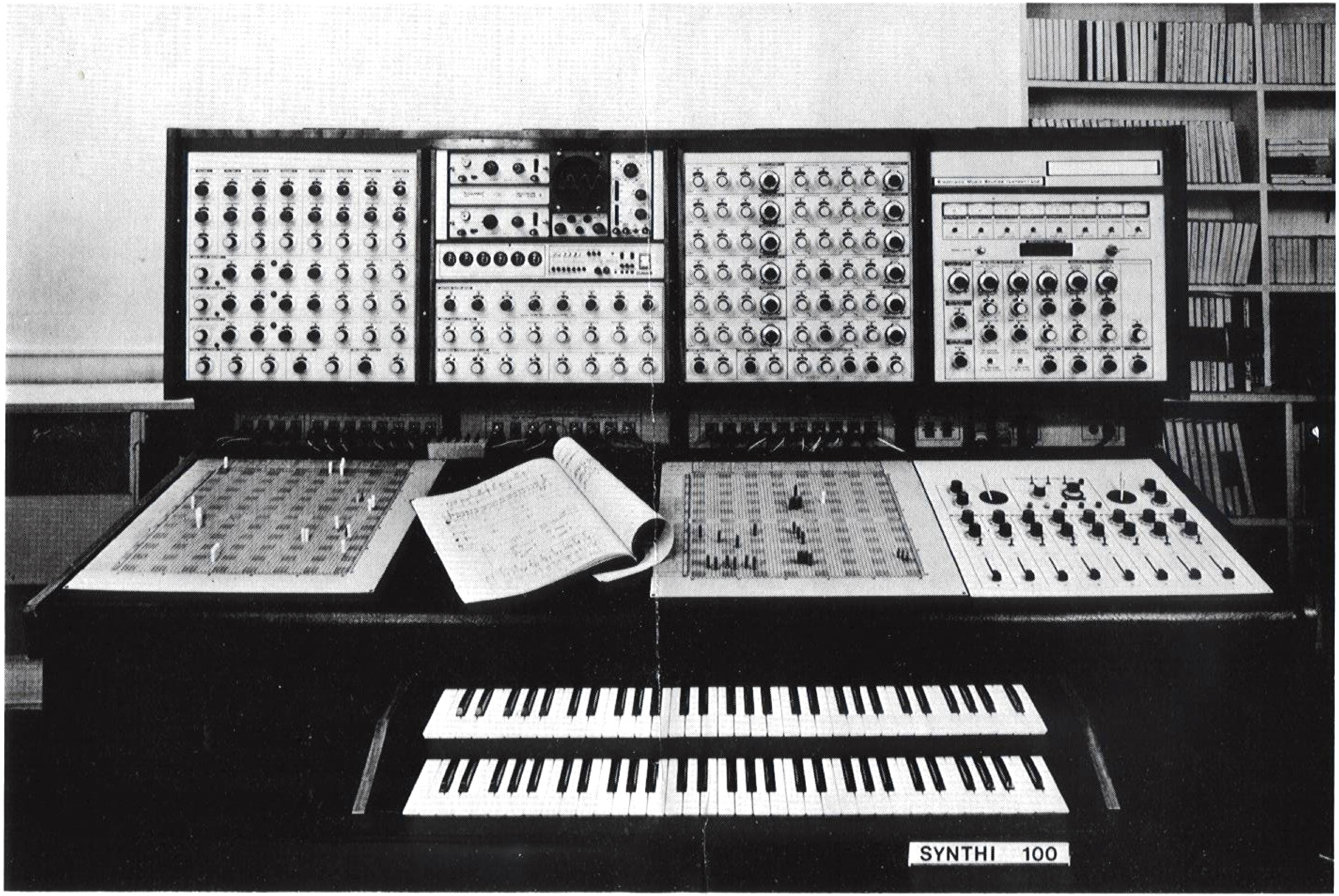
SYNTHI 100

The Synthi 100 — Professional Electronic Music Studio

The SYNTHI 100 studio has at its heart a digital sequencer, which makes conventional analogue controllers, with their gigantic array of knobs, seem old-fashioned, inaccurate and cumbersome. With a solid state storage capacity of 10,240 bits, the new sequencer is capable of precisely controlling 6 different simultaneous parameters over a sequence of 256 successive events. There are several modes of operation and full, easy to operate editing facilities, so that any or all of the 256 stored items and their time relationships may be changed without difficulty.

For example, two five-octave dynamically proportional keyboards are included, to operate the studio in real time, on six tracks, with the sequencer remembering what is played. This performance can then be played back backwards or forwards, at any speed, and edited to any degree of precision, prior to recording on magnetic tape.

The SYNTHI 100 also contains new electronic devices exclusive to EMS, such as voltage controlled slew limiters, a frequency to voltage converter and a two-output random staircase generator with controllable time and amplitude variances. Also included are a very full complement of 12 drift-free oscillators, eight dynamic filters and three transformerless i.c. ring modulators (which can be cascaded for double and triple modulation), as well as eight voltage controlled output channels with full panning facilities, eight input amplifiers, two X-Y joystick controllers, a filter bank, three elaborate envelope shapers and followers, noise generators and reverberation units. A double-beam oscilloscope and six-digit crystal-controlled counter/timer/frequency meter ensure accurate setting up and logging of parameters, and patching is by cordless pin matrices (two boards each with 60 x 60 locations).

In the same price range as the larger voltage controlled synthesizers, the SYNTHI 100 offers far more, and is intended for really exacting composition and realisation work in professional recording and electronic music studios, broadcasting companies and universities. First customers include the BBC, Radio Belgrade and the University of Wales.

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This photograph shows the EMS Synthi 100. The patching matrixes are on the main desk; the right hand matrix is used for control voltages and is connected to the Digital Interface via two 60 way junctions. The knobs above the desk are used as presets when the SYNTHI is controlled by computer.

General Points

Appearance

The SYNTHI 100 is presented in an afrormosia case, with padded black leather. A cupboard stand and seat are available as extras. The working surfaces are illuminated by dimmer lights, and all outputs and inputs are available behind a sliding screen in the front of the unit, while the input/output cables are channelled on to the rear. The SYNTHI 100 is designed for computer interface, and therefore all control inputs are available for direct connection to digital/analog converters on multiway connectors. The overall size base of the SYNTHI 100 is 79 in. length by 37½ in. depth, the height is 33 in. and the height from the underside to the ground is 30 in.

Signal Levels

The levels of all signal outputs available at the patchboard are controlled by panel mounted potentiometers. In fact, these potentiometers provide control voltages which operate on voltage controlled amplifiers. The advantages of this system include:

- Constant low output impedence.
- No 'fader scratch' as levels are changed
- Less conveying of signals at high impedance (where they are susceptible to crosstalk)
- Much simplified wiring system
- Ideal logarithmic control of level

In general, signal levels are about ±1V p-p, although most outputs can deliver much more than this. Most devices which have signal inputs are adjusted for optimum operation at this level, although it can be usually considerably exceeded without serious distortion.

Control Voltage Levels

All EMS control voltage outputs are bipolar, that is to say they go both positive and negative. This allows control signals and audio signals to be interchanged, and also allows the magnitude of a control output to be adjusted without altering the mean level of the parameter controlled.

Input Impedances

All input impedances are approximately 10 KOHM. This comparatively high figure was chosen as a compromise between the conflicting requirements of 'fan out' (i.e. the number of inputs an output may drive before it runs out of power) and susceptibility to crosstalk when an input is left open circuit. Screened cable is used for all signal paths in the studio, and impedance at certain central inputs is made infinitely low so that secondary control parameters can be added without readjusting the magnitude of the primary ones.

Noise Levels

The signal to noise ratio of all voltage controlled amplifiers is better than 74 dB for an input signal level which produces a T.H.D. of 3%. This ratio is constant over the upper 30 dB of the control range. In other words, as the amplifier gain is reduced, the noise is proportionally reduced as well. When the amplifier is cut off, the noise at its output is immeasurable.

Specification

Source Modules

Three Voltage Controlled Audio Waveform Generators, Sine and Ramp

Manual Frequency Range: Greater than 1Hz - 10 KHz (extendible by voltage controls in both directions — to 0.25 Hz and 20 KHz).

Sine Purity: Better than 50% total distortion between 10 Hz and 10KHz.

Ramp Output Linearity: Departure from linearity ± 1% of best straight line between 10Hz and 10KHz.

Voltage Control: 5v/octave. Accuracy 0.3% departure from best straight line between 100 and 2000 KHz.

Frequency Stability: Generally better than 2% from month to month, but the oscillators usually hold their setting to within 2 cycles in a thousand during a working session.

A sine shaper is included by which variable amounts of even harmonic distortion may be added.

Three Voltage Controlled Audio Waveform Generators, Triangle and Square.

These can be varied from triangle to sawtooth ramp, and from symmetrical square to short pulse, in either polarity.

Manual Frequency Range: Greater than 1 Hz to 10 KHz.

Triangle Symmetry: ±5% rise time to fall time equality.

Other specifications as for sine/ramp oscillator.

Three Voltage Controlled Low Frequency Waveform Generators

Same details as before, but oscillators are twenty times as slow.

Frequency range: Greater than 0.025 Hz (40 secs. per cycle) to 500 Hz.

Voltage Control: .5v/octave.

These three oscillators are intended mainly as control sources, but can be used for tone generation at the upper end of the range.

All nine of the above oscillators have synchronisation inputs so that they can operate at an integral multiple of another oscillator, providing a huge variety of waveforms which can be used in additive synthesis.

Three Noise Generators.

Variable from white (central position of colouration control) to dark or light positions (low or high pass filters).

Distortion: In white position, frequency content is flat ±3 dB from 100 Hz - 10 KHz.

We recommend several noise sources, because with different filterings more than one can be used for different purposes.

Dual Output Random Control Voltage Source

This device produces two control voltages which move abruptly from one level to another. The distribution of levels is rectangular rather than Gaussian, and the two outputs are uncorrelated in level, but synchronous in time. The mean time between changes, and the variance about that mean are manually controllable. The distribution of times is rectangular, and in common with all other time controls devices in the studio, a control range of at least 1000:1 is available.

Controls:

Amplitude Variance: Up to 2.5v symmetrically positive and negative (x2, each output separately controllable).

Time Range: From approximately 10 secs to 10 ms if no time variance is applied.

Time Variance: From equal steps to 1000:1 variance. Effect of variance control is obviously limited when time range control is at either entrance.

Treatment Modules

Three Voltage Controlled Trapezoid Generators with Integral Envelope Shapers

These devices might be described as voltage programmable four segment curve synthesizers, the output being available as two control voltages and as the modulation of an audio signal.

The basic waveform produced (at each control output) has four stages:

1 **Delay.** The output remains constant and negative for a controllable time after the generator is triggered.

2 **Attack.** The output rises to a fixed positive value at a controlled rate.

3 **On.** The output remains constant and positive for a controllable time after the completion of 'attack'.

4 **Decay.** The output falls at a controlled rate to its initial value.

In addition, there is a second output which lags behind the first by one quarter of a complete trapezoid cycle. Thus the time set for, say, 'on' in respect of output 1, becomes the time for 'attack' from output 2, and so on.

The amplitude and polarity of both outputs may be adjusted independently so that if they are summed (on the patchboard) any continuous four line function which ends at the value at which it starts may be produced. This arrangement gives an extraordinary flexible range of envelopes.

The envelope shaper portion consists of a logarithmic voltage controlled amplifier permanently connected to one of the trapezoids.

The overall control of each cycle of operation may be in a number of ways selected by a switch, having the following positions:

1 **Signal threshold.** Any signal above a certain level initiates a single cycle.

2 **Hold** sequence starts when control is positive. Decay does not start until control goes negative.

3 **Single shot** positive zero crossing initiates a single cycle.

4 **Free run.**

5 **Gated free run** positive level allows the sequence to free run. Sequence stops at the end of a cycle when level goes negative.

Panel Controls

Initial delay time	2 ms to 20 sec.
Attack time	2 ms to 20 sec.
On time	2 ms to 20 sec.
Decay time	2 ms to 20 sec.

(these parameters may also be voltage controlled over their entire range.)

Trapezoid phase 1 output level (centre zero knob)
Trapezoid phase 2 output level (centre zero knob)
Signal level control
Push button (to initiate cycle)
Trigger mode selector switch

Envelope shaper is logarithmic to within 3 dB over its 60 dB range.

Voltage control function of time parameters is ideally exponential to within 10% (of dependent parameter) over a range of 1000:1. Departure from ideal is gradual beyond these limits. This permits a single voltage applied to all inputs to compress the time scale.

Four Voltage Controlled Filter/Oscillators (Low Pass to Resonating)

Operation as a sine source.

Frequency Range:
Greater than 5 Hz–20 KHz.

Sine Purity:
Better than 3% total distortion between 10 Hz and 10 KHz.

General Noise Figure for Oscillators:
Spurious outputs not greater than 0.1%.

As filters, they are adjustable from Low Pass to Resonating Filters, covering the entire sonic range.

Frequency Range:
Greater than 5 Hz to 20 KHz.

Low Pass Position.
Cut off rate 12 dB for first octave and 18 dB per octave thereafter.

Resonator Position:
Maximum stable 'Q' factor–20.

Accuracy of Exponential Voltage Control Function:
± 1% between 100 Hz and 2000 Hz.

Note: Operation as a voltage controlled oscillator is limited by the time taken to respond to an abrupt change. Maximum slew rate is about 2 ms per octave.

Four Voltage Controlled Filter/Oscillators (High Pass to Resonating)

Similar, but complementary to Low Pass Filters.

One Octave Filter Bank

This consists of eight resonating filters, fixed-tune one octave apart, in the range 62.5 Hz–8 KHz, seperately controllable.

Two Voltage Controlled Reverberation Units

Each spring unit has two elements with delays of 35 and 40 ms.

Maximum Reverberation Time:
2.4 seconds.

Useful Frequency Range:
30 Hz–12 KHz.

Voltage Control Range:
±2v from no reverberation to maximum reverberation.

Three Voltage Controlled Slew Limiters

This device is a unity gain amplifier in which the output exactly follows the input at a rate whose maximum (slew) is defined by a control voltage. One application might be to interpose the device between the pitch control voltage from a keyboard and the oscillator whose pitch is to be controlled. If the key velocity voltage were then applied to the slew control input, the player could produce a glissando between any two notes that he played, the rate of glissando being controlled by his touch.

Steady State Gain:	1 ± 1%
Steady State Linearity:	± 0.05% (BSL)
Range of Slew Control:	1 ms to 10 sec.

Voltage control of slew is exponential.

Note: Unlike all other devices, no output level control is provided as the device has unity gain.

Three Integral Circuit Transformerless Ring Modulators

These very efficient modulators also include amplifiers, and can therefore be used in series for double or triple modulation.

Maximum Input for
Undistorted Output: 1.5v p-p to each input.
Breakthrough with 1.5v
on one input only: 5mV p-p (—60 dB)

One 256 Event, 6 Simultaneous Parameter Digital Sequencer

This machine is, in fact, a small special purpose digital computer, complete with analog to digital and digital to analog converters. It provides a sequence of control voltages which may be used on any of the devices in the studio.

The operation of the sequencer may most easily be described in terms of conventional music, although it must be remembered that the design by no means limits it to this kind of operation.

The sequencer stores 256 'notes' and plays each note at the correct time and for the correct duration. It simultaneously provides two voltages, one of which might be used to define pitch and the other loudness. It is capable of controlling three voices, each with duration, pitch and loudness. The 256 note storage may be distributed to each voice in any proportion, for instance, 254 notes may go to one voice and one each to the others. In fact, the second and third voices need not be used as such, their voltages could be used to control parameters (filtering, decay time, etc.) of the first voice.

The information which is to be stored and subsequently reproduced is presented to the machine as control voltages, which are most easily supplied from the keyboards.

All timing data is entered by playing the keys. To record a sequence the composer sets the speed of a clock and starts it running. As he plays each note, the machine at that instant records how many clock pulses have elapsed since the start of the sequence, and how many during the time that the note was held down. It simultaneously remembers which note on the keyboard was pressed and with which velocity it was struck. (The second parameter, or, indeed, the first, could equally be derived from any voltage source.) The composer continues until he has recorded perhaps sixty notes. He then restarts the clock and turns a switch which tells the machine that the next notes he plays will be directed to the second envelope shaper. While recording each sequence, he can simultaneously hear the results of what he has previously recorded.

The machine may then be set to the edit mode. In this mode the sequence may be advanced at any speed, or step by step, so that each note may be modified or erased. A special feature allows time to be *reversed*. A control rather like the spooling knob on studio tape recorders allows one to go forwards or backwards at any speed. Unlike a tape recorder, however, there is no inertia in the system, so that one can quite easily 'zero in' on a particular note.

Sequencer Controls

Ten controls are provided to adjust the amplitude of the sequencer's output voltages, and a further ten supervise the actual operation.

1 **Range of Layer 1 Output Voltage A**

This control is a slow motion dial calibrated 0-100. If Voltage A were used to control the pitch of an oscillator, then this control could be used to define the musical interval for each step of the output. At 25, for instance, a range of sixty-four quarter tones (covering about $2\frac{1}{2}$ octaves) will be available.

2 **Range of Layer 1 Output Voltage B**

The range of the second parameter for each event may similarly be adjusted with this control.

3 **Range of Layer 1 Keying Voltage**

This voltage, which is positive for the duration of each note in Layer 1, would normally be used to control the envelope shaper. It can also be used to assist in the synthesis of certain instrumental sounds. For this reason, a centre zero control is provided. This inverts the polarity of the voltage when it is counterclockwise.

4 5 and 6 are controls identical to 1 2 and 3, except that they apply to the second layer. Likewise 7, 8 and 9 which apply to the third layer.

10 **Range of 'Key 4'**

A fourth kind of event may be recorded which is similar to the three layers, except that there are no parameter control voltages available with it — just the keying voltage. It is primarily intended to stop or reset the sequencer's clock, allowing one to produce a single finite sequence or a repeating pattern. If not used for this purpose it might be used in conjunction with a slew limiter and a voltage controlled amplifier to initiate a crescendo or a number of other things.

Note that all controls, 1-10, can be adjusted after the sequence is entered, without changing the basic data.

11 **Clock Rate**

This slow motion dial is a centre zero control in a rather special sense. When it is less than halfway, the sequence runs backwards. It controls the clock rate over a range of $\pm$1000:1. That is to say, with the control near its centre position, the clock pulses occur at about 2 per second, allowing a total sequence length of over six minutes. In this case, however, the resolution in time of each event is only half a second. The control has a distinct dead space around half-way, which prevents the clock from 'drifting' during editing. A voltage proportional to the absolute clock speed is available at the control patchboard, so that it can simultaneously control all time variant parameters — envelope shapers, slew limiters and even oscillator frequencies — as the clock rate is adjusted.

12 **Note Distribution**

This control is a four way switch; it tells the machine which of the three layers is being recorded, so that on replay the voltages will appear at the appropriate output. The fourth position denotes 'Key 4' as described above.

13 **Stop at each note**

When this toggle switch is down, the sequencer clock stops at the start of each note that it reproduces.

14 **Stop at end of note**

Similar to 13, except that the sequencer stops at a time corresponding to when the key was released as the note was recorded.

These switches operate in conjunction with the note distribution switch, in that they only stop at a note in the layer defined by the latter.

The purpose of 13 and 14 is to facilitate the editing of events after a tentative sequence has been entered.

15 **Erase note button**

While this button is pressed, any notes in the layer selected by the note distribution switch which start at the time shown by the clock display, will be erased.

16 **Clear memory button.**

This is the 'bulk erase' button.

17 **Reset button**

This button sets the clock to zero, and holds it there as long as it is pressed. It does not stop the clock, it simply restarts the sequence from the beginning.

18 **Start button**

This button allows the clock counter to start or continue counting. It would be used continually during editing, to advance the sequence note by note.

19 **Stop button**

This button stops the clock from counting.

Note that 17 18 and 19 are momentary action push-buttons, not switches. They roughly correspond to the controls on a stop-watch.

When the sequencer clock is driven from pulses previously recorded on tape, or, indeed, from any external source, it will ignore them until the start button is pressed. Remote operation of the sequencer is facilitated by electrical inputs at the signal patchboard.

20 **Rewrite B, D, F**

When this switch is down, the second parameter voltages in each layer may be rewritten without disturbing the first parameter, or the event timing.

Note: In this section, 'Note' is used for musical convenience, but, it must be remembered, can be used for any parameter which has been selected.

Summary of Specification

Total storage capacity: 10,240 bits (of which 9,216 bits are normally used).

Organisation of Data

36 bit words — each word representing one event.

Start-of-event time (referred to start of sequence) 10 bits.

End-of-event time (referred to start of sequence) 10 bits.

Selection of one of three envelope shapers and one pair (out of three pairs) of digital analog converters.

Also internal functions 4 bits.

Data, for digital analog converters 2 x 6 bits.

Details of Coding

The 10 bit event time allows the start of each event to be defined to an accuracy of 1 part in 2 to the power 10 (viz. 1024). Thus, if the clock is set to a rate of, say, one hundredth pulses a second, each event may be adjusted forwards or backwards in increments of one hundredth of a second. The total sequence length would be ten seconds.

The 'end of event' time, i.e. the time at which the key is released, is similarly recorded. Thus three control signals are reproduced, each being positive during the duration of a note intended for one of the three layers of the sequence. They are available at the patchboard as switching voltages which would normally go to the supervising inputs of the envelope shapers.

Digital Analog Converters

Of the six converters, three are of accuracy appropriate to exact control of pitch on the diatonic scale. Six bits give a range of 64 notes. If greater range and/or finer resolution is required, then the output of the second converter may be added to that of the first. In this case, the player might use one keyboard to define a note on the diatonic scale, and the second to raise or lower that note by increments of one thirty-second of a tone.

The precise converters are accurate to ±0.15% (BSL). The second parameter converters are accurate to ±0.78% (BSL).

Eight Multifunction Output Amplifiers

These amplifiers are primarily intended to be the last link in the signal chain before the tape recorder or monitor, but they provide certain subsidiary functions which will make them otherwise useful. All eight are voltage controlled (0.5V per 6 dB).

Controls

Level: Slider type fader.

Pan: A knob which distributes the output to between the left and right bus, these being common to four of the eight amplifiers.

Filter: A single knob providing continuous transition between first order low pass and first order high pass.

Off Switch: Totally disconnect output from the pan control, allowing the amplifier to be used earlier in the signal chain.

Meter Switch: The meter may be used as a centre zero DC voltmeter, or as an AC level meter.

Two X-Y Joystick Controllers

These give continuous control of two parameters together, which is very useful in live performance. The control sticks have a range of 2 x ±2V DC.

Two Five Octave Dynamically Proportional Keyboards

Five octave keyboards giving precise divisions of pitch or any other controllable parameter. In the case of pitch, the range would give anything between 4 and 40 notes per octave. This is useful for microtonal work. By setting 12 notes per octave, the keyboard can be used as a normal melodic source.

A second voltage output is proportional to touch — actually the velocity with which a key is struck.

A third voltage switches positive when one or more keys are pressed. Note that the keyboard produces only one pitch voltage at any instant; when several notes are pressed, the voltage of the highest appears.

Both the pitch voltage and dynamic voltage are 'remembered', even when a key is released.

Keyboard voltage: 0.5V per octave maximum, accurate to better than 0.15% at all points.

Dynamic voltage: ±1.5V depending on key velocity. Output function was synthesized to be a compromise between a strict proportionality to velocity over a range of about 100:1, and a function that would distribute seven subjectively equal increments of playing force evenly over the output voltage range. The keyboard feels most natural when the dynamics voltage is used to control a modulator over a 40 dB range.

Eight Way Fading/Panning Console (See Multifunction Output Amplifiers)

60 x 60 Pin Matrix Patchboards (7,200 Pin Locations) These patchboards allow any input to be connected to any output by the insertion of a single cordless pin. Each output is connected to a row of sixty horizontal holes. The holes appear as a square array of 3,600 (x2) cross-points, in any of which a jack may be inserted. The jacks contain resistors so that several outputs may be mixed into a single input. All device outputs are fed to the board at a low impedance, blocking any reverse signal paths.

Two patchboards are provided, one intended for control signals and one for audio signals. A small number of interconnection patches between the patchboards are hard wired, as some signals can be used in both domains.

It is also possible to route external signals to the patchboards by using the jacks in the conventional way. All contacts, including the jacks have a surface coating of silver.

Eight AC/DC Input Amplifiers

Maximum distortion at rated inputs: 0.1%.

Input Sensitivities: Line Input: maximum 1.8V AC (rms) or ±2.5V DC.

These amplifiers convert input signals to a suitable level and impedance to feed treatment devices. The line inputs are directly coupled and are therefore suitable for both signal and low frequency or DC control inputs. Two separate microphones amplifiers are supplied, which can feed any two of the above channels.

Four External Treatment Send and Returns

Provision for sending out to external echo plates and other equipment, and returning to the Studio.

One Frequency to Voltage Converter

This device accepts inputs from a variety of sources, including acoustical instruments (via a microphone or pickup and pre-amplifier) and produces a voltage proportional to the fundamental pitch of the note played. Sophisticated analog circuitry is incorporated to remove overtones, provided that their energy constitutes no more than 90% of the total signal.

Unlike conventional frequency measuring techniques, which count the number of zero crossings of a waveform in a fixed interval of time, the converter measures the period of the signal and transforms this data to a voltage which is compatible with the other devices in the studio. The advantage of this method is that an accurate measure of the pitch can be made in a much shorter time. The output is gated into a track and hold buffer by a discriminator, which suppresses spurious outputs when the signal is dying away.

A single output control adjusts the range and polarity of the output voltage.

Two Envelope Followers

These devices produce a voltage proportional to the mean level of an audio signal. The output is passed through a second order low pass filter to remove ripple while keeping a fast response. Cut off is about 50Hz. Output amplitude is adjustable by a centre zero knob to give positive or negative excursions of up to 1 volt per 6 dB.

Items from other Manufacturers

Dawe 3000 AR/6 Digital Frequency Meter

Brief details as follows:

Crystal frequency:	100 KHz ± 0.002%
Frequency Measurement:	Range — 0-1 MHz Accuracy — ±1 digit ± crystal accuracy Gating Time — 1 ms to 10 seconds
Period Measurement:	Range — 0-300 KHz Time Units 1 10 s to 10 ms Gating Period — 1/7 to 1,000 cycles of input frequency
Time Measurement:	Range — 10 s — 10 secs (nearly four months)

Telequipment Double Beam Oscilloscope, D43R

Rack mounted double gun laboratory oscilloscope, with 6 x 8 cm display area.

Electronic Music Studios (London) Ltd. reserve the right to vary the specification and/or price of the SYNTHI 100 studio without notice, should it be necessary or desirable.

Why a Computer?

In recent years the most important single problem in designing an Electronic Music Studio has been finding a way in which reasonable complexity is achieved without an absurd proliferation of manual controls. Essentially, the problem is one of storing and manipulating data, and for a number of reasons a small computer is suited to this task.

A large quantity of information can be stored. Using a 12 bit word, the EMS configuration can store 4,000 events in the computer's core store, 32,000 events on the magnetic Disc and over a quarter of a million on each reel of magnetic tape.

There is no redundant information. 64 levels of control are adequate for most devices and EMS use 6 data bits as standard (the other 6 bits are used to specify the device). Controls, such as oscillator frequencies for which precision is required, use converters in pairs giving a resolution of 10 bits, corresponding to 0.1 semitone over the audio range, which is adequate for glissando.

The computer is fast enough for all musical requirements. When necessary, it will perform calculations during the performance without the risk of degrading the music.

Composers can do much of their preparatory work away from the studio. They can write the score as a computer program and realise it as sound very quickly when they come to the studio.

When a composer leaves the studio, all control settings are stored digitally on his own tape, and when he returns he can start from exactly where he left off regardless of who has used the studio in the meantime. This is particularly advantageous in a University studio, where many students will be allowed short periods in the studio.

A composition stored digitally does not deteriorate as an audio recording does. A piece can be re-recorded at any time from the original program.

What Equipment is needed?

A computer studio has conventional voltage controlled equipment (oscillators, filters, modulators, etc.), a Computer to control them, and an interface which converts the digital computer information to voltages for device control. In addition, programs for the computer are required, and these are referred to as the **software** of the studio: EMS provide a studio consisting of an EMS SYNTHI 100 Synthesizer; a set of digital to analogue (DAC) and analogue to digital (ADC) converters; a crystal clock; and a computer system. The system can be enlarged at any time by adding analogue or digital equipment. The equipment provided by EMS does not include tape-recorders, monitoring amplifiers or loudspeakers. EMS will negotiate a price and delivery time based on the following equipment:

EMS Synthi 100

EMS Digital Interface and Clock

PDP8 Processor, 4K Core, 32K Disc and Teletype

EMS Software

What can it do?

The Synthi 100 is a comprehensive e.m. studio by itself.

The MUSYS software provided by EMS enables compostiions to be stored, modified and performed by the computer.

Miscellaneous chores such as tuning oscillators and measuring frequency responses can be performed by the computer.

Appropriate software is provided by EMS and additional programs can be written by the user, using the DEC assembly system.

An added bonus is that several hundred programs are available free from the computer manufacturer (DEC) which enable the computer to be used for non-musical tasks such as calculation, accounting, circuit-design, or even playing games.

Why Musys?

EMS bought its first computer four years ago, and the first public appearance of the computer was in the Royal Festival Hall in January, 1968, performing "Partita for Unaccompanied Computer" by Peter Zinovieff. Later in the same year, the system was the most spectacular exhibit at the Cybernetic Serendipity exhibition at the ICA, where it improvised and accompanied melodies whistled to it by visitors. At this time, each piece realised in the studio required a separate program, and it became apparant that each program had many things in common which could be incorporated into a single generalised program. Peter Grogono proposed that a translation program should be available to relieve the composer of the task of writing down long strings of numbers, and designed MUSYS. MUSYS 1 and MUSYS 2 were both short-lived, but they provided valuable experience and led to MUSYS 3 which was completed in early 1970 and is still the principal program used. The first two compositions which used MUSYS 3 were "Medusa" by Harrison Birtwistle and "A Lollipop for Papa" (variations on a sonata by Hadyn) by Peter Zinovieff, and the language was taught to fifteen musicians who attended the BSEM course at Putney in June 1970. Since then, MUSYS 4 has been written to control the studio's Filter Bank, and MUSYS 5 is being prepared for Autumn 1971 to allow larger compositions to be realised in one piece.

How is it used?

The system can be used as a Sequencer, in which case no programming is necessary: the Digital Interface has controls which permit data for each device in the SYNTHI 100 to be stored, examined, altered and played back. Alternatively, MUSYS 3 can be used, in which case the composer writes a program which constitutes the "score" of his piece. Very short "scores" may be typed directly on the computer's typewriter, but this technique is normally used only to try out ideas or test the devices. The score is **compiled** by the MUSYS Compiler, a program which translates the composer's

◀ *This photograph shows the original computer studio in Putney. The computer and its typewriter are at the left hand side and the Digital Interface is on the fourth equipment rack, underneath the oscilloscope. In this studio the computer is used to control devices in the centre racks which were built before the SYNTHI.*

score into a string of numbers for delivery to the SYNTHI 100. At each step, the process can be closely controlled by the composer or interpreter, using both hardware and software.

The requirements for a programming language for a system of this kind are simplicity, efficiency and flexibility; EMS feel that MUSYS meets these requirements adequately. In a MUSYS score, the "instruments" are given abbreviated names, so that, for example, 02., E3., F7., refer to Oscillator 2, Envelope Shaper 3 and Filter 7 respectively. In the simplest case, data is sent to a device simply by writing a number after the device name — 02.15., F7. 30., etc. The effect of the number depends on the device — for an oscillator it represents a pitch, for an Envelope Shaper the length of Attack or Decay, and so on. Arithmetic and algebra are possible, using letters to denote variables; these have an obvious use in compositions of a mathematical nature, but are also necessary for quite mundane tasks, such as transposition, repetition, calculating rests, etc. MUSYS also has structural facilities, allowing any sound or group of sounds to be given a name, and subsequently referred to by that name. This means that scores can use as much conventional terminology as the composer desires. For example, a crescendo can be called CRESC and a glissando called GLISS. There are six simultaneous systems, each with its own time control, so it is not necessary to work out time interrelationships for complex rhythms. There is a random number program which generates randomly distributed numbers in a repeatable sequence, which is useful in aleatoric composition.

The studio can be used immediately, without learning MUSYS, since the computer can be used simply as a large sequencer.

However, a unique advantage offered by the studio is programmed scoring, and for this it is necessary to learn MUSYS. The course given last year demonstrated that composers without previous knowledge of programming do not find MUSYS a difficult language to learn. EMS offer free courses in MUSYS hardware and software, each lasting one week, to purchasers of computer studios, and the computer manufacturers offer courses in computer programming.

What Software does EMS provide?

If you buy a computer studio from EMS, all the currently available EMS software and documentation is given to you as part of the studio. New programs and program enhancements will also be issued free for a minimum period of two years from the date when the studio is commissioned. In addition, as the owner of a PDP8 computer, you are entitled to all software issued by DEC, and to membership of DECUS, the DEC Users Society which issues information about new and improved sofeware. EMS will also act as a pool for programs written by owners of EMS computer studios, so you will receive software written by other users, and may contribute your own to the pool. Complete pieces will also be pooled by EMS and made available to other users, copyright permitting.

If you do not buy an EMS computer studio, you may purchase programs and documentation from EMS at the listed prices. EMS will not maintain programs run on machines they did not provide.

Specifications

Synthi 100

The SYNTHI 100 is described fully in the first half of this brochure. It contains the voltage controlled analogue equipment of the studio: the outputs are at line level for feeding to amplifiers or tape recorders.

The devices included are these:

6 sine/ramp oscillators
6 square/triangle oscillators
2 coloured noise generators
8 swept filters
3 envelope shapers
3 ring-modulators
1 random voltage generator
2 envelope followers
1 pitch-voltage converter
3 slew-limiters
8 input amplifiers
8 output amplifiers (8 line outputs, 4 panel outputs)
1 octave filter bank
6 track, 256 event Sequencer and Clock
2 keyboards

The SYNTHI 100 has a patching matrix for signals and a patching matrix for control voltages, each 60 x 60; when used with a computer, the 60 control inputs are provided by the Digital Interface.

The Digital Interface

The Digital Interface has 64 6-bit DACS and 4 6-bit ADCs; the digital to analogue converters enable the computer to control all of the SYNTHI 100 devices, of which 4 have high precision (10 bit) control, and the ADCs enable the analogue equipment to signal the computer, for cueing, etc. It also contains a clock, which can be controlled by a crystal oscillator, by an external oscillator, or manually. The external oscillator is usually a prerecorded pulse train on one track of a multitrack tape, permitting exact synchronisation between tracks in a piece which is realised in several passes, and manual control is used in editing and correction.

The Digital Interface has a number of illuminated push-buttons which enable any device to be selected and controlled manually, and entire pieces can be constructed on it by using the Sequencer program and Keyboards. When using MUSYS, the manual controls are used for monitoring and making detailed changes, large scale changes being done in terms of the original score.

The Computer

The basic configuration as provided by EMS enables scores of up to 6,000 characters to be compiled, and the composition may have up to 20,000 events. Longer compositions can be realised in several sections. The clock has a maximum rate of 400 Hz, giving time discrimination to 2.5 msec which is adequate for musical applications. The basic software comprises a Text Editor, for the preparation and correction of the MUSYS scores, a Compiler, which translates the scores into lists of numbers to the devices under the control of the clock. There is also a program called Sequencer, which simply uses the storage units of the computer to store data provided by the SYNTHI 100 (from the keyboards, for example).