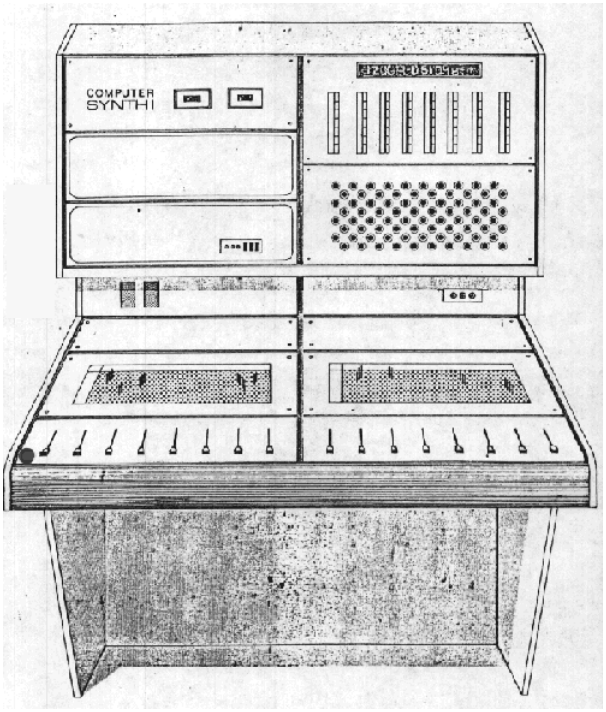
EMS Computer Synthi



EMS Computer Synthi

- Construction
  - The Computer Synthi is constructed in a wooden cabinet similar to one half of the Synthi 100. However, the units which make up the Computer Synthi are housed in individual 19 rack mounting cases, facilitating their removal for transportation or installation in the purchasers own housing. An optional stand is available to match that available for the Synthi 100.
    The rack mounting cases which make up the unit are:-
  - 1. One, optionally two, digital tape decks mounted at the top left of the front panel.
  - 2. An alpha-numeric display, user push buttons, and a digital oscillator mounted at the top right of the front panel.
  - 3. Analogue to digital converters and digital to analogue converters both with software, range and offset controls - mounted at the bottom right of the front panel.
  - 4. Input/output plugs and sockets mounted in cable trough.
  - 5. Input and output patch panels, together with manual slider controls. Mounted in a similar position to the Synthi 100 patch panels.
  - 6. The PDP/8A computer mounted at the bottom left of the front panel.

- Tape decks
  - Type: Single (optionally dual) AJ7OO high speed (12 IPS) bi-directional cassette deck(s) with automatic cassette re-wind and reject.
  - Cassettes: Philips style digital cassettes certified for 800 bits per inch. (Audio type cassettes are not suitable and may damage the tape heads). Digital cassettes cost approximately UK pnd 5.
  - Record block size: 256, 12 bit words (16 bit words are actually written but four of these are used for error checking and recovery).
  - Cassette capacity: 512 blocks. (Giving approximately 65,000 events per cassette).
  - Transfer rate: 590 mSec per block including start and stop times.
  - Operating restrictions: None. Hardware protection is provided, guaranteeing correct operation under all conditions.
  - Directory: The first and last block of each cassette contains the users name: titles of the pieces on the tape, dates of creation and modification and status i.e. file copy, composers copy, write project, blank tape, amount of remaininy space, etc.
  - High speed bi-directional drive with short (.035 mSec) start and stop times and all digital read synchronisation allow a transfer rate of 600 12-bit words per second using the computer interupt system. The tape may be read in either direction reducing wind time, read after write verification of recorded data is standard thus halving the time required to write data on tape.

- Alpha-nummeric display
  - A 16 position light emitting diode seven segment display with a character height of I5mm (.6 inches) is provided for communication from the computer to the user. It is capable of using the following characters:
  - Ol 23456789ABCDEFGHIJLNOPRSUYZ ! " '( ) = - ? /
  - All the computer messages have been structured to use only this character set. Users wishing to convert the computer output to another language will find synonyms are nearly always available to avoid the illegal characters.

- Push buttons
  - 64 push buttons are provided, the depression of one of which will send a unique six bit code to the computer. This code is then used to initiate or modify some action of the machine, or to feed in numeric or alphabetic data. These push buttons are connected to the computer interupt system.

- Oscillator/clock
  - A digital clock whose frequency is programmable over the range 16Hz to 8MHz with a resolution of better than 1/230th of a semitone between 16Hz and 8kHz forms the central timing and frequency reference for the digital and analogue parts of the system. The Computer defines the frequency which is governed by a crystal oscillator of 10 parts per million accuracy and stability. A variable square wave at the oscillators' frequency is available at the patch panel and at a cannon type connector in the cable trough. This signal may be used to tune external analogue oscillators, or may be recorded as a combined synchronisation track and start mark on an audio tape recorder.
  - The Computer may gain its time reference either directly from the digital oscillator or may be instructed by the user to utilise a previously recorded timing track via an input cannon plug.

- Analogue to Digital Converters (ADC's)
  - SYSTEM: Multiple comparator single ADC type. A synchronous sampling under computer control is used: see Speed. All inputs are fitted with hardware, new voltage detectors (NVDS) which may be instructed by the computer to produce interupts when an input level changes.
  - RESOLUTION: 12 bits guaranteed monotonic over complete range.
  - LINEARITY: Better than .025% over full temperature range.
  - NPUTS: 20 from patch panel, optionally 24.
  - RANGE: A virtual earth input system is used on the patch panel. The range of the ADC may be adjusted by means of individual software range and offset controls for each input to cover any part of the scale -0.2 MA to +0.2 MA. The settings of these controls may be stored on tape and recalled when the system is next used thus removing the need to set up the ADCs by hand for each use. The Computer can detect tne presence of input overloads and pass a warning to the user, though electrically no damage will occur if this is ignored.
  - SPEED: 44 uSec (optionally 24 uSec) per 12 bit word. Because the Computer selects which ADC input is to be sampled next, the user may dictate any number of inputs to be used. For one input, a sampling rate of 22kHz is available giving a bandwidth of 10kHz, while for all inputs used a sampling rate for each input of 1kHz may be attained yielding a bandwidth of 400Hz.
  - KEY VOLTAGES: Any or all inputs may be used as key voltages due to hardware new pitch detectors, thus allowing all twenty inputs to be used as control voltage inputs if desired.

- Digital to Analogue Converters
  - SYSTEM: Multiple digital comparator and binary reversed counter type. No analogue demultiplexers or sample and holds are used, thus no output drift or sag is experienced.
  - RESOLUTION: 12 bits guaranteed monotonic over full temperature range.
  - LINEARITY: Better than .025%
  - OUTPUTS: 20 to patch panel, plus one spare for user connection. Three optional outputs may be added giving 24 total outputs.
  - RANGE: Any section within limits +2V to -2V, offset and gain adjustable by individual software controls for each output.
  - SPEED: Settles to .025% of full scale range as adjusted in ImSec. A 3-pole Butterworth low pass filter of 1kHz bandwidth is attached to the output of each DAC.
  - SEQUENCE: Each DAC may be updated at any time regardless of previous or subsequent updating of any DAC.

- INPUT/OUTPUT CONNECTIONS
  - MAIN OUT: 71-way Plessey connector (socket) as fitted to Synthi 100, mating lead to fit Synthi 100 supplied, length l.5m (4.5 ft). Longer lead supplied at extra cost.
  - MAIN IN: 71-way Plessey connector (plug) similar lead and facilities as for main out.
  - OSCILLATOR OUT: 3-pole cannot socket.
  - CLOCK IN: 3-pole cannon plug.
  - OPTIONS: 71-way leads may be supplied with one free end for non-Synthi 100 users, specify on order. Buffered digital inputs and outputs may be supplied by negotiation - consult EMS first.'

- PATCH PANELS
  - INPUT: 61 outputs from Synthi 100 control patch panel, or external devices, feed 20 ADC's and one clock input. Panel size: 61 x 21.
  - OUTPUT: 20 DAC outputs and 1 oscillator output feed 61 Synthi 100 control patch panel inputs. Panel size: 21 x 61.

- SLIDERS
  - 16 slider potentiometers feed 16 ADC inputs. A dead band is provided at each end of slider travel so that all codes may be generated. Computer has provision for anti-dither and movement detection routines. As with push buttons, a space is available for the insertion of permanent or temporary labelling.

- COMPUTER
  - Digital Equipment Corporation PDP8/A minicomputer.
  - MINIMUM SYSTEM:
  - KK8 -A Central processor
  - MS8-A 4096 word 12 bit memory
  - KM8-A Power fail/auto-restart, Memory extension control, Time-share control, Bootstrap loader
  - H763 Power supply
    - MUSYS SYSTEM:
    - KK8-A
    - M58-A x2 L.E. 8192 word 12 bit memory
    - KM8-A
    - H763
    - DKC8-AA Serial line unit, Parallel 1/0,Real time clock, Programmer's console control
    - Plus external to the Synthi Computer cabinet alpha-numeric terminal with print-out suggest VT5O DECtape of disc to give a DEC system capable of running 0S8 version 3.

- MECHANICAL AND ELECTRICAL DATA

- INTERNAL POWER SUPPLY: +5V, +15V and -15V
- POWER SUPPLY: 95-130V/190-260V, 47-63 Hz, 4A/2A 660W. From three pole mains socket
- TEMPERATURE: 0-55C I 32-121F
- HUMIDITY: Relative humidity 20-90% without condensation
- WEIGHT: 51.7 kg (114 lb)
- RELIABILITY: Computer 8000 hrs MTBF; Interface (including tape decks) 4000 hrs MTBF
- VENTILATION AND NOISE: The PDP8/A computer contains silent running ventilation fans and a slight level of residual noise is unavoidable.

- BASIC SOFTWARE
  - The Synthi Computer is expected to have many issues of software. Most of the programs listed here will be issued at the time of delivery of the first machines. However, any routines listed and notprovidedwith the first machines will be released with subsequent deliveries together with programs that will be developed at later stages.
  - The term Basic Software is intended to describe all EMS supplied software other than the MUSYS system (which requires an expanded computer as detailed in the description).

- Sequence
  - This program allows the user to store up to 24 (depending on number of ADC/DAC channels available) layers of independently times control voltages, either simultaneously or sequentially. Replay of a stored sequence is handled by this program when required.

- Editor
  - This program allows the user to edit a sequence on tape or the computer's memory, which can store 1024 events at one time without use of cassette tapes. Edit modes are:
  - Delete: Removes part of sequence and joins the gap, so that no silence is inserted where the removed part was.
  - Erase: Removes part of sequence leavling silence in its place.
  - Insert: Puts a piece of a sequence layer, or new data entered through the ADC's, between two notes in an old sequence layer pushing the two notes to make room.
  - Overlay: Places part of a sequence layer or new data instead of part of a previously recorded layer. Erases what was there before
  - Prefix: Places part or all of a sequence layer or output before an existing sequence layer. Pushes existing layer in time to make room.
  - Superimpose: Places part or all of a layer or input on top of an existing layer, so that both new and old notes now form part of the existing single layer.
  - Repeat N: Repeats part of all of a layer N times.
  - Time Invert: Reverses temporarily part or all of a layer.
  - Other facilities will probably be added to Editor before the delivery of the first machines.

- Modify
  - This program allows the user to modify the time and voltage scale of stored layers.
  - V Expand Voltage range of output increased under user control.
  - V Contract: Voltage of output decreased under user control
  - V Shift: A user selected amount of DC shift is added to layer.
  - V Invert: Inverts voltage range of layer about its centre.
  - T Expand: Increases length of layer under user control.
  - T Contract: Decreases length of layer under user control.
  - T Shift: Moves layer backwards or forwards in the time by user variable amount.
  - T Invert: Same as Time Invert under Editor.
  - Control Method The user control in each of these functions may be a slider, an ADC input or a number entered by the push buttons.

- Key in
  - This program allows the user to replace any or all AD,C inputs when recording a sequence by punching in on the push buttons the time and voltage values he wishes to enter.

- Linearise
  - This program, applicable to voltage control keyboard entry only, provides for the computer to compensate for any non-linearity in a users analogue keyboard. It requires, at initial setting up, that each of the keyboards notes is played once in an ascending order so that the computer can calculate an internal correction table for that particular keyboard. In subsequent use the user need only inform the computer, via the push buttons, which of his keyboards is connected to which ADC.

- Tune
  - This program, similar to Linearise, performs the same function for analogue oscillators. To initialise the user connects a DAC to the voltage control input of a VCO, and the VCO output to an ADC, he or she then informs the computer via the push buttons which ADC, DAC and oscillator are being used. The computer then calculates a correction table fo voltage against frequency for that oscillator, using the crystal controlled digital oscillator as its accurate frequency source. In subsequent use, the user informs the computer which oscillator is connected to which DAC, then the computer uses the previous correction table to linearise the VCO voltage/frequency characteristic.

- View
  - A series of routines to allow the user to see what is in the computer and tape. Layer: Shows which layers contain data. Volts: Displays maximum and minimum voltage levels on a layer. Time: Displays start and end times of a layer. Labels: Displays labels found on a layer (see program Label). Event Count: Displays number of events on a layer. Event Time: Displays time of last executed event. Event Volts: Displays voltage of last event. Store: Displays amount of tape storage remaining. Date: Displays date of creating of tape. User: Displays name of user of cassettes on both tape decks. All the above routines use the alpha-numeric display as their mthod of communication to the user.

- Re-cycle
  - Allows the user to replay continuously part or all of the 1024 events in core memory at a controlled rate for editing or correction of data.

- Label
  - Allows the user to label either an event on a particular layer, or a particular time with any alpha-numeric name of six characters or less.

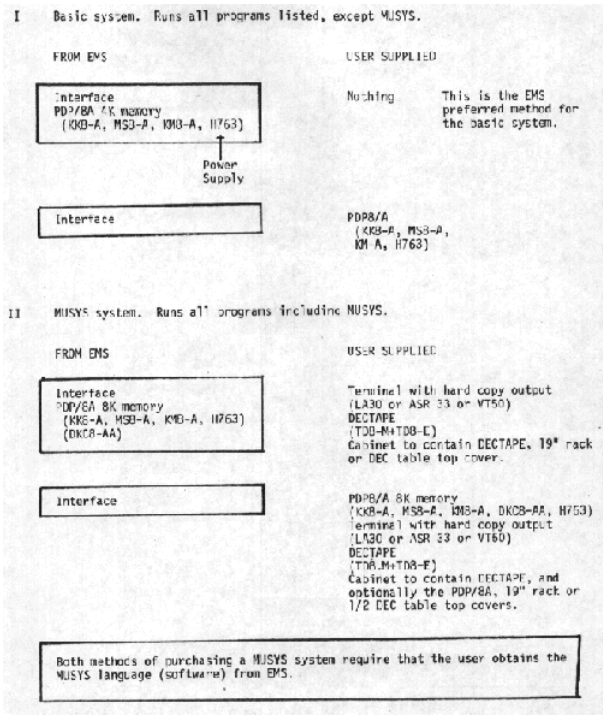
- Search
  - Allows the user to search backwards or forviards through his sequence, or an individual layer, for a particular label, voltage time or event count.

- Transfer
  - Allows the transfer layers or sequences between cassettes so that a library of sequences may be built on one tape, from small parts held on many cassettes.

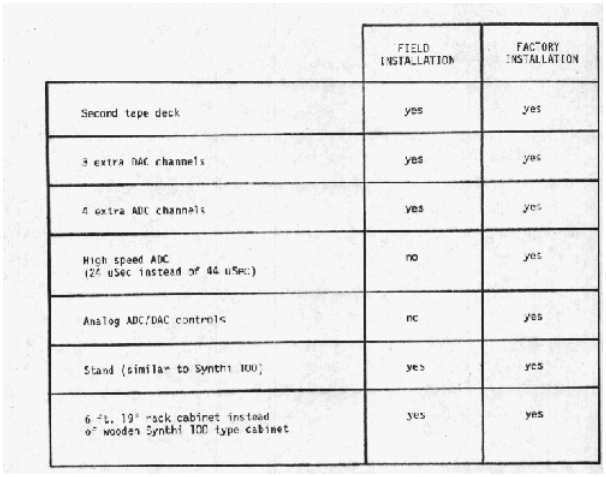
- Instruct
  - Allows the user to prefix a piece of free form alpha-numeric data, patch instructions synthesizer knob settings etc., to aid the replay of the piece at a later date.

- Handlers for the interface devices will be supplied in PDP8 machine code for those users who wish to write their own programs. It is hoped that users will contribute programs and operating suggestions to a central file to be held at EMS for distribution to all Computer Synthi users on a regular basis at duplication and postage cost. Those users who wish to contribute to this important aspect of the Computer Synthi will be greatly appreciated, by both EMS and their fellow users.

Basic/Musys system



Computer Synthi Options



	FIELD INSTALLATION	FACTORY INSTALLATION
Second tape deck	yes	yes
3 extra DAC channels	yes	yes
4 extra ADC channels	yes	yes
High speed ADC (28 uSec instead of 44 uSec)	no	yes
Analog ADC/DAC controls	no	yes
Stand (similar to Synthi 100)	yes	yes
6 ft. 19" rack cabinet instead of wooden Synthi 100 type cabinet	yes	yes

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IMPROVEMENTS TO THE ORIGINAL SPECIFICATION

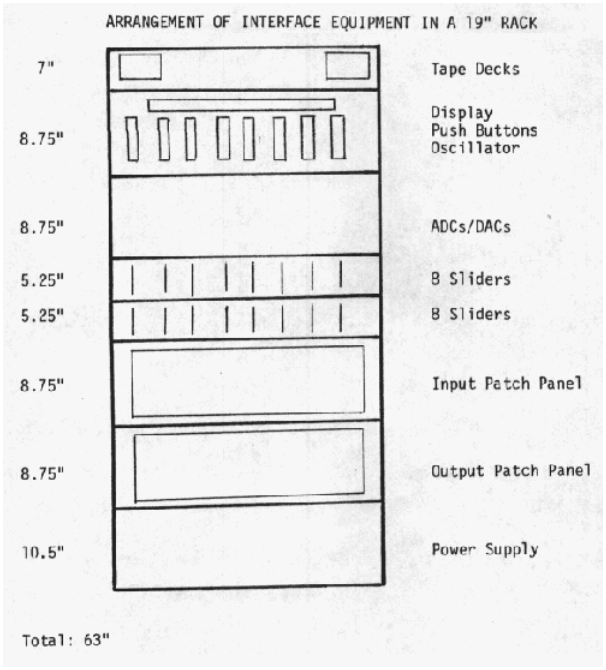
The front page illustration shows the wooden cabinet in which the Digital Equipment Corporation PDP8/A and the EMS produced rack mounting cases are normally supplied.

- Also shown are the following options:-
  - Matching stand (similar to that available for the Synthi 100).
  - Extra high speed b-directional cassette deck.
  - Analogue (non-computer controllable) ADC and DAC offset and range controls.

IMPROVEMENTS TO THE ORIGINAL SPECIFICATION

- TAPES: The Memodyne model 98 incremental tape decks previously specified have been found to be slow for the program facilities required by a real time music system. These have been replaced by AJ7OO high speed (30.5 cm/sec read or write 230 cm/sec search) bi-directional decks with fast start/stop times of 0.035 sec, and dual gap read after write heads to allow for high speed verification of data written on tape. The improved performance of these decks has allowed us to use only a single tape deck for all the facilities planned. This also reduces tape cost to the user by 75%, Since only one cassette is required per piece of music and each cassette may be used on both sides, unlike the original decks which wrote on the full width of the tape. Data transfer rate has been nearly quadrupled, from one 128 word block in 9OOmSec, to one 256 word block in 480 mSec. Capacity is also increased from 43000 events per cassette to 65000 events per cassette. The operating restrictions present with the original decks have been removed (the need to manually initiate the rewind of cassettes). Since the AJ7OO exercises complete automatic control of cassette ejection, solenoide interlocks prevent the removal of the cassette until the computer has accepted commands to finish, or suspend the present job. The ability is retained to adda second tape deck, either at the time of manufacture or as a field installed option at a later date.
- CABINET: The original position of the computer (in the pedestal of a single width cabinet) was thought ot be inadvisable for ease of servicing and later expansion of the Computer system. Also on the grounds~of future expansion of the interface equipment and possible heat build-up, it was decided to allow at least a further 26cms of spare mounting space. To this end the cabinet has been changed to a double width configuration (similar to one half of a Synthi 100). To maintain complete visual similarity with a Synthi 100 a stand is available as an optional extra to complete the package.
- ADC/DAC SYSTEM: Several improvements have been made:
  - 1. One extra DAC is provided as standard, bringing the total to 21. Physical provision and digital storage is provided for a further 3 DAC channels which may be added either at the time of ordering or as a field installed option.y
  - 2. Provision is made for the addition of a further 4 ADC channels, either during manufacture or in the field.
  - 3. The increased ADC/DAC capability is fully supported by extended software to handle 24 ADC and DAC channels. The original 8 layers provided for in the program has been extended to 31 allowing each input/output combination to be placed on a separate layer.
  - 4. Each input channel is further equipped with a hardware New Voltage Detector, linked to the interupt system of the computer. This considerably reduces the time spent by the computer polling round the inputs waiting for a new event to occur. Each cannel of NVD (New Voltage Detector) may be individually enabled or disabled.
  - 5. The analogue offset and range controls on each ADC/DAC have been replaced by digital controls built into the software of the computer, utilising the push buttons and sliders. The tedious adjustment of 80 knobs is thus no longer needed since the range and offset required for each ADC/DAC used by a piece may be stored with the rest of the data on the cassette tape, for recall at any later time without manual effort. To this end the nominal range of the ADCs and DACs is referenced to +2V. This is completely compatible with the Synthi 100. However, for users of other machines, variable outputs in the range +lOV with analogue adjustments are available as a factory installed option. The provision of this option in the field involves the removal of components from 12 cards as well as extensive back plane modifications and is not recommended.
  - 6. 1kHz three pole Butterworth filters are provided on all DAC outputs to prevent ailiasing due to the computer sampling rate.

Interface Equipment



Music V on EMS Systems

- MUSIC V is accepted as a standard language for computer music.
- MUSIC V is also a method of digital waveform synthesis used to implement this language.
- MUSIC V was developed by Max Mathews at Bell Laboratories, New Jersey and is a FORTRAN-based version of the earlier MUSIC IV. It is widely used in North America and some places in Europe. It is well suited to complex sound synthesis such as Chowning's work on frequency modulation.
- MUSIC V language can also be realised on hybrid computer music systems such as the EMS computer controlled digital studio, the Computer Synthi and the Synthi 100.

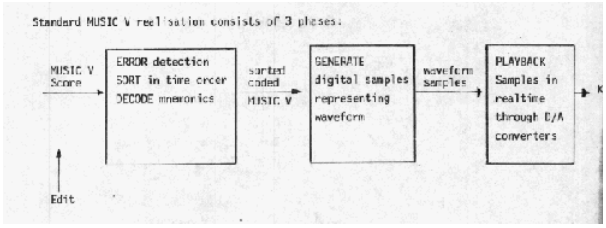
EMS has started to implement both these methods. Compare our approach with standard MUSIC V implementation.

Hybrid/Waveform

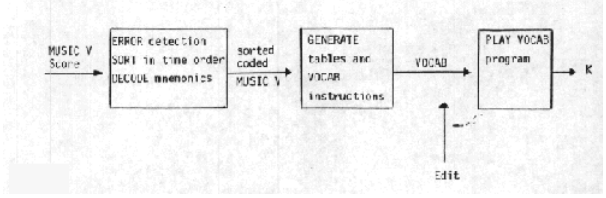
	HYBRID SYSTEM		WAVEFORM SYNTHESIS
	Advantages		*Disadvantages*
a.	Comparatively little computer time needed	a.	Expensive of computer time
b.	Runs on small computer and synthesis hardware	b.	Requires a large computer
c.	No second system	c.	Usually needs second system to control playback
d.	Rapid response	d.	Usually slow turn round
e.	Object code can be edited without recompilation	e.	Waveform output cannot be edited
f.	Low quality D/A converters sufficient	f.	High quality D/A converters needed
	Disadvantages		*Advantages*
a.	Resources limited by synthesizer.	a.	No limit to resources
b.	Subject to synthesizer performance.	b.	Independent of synthesizer hardware

Standard Music V realisation consists of 3 phases:

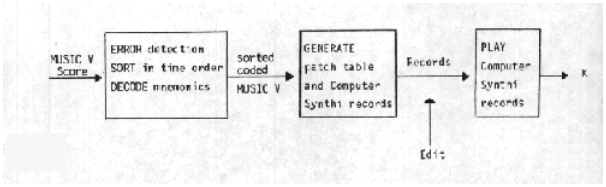
Music V Phase I



Music V Phase II



Music V Phase III



EMS will thus be offering the most widely accepted music language in a form that will be much less expensive to run and more interactive than waveform synthesis

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