitry that requires calibration. This should be carried out by applying 0 V to the input and

adjusting RV14 to obtain 0.156 V, and then by applying 5 volts to the input and adjusting RV13 to obtain 5 volts output. The 0 V input should then be rechecked and the input/output relationship detailed in Table 4 should then exist. This characteristic ensures that a 1 volt change in input voltage will produce an output that, when applied to an oscillator or filter, will change its frequency by one octave. Thus a 5 volt input range provides a five octave frequency range.

The control range may be extended by reducing the 0.15V volt output at 0 volt input (R26 may need to be increased to obtain required range) however the 1 volt/octave relationship will no longer apply.

NOTE: Presets RV10, 11 and 12 are mounted on the tags of the joystick control potentiometers.



VIEW OF UNDERSIDE

Fig. 48.

JOYSTICK ASSEMBLY

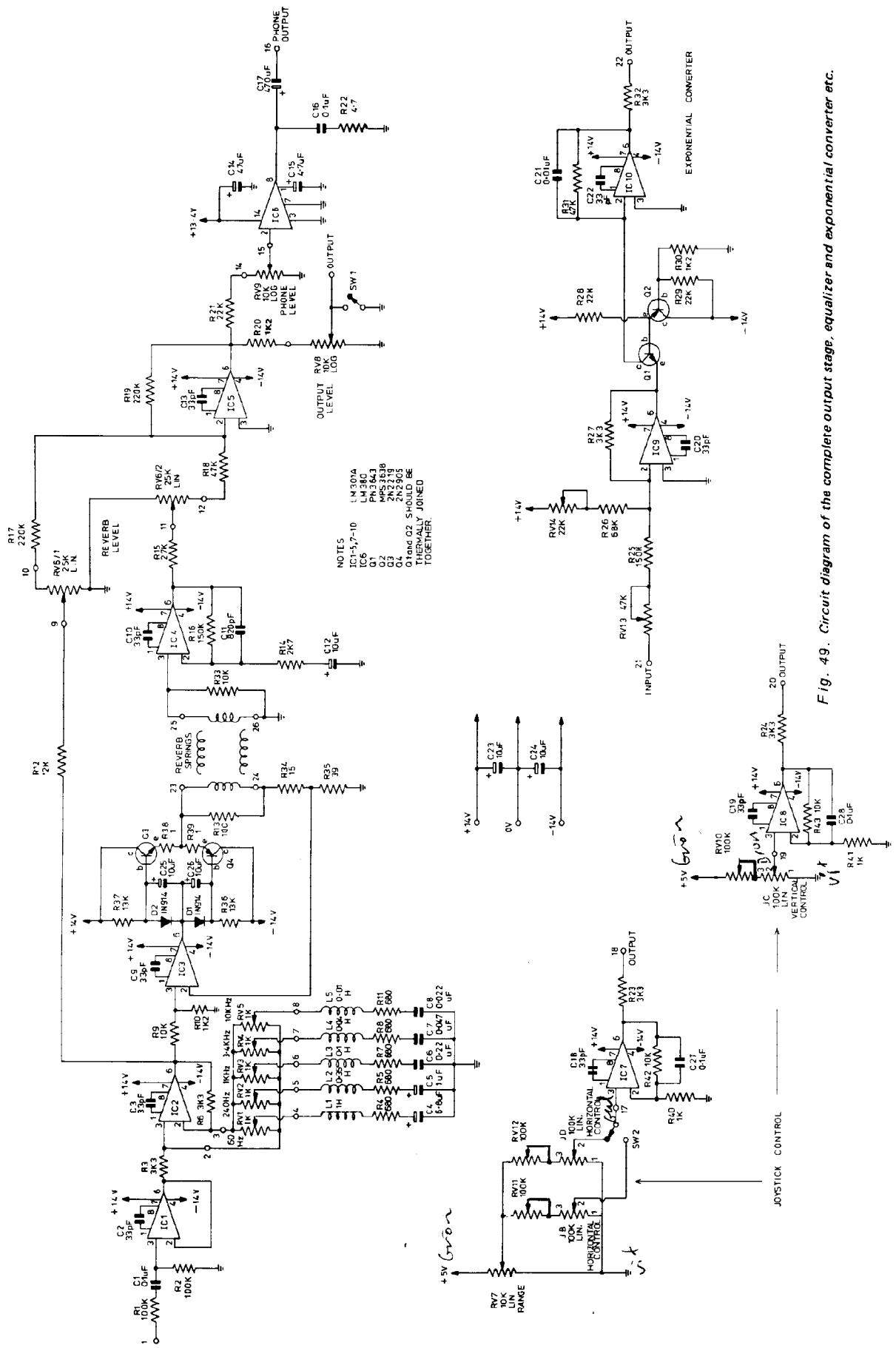
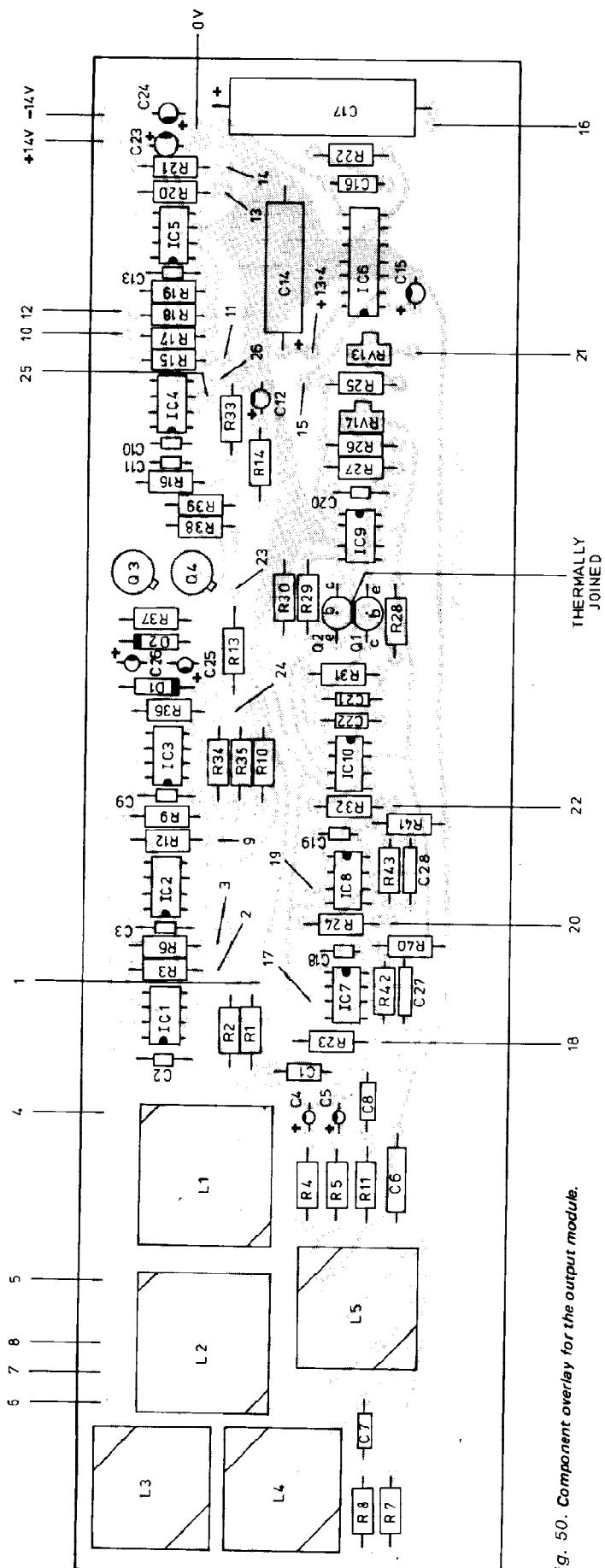


Fig. 49. Circuit diagram of the complete output stage, equalizer and exponential converter etc.



PARTS LIST

OUTPUT STAGE

R1,2	Min Res 100k
*R3,6,23,24,27,32	Min Res 3k3
R4,5,7,8,11	Min Res 680Ω
*R9,33,42,43	Min Res 10k
*R10,20,30	Min Res 1k2
*R12	Min Res 12k
*R13	Min Res 100Ω
R14	Min Res 2k7
R15	Min Res 27k
*R16,25	Min Res 150k
*R17,19	Min Res 220k
*R18,31	Min Res 47k
*R21,28,29	Min Res 22k
R22	Min Res 4.7Ω
*R24	Min Res 68k
R34	Min Res 15Ω
R35	Min Res 39Ω
R36,37	Std Res 13k
R38,39	Std Res 1Ω
*R40,41	Min Res 1k
RV1-5	Pot Lin 1k
RV6	Pot Dual Lin 25k
RV7	Pot Lin 10k
RV8,9	Pot Log 10k
*RV10,11,12	Vert S-Min Preset 100k
RV13	Vert S-Min Preset 47k
*RV14	Vert S-Min Preset 22k
*C1,16	Polyester 0.1μF
C2,3,9,10,13,18,19,	Ceramic 33pF
20,22	Tant 6.8μF 35V
C4	Tant 1μF 35V
*C5	Polyester 0.22μF
*C6	Polyester 0.047μF
*C7	Polyester 0.022μF
*C8	
C11	Polystyrene 820pF
C12,23,24,25,26	Tant 10μF 25V
*C14	Axial 47μF 25V
*C15	Tant 4.7μF 35V
*C17	Axial 470μF 10V
*C21	Polyester 0.01μF
*C27,28	 <i>Polyester 0.1μF</i>
Q1	PN3643
Q2	MPS3638
Q3	2N2219
Q4	2N2905
IC1-5,7-10	LM301A
IC6	LM380
DI,2	IN914
L1-5	See Table 5
SW1,2	Sub-Min Toggle A
Other Parts Required	
1	Output Stage PCB
1	Output Stage Mtg Bracket
9	15mm Collet Knob Black
5	15mm Collet Cap Green
3	15mm Collet Cap Grey
1	15mm Collet Cap Yellow
9	15mm Collet Nut Cover
2	Bolt 6BA 1/4in.
2	Nut 6BA
2	Shakeproof Washer 6BA
1	Spring Line
1	Joystick Pot
1	Joystick Mtg Plate
2	Jack Skt Open
1	Patchboard
	Patch Plugs (as required)
1	Waferton Socket 3-way
1	Waferton Socket 8-way
11	Waferton Terminals

HOW IT WORKS

OUTPUT MODULE

This section can be broken into sections as follows.

INPUT BUFFER

EQUALIZER

REVERBERATION

OUTPUT AMPLIFIER

HEAD PHONE AMPLIFIER

JOYSTICK BUFFERS

EXPONENTIAL CONVERTER

The input buffer (IC1) has a 200 k Ω input impedance and gives an attenuation of 6 dB ($\frac{1}{\sqrt{2}}$). The attenuation is required to prevent clipping in the equalizer output stage.

The output from the buffer is directly coupled to the input of the equalizer stage. This stage is a little unusual, since the equalizing networks are arranged to vary the negative feedback. If we consider one section with the others disconnected, at the resonant frequency of the series LCR combination the impedance of the entire network will be equal to 680 ohms. Either side of resonance the impedance of the network will increase (with a slope dependent on the Q of the network), due to uncancelled inductive reactance above resonance and uncancelled capacitive reactance below resonance. We can therefore represent the equalizer stage with equivalent circuits as reproduced below. These circuits consider only one network in circuit, the input signal frequency is the resonant frequency of the network, and the resistance of the inductor is negligible.

With the slider of the potentiometer at the top end (Fig. A) we have 680 ohms to the zero volt line from pin 2 of IC2, and a 1 k ohm between pin 3 and pin 2. The IC will act due to the feedback to keep the potential between pins 2 and 3 virtually zero, thus there is zero current through RV1. The voltage on pin 3 (IC2) is therefore equal to the output of the mixer since there is virtually no current through and no voltage drop across R3.

The output of IC2 in this case is approximately the input signal times $(R6 + 680)/680$ ohms, indicating a gain of about 15 dB. If the slider is at the other end of the potentiometer (Fig. B) the signal appearing at pin 3 and thus also at pin 2 is about 0.2 of the output of the previous stage due to the voltage division of R3 and the 680 Ω . There is still zero current through RV1 and also zero current through R6 since there is no path. The output voltage is therefore the same as that at pin 2, which happens to be about 0.2 times the output of the previous stage. The gain is therefore 0.2 or -13dB.

With all networks in circuit, the maximum boost and cut will be reduced, but a range of ± 10 dB is still available. With the wiper of the potentiometers set midway - Fig. C, the gain will be unity regardless of frequency, due to the symmetry of the entire network.

The equalizer output is fed into the reverb drive circuit (IC3, Q3, Q4). The reverb is connected in the feedback of the IC in such a way that the drive is mostly constant current and not constant voltage. This drive method provides a more uniform frequency response. The output of the reverb is a very low amplitude signal which is amplified by IC4. The output of IC4 and the output of the equalizer (IC2) both go to RV6 which selects the percentage of each required.

The final amplifier, IC5, amplifies the output of RV6 and applies it to RV8 which adjusts the output level to the main amplifier. The output of IC5 also goes to the headphone amplifier IC6 (LM380). This IC will supply up to 1.5 watts into either headphones or a small loudspeaker.

The joystick simply provides two voltages which vary between 0 and +5V. The horizontal axis has two potentiometers connected through a switch so that the range can be reversed and RV7 allows the range itself to be adjusted. Buffer amplifiers IC7 and IC8 prevent loading of the control potentiometers.

The exponential converter consists of IC9, Q1, Q2 and IC10. The input signal is inverted and attenuated by IC9. Potentiometer RV13 adjusts the gain and RV14 provides the required offset. The exponential relationship between the base-emitter voltage and collector current of a transistor (Q1) is used to provide the required law. Transistor Q2 provides temperature compensation. Note that Q1 and Q2 must be glued together to provide intimate thermal contact (see photograph). The collector current of Q1 is converted into a proportional voltage thus providing the input/output relationship detailed in Table 4.

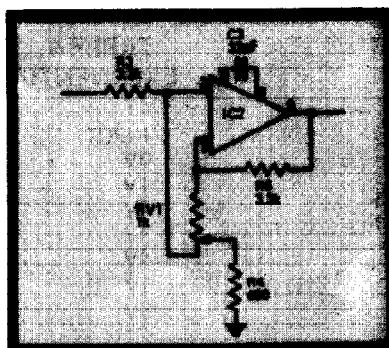


Fig. B. Equivalent circuit of the equalizer with the potentiometer set for maximum cut at the resonant frequency of the network.

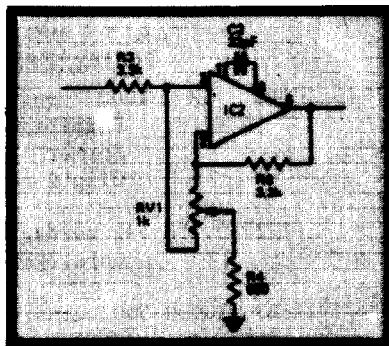


Fig. C. Equivalent circuit of the equalizer with the potentiometer set for unity gain regardless of frequency.

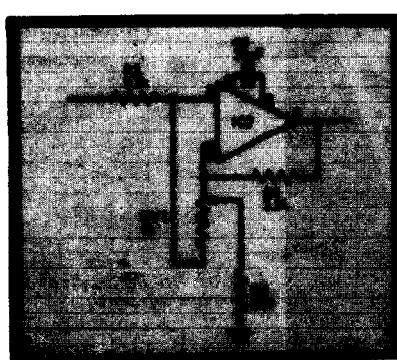


Fig. A. Equivalent circuit of the equalizer with potentiometer set for maximum boost at the resonant frequency of the network.

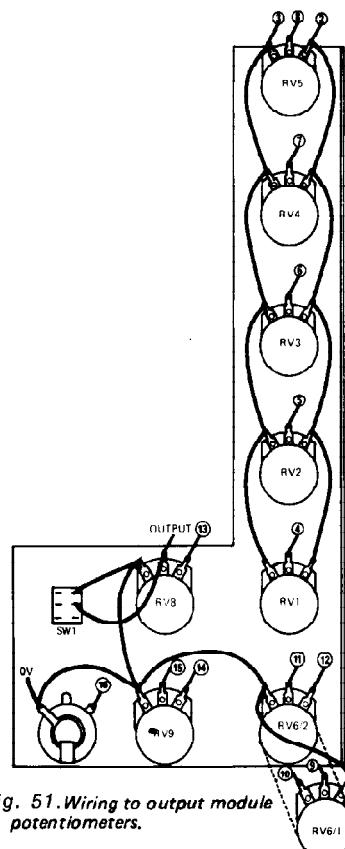


Fig. 51. Wiring to output module potentiometers.

TABLE 4. CALIBRATION EXPONENTIAL CONVERTER

INPUT	OUTPUT
0V	0.15625V *
1V	0.3125V
2V	0.625V
3V	1.25V
4V	2.5V
5V	5V **
6V	10V

* adjust RV15 with 0V input to obtain 0.156V output.

** adjust RV14 with 5V input to obtain 5V output
(note that these adjustments must be done in the above sequence).

TABLE 5. WINDING DATA EQUALIZER CHOKES

- L1 1H 1000 turns, EC Wire 38swg
Ferrite Core Type 3 Core
Former Type 3 Bobbin
Clip(2 required) Type 3 Clips
- L2 0.35H 592 turns, EC Wire 36swg
Core, Former and Clips as L1
- L3 100mH 500 turns, EC Wire 38swg
Ferrite Core Core Type 2
Former Bobbin Type 2
Clip(2 required) Clips Type 2
- L4 40mH 316 turns, EC Wire 38swg
Core, Former and Clips as L3
- L5 10mH 158 turns, EC Wire 36swg
Core, Former and Clips as L3

The output module.

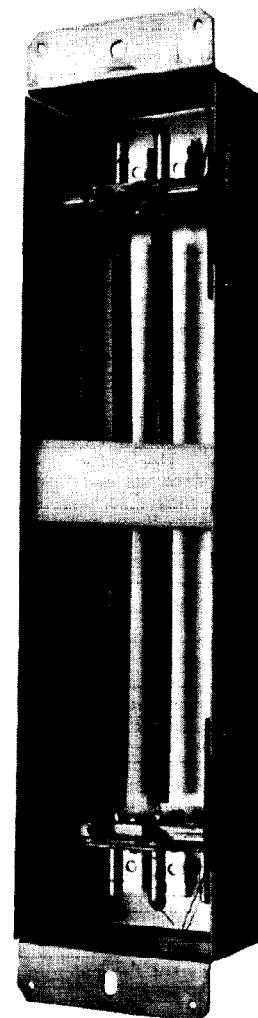
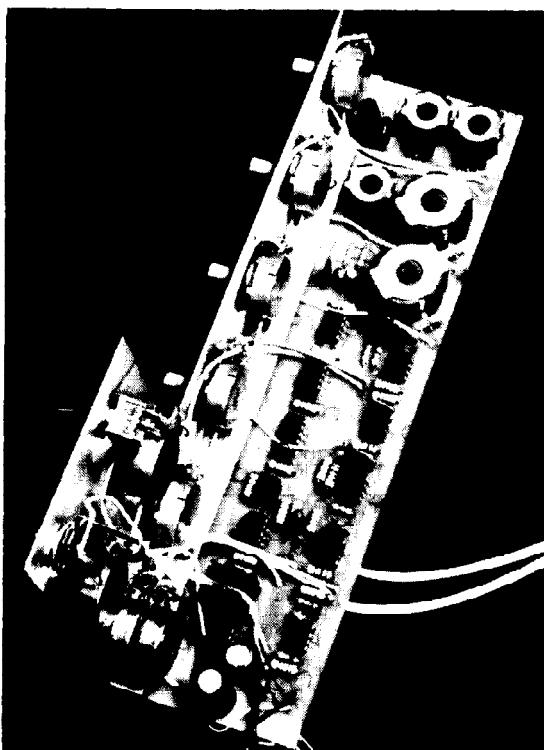


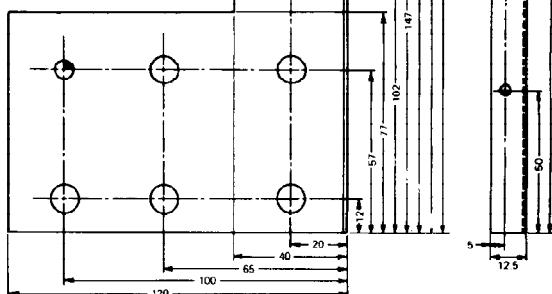
Fig. 52. Short spring line

ALL DIMENSIONS ARE IN MILLIMETRES

MATERIAL 18 GAUGE ALUMINIUM OR STEEL

- 9 HOLES 9.6 mm DIA
- 1 HOLE 6.4 mm DIA.
- 2 HOLES 4 mm DIA.

Fig. 53. Drilling details of output module sub-panel.





The exponential converter transistors Q1 and Q2 (arrowed) are glued together to ensure thermal balance.

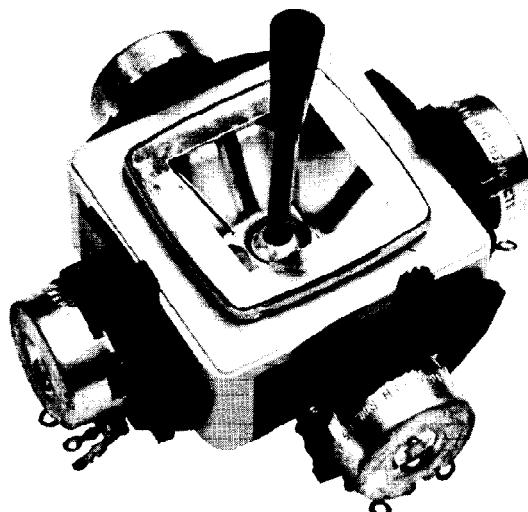


Fig. 54. The Joystick potentiometer.

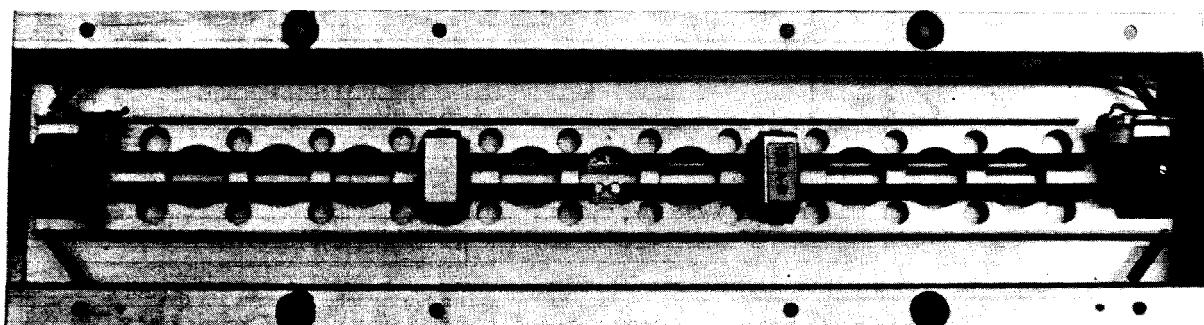


Fig. 55. Long Spring line

Only one spring line is required. Either the short line shown in Fig. 53 or the long line shown in Fig. 55 may be used. The short line is approx. 206mm long and the long line is approx. 432mm long. The short line gives a reverb time of 2.5 secs. and the long line gives a reverb time of 7 secs.

External input module

Using the external input circuitry, other electronic instruments (such as an electric guitar) may be fed into the synthesizer modules in order to obtain new and different sounds. One of the two inputs has circuitry which generates trigger pulses from the external instrument's signal, thus allowing the transient generators to be triggered.

CONSTRUCTION

As with all other modules, a small aluminium bracket is used to support the printed circuit board, potentiometers and switches. The components should be mounted onto the printed circuit board in accordance with the component overlay Fig. 58, taking care with the orientation of polarized components.

The switches and potentiometers should then be wired as shown in Fig. 57. The input sockets are mounted on the rear panel of the synthesizer.

HOW IT WORKS— External Inputs

The two preamplifiers for the external inputs are provided by a low-noise dual integrated circuit type LM381. A 50 k potentiometer at the input allows attenuation of the input and sets the input impedance.

The LM381 IC differs from the normal operational amplifier we have been using in that it uses a single power supply of +14 volts and, in that the output has to be biased to mid-voltage (7 to 8 V) by an external network – in our case R5 and R7. Gain of the amplifier is set by $R7/(R1+R3)$ and, since R3 may be switched in or out, two gain ranges are available. These are 56 dB and 32 dB (voltage gains of 630 and 40). These, of course, are fully variable by means of the input potentiometer.

The frequency response of the amplifiers is 20 Hz to 50 kHz ± 0 -3 dB.

Input 1 is provided with a trigger facility. If the peak negative output falls below the voltage selected by RV3, the output of IC2 (acting as a comparator) will go to +6 volts and remain there whilst the RV3 voltage is exceeded. At all other times the output of IC2 will be at -6 volts.

During the positive excursion of IC2, C8 charges rapidly to +6 volts and when IC2 goes negative again C8 discharges slowly via R17 to -7 volts. Another comparator, IC3, will have its output at -6 volts if the voltage on C8 is above 0 volts, and at +6 volts if the voltage on C8 is below 0' volts.

The envelope from a conventional instrument will usually have an initial attack period, a sustain period and then a decay. With this type of envelope the trigger will start high, go low whenever the envelope is greater than the preset level and then go high again. It will not respond to individual cycles due to the slow discharge of C8 by R17. The release time is about 20 milliseconds.

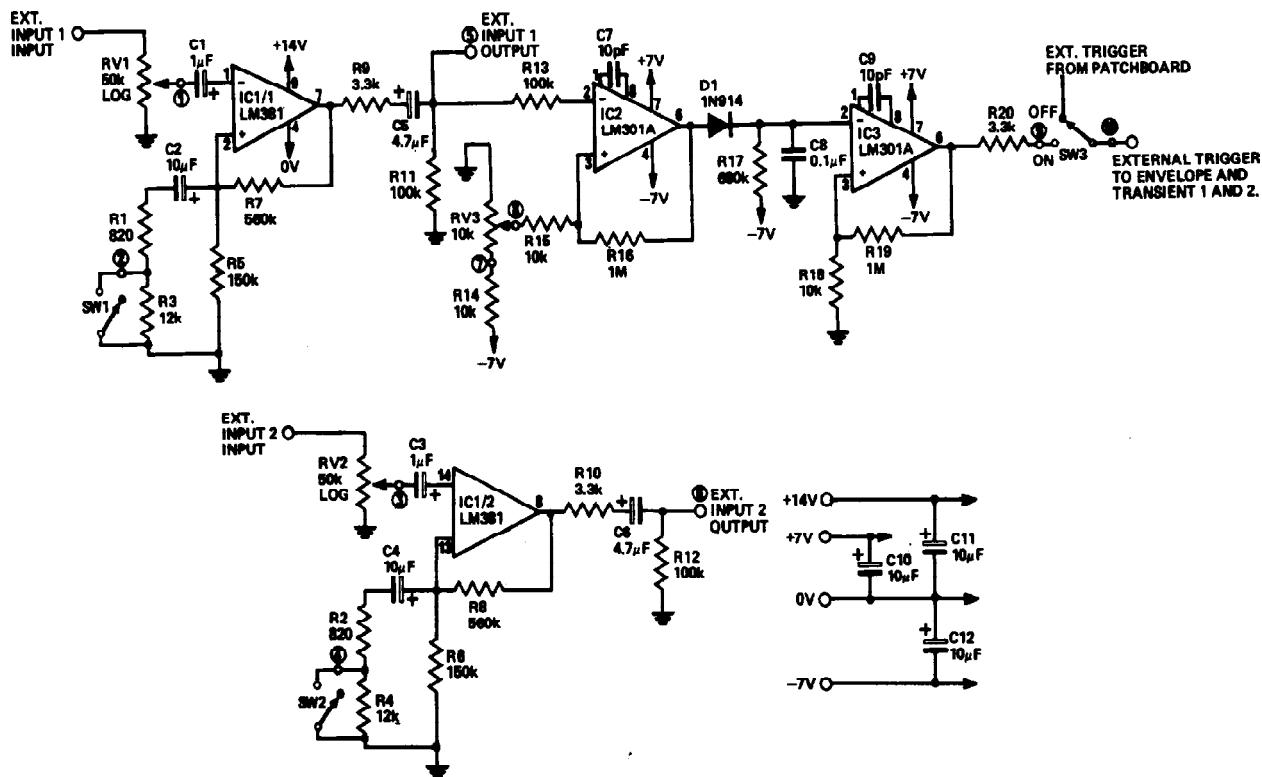


Fig. 56. Circuit diagram of external input module.

SPECIFICATION EXTERNAL INPUT MODULE	
Input levels	2 mV–5 V rms
Input Impedance	50 k
Frequency response	+0–3 dB
20 Hz–50 kHz	
Maximum gain	56 dB
high sensitivity	34 dB
low sensitivity	adjustable 0 to +5V
Trigger level	approx 20 mS
Trigger release time	

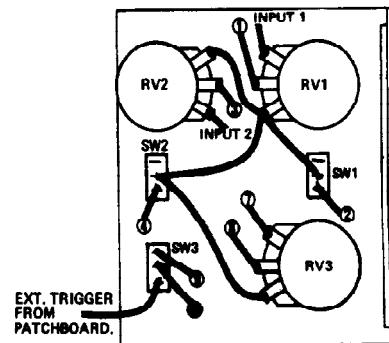


Fig. 57. Wiring to potentiometers and switches – external input module.

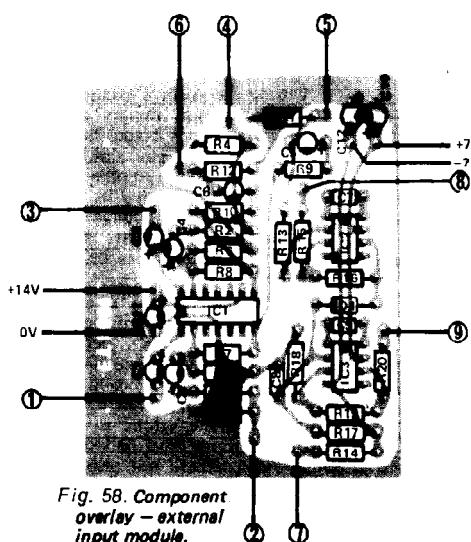
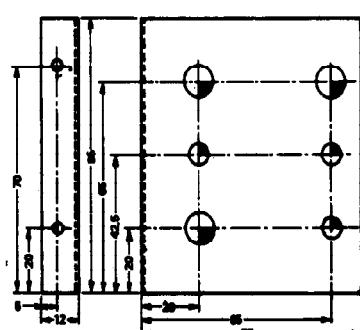


Fig. 58. Component overlay – external input module.



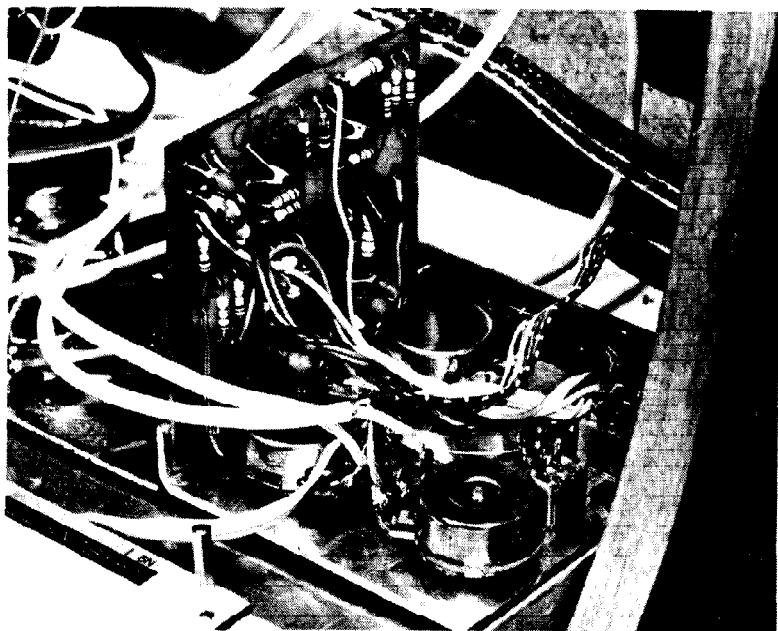
ALL DIMENSIONS ARE IN MILLIMETRES
MATERIAL: 16 GAUGE
ALUMINIUM OR STEEL

- 2 HOLES 4 mm. dia.
- 1 HOLE 6.4 mm. dia.
- 3 HOLES 6.6 mm. dia.

Fig. 59 Drilling details for external input mounting bracket.

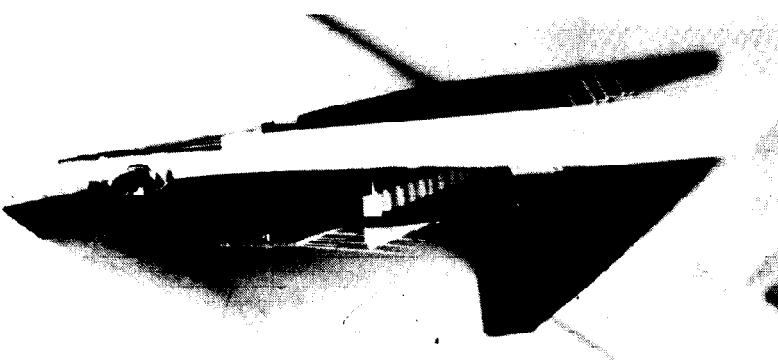
PARTS LIST — External Inputs

R1,2	Min Res 820Ω
R3,4	Min Res 12Ω
R5,6	Min Res 150k
R7,8	Min Res 560k
R9,10,20	Min Res 3k3
R11,12,13	Min Res 100k
R14,15,18	Min Res 10k
R16,19	Min Res 1M
R17	Min Res 680k
RV1,2	Pot Log 50k
RV3	Pot Lin 10k
C1,3	Tant 1.4F 35V
C2,4,10,11,12	Tant 10.0F 16V
C5,6	Tant 4.7μF 25V
C7,9	Ceramic 10pF
C8	Polyester 0.1μF
IC1	LM381
IC2,3	LM301A
D1	IN914
SW1,2,3	Sub-Min Toggle A
Other Parts Required	
1	External Inputs PCB
1	Ext. I/P's Mtg Bracket
3	15mm Collet Knob Black
1	15mm Collet Cap Yellow
2	15mm Collet Cap Black
3	15mm Collet Nut Cover
2	Bolt 6BA 1/4in.
2	Nut 6BA
2	Shakeproof Washer 6BA
2	Jack Skt Open
1	Wafercon Socket 8-way
8	Wafercon Terminals

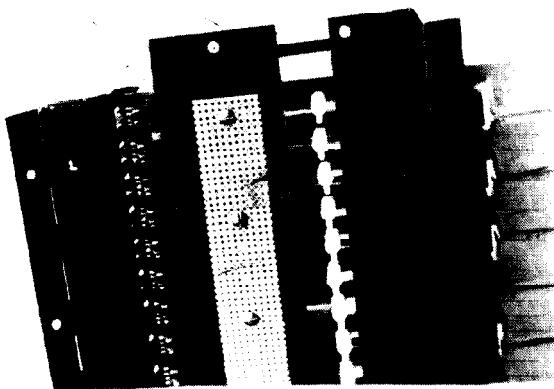


The external input module mounted in position.

KEYBOARD



Side view of the keyboard showing how the gold-wire contacts are fitted.



Underneath view of the keyboard showing how the wire fits to the SRBP.

The keyboard is a 48-note F to E with flat-fronted hard-wearing plastic keys. The keyboard is ready-sprung and touch adjustable

with hard steel pivots for long life and minimum side-slop. The whole keyboard is hinged along its length allowing it to be lifted at

the front for access to the contacts.

Contact blocks may be used, but these are quite expensive and since only one make contact is required per key, a simple but effective contact can be made using gold-clad phosphor-bronze wire.

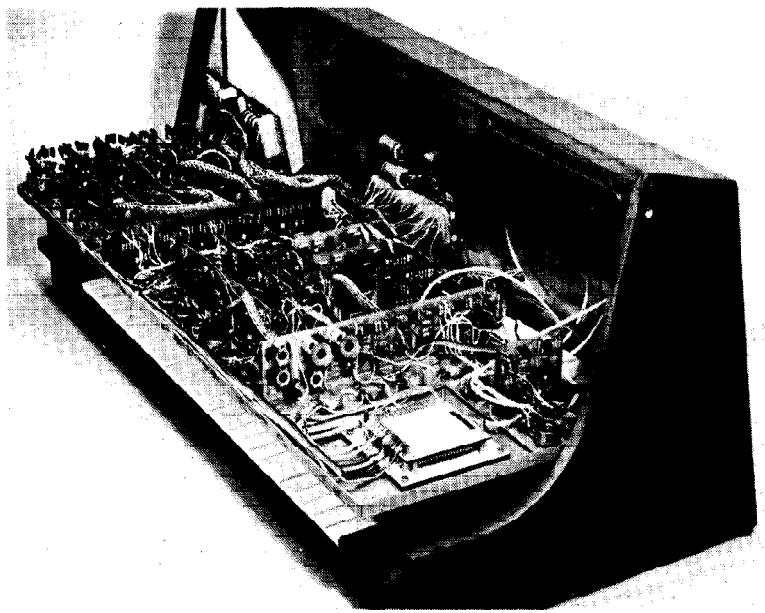
Cut a 6" x 4" piece of 0.1" matrix SRBP into five 0.8" x 6" pieces and mount each one on the keyboard by means of four 1/2" No 4 self-tapping screws. These can be screwed into the holes provided in the keyboard chassis and the SRBP is held off the chassis using 1/4 in. long 6BA spacers. The screw holes in the SRBP should be made with an 1/8" drill bit.

Cut two 2" pieces of gold clad wire, lay one end of one piece on the unoperated nylon key plunger and thread the other end through two or three holes in the SRBP board to hold it firmly in position. Fix the second piece of wire to the SRBP board in the same way so that its other end just reaches the key plunger. With a pair of wiring pliers put a 90° bend in the wire about 1/4" from the plunger so that this wire lies across the first wire at 90°. Now gently bend the wire away from the straight wire until the point is reached where the first wire makes with it again when the key is depressed about two-thirds of its total travel. The ends of the wires can be left sticking up through the SRBP board to facilitate soldering to the leads going to the Keyboard Controller module.

MODULE/PATCHBOARD—INTERWIRING

MODULE	INPUTS	OUTPUTS	DESTINATION	MODULE	INPUTS	OUTPUTS	DESTINATION
Oscillator 1	Input	Output	Patchboard 1H Mixer point 2	Transient 1	Key Output Ext. Trigger Key Trigger		Patchboard 16V Ext. Input mod-10 Patchboard 12V Patchboard 13V
Oscillator 2	Input	Output	Patchboard 2H Mixer point 4	Transient 2	Ext Trigger Key Trigger		Ext. Inp. mod-10 Patchboard 12V Patchboard 14V
Oscillator 3	Input	Output	Patchboard 3H Mixer point 6	VCF 1	Signal Inp. Control Inp.		Patchboard 14H Patchboard 5H Patchboard 7V
Oscillator 4	Input	Output A Output B	Patchboard 4H Mixer point 8 Mixer point 10	VCF 2	Signal Inp. Control Inp.		Patchboard 15H Patchboard 6H Patchboard 8V
Keyboard Controller	Transient 2 Patchboard	Trig. Output Key Output. Mod Input	Patchboard 14V Patchboard 11H Patchboard 12V Patchboard 16V Patchboard 17V	Amp 1	Signal Inp. Control Inp.		Patchboard 16H Patchboard 7H Patchboard 9V
Noise and Controller	Controller Input	Noise Output Noise Output Cont. Output Cont. Output	Patchboard 10H Osc 4B selector Patchboard 11V Osc 4B selector Patchboard 20V	Amp 2	Signal Inp. Control Inp.		Patchboard 17H Patchboard 8H Patchboard 10V
Mixers	2 4 6 8 10 RV61 RV62 RV81 RV82		Osc 1 Output Osc 2 Output Osc 3 Output Osc 4 Output Osc 4B Output Patchboard 18H Patchboard 19H Patchboard 20H Patchboard 21H Output 1 Output 2 Output 3 Output 4 Output 5	Output Module	Input 1 17 19 21		Patchboard 22H Horiz. Joystick Vert. Joystick Patchboard 9H Patchboard 18V Patchboard 19V Rear phone jack Patchboard 15V Phone Out.
						Output 18 Output 20 Output SW1 Output 22	
Envelope	Keyboard Output Ext. Output Key Trigger Signal Control		Not used Ext. Input mod-10 Patchboard 12V Patchboard 13H Not used ext. Patchboard 6V	External Inputs	Ext. Input 1 Ext. Input 2 Ext. Trigger from patch-board	Ext. 1 Out. Ext. 2 Out. Ext. Trigger (10) Out.	Rear phone jack Rear phone jack Patchboard 12H Patchboard 21V Patchboard 22V Envelope Transient 1 Transient 2

Notes: The patchboard is numbered 1H to 22H left to right and 1V to 22V top to bottom.



The synthesizer front panel was hinged to allow ease of service.

PHOTOGRAPHS IN THIS BOOK

Except for the photographs of the joystick and spring lines and the cover photographs, the other photographs are of the original prototype and differ in some details from the parts now supplied.

OTHER PARTS REQUIRED

In addition to the parts shown in the parts lists through this book, the following are required:-

- 1 4600 Front Panel
- 1 4600 Rear Panel
- 2 Hinges
- 1 4600 Woodwork
- 4 Bolt 6BA ½" for mounting patchboard
- 4 Nut 6BA " "
- 4 6BA Shakeproof Washer "

If using the short spring-line space it from the woodwork with four small rubber grommets.

Maplin Electronic Supplies are normally able to supply everything you need to build this synthesiser (including wire, mains cable, solder, tools etc.) except the wood screws you will need to mount the spring-line, transformer and power supply module.

COME AND PLAY A 4600 SYNTHESISER

A working model of this synthesiser is usually on display in Maplin's shop at 284 London Road, Westcliff on-Sea, Essex, but occasionally it is away for demonstration elsewhere. Therefore we strongly advise anyone wishing to come and try it out to telephone first, Southend (0702) 44101 to avoid disappointment.
(Please ask for the shop when telephoning).

COMPLETING THE 4600 SYNTHESISER

Having finished making and setting-up the modules, fit them to the front panel using the potentiometer fixing nuts (where smaller holes are drilled in the front panel) to hold them. Pilot holes are drilled in the ready-made woodwork to accept the screws for the hinges. Full details are supplied with the woodwork. The finished synthesiser may be table-mounted or legs can be fitted. Suitable legs are obtainable from most do-it-yourself shops, but check that the length of them suits the height at which you like to play.

ERRORS ON COMPONENT SCHEDULE

We regret the following errors on the enclosed component schedule sheet. Please amend the sheet as follows.

Two Mylar $0.005\mu F$ capacitors are required in the Keyboard Controller and no Carbonate $0.0056\mu F$ are required.

The Maka Wafer required is a 1 pole 11-way not 12-way as stated.

Four Maka Wafer 2 pole 5-way are required in the total not two as stated.

This book has been painstakingly checked for errors, but in a project of this complexity it clearly is possible for an error to be overlooked. If you find any errors please write to Maplin and we will publish the correction in our newsletter for the benefit of other constructors.

