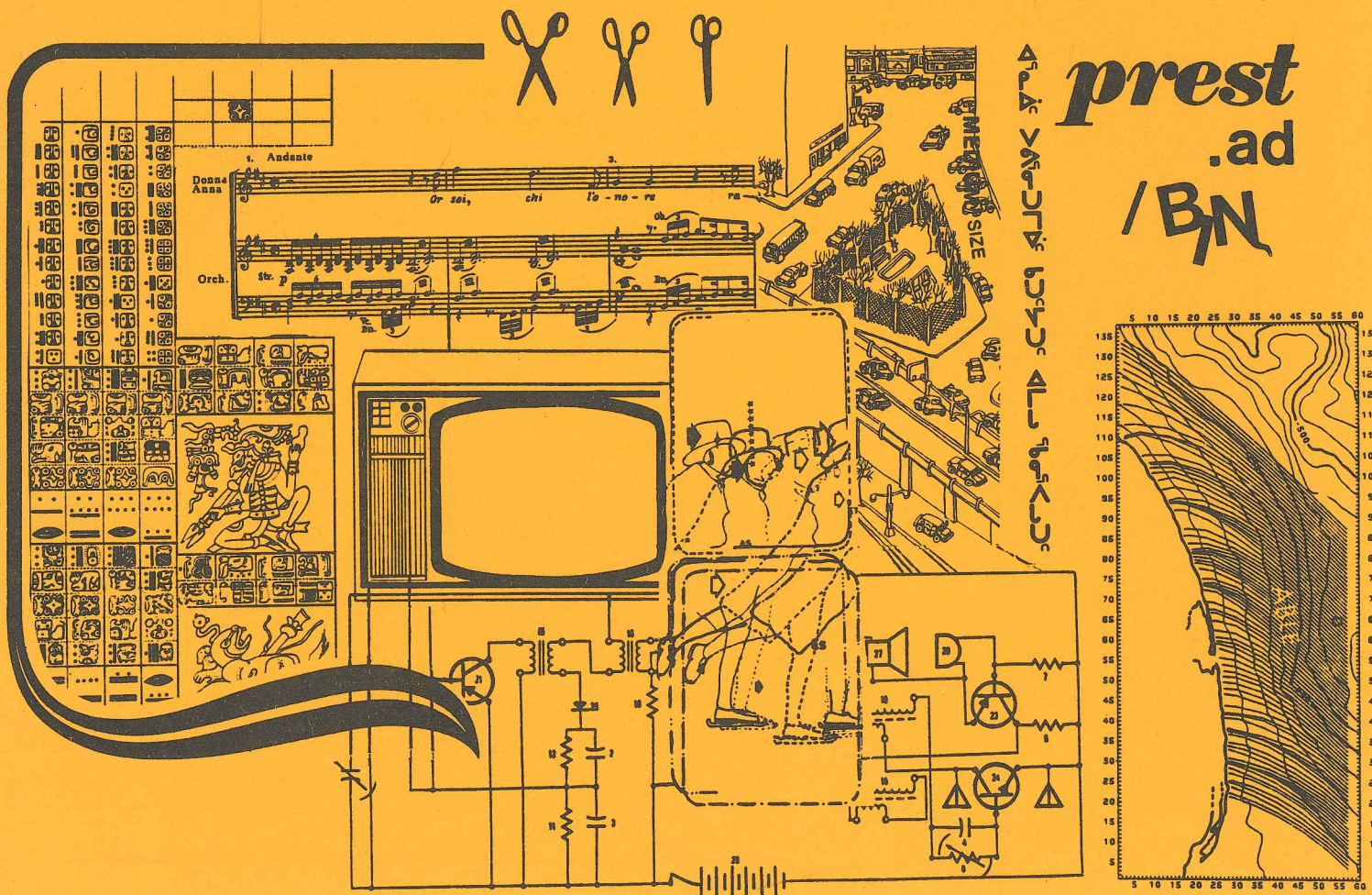


THE LANGUAGE OF COMPUTER MUSIC

David Huron



THE LANGUAGE OF
COMPUTER MUSIC :
A GLOSSARY OF TERMS

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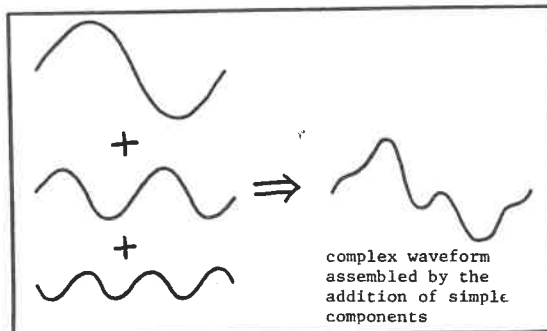
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ADC

See **analog-to-digital converter**.

additive synthesis

A **sound synthesis** technique in which complex sounds are assembled through the addition of simple **sinusoidal** (pure tone) components. Very often these components are **harmonically related** (i.e. have frequencies with large common divisors), however additive synthesis may instead employ non-harmonically-related components or **pseudo-harmonic** components. If **amplitude**, **frequency**, and/or **phase parameters** are varied during the process of additively synthesizing tones, the technique is called **time-variant additive synthesis**. At present, when coupled with **Fourier analysis**, time-variant additive synthesis is the most general-purpose method of sound synthesis -- capable of convincingly recreating most natural sounds. (Time-variant additive synthesis is also one of the most computationally inefficient synthesis methods.) See also **synthesis**, **piecewise-linear additive synthesis**, **complex tone**, **waveform**.



address

Computer data is stored and accessed in various locations in memory. Like houses arranged on a street, data is referenced according to sequential addresses. Consideration of the arrangement of data storage and access is referred to as "addressing". See also **table lookup oscillator**.

AI

See **artificial intelligence**.

ALGOL

A structured programming language originally employed as a language simply for publication of **algorithms** rather than as a computer programming language per se. ALGOL is sometimes used in music analysis applications.

Algorithm

A recipe for doing something; any set of instructions which completely describes an operation or process -- the only restriction being that each instruction is unambiguously understood by the entity following the algorithm.

aliasing

To assume another name or identity. In signal processing, **aliasing** is a general term referring to any unintentional transformation of one entity into another. The most common form of aliasing is the transformation of one frequency into another frequency, called **spectral aliasing**.

allocation algorithm

Software designed to efficiently allocate tasks to a limited number of real devices. In **real-time** computer **sound synthesis** systems a major problem arises when the number or complexity of musical tasks exceeds the available computing power. This problem may arise in both real-time **software-dominated** systems and in real-time **hybrid** configurations which employ a necessarily finite number of dedicated task devices (such as digital or analog oscillators, amplifiers, etc.). This problem does not exist in **non-real-time** sound synthesis systems as increased task complexity can usually be offset by increased calculation time. A good allocation scheme will order concurrent task requests according to a priority which reflects the relative perceptual importance of each task. When resources are scarce, the allocation algorithm will decide how some tasks of lesser importance may be combined into a single simple process, or abandoned altogether. Several types of trade-offs may occur depending upon the specific configuration of the sound synthesis system. For example, timbral complexity may be exchanged for an increase in the number of simultaneous **voices** or parts; or detailed sound envelopes might be sacrificed in order to permit the control of spacial trajectories of sounds. A finely tuned allocation algorithm can substantially increase the musical utility of most fixed-resources hardware configurations.

all-pass filter

A **filter** which passes all frequencies equally but produces a time delay or shift in **phase**.

ALMA

Alphanumeric Language for Music Analysis. An **encoding language** for translating musical scores into a computer-readable format, developed by Murray Gould and George Logemann in 1966. ALMA was developed as an extended version of Barry Brook's SPEC, and has been intended primarily for stylistic and structural analysis of musical scores. (Gould & Logemann, in Musicology and the Computer, B.S. Brook, editor; City Univ. of New York Press, -1970, pp. 57-90)

AM

Initialism for **amplitude modulation**.

amanuensis

(Pronounced: a-man-u-wen-sis.) Any program which 'takes musical dictation' -- that is, which derives musical score information by attending to some musical performance activity. Usually amanuensis programs transcribe into musical notation from information gathered through a computer-monitored keyboard performance. More sophisticated amanuensis programs have attempted to transcribe directly from the sound pressure function itself. See also Mockingbird. (Raskin, Byte Magazine, Vol. 5, No. 5 (1980) pp. 120-128)

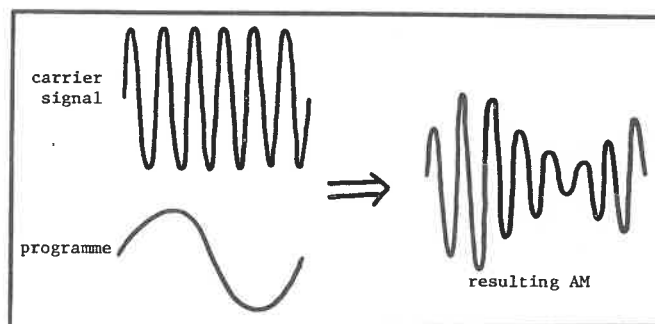
amplitude

The magnitude or strength of a **signal**. Amplitude is the degree of excursion about an average or equilibrium value exhibited by some oscillating quantity. For a vibrating object, amplitude may be expressed in terms of the velocity of the object in space, or the pressure it exerts, or other physical quantity. For electrical

vibrations, amplitude is usually expressed in terms of voltage or current. Amplitude is commonly measured by one of three methods:

- 1) the difference between the maximum excursion and the equilibrium point ('peak amplitude')
- 2) the difference between the maximum positive and maximum negative points of excursion ('peak-to-peak amplitude')
- and 3) the standard deviation of all values ('RMS amplitude')

For signals of audible frequency, amplitude corresponds roughly with our perception of **loudness**.



amplitude modulation

(Initialism: AM) The varying of the **amplitude** of a **signal**, usually repetitively. When the rate of variation or modulation is very fast (as is possible electronically) associated frequencies called **sidebands** are generated. The sound source is called the carrier signal while the modulating signal is called the programme. Amplitude modulation at audio frequencies is sometimes employed in computer **sound synthesis** in order to create complex **timbres**.

analog

Literally "analogous" -- that is, a direct correspondence exists between two entities. Traditionally, the term analog is used interchangeably with **continuous** which has a subtle meaning: between any two points within a given domain (e.g. space, time, colour, voltage, pressure, etc.) there exists an infinite number of other points or conditions or gradations. Analog is employed in contrast to **digital**. See also **continuous**, **discrete**.

analog-to-digital converter

(Initialism: ADC). An electronic device which periodically measures the voltage of a given varying **signal**, and places a binary number representing that measure in a specific memory register which a computer may then retrieve. Analog-to-digital converters are commonly used in computer music applications to permit the recording of external sounds or to monitor analog control information. See also **analog, digital, continuous, discrete, digital sound recording and reproduction, sampling**

anti-aliasing filter

A **low-pass filter** inserted in the **analog** input stream during **digital sound recording** in order to block **signals** greater in **frequency** than the Nyquist frequency and thus prevent a type of noise called **spectral aliasing**. See also **digital sound recording and reproduction, foldover**.

ANON

A music **encoding language** for translating musical scores into a computer-readable format used at the Eastman School of Music by Stefan Kostka. (Kostka, PhD dissertation, Univ. of Wisconsin -1969)

artificial intelligence

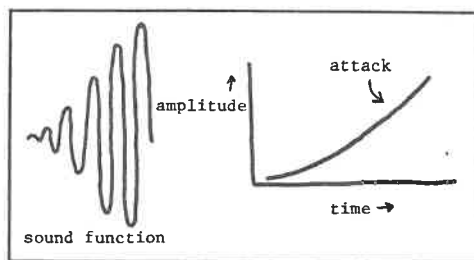
(Abbreviated AI.) The study of computer activities which appear (or are) "intelligent", e.g. learning, pattern recognition, natural language translation, etc. In musical applications, artificial intelligence addresses two primary questions: what is musical intelligence? and, what is the creative role of machines in music, if any?

assembler

A simple form of **compiler** which changes a symbolic language into a conventional machine language and hence frees the programmer from cumbersome numerical coding. In general, one assembler instruction corresponds to one machine instruction.

attack

The rising of **amplitude** with respect to time as a sound source begins to emit sound. The attack is considered a component of the **onset** portion of a sound **envelope**. Attack times of 30-100 **milliseconds** (thousands of a second) are very percussive; shorter attack times often produce accompanying **clicks**. Attack times of 100-400 milliseconds are moderate, while attack times greater than 400 milliseconds are perceived as sluggish.



attenuate

To lessen; especially to lessen the **amplitude** of a **signal**. When audio signals are attenuated, typically a decrease in **loudness** occurs, however attenuation need not always affect loudness -- for example, the attenuation of a **vibrato** control signal will result in a lessening of the 'depth' of vibrato.

audio frequency

Any **frequency** audible to the human ear. The range of audio frequencies is usually considered to lie in the region of 20 **hertz** to 20,000 hertz, and most audio equipment is designed to this criterion. However the specific range of audio frequencies varies substantially from individual to individual -- varying particularly with respect to age. See also **frequency**.

bandpass filter

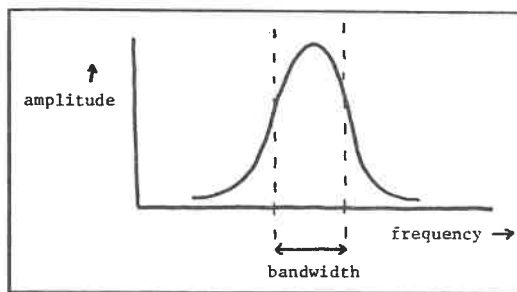
A type of audio filter which rejects extremely high and extremely low frequencies -- thus permitting a central range or band of frequencies to be passed as output. See also **filter**, **filter response**

bandreject filter

A type of audio filter which passes high and low frequencies, while rejecting a central range or band of frequencies. See also **filter**, **filter response**, **notch filter**.

bandwidth

The **interval** between the highest and lowest frequencies of a band or range of frequencies. Bandwidth is expressed either in hertz (Hz) or in octaves (e.g. 1/3 octave bandwidth). See also **centre frequency**, **filter**, **critical band**.



bel

Unit of **level** (named after Alexander Graham Bell). The bel unit is itself rarely used -- the **decibel** (or one-tenth of a bel) being much more common. The level (in bels) between two signals may be determined by evaluating the logarithm (base-10) of the ratio of two quantities proportional to power.

bit

Acronym for binary digit, first coined by J. W. Tukey. The bit is a single two-valued element of information used as the atom of information representation and storage in virtually all digital computers. The bit is also the unit of measure for the information content (or quantity) as narrowly defined by **information theory**. See also **data representation**.

Bessel functions

See **frequency modulation**

Blessner's equation

A formula by which the **signal-to-noise ratio** of a digital audio system can be calculated given the number of bits of resolution (n) :

$$S/N \text{ (db)} = 6.02n + 1.76$$

(B.A. Blessner, **Journ. Audio Engineering Soc.**, Vol. 26, No. 10 (1978) pp. 739-771)

BTL

Initialism for Bell Telephone Laboratories. Throughout the 1960s and 1970s Bell Telephone (U.S.) actively promoted computer music research under the direction of Max V. Mathews at its Murray Hill, New Jersey laboratory. Several important landmarks in computer music were first achieved by Mathews and his colleagues at BTL.

breakpoint

An x,y coordinate-pair which defines the intersection of two line segments used to approximate complex functions as employed in **piecewise-linear additive sound synthesis**. Usually several breakpoints are required to represent functions of **time-variant** amplitude and time-variant frequency deviations for each **partial** component contributing to a **complex tone**. See also **data reduction**.

buffer

A section of fast memory used for the temporary store of data, often for input and/or output operations (I/O). I/O buffers are especially necessary when either input or output (or both) is intermittent. See also **double buffering**.

C

A versatile high-level/low-level structured programming language frequently used in music sound synthesis applications. See also UNIX. (C. Roads, "Machine Tongues I", **Computer Music Journ.**, Vol. 2, No. 1 (1978) pp. 4-5,18; B. Kernighan and D. Ritchie The C Programming Language, Prentice-Hall (Englewood Cliffs, N.J.) -1978

CAL

Computer Aided Learning; a broad term denoting all applications of computers to educational or learning, including drill-and-practice methods, games, dialogues, simulations, etc. A subcategory under CAL is Computer Aided Instruction (CAI) -- an explicitly instructional approach, CAI is traditionally the most common type of CAL. See also **CAML**, **PLATO**.

CALLIOPE

Computer Assisted Learning in Listening, Improvisation and Other Perceptual Exercises -- an ear-training and keyboard-harmony skills **CAL** system devised by W. J. Dowling and William Hutchinson at UCLA in 1970. (Dowling, *Journ. Acoustical Soc. of America*, Vol. 51, No. 1 (1972) p.138)

CAMI

Centre d'Applications Musicales de l'Informatique; music information research group of the University of Montreal's Faculty of Music.

CAML

Computer Aided Music Learning -- the use of computers in musical education applications. See also **CAL**, **CHORDAL**, **CLEF**, **CALLIOPE**, **GUIDO**, **ICCBMI**, **MOM**.

Canonizer

A program to translate the abbreviated **DARMS** encoding language to long form (or canonical) **DARMS**.

CCMN

Current Common Musical Notation. An initialism coined by Michael Kassler to denote the traditional music notational symbols and methods as developed and used in the so-called 'period of common practice'.

CCRMA

An initialism for the Center for Computer Research in Music and Acoustics, located at Stanford University.

CEMAMU

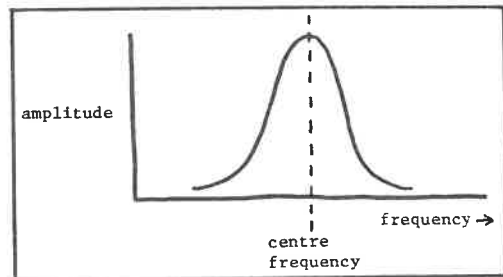
Centre d'Etudes de Mathematique et d'Automatique Musicales (the Centre for Studies in Mathematical and Automated Music), Paris. (Rogers, Numus West, Vol. 4 (1973) pp. 6-10)

centonization

A technique by which new melodies are composed by piecing together fragments of already existing melodies. In **Markovian synthesis** centonization commonly occurs when the constraining predictive frame is large and the sample is small -- the synthesized results degrade to a collage of direct musical quotations taken from the body of music used in the analysis. Centonization, as a compositional technique, originated in the time of Pope Gregory I.

centre frequency

The average or middle frequency of a band of frequencies, usually associated with **band-pass** or band-reject filters. The centre frequency is commonly the point of greatest (or in the case of the band-reject filter -- the least) power. See also **bandwidth**, **filter**.



CHORDAL

Acronym for Crane Heuristic ORgan DATA Language. CHORDAL was the first programming language designed specifically for musical instruction. It was developed by Earle Hultberg and Mary Lou Hultberg at the Crane School of Music, State University of New York (Potsdam). See also **CAML**, **CAL**, **PLATO**.

chorus effect

See also **unison**.

Chronochroma

A compositional language developed by Christos Hatzis, based on the notion of colour as a pervading musical principle. (Hatzis, Interface, Vol. 8, No. 2 (1979) pp. 73-90)

CIPHOR

A data base bibliography of organ and harpsichord music compiled by Gordon Rowley. (Rowley, Current Musicology, Vol. 19 (1975) pp. 122-129)

CLEF

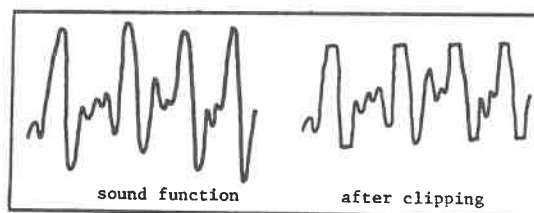
Computer-based Learning Experiences in music Fundamentals; one of the earliest computer-aided music learning (CAL) programme sets, developed by Earle Hultberg and Mary Lou Hultberg beginning in 1967.

click

When the duration of a sound is less than a time threshold (about 20 milliseconds) required for **pitch** recognition, the sound is heard as a click rather than a tone. In computer sound generation, clicks may also occur because of discontinuities in a sound function, or because of sharp excursions of a synthesized sound function, or because of abrupt envelope onsets, or because of high-order bit errors. (See also **glitch**.) Clicks are a common plague in the installation stage of a computer sound generating system, and may be caused by a variety of sources.

clipping

The distortion caused when the **amplitude** of a **signal** is greater than the maximum and/or minimum values which a computer-music system is capable of storing or handling. Clipping is typically caused by "over-recording" during **digitizing** of analog sounds, or by improper internal processing of digitally stored sound functions.



clock jitter

Temporal deviations of the computer's internal clock which may cause small amounts of audio distortion when sampling or reproducing analog signals through the use of an **analog-to-digital converter** or through a **digital-to-analog converter**.

CMI

See **computer music instrument**.

CLML

Initialism for Chicago Linear Music Language. A music **encoding language** for translating musical scores into a computer-readable format developed by Lawrence Bernstein and Joseph Olive. CLML is a dialect of the **DARMS** music encoding language, specially modified for the encoding of musical materials of the 16th century. (Bernstein & Olive, Computers and the Humanities, Vol. 3, No. 3 (1969-70) pp. 153-160)

CMN

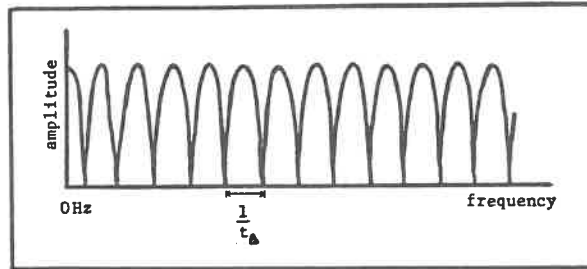
An initialism for Common Musical Notation which is used to denote the traditional music notational symbols and methods as developed and used in the so-called 'period of common practice'. Same as **CCMN**.

coloured noise

Any broadband noise which is not **white noise**. Broadband noises which have an uneven frequency distribution are considered 'coloured'. See also **pink noise**, **filter**, **frequency distribution**.

comb filter

A type of filter typical of **digital delay** in which frequencies separated by a fixed distance in **hertz** are severely **attenuated**. The shape of the frequency distribution has a distinct comb-like appearance when plotted graphically.



COMN

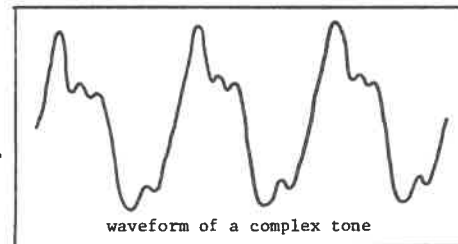
Computer Oriented Music Notation. An initialism coined by Charles Boody to refer to the **encoding language** for translating musical scores into a computer-readable format developed by Jerome Wenker; now known as **MUSTRAN**.

compiler

A program which translates another program (called the source language) into its equivalent **assembler** code or executable object code. A compiler may perform several 'passes' of the submitted program before translation is completed.

complex tone

The term complex tone is used to identify tones consisting of more than one pure frequency component. Often the component frequencies (called **partials**) of a complex tone are related **harmonically**,



but many times they are not. Occasionally complex tones will produce the sensation of more than one pitch. Whether a tone is recognized as being a single complex tone or a group of simple sine tones is in part dependent upon the auditory context, as well as the experience, ability and attitude of the listener. Virtually all naturally occurring tones are complex. (Contrasts with "simple," "pure," or **sine tone**.)

COMPOSE

A program for **computer music composition** developed by Gary Nelson.
(Nelson, Computational Musicology Newsletter, Vol. 1, No. 1 (1973)
p. 11)

computational music

See **computer music composition**.

computer-aided mixdown

The use of computers to record and execute the complex control
information used to manipulate large sound-mixing consoles in
multi-track recording studios. (db: The Sound Engineering
Magazine; see November 1976 issue)

computer music

1. Any application of computers for musical purposes.
2. Musical scores composed or produced by a computer program;
see **computer music composition**.
3. Musical sounds generated by computer. (According to a
definition proposed by Lejaren Hiller Jr., computer music
denotes music **sound synthesis** by computer -- in contrast with
computational music.) See also **computer sound synthesis**,
computer sound generation.

Computer Music Association

Established in 1979, the CMA is the official international body
representing scholarly and research interest in computers and
music. It publishes periodic newsletters and coordinates
international conferences. Address: P.O. Box 1634, San Francisco,
California 94101, U.S.A.

computer music composition

Music "composed" or produced by a computer program according to a set of rules or procedures implemented or selected by a human operator. (The term computational music was proposed by Lejaren Hiller Jr. to denote music so-composed.) See also Markov music, stochastic music, Illiac Suite.

computer music instrument

A portable special-purpose computer dedicated to **real-time** sound generation, with attendant controllers to facilitate human performance. Currently marketed computer music instruments include: Crumar GDS, Con Brio ADS-100, NEDCO Synclavier II, E-mu 4060, Yamaha DX series, and the McLeyvier. (Strawn, Computer Music Journ., Vol. 4, No. 3 (1980) pp. 69-73)

Computer Music Journal

A journal devoted to the scholarly discussion of issues related to computers and music. Begun in 1977, it is currently published four times a year by M.I.T. Press. (Subscription information may be obtained by writing: Journals Department, MIT Press, 28 Carleton St., Cambridge, Mass. 02142)

computer sound generation

The production of sound by computer through any possible means. Methods of computer sound generation include the 'singing line printer', CPU radio music, direct square wave output, A-D-A reproduction of digitally recorded sounds, and a wide variety of **computer sound synthesis** techniques. See also **sound generation**. (Dompier "Music of a sort", Dr. Dobb's Journ. of Computer Calisthenics & Orthodontia, Vol. 1, No. 2 (1976) pp. 6-7; O'Beirne, "Computer programs which play music with microtones," Computer Journal, Vol. 13, No. 4 (1970) pp. 344-349)

computer sound synthesis

Sound **synthesis** by computer. The combining or assembling of parts or elements so as to construct a sound; or the reconstituting or modification of existing sounds or signals. Conventionally, computer sound synthesis is divided into direct digital synthesis, and hybrid, where hybrid synthesis employs computer control of analog sound generating or sound modifying equipment. Direct digital synthesis uses computer software to numerically construct appropriate **sound functions** according to user-defined parameters;

direct digital synthesis employs a **digital-to-analog converter** for the actual production or generation of the output sound function. Computer sound synthesis may be performed in **real-time** or **non-real-time** depending on the complexity of the desired musical output, the efficiency of the generating algorithms, and the speed of the computer's central processor. A variety of techniques, algorithms, and methods are employed in computer sound synthesis. See also **sound synthesis, hybrid synthesis, digital oscillator, computer sound generation, real-time, non-real-time, unit generator, table-lookup oscillator, additive synthesis, subtractive synthesis, fixed-waveform synthesis, piecewise-linear additive synthesis, frequency modulation, linear prediction, waveshaping, Karplus-Strong algorithm, IRMA, MUSIC I-V, MUSIC7, MUSIC-11, MUSIC 65, MUSIC 360, MUSIC 3150, MUSIGOL, PILE, VOSIM.**

conditional probability

(Also known as transitional probability.) When rolling dice, we know that the number rolled is independent of numbers previously rolled (this is true even for loaded dice). In contrast, other types of probabilities may be dependent upon preceding states -- for example, the probability of the occurrence of the letter "u" in English text is considerably increased when the preceding letter is "q". Likewise, in tonal music, the probability of occurrence of the 'tonic' degree is increased when preceded by the 'leading tone'.

One concern of conditional probability is the depth of the context of dependency -- that is, do remote previous states also constrain the probability of occurrence, or only just the immediately neighboring states? The size of the context of probabilistic influence is called the frame of predictability. When the probability of occurrence for elements is totally independent of preceding elements (as with fairly thrown dice) the predictability frame is called a monogram; frames which take into account a single immediately preceding element are called digrams; trigrams denote frames of predictability which take into account two immediately preceding elements, and so on. See also **Markov chains, information theory.**

conductor program

A computer music program which modifies the performance of a prepared score, usually in **real-time**. Most conductor programs permit the manipulation of tempo, loudness, and timbre or instrumentation. (Buxton et al, Computer Music Journ., Vol. 4, No. 1 (1980) pp. 8-21)

constant-Q transform

A variant of the **Fourier transform** for the **frequency-domain** analysis of **periodic** functions. The constant-Q transform differs from the Fourier transform in that its frequency resolution is logarithmic rather than linear. For the Fourier transform, resolution is equal for distances of equal hertz; for the constant-Q transform resolution is equal for distances of equal musical intervals (e.g. semitones, octaves, etc.). The constant-Q transform is psychoacoustically more valued since its results are in greater accord with human auditory perception. See also **critical band**. (Petersen, "Time-frequency analysis in the context of a perceptual model", Proc. 1978 Internat. Computer Music Conf., Vol. 2, pp. 582-584)

context-dependency

Whenever the meaning of a symbol is dependent upon or modified by preceding and/or subsequent symbols, it is said to be context-dependent. Nearly all natural languages or grammars show some degree of context dependency. A commonly desired design objective of computer programming languages and music **encoding languages** is to maintain a low level of context-dependency in order to minimize difficulties of programming or encoding as well as minimize problems of language **parsing**. Languages or grammars which have no context-dependency are said to be context free.

continuous

Having a connected existence. The property of a domain in which infinite gradation is possible. An example of a continuous numerical scale is the set of real numbers -- each pair of neighboring values in such a continuous scale has an infinite number of intermediate values and so any quantity may be represented accurately. A continuous computer (i.e. "analog" computer) is limited in its capability for the representation of values only by the inescapable **noise** which accompanies any system. Contrast with **discrete**.

controllers

See **effectors**

conversion rate

The rate at which a **digital-to-analog converter** produces an output analog signal. Conversion rates are usually fixed and so are expressed in **hertz** or samples per second. Higher conversion rates generally provide more accurate representations of signals than lower conversion rates. See **sampling, sampling rate, smoothing filter**.

critical band

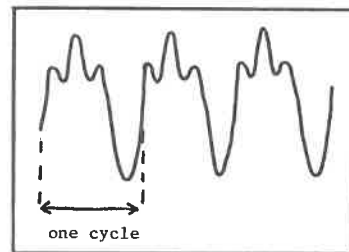
The human ear is comparatively insensitive for some auditory phenomena. For many of these phenomena (for example, **masking**), the frequency range of auditory resolution has been termed a 'critical band'. As a general rule of thumb, a critical band is about equivalent to the interval of a minor third (i.e. $\frac{1}{3}$ octave). (Fletcher, Review of Modern Physics, Vol. 12 (1940) pp. 47-65)

cross-synthesis

Any **sound synthesis** technique in which synthesis information for two different instrumental tones is averaged or interpolated to produce a new composite instrument or sound. Thus, for example, time-variant additive synthesis data for the creation of flute and saxophone tones could be interpolated to produce a "saxoflute." Depending upon the circumstances, tones created using cross-synthesis may be perceived as a true hybrid instrument, or as two distinct instruments playing in unison, or as a new tone which is seemingly unrelated to either of the two parent tones. The results of cross-synthesis are often unpredictable. (J. A. Moorer "On the segmentation and analysis of continuous musical sound by digital computer" Stanford University, CCRMA report STAN-M-3, 1975)

cycle

1. The action of a vibrating system such that its pattern of change passes through a complete turn of events. The elapsed time for the completion of one cycle is called the **period**. The number of cycles occurring in one second is called the **frequency**.



2. The execution by a computer, of (generally) one machine instruction; cycle time -- the time taken for a computer to cycle.

cycles per second

The number of complete repetitions or occurrences in one second.
See **hertz**; see also **frequency**, **cycle**.

DAC

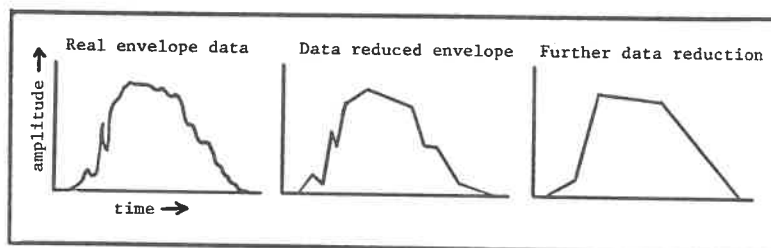
See **digital-to-analog converter**.

DARMS

Initialism for Digital Alternative Representation of Musical Scores, also known as the 'Ford-Columbia Input Language'. DARMS is a music **encoding language** for translating musical scores into a computer-readable format, developed chiefly by S. Bauer-Mengelberg. (Bauer-Mengelberg, in Musicology and the Computer, ed. B.S. Brook (1970) pp. 48-52)

data reduction

Any technique used to simplify large quantities of data when detail is irrelevant or



high accuracy wasteful of computing resources.

data representation

The internal code used to represent various quantities. In digital computers all quantities are ultimately represented by **bits**, however data may sometimes be represented several levels removed from the level of bits. Many conventions have been established for the interpretation of bits or groups of bits -- for example, ASCII (American Standard Code for Information Interchange) is a scheme by which groups of 7 bits are interpreted as alphabetic, numeric, and special written characters; BCD (Binary Coded Decimal) is another (obsolete) scheme by which groups of 4 bits are interpreted as single decimal digits (0-9). Digital sound functions are represented in a variety of formats including **fixed-point** integer representations (pulse code modulation - PCM), and **floating-point** numerical representations. Nearly all schemes

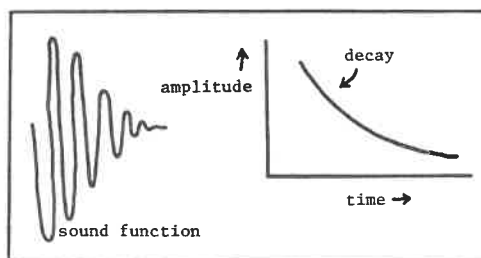
to represent the symbols of common musical notation have relied on transliterative mappings to numerical or alphanumerical codes like ASCII. See also **encoding language, word, fixed point, floating point, PCM**.

data structure

The internal management of computer data, especially the relationship between items of information. Examples of data structures include: arrays, rings, trees, files, stacks, queues, linked-lists, variables, etc. Undue complexity in data processing **algorithms** can be avoided by the use of appropriate data structures.

decay

1. The process by which the **amplitude** or energy of a vibrating system dissipates with time.
2. The initial diminishing of sound **amplitude** or energy forming part of the sound **onset** of a complex **envelope**.
3. The ultimate diminishing process or loss of sound **amplitude** in a complex envelope (also known as "release"). See also **envelope**.



decay time

The time taken for the **amplitude** of a **signal** to decrease by 60 **decibels**. The time taken for a sound to diminish to the point of inaudibility. See **decay**.

decibel

One-tenth of a **bel**; unit of sound level expressed as the logarithm (base-10) of the ratio of two quantities proportional to power.

deterministic

A mathematical term referring to a fixed relationship between two or more variables. A deterministic model contains no random

elements, therefore consequent states are determined wholly by the initial state of the model or system. (Contrast with **stochastic**.) See also **computer music composition**.

detune

The process of modifying the frequencies of **harmonics** so they become **pseudo-harmonics**. A means of increasing the **inharmonic**ity of **complex tones**. See **inharmonic**ity.

DFT

Initialism for discrete Fourier transform. See **Fourier transform**.

digital

From "digitorum" (finger), meaning countable in discrete steps. (Contrast with **analog**; compare **discrete**.)

digital delay

A technique (often embodied in special-purpose **hardware** devices), the most common purpose of which is to simulate acoustic **reverberation**. Successive **samples** of a **discrete** signal are delayed in time and mixed together with the original signal -- the resulting auditory effect being perceived as a single echo. If the output from the digital delay is **attenuated** and reintroduced into the input (i.e. controlled feedback) a regular series of echoes of successively decreasing **amplitudes** results. In longer delay lines, several taps may be included in the delay so signals of various delay times may be simultaneously accessed.

digital oscillator

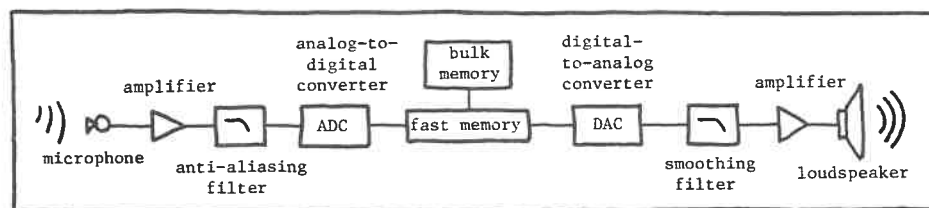
A special-purpose digital **hardware** device, vaguely similar in function to an electronic analog **oscillator**. Digital oscillators have been constructed according to widely varying designs, but are all derived from table-lookup methods. See **table-lookup oscillator**.

digital sound processing

See **signal processing**.

digital sound recording and reproduction

The process by which audio signals are recorded, stored, and reproduced by digital devices. The diagram below schematicizes the hardware components and flow of information in a digital



recording and reproduction system. See also **analog-to-digital converter**, **digital-to-analog converter**, **anti-aliasing filter**, **smoothing filter**, **sampling**, **digitizer**.

digital synthesizer

See **computer music instrument**.

digital-to-analog converter

A **hardware** device which outputs a steady voltage, the magnitude of which corresponds to the value of a binary number found in a special register. The value or **sample** may be up-dated many times each second. See also **digital sound recording and reproduction**.

digitizer

Any program which functions like a sound recording device such as a tape recorder. A digitizer program takes audio or sub-audio signals from an analog-to-digital converter and stores the corresponding numerical representations on digital magnetic tape or disk. Digitizer programs may include sophisticated features such as remote start and stop, signal detection start and pause, automatic rewind, and so on. See also **digital sound recording and reproduction**, **sampling**.

discrete

Having a separate existence; identifiably distinct. The property of a domain in which infinite gradations is not possible. An example of a discrete numerical scale is the set of integers -- although an infinite set, no intermediate values are possible between two consecutive integers and so fractional or irrational values may only be approximately represented by the nearest integer. A discrete spectrum of values much like a finite set of integers. The noise resulting from this inaccuracy must be considered when attempting to produce or reproduce high fidelity sound by computer. Contrast with **continuous**; see also **analog**, **digital**, **quantizing error**, **sampling**.

discrete Fourier transform

See **Fourier transform**.

discriminatory analysis

A statistical method which facilitates the creation of rules by which two or more populations can be distinguished. The rules so-constructed may then be used to classify an unknown element as belonging to one or another of the original populations with a minimal probability of misclassification. The rules are created through an examination of multivariate observations made on specific samples from the populations to be distinguished. These rules are usually expressed in a complex polynomial function (called a "discriminant function") which may be evaluated for any given series of observations for a single sample.

Discriminatory analysis is used in computer music applications chiefly to aid in various recognition tasks: e.g.1 recognizing bars of music as belonging to one of a finite number of defined styles, e.g.2 recognizing input sound functions as belonging to one of a finite set of musical instruments, etc.

distortion

Any unwanted change in a **sound function**. See also **clipping**, **noise**.

distributed synthesis

Any **sound synthesis** method in which the computational task is divided up between two or more **hardware** processors. Distributed synthesis typically involves two hardware processors: a special

purpose (slave) device used for the calculation of discrete sound function values, and a second more general-purpose (host) device which schedules tasks and delivers control information to the slave device. See also **hybrid synthesis**, **DMX-1000**

DMX-1000

DMX-1010

A special-purpose audio signal processor designed by Dean Wallraff. Suitable for audio-signal manipulation and digital sound synthesis. The DMX-1000 and DMX-1010 are small computers (with their own special instruction sets) intended to be configured as peripheral "slaves" to a general-purpose host or "master" computer which controls the signal processor in **real-time**. (Wallraff, **computer Music Journ.**, Vol. 3, No. 4 (1979) pp. 44-49

DO-RE-MI

A program written by David Prereau for the optical recognition of printed music. (Prereau, Computers and the Humanities, Vol. 9, No. 1 (1975) pp. 25-29)

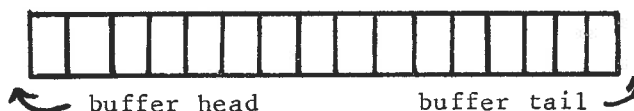
double buffering

A data transfer technique in which two storage buffers permit continuous data output despite intermittent bursts of data input. Double buffering is useful in computer sound generation by digital-to-analog conversion (DAC) where it is imperative that sound output be uninterrupted. Single buffers are not suitable due to pauses for reloading data. When double buffers are employed, the contents of one buffer are "clocked" to the DAC while the other buffer is loaded with new data. The tail of each buffer is followed by the head of the other buffer so continuous operation is possible. See also **digital sound recording and reproduction**, **computer sound synthesis**.

first data buffer



second data buffer



buffer head

buffer tail

DUPAK

Proposed **DARMS** utility package -- a group of programs written by Anthony Wolff, Ray Erickson and others for use with the DARMS music **encoding language**. (Erickson, Computers and the Humanities, Vol. 5, No. 5 (1971) p. 313)

dynamic

Change with respect to time. See **time-variant**.

dynamic range

Dynamic range is that range of signal levels for which the **signal-to-noise ratio** remains subjectively adequate. For acoustical environments, the dynamic range is the difference between the loudest sound (the loudest sound a person may hear without damage) and the softest sound (being usually determined by the **masking** effect of background **noise**). The dynamic range for electroacoustic systems is often expressed as the difference, in **decibels**, between the maximum unoverloaded level and the minimum acceptable signal level. The signal-to-noise ratio, by contrast, is usually expressed as the difference between the maximum unoverloaded level and the background or idle noise. For systems in which the idle noise is more serious than the dynamic noise (i.e. noise which results from, and rises with the input signal level), the dynamic range is usually smaller than the signal-to-noise ratio. For systems in which the idle noise is less serious than the dynamic noise, the dynamic range is frequently better than the signal-to-noise ratio.

dynamics

The variations of loudness in a musical composition, traditionally expressed through the use of descriptive Italian words: e.g. forte, mezzo-piano, crescendo, sforzando.

dynamic spectra

Synonym for time-variant spectra.

echo

A distinctly detected single repetition or attenuated repetition of a sound (in nature, due to a reflection from an acoustic barrier). Although **reverberation** is also composed of repeated sound, in reverberant signals the separate repetitions of the original sound are not perceptually distinguishable and so are not considered echoes. A repetition may be perceptually distinct only if at least 50 milliseconds (thousandths of a second) transpires after the original sound statement without any other accompanying or confound signals being present.

echo removal

A **signal deconvolution** technique used to remove echoes or repetitions from a complex audio signal. Although some preliminary research has been carried out (particularly in deconvolving echoes from seismic recordings), the removal of echoes from complex sound signals is an as yet unsolved problem.

editor

1. Any computer program which permits or facilitates the addition, deletion, or rearrangement of data within computer files.
2. A system program used to edit user-created text files.
3. A program which permits or facilitates the addition, deletion, or rearrangement of music "notations" -- loosely analogous to the traditional manipulations of musical manuscripts; also called a music editor.
4. A program used to rearrange digitally-represented sounds -- analogous to the cutting and splicing of analog magnetic tape; also called a digital sound editor or simply **sound editor**.
5. A program used to define or redefine computer synthesized **sonic objects**; also called a **sound editor** or object editor.

effectors

The physical controls by which a human operator or performer communicates with a machine. Typical effectors include typewriter-like keyboards, piano-like keyboards (called "claviers"), x-y joysticks, rotary knobs, levers, linear sliders, mouse, bit-pads, breath controllers, pedals, footswitches,

push-buttons, and proximity sensors. Traditional musical instruments such as violins or clarinets may be modified or monitored in order to provide controlling information to some other device.

Elektronisches Musik

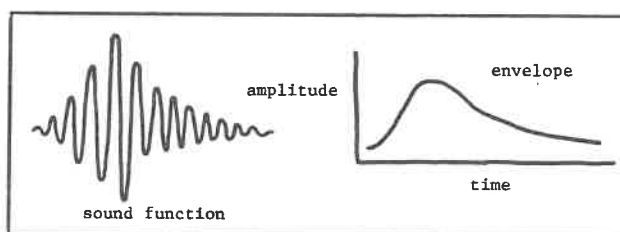
A term coined at Cologne in the early 1950s denoting music of purely electronic origin. The term Elektronisches Musik is commonly contrasted with *musique concrète* in which prerecorded natural sounds are manipulated by electronic means.

encoding language

A method of data representation. Any system of conventions which transliterates musical notation (i.e. scores) into computer-readable format using alphabetic and numeric characters, e.g. DARMS, ALMA, MUSICODE, FASTCODE, Mustran, MUSTUD, IML, LMT. See also **data representation**.

envelope

The dynamic variation of the **amplitude** of a sound; the **time-variant** amplitude characteristics (usually of a single note). An envelope may be conceptually divided into



'onset' (attack) and 'release' portions; if the sound is non-percussive, it may be possible to also define a 'steady-state' portion. Envelopes contribute significantly to human perception of timbres and identification of classes of sounds. See also **attack**, **decay**, **onset**.

equal temperament

Any set of discrete pitches in which the interval of an **octave** is divided into a whole number of equal divisions. In traditional western-european practice, an equally tempered system employing twelve intervals (called **semitones**) is used.

EUTERPE

A unique computer music language developed by Stephen Smoliar based on a parallel-processing model of musical structures. EUTERPE is particularly suited to the expression of contrapuntal music in which each part is treated as a process with synchronization cues provided in order to coordinate parallel parts. (Smoliar, Journ. of Music Theory, Vol. 20, No. 1 (1976) pp. 105-131)

FASTCODE

A music **encoding language** for translating musical scores into a computer-readable format. FASTCODE is an abbreviated form of the IML music encoding language developed by H. Howe and A. Jones.

fast Fourier transform

An(y) **algorithm** which computes the finite **Fourier transform** of a series of N (complex) data points from a **sound function** in approximately $N \log_2 N$ operations (see **Fourier₂ analysis**). Previous slower algorithms required on the order of N^2 operations to calculate the same result, so the widespread use of FFTs has saved literally hundreds of hours of computing time. Although commonly thought to have been discovered by Cooley and Tukey in 1965, a fast Fourier transform was first described in 1942 by Dannielsen and Lanczos. (Cooley et al, Proc. I.E.E.E., Vol. 55, No. 10 (1967) pp. 1675-1677)

FFT

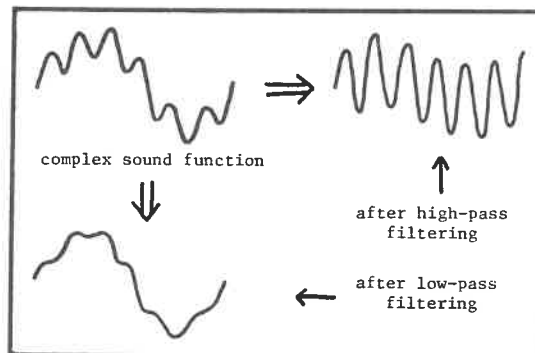
See **fast Fourier transform**

filiation

The process by which two or more sources of a particular piece of music are compared and the relationship between them determined. Stemma is proposed for each work. (History of filiation is given in Karen Bryan "A Filiation Study of Selected Madrigals of Jacopo da Bologna" M.A. thesis University of Georgia - 1979)

filter

A device used to affect certain parts of the frequency **spectrum** of a sound, by causing the **attenuation** of certain frequencies while allowing other frequencies to pass unattenuated or amplified. Some common types of filters are: high pass filters (which attenuate low frequencies, hence permitting the passage of high frequencies), low pass filters (which attenuate high frequencies, permitting the passage of low frequencies), band pass filters (which attenuate high and low frequencies, leaving a central band of frequencies). Groups of filters may be variously combined to form filter networks which can be used to modify complex sounds. See also **filter response**, **subtractive synthesis**, **moving-average filter**, **formant**.



filter response

The property of a **filter** with respect to its ability to pass or reject **signals** of various **frequencies**. Filter responses can be algebraically represented, but they are more commonly given in the form of a two dimensional graph with frequency as the domain and **amplitude** as the range. The area under the response function indicates the pass band of the filter, while the area above the response function indicates the reject band of the filter. See also **frequency domain**, **frequency distribution**, **subtractive synthesis**.

fixed field format

The layout of data on punched cards or records where information is expected in certain predetermined columns or fields.

fixed point

A binary form of **data representation** suitable for the representation of integer numbers. Contrast with **floating point**.

fixed-waveform synthesis

A **sound synthesis** technique (usually employing **table-lookup oscillators**) in which no change in **waveshape** (hence spectral content) occurs over the duration of the sound. While this method of sound synthesis is computationally efficient, unless carefully used, the results are often noticeably lacking in timbral interest. Fixed-waveform methods contrast with **time-variant** methods of sound synthesis.

floating point

A binary form of **data representation** of numerical values by a method analogous to scientific notation: one or more computer **words** are logically divided into exponent and mantissa parts, and all numbers represented in this way. Contrast with **fixed point**.

FM

Initialism for **frequency modulation**.

foldover

An **aliasing** condition in which high frequency **signals** are transmuted into **noise** due to the violation of the **Nyquist criterion**. Folover is caused when frequencies greater than or equal to one-half of the **sampling rate** are digitally recorded or produced. In general, any frequency f greater than $SR/2$ will foldover to the frequency $SR-f$, that is

$$f' = SR - f \quad (\text{iff } f > SR/2)$$

-- where SR is sampling rate, f' is the foldover frequency, and f is the original frequency.

Ford-Columbia input language

See **DARMS**.

form

A musical term employed to denote the internal relations or structure of a musical composition. A significant application of computers in musicological processing and analysis is the creation of theory-based analytical programs which elucidate the form or structure of musical works. See also **EUTERPE**, **MUSE**, **SCHENKER**.

formant

A distinctive or characteristic resonance, often important in the auditory identification of an acoustic source or the means of acoustic production. The human voice shows formant resonances particularly in the production of vowel sounds. These formants are dictated by the volume and shape of the nasal, oral and pharyngeal cavities. Musical instruments may also display characteristic formants as determined by the physical properties of the specific instrument. Vocal formants are usually dynamic in pitch while instrumental formants are fixed. See also **vocoder**.

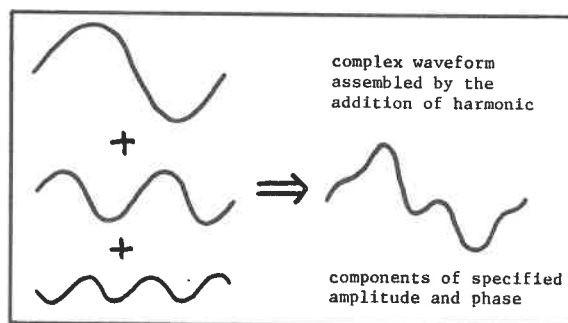
Fourier analysis

A mathematic technique for the decomposition of complex **periodic** functions into simple component **sine waves**, each of which is a member of a single **harmonic series**. Fourier analysis produces a series of coefficients which specify the **amplitude** and **phase** for each simple frequency component. Fourier analysis is properly limited to the analysis of periodic signals. See also **Fourier synthesis**, **Fourier transform**.

Fourier synthesis

A **sound synthesis** technique in which the harmonic components comprising a complex tone are assembled using phase and amplitude coefficients derived from a **Fourier analysis**.

Fourier synthesis is a special case of **additive synthesis** in which only harmonically related sine waves may take part. See also **piecewise-linear additive synthesis**.

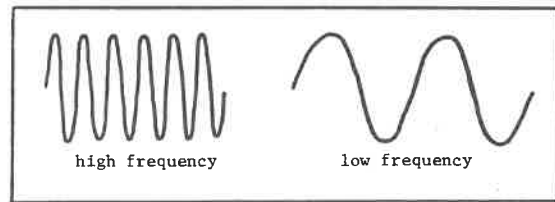


Fourier transform

The specific mathematical process invented in 1822 by French mathematician Jean-Joseph Fourier employed in **Fourier analysis**. The Fourier transform changes **time domain** representations to **frequency domain** representations. For analysis of digitally represented sound functions a special form of the Fourier transform called the Discrete Fourier transform (DFT) is employed. See also **constant-Q transform**, **fast Fourier transform**.

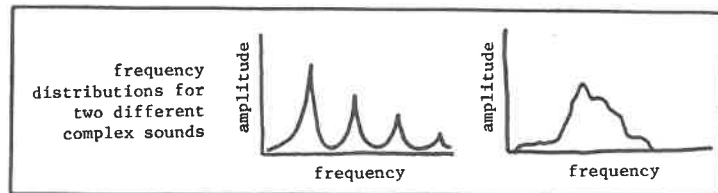
frequency

Rate of occurrence or rate of repetition. Frequency is measured in **hertz** (abbreviated Hz), where one hertz is defined as a single **cycle** per second. Frequencies which are audible to the human ear (frequencies roughly between about 20 Hz and 20,000 Hz) are often called **audio frequencies**. Compare **pitch**.



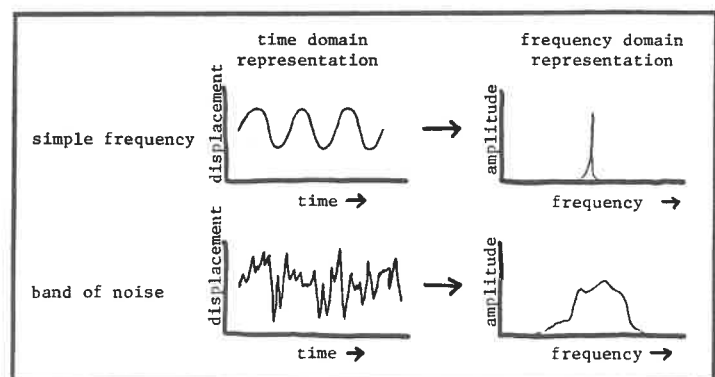
frequency distribution

The frequency content of a **sound function** represented mathematically or plotted graphically; the overall shape or distribution of frequency components over a complete **spectrum**. Frequency distributions may be determined through **Fourier analysis** or through a sound analyser. See also **filter response**, **frequency domain**, **spectrum**.



frequency domain

Frequency is defined as the rate of occurrence (or repetition) with respect to time. It follows that for a frequency to exist, it must have some duration (however small). Nevertheless, it is useful to speak of frequency abstractly divorced from any notion of time: hence

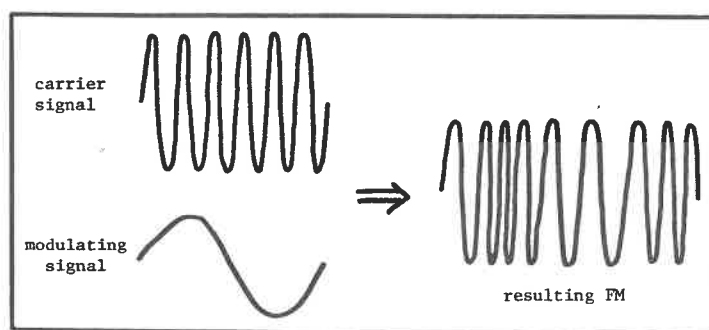


it is common to speak of the frequency "100 hertz" as though it has no duration. In the limit, one might wish to collapse a specified time frame into a single timeless instant in order to describe the frequency spectrum at that instant. In theory it is not strictly possible to do this, however in practice, workable methods have been established. The resulting frequency domain representations are convenient for a variety of purposes. Contrast with time domain; see also frequency distribution, spectrum, Fourier analysis.

frequency modulation

(abbreviated FM)

The variation of the **frequency** of a signal, usually repetitively. The violinist's vibrato is a good example of frequency modulation. The frequency is modified as the length

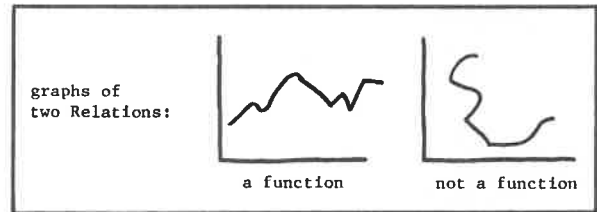


of the vibrating string is continually altered by a back-and-forth movement of the finger and wrist. When the rate of variation or modulation is very fast, associated frequencies called sidebands may become audible. The controlling (modulating) signal may be exponential or linear in its effect -- when linear, it is possible to tune the sidebands such that they are **harmonically** related. Linear frequency modulation is widely used in **computer sound synthesis** for the production of complex harmonic and inharmonic timbres. (Chowning, Journ. Audio Engineering Soc., Vol. 21 (1973) pp. 526-534)

function

1. A term borrowed from the mathematics of relations to denote the subclass of relations which comply with the 'vertical line test'; the relationship between a single variable quantity with respect to another isotonic (i.e. constantly increasing) quantity (often time). Functions may be graphically represented as a single smooth or disjointed curve or line plotted on a two-dimensional surface. Physical variations in a medium due to sound may be represented as functions. See also **sound function**.
2. A special-purpose user-defined relation used for parameter control in **computer sound synthesis**, e.g. transient generation for **piecewise-linear additive synthesis**.

3. A special-purpose procedure or routine employed in a computer program, e.g. to compute the mean between two numbers.



fundamental frequency

The principal frequency component of a complex **harmonic** or **pseudo-harmonic** tone -- the basic cycle of repetition for a **periodic waveform**. The fundamental frequency is commonly (though not always) equated with the perceived pitch of a tone.

glissando

A continuous gliding of pitch. Digital computers are incapable of producing truly continuous pitch glides and so glissandi are approximated by very detailed discrete pitch scales -- the result is perceptually indistinguishable from continuous glissandi.

glitch

1. Any intermittent or occasional problem found in a computer system.
2. An error in digital audio generation caused by an erroneous value being fed to the digital-to-analog converter. See also **click**.

granulation noise

A 'sandy-sounding' noise which results from the odd harmonic components of **quantizing noise** beating against the **sampling rate**. In general, granulation noise may be made less audible by increasing the sampling rate, and/or decreasing the **quantizing error**.

GROOVE

A program written by Max Mathews and Frank Moore at the Bell Telephone Laboratory in Murray Hill New Jersey to control analog sound synthesis equipment in **real-time**. A system for **hybrid synthesis**. (Mathews & Moore, Communications of the ACM, Vol. 13, No. 12 (1970) pp. 715-721). See also **programmed control**.

hardware

Real electrical, electro-mechanical or electro-magnetic physical devices; contrasts with **software**.

harmonic

1. (adjective:) The relationship between two frequencies such that one frequency is an integer multiple of the other (e.g. the frequencies 101 Hz and 303 Hz are harmonically related since $101 \times 3 = 303$).
 2. (noun:) Harmonically related (or nearly harmonically related) frequencies are called harmonics. Harmonics are of special interest because of some unique auditory properties. Many natural vibrators oscillate such that they produce several harmonics simultaneously. For example, if the first harmonic or "fundamental") of some complex tone is of frequency 200 Hz, subsequent harmonics might be of frequencies 400, 600, 800, 1000, 1200 Hz, et. -- called the **harmonic series**. Compare **inharmonic**, **pseudo-harmonic**.
-

harmonic series

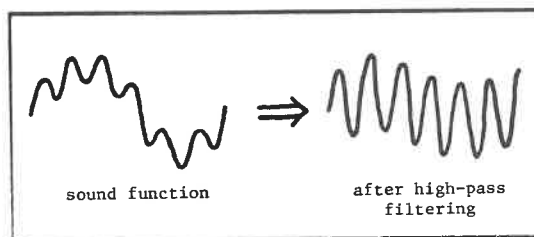
Any numerical sequence of ascending frequencies, where successive numbers are integral multiples or share a large common divisor. For example: the sequence 100, 200, 300, 400, ... represents a harmonic series, as does 29, 58, 87, 116, ... The sequence 500, 700, 930, 1190, ... is not a harmonic series, while 100, 150, 200, 250, ... is considered an incomplete harmonic series because of the missing first harmonic component (50). The frequency components of naturally occurring **complex tones** often conform to the harmonic series. See also **harmonic**, **inharmonic**, **pseudo-harmonic**, **inharmonic**ity, **Fourier analysis**.

hertz

The unit of **frequency**, defined as the number of cycles or complete oscillations per second. The unit is named after the German scientist Heinrich Hertz; it is abbreviated using a capital letter ("Hz") and is written in full using a lower-case letter ("hertz").

high-pass filter

A type of **filter** which blocks or attenuates the transmission of low frequencies and permits or accentuates the passage of high frequencies. See also **low-pass filter**, **frequency distribution**, **spectrum**, **frequency domain**.



HPSCHD

A well-known work of computer music co-composed by John Cage and Lejaren Hiller Jr. The piece is arranged for harpsichords, recorded audio tapes, and films. (Cage et al, Source, Vol. 4 (1968) pp. 10-19)

hybrid synthesis

A type of distributed synthesis in which both digital and analog devices are employed. Ordinarily, hybrid synthesis entails the use of digital hardware to drive or control analog sound-generating and/or analog sound-modifying components (like voltage-controlled oscillators and filters). See also **computer sound synthesis**, **GROOVE**, **computer music instrument**.

I

See Index of Modulation

ICCBMI

International Consortium for Computer-Based Music Instruction (formerly the National Consortium for Computer-Based Music Instruction). See also **CAL**, **CAML**. (Hofstetter, "Foundation, Organization, and Purpose of the National Consortium for Computer-Based Musical Instruction", MENC, March 11, 1976; Reprints available c/o Music Dept. Univ. of Delaware)

Illiac Suite

One of the earliest musical compositions composed via computer. Programmed/composed by Lejaren Hiller Jr. and Leonard Isaacson, this four movement work was arranged for string quartet and performed in public in 1957. See also **Push-button Bertha**. (Hiller & Isaacson, Experimental Music, McGraw-Hill (New York), 1959)

IML

Intermediate Music Language. A music **encoding language** for translating musical scores into computer-readable format, developed by H. Howe and A. Jones. See also **FASTCODE**.

incipit

See **thematic incipit**.

Index of Modulation

The amount or degree of effect that a modulating signal has on a carrier signal. See also **modulation**, **frequency modulation**, **amplitude modulation**.

information theory

A theory of communication inaugurated by Claude E. Shannon of Bell Telephone Labs in 1949 and since elaborated by numerous others. Through a restricted definition of the word information (which is divorced from any notion of meaning), information theorists are able to construct a continuum of messages from the highly 'redundant' (low information content) to the highly 'original' (high information content). The quantity of information in a message is measured in **bits** and is inversely related to the

predictability of the message. Messages of low predictability have a high information content, while messages of high predictability have a low information content. One bit of information is equivalent to the information of a single question which may be answered with only yes or no. Such questions may be simple or sophisticated. Among other activities, information theorists attempt to devise sophisticated "questions" by which messages of apparent high information content are reduced to a minimum. See also **Markov music**, **computer music composition**, **conditional probability**. (A. Moles, Information Theory and Esthetic Perception, Illini Books (Urbana) 1966; original French work - 1958)

inharmonic

A **partial** is considered "inharmonic" when its **frequency** is not an integer multiple of a given **fundamental frequency**. Two and three dimensional vibrators (such as plates, drumheads, bells and gongs) typically produce inharmonic partials. Inharmonic is used both as a verb and as a noun. Compare **harmonic**, **pseudo-harmonic**. See also inharmonicity.

inharmonicity

Partial components of a complex tone may be characterized according to the degree to which their frequencies conform with the **harmonic series** of **overtones**: partials which coincide exactly are called **harmonics**, partials which vaguely correspond are called **pseudo-harmonics**, partials which are clearly different are called **inharmonics**. Inharmonicity is a descriptive term applied to the cumulative effect of inharmonic components -- the greater the inharmonicity, the greater the "clangorousness" of the sound.

instrument

A **user-created** or user-selected **patch** of **unit generators** or real sound processors, used to define an imaginary instrument or **voice** for **computer sound synthesis** purposes.

interface

A mode of connection between two entities for the purpose of rendering inter-communication compatible. Interfaces may occur between electronic and mechanical devices, between computers and chemical or biological systems, or between two electronic devices (as in **digital-to-analog converters**), etc. Interfaces may also exist between one program and another program operating within the same computer. The word "interface" is used as both a noun and as a verb.

intersample interval

(abbreviated ISI) The elapsed time between the measuring of one sample and the measuring of the successive sample of a sound function -- usually expressed in **microseconds** (millionths of a second). In digital recording schemes with fixed **sampling rates**, the intersample interval remains fixed. In such cases the intersample interval is inversely proportional to the sampling rate.

intertone

The subjectively perceived tone resulting when two (primary) tones of nearly equal frequency, produce beats. The pitch of this compromise or inter-tone lies between the two primary tones. (American National Standards Institute, Psychoacoustical Terminology, S3.20 (1973) p.23)

interval

The distance between two pitches, usually identified by the ratio of two frequencies or according to the diatonic/chromatic interval system of traditional western music.

intimacy

The quality of an acoustic signal in which a listener's impression is of a small, close or intimate space. A term used in architectural acoustics to denote the time interval which elapses between the arrival of the direct sound and the arrival of the first reflection from the nearest wall or ceiling. Intimate sounds tend to have a significant first reflection less than about 20 milliseconds after the arrival of the direct sound. See also **digital delay, proximity, reverberation, reverberation time.** (L.L. Beranek, Music, Acoustics & Architecture (1962) p.63)

INV

A digital signal processing program developed by for the mixing and editing of digitally stored sound functions. See **sound editor.** (See Roads, Computer Music Journ., Vol. 2, No. 1 (1978) pp. 19-23)

IRCAM

Institut de Recherche et de Coordination Acoustique/Musique. A component institute of the Centre Georges Pompidou (Paris, France) dedicated to research and development of a wide variety of music and science related subjects including computer music. (Gardner et al, Centre Georges Pompidou Rapports IRCAM No. 3 (Paris) - 1978) IRCAM has been under the directorship of Pierre Boulez since it opened in 1977. The head of the Computer Department has been Jean-Claude Risset.

IRMA

A **real-time computer sound synthesis** program written by John Clough. (Clough, I.E.E.E. Convention Digest, (1971, March) pp. 40-41)

ISMUS

Iowa State Computerized Music System. (Silverston & White, Numus West, Vol. 7 (1975, Winter) pp. 32-37)

Josquin project

One of the most well-know computer-aided musicological studies, the Josquin project used a filiation technique called stemmatics to help uncover the recension of existing manuscripts of the masses of Josquin Despres (1450(?)-1521). The purpose of the project was to identify points of dispute between copies of the same masses and establish the most likely interpretation based upon a statistically-derived tree showing the history of transcription for each manuscript. The chief architect of this work was Thomas Hall at Princeton University, and the project made extensive use of the **MIR** music information retrieval system. (Hall, Tijdschrift van de Vereniging Nederlandse Musiek Geschiednis, Vol. 25, No. 1 (1975) pp. 38-53)

linear prediction

A complex numerical technique commonly used in speech sound synthesis. Future samples of a digitized speech waveform are predicted based on a linear extrapolation of previous samples modified by an error function. The linear prediction method has been explored primarily in **vocoder** applications where speech must be transmitted along restricted channels of communication. Linear prediction may potentially be employed in **computer sound synthesis** applications to simulate natural instrument sounds or synthesize new sounds. (Makhoul, "LPC Tutorial Review," Proc. I.E.E.E., Vol. 63, No. 4 (1975) p. 561-)

loudness

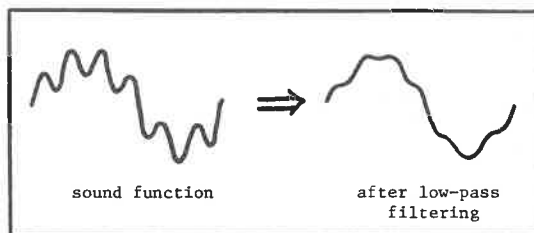
The subjective psychological correlate of **amplitude** or sound intensity. Perceived loudness is dependent upon many attributes of a sound including frequency, timbre, amplitude, duration, etc. To a certain degree perceived loudness is also dependent upon experience and learning.

LMT

Linear Music Transcription. A music **encoding language** for translating musical scores into a computer-readable format, developed by Eric Regener at Princeton University. (Regener, Computers and the Humanities, Vol. 4, No. 3 (1970) pp. 213-214)

low-pass filter

A type of **filter** which blocks or attenuates the transmission of high frequencies while permitting or accentuating the passage of low frequencies. See also **anti-aliasing filter**, **smoothing filter**, **moving-average filter**.



LPC

Initialism for Linear Predictive Coding; see **linear prediction**.

Ludwig

An interactive graphic score **editor** developed by Bill Reeves, Bill Buxton, et al of the Structured Sound Synthesis Project (SSSP) at the University of Toronto. (Reeves, et al, Internat. Computer Music Conf., Proc. (1978), Vol. 2 pp. 392-409)

Markov chains

Probabilistically linked chains of events, where the occurrence of an event is dependent upon preceding outcomes. Markov chains are ordered sequences of symbols (or elements) which are related to neighboring symbols by consistent **conditional probabilities**. Such sequences were first studied by the Russian mathematician Andrei Markov (Sr.) in 1906-1907. See also **conditional probabilities**, **information theory**, **Markov chain music**, **Markovian analysis**, **Markovian synthesis**.

Markov chain music

Music generated by the process of **Markovian synthesis**; also called "Markov music". (Hiller & Isaacson, Experimental Music McGraw-Hill Co. -1959)

Markovian analysis

The statistical process by which a table of **conditional probabilities** is created from an analysis of a sample of representative messages (in **Markov music** these messages are musical compositions or parts thereof). See also **Markov chains**, **Markovian synthesis**, **Theory of Analysis/Synthesis**.

Markovian synthesis

A specialized technique used to generate sequences of elements or symbols. The process prescribes a constrained random selection of elements (or symbols) conforming statistically to a table of **conditional probabilities**. The result of Markovian synthesis is a **Markov chain**. When the selected elements are musical pitches and/or durations, etc., the generated results are referred to as **Markov chain music** or simply Markov music. See also **information theory**, **Markovian analysis**, **synthesis**.

masking

The difficulty or impossibility of hearing one sound due to the presence of another sound. Masking commonly results when a loud (masking) sound occurs concurrently with a quieter (masked) sound. Masking may also occur even when the masker and masked sounds don't sound concurrently: if the masking sound follows after the masked sound in time the effect is known as backward masking; when a masking sound appears prior to the masked sound it is called forward masking.

microsecond

Unit of time equivalent to one millionth of a second. The **intersample interval** between successive sample points as used in digital sound recording or computer sound synthesis is typically measured in microseconds. Compare **millisecond**.

millisecond

Unit of time equivalent to one thousandth of a second. The features of a sound **envelope** as used in digital sound synthesis are typically measured in milliseconds. Compare **microsecond**.

MI

See **Index of Modulation**

MIR

Music Information Retrieval. A programming language developed by Michael Kassler at Princeton University for the purpose of musicological processing and analysis. (Kassler, in The Computer and Music, H. B. Lincoln, editor; Cornell Univ. Press -1970, pp. 299-327)

MITSYN

Musical Interactive Tone Synthesis.

mnemonic

Easy to remember; the choice of command names, instruction names, acronyms, initialisms, transliteration encodings, etc. such that they and their functions are conjointly remembered.

mod notation

See **piano-roll notation**.

Mockingbird

A music printing and **amanuensis** system developed by Severo Ornstein and John Maxwell at the Xerox Parc research center in Palo Alto, California.

modulation

1. The process by which some acoustical property is varied. **Vibrato**, for example, may be regarded as a form of frequency modulation; the **envelope** of a sound may be regarded as a form of **amplitude modulation**; and **phasing** may be regarded as the summation of a sound with its phase modulated counterpart.

2. The rapid variation of some acoustical property. In a more restricted sense, the term modulation is applied only to those radical rates of change (specifically **frequency modulation**, **amplitude modulation**, **ring modulation**, time modulation, phase modulation) which produce audible ancillary frequency components called **sidebands**.

MOM

Materials of Music project. A computer-aided retrieval system and thesaurus for information on music education. (Edwards, Journ. of Research in Music Education, Vol. 21, No. 1 (1973) pp. 20-29)

monophonic

1. A musical term denoting music consisting of (at most) one **note** or **voice** at a time; multiple 'lines' or voices occurring simultaneously are not monophonic. In computer music applications the term monophonic is usually used to refer to a system incapable of processing two or more simultaneous sounds or voices. Monophonic is used in contrast to **polyphonic** and is often employed in reference to the properties of keyboard or clavier **interfaces**.
2. High fidelity sound reproduction in which only a single channel of sound is reproduced. (Contrasts with stereophonic.)

moving-average filter

A type of **low-pass filter** in which the ordinate sample values of adjacent sample points in a digitally represented sound function are averaged together to produce a new sound function with attenuated high frequency content.

MPL

A library of computer routines and programs for musical data processing, developed by Gary Nelson. (Nelson, Creative Computing, Vol. 3, No. 2 (1977) pp. 76-81)

MUSE

An early computer system for musical analysis devised by George Logemann and Gary Berlind. (Logemann & Berlind, "The MUSE system for music analysis", New York Univ. Institute for Computer Research in the Humanities, -1966)

Music encoding language

See **encoding language**.

music setting

A term coined by David Gomberg to denote the preparation of master copies of music prior to printing. Traditional music setting involves two layout processes: casting-off (deciding system length and pagination) and punctuation (locating the individual positions of note-heads and barlines). See also **Musicwriter**, **phototypesetter**. (Gomberg, DSc dissertation, Washington Univ. -1975)

MUSIC I

1. The first **computer sound synthesis** program developed by Max V. Mathews and colleagues at Bell Telephone Laboratories in 1957. Employing a 704 computer at the IBM Headquarters in New York City and a 12-bit vacuum tube **digital-to-analog converter**, MUSIC I permitted the monophonic specification of a single pitch, an **amplitude**, and a duration for each note. (Roads, Computer Music Journ., Vol. 4, No. 4 (1980) pp. 15-22)
2. A computer sound synthesis program developed by Hélène Charnassé and Henri Ducasse.

MUSIC II

1. The second **computer sound synthesis** program developed by Max V. Mathews and colleagues at the Bell Telephone Laboratories in 1958. MUSIC II was capable of producing four independent **voices** of sound with a choice of 16 **waveforms** stored in memory.
 2. Computer sound synthesis program developed by Hélène Charnassé and Henri Ducasse.
-

MUSIC III

The third **computer sound synthesis** program developed by Mathews et al at Bell Telephone Labs in 1960, significant for its introduction of the **unit generator**.

MUSIC IV

A **computer sound synthesis** program written at the Bell Telephone Laboratory by Max Mathews, Joan Miller and associates in 1963. MUSIC IV was the first computer sound synthesis program to be widely distributed beyond the Bell Lab.

MUSIC V

A **computer sound synthesis** program written at the Bell Telephone Laboratory by Max Mathews, et al. MUSIC V was an extended machine-independent version of MUSIC IV. (Mathews et al, The Technology of Computer Music, M.I.T. Press -1969)

MUSIC 4B

A **computer sound synthesis** program developed by Gerald Warfield and Godfrey Winham. (Winham, "Reference Manual of MUSIC 4B", Princeton University Music Dept. unpub. ms.)

MUSIC 4BF

A **computer sound synthesis** program written by Hubert Howe Jr.; a FORTRAN version of MUSIC 4B. (Howe, "MUSIC 4BF", Princeton University Music Dept., (1967), unpub. ms.)

MUSIC 4F

See **ORPHEUS**

MUSIC 5B

A **computer sound synthesis** program developed by John Gardner.

MUSIC 65

A **computer sound synthesis** program developed by Gary Nelson.
(Nelson et al, Computers and the Humanities, Vol. 8, No. 1 (1974)
p. 50)

MUSIC 7

A **computer sound synthesis** program written by Hubert Howe Jr. for
operation on Xerox Corporation Sigma 7 minicomputers. (Howe,
Computers and the Humanities, Vol. 5, No. 5 (1971) p. 311)

MUSIC-11

A **computer sound synthesis** program written by Barry Vercoe for
operation on digital Electronics Corporation PDP-11 minicomputers.

MUSIC 360

A **computer sound synthesis** program written by Barry Vercoe and R.
F. Taylor, for operation on IBM 360-series computers. (Vercoe,
Proc. American Society of University Composers, Vol. 6 (1971) pp.
16-20)

MUSIC 3150

A program for music composition intended for conventional
instruments, developed by Justus Matthews. (Matthews, Proc. 1978
Internat. Computer Music Conf., Vol. 1, pp. 251-271)

MUSICODE

A music **encoding language** for translating musical scores into a
computer-readable format, developed by Fred Hofstetter.
(Hofstetter, Journ. Graduate Music Students at Ohio State Univ.,
Vol. 3 (1972) pp. 4-42)

MUSICOL

An acronym for MUSical Instruction COMposition Language written in FORTRAN by Peter Gena. It provides facilities for **stochastic** compositional processes. (Gena, in Computing in the Humanities: Proc. of the Third ICCH, Lusignan & North, editors; Univ. of Waterloo Press, -1977, pp. 165-173)

musicology

A general term which is intended to apply broadly to all aspects of the study of music. See also **Josquin** project.

MUSICOMP

An acronym for MUsic Simulator-Interpreter for COMpositional Procedures; a programming language for music composition developed by Lejaren Hiller Jr. and Robert Baker. (Hiller & Baker, Perspectives of New Music, Vol. 3, No. 1 (1964) pp. 62-90)

Musicwriter

A teletype-like terminal invented by Hiller et al, used for the **setting** of music notation. (Hiller & Baker, "Automated music printing", Journ. Music Theory, Vol. 9, No. 1 (1965) pp. 129-152)

MUSIGOL

A **computer sound synthesis** program written in extended **ALGOL** by Donald MacInnis. (MacInnis, Perspectives of New Music, Vol. 7, No. 1 (1968) pp. 66-79)

musique concrète

Recorded electroacoustic music derived from the assembly and manipulation of recorded natural sounds; a term coined in Paris in the early 1950s, often used in contrast to music of purely electronic origin (sometimes called **Elektronische Musik**). See also **sonic object**. (Schaeffer, P. La Musique Concrète (Paris) - 1967)

MUSPEC

A programming language for music composition developed by Jack Citron. (Citron, in The Computer and Music, H. B. Lincoln, editor; Cornell Univ. Press, -1970, pp. 97-111)

MUSTRAN

Acronym for MUSic TRANslator; an **encoding language** for translating musical scores into a computer-readable format, developed by Jerome Wenker (Wenker, in Musicology and the Computer, B. Brook editor; City Univ. New York Press -1970, pp. 91-129)

MUSTUD

A group of FORTRAN programs developed by Gerald Lefkoff for score-based musical analysis. The MUSTUD system is particularly suited to examination of relatively large populations of musical specimens. MUSTUD includes its own music encoding conventions for the translating of scores into a computer-readable format. (Lefkoff, "Computers and the Study of Musical Style" in Lefkoff Computer Applications in Music, McClain (Parson, West Virginia) - 1967)

MUSYS

A **hybrid synthesis** system for computer control of an analog electronic music studio; developed by Peter Grogono, David Cockerell and Peter Zinovieff. (Grogono, Software-Practice and Experience, Vol. 3, No. 4 (1;973) pp. 369-383)

NCCBMI

See ICCBMI.

noise

1. Unwanted sounds or signals (contrasts with **signal**).
2. Non-periodic sound (contrasts with **periodic**).

Noise may be erratic or steady statistically random variations. Types of noises are commonly differentiated by their source or cause; and noises are commonly described by reference to their frequency distributions. See also **coloured noise**, **white noise**, **pink noise**, **distortion**.

non-periodic

See **periodic**.

notch filter

A type of band-reject filter whose bandwidth is quite narrow. A notch filter is typically employed to remove a specific frequency or narrow band of frequencies from a composite sound signal.

note

A musical term which has a rich variety of meanings; of the following four definitions the first three are traditional, while the last definition is unique to computer music:

1. A sign used in the writing of music.
2. The sound corresponding to, or indicated by, a sign used in written music.
3. Another name for an activating key or lever as found on pianos, organs, etc.

N.B. The notion of note connotes a perceptually distinct sonic entity of stable pitch whose duration falls roughly within the range of 40 milliseconds to 40 seconds.

4. In computer music, a note is a sonic event which is defined through the specification of note attributes called parameters. The note concept in computer music is a noticeable exaggeration of the traditional view of a note: it does not necessarily connote stable pitch, and in many cases its duration will exceed 40 seconds or be shorter than 40 milliseconds; further, a note may contain several simultaneous "streams" or **voices**. See **note-record**, **P-field**.

note-card

See **note-record**.

note-record

A punched card, card-image or record containing numerical synthesis data for a music sound synthesis program (e.g. MUSIC V). A note-record contains several "parameters fields" (or **P-fields**) which may be used to specify such aspects as duration, intensity, pitch or frequency, or other user-defined parameters.

Nyquist criterion

1. The requirement that the **sampling rate** of an **analog-to-digital conversion** process be at least twice the frequency of the highest frequency component for which representation is desired. At least two samples are required to represent a single cycle of any **waveform** -- one to represent a positive deviation and one to represent a negative deviation from the equilibrium point.
 2. The requirement that sound generation programs not produce frequencies exceeding half the **conversion rate** ($1/2SR$). See also **foldover**.
-

Nyquist frequency

The highest frequency for which the **Nyquist criterion** remains unviolated; the highest frequency which may be theoretically represented in a digital sound recording or generation system. The frequency corresponding to one-half the **sampling rate** or one-half the **conversion rate**.

object

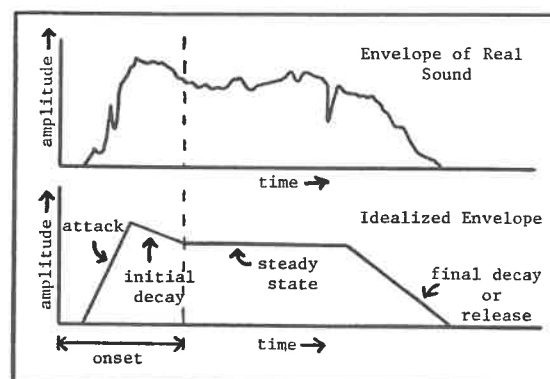
See **sonic object**.

octave

A musical term denoting an interval of pitch between two pitches whose frequencies are related in the approximate ratio of 2:1 (e.g. the frequencies 114 and 228 are an octave apart). Since exact octaves are frequently not always precisely related by a 2:1 frequency ratio, psychoacousticians have also defined the octave as the pitch interval between two tones such that one tone is perceived as duplicating the basic musical import of the other tone at the nearest possible higher or lower pitch. (American National Standards Institute, **Psychoacoustical Terminology**, S3.20 (1973) p. 34)

onset

The initial portion of a sound **envelope**. For most natural sounds the onset is characteristically complex; perceptually this onset of a sound is most important in its identification by a listener. Traditional electronic music terminology idealizes the onset as consisting of an **attack** and an initial **decay**. See also **envelope**.



orchestra

1. An assemblage of user-defined **instruments** used in **computer sound synthesis** programs.
2. An executable program assembled by a music compiler which is run in order to produce the sound function from a **score file**.

ORPHEUS

A **computer sound synthesis** program developed by Arthur Roberts at the Argonne National Laboratories. Formerly known as MUSIC 4F, ORPHEUS is a dialect of **MUSIC IV**. (Roberts, IN: Music by Computers ed. von Foerster & Beauchamp, Wiley & Sons (New York) - 1969 pp. 63-68)

oscillator

1. Any mechanical system which oscillates -- that is, produces a continually repeating motion (such as a pendulum or vibrating string).
2. An analog electrical device (commonly used in acoustic research and electronic music) which produces a continually repeating fluctuation in voltage or current conforming to a selected **frequency**.
3. A computer program -- often a **unit generator** -- designed to produce a more or less repetitive pattern of numbers for sound generating purposes (see also **table-lookup oscillator**).
4. A special-purpose digital electronic device which outputs more or less repetitive patterns of numbers for sound generating purposes (see **digital oscillator**).

overtone

1. Any simple **sine tone** (not necessarily **harmonic**) which exists above a fundamental frequency and which fuses with other components to comprise a single **complex tone**; a **partial** which occurs above the perceived pitch of a complex tone. (Contrast with **undertone**.)
2. Overtone has frequently been used interchangeably with **harmonic** -- meaning a simple frequency component of a complex tone which is an integer multiple of some given **fundamental frequency**. The fundamental frequency (or simply "fundamental") is also called the first harmonic but is not called an overtone -- the second harmonic is called the first overtone, the third harmonic is called the second overtone, and so on.

parallel

The processing or transmission of **data** in groups, rather than one one bit at a time.

parameter

A dimension or element of music construction which is subject to change or control, in particular the elements of pitch, rhythm, dynamics, articulation, register, texture, etc. A term borrowed from the field of mathematics, it was introduced to musical discourse by Robert Beyer in the early 1950s.

partial

Any simple **sine tone** component which perceptually fuses with other components to comprise a **complex tone**. Partial's need not be **harmonics** and may occur either above or below the fundamental frequency or perceived pitch of a complex tone. **Harmonics, inharmonics, pseudo-harmonics, overtones, undertones** and **subharmonics**, are all types of partials.

partial timbres

A **sound synthesis** technique in which complex sounds are assembled through the addition of two or more complex sound components. The partial timbres method differs from **additive synthesis** in that the component parts of a complete timbre are not simple **sine tones**; each component has its own independent envelope and **time-variant** spectrum. Careful programming and coordination of the component parts can lead to the creation of many valuable **harmonic** and **inharmonic** time-variant **timbres**. The partial timbres method is extensively used in conjunction with **frequency modulation** synthesis in New England Digital's Synclavier computer music instrument. Compare **additive synthesis**.

patch patching

Terms adopted from analog electronic music synthesis denoting the interconnecting of sound sources, processors, and controllers. In **computer sound synthesis** "patching" is applied broadly to denote the **software** interconnection of sound processors (usually **unit generators**) through the use of variables. Any specific inter-configuration of generators is referred to as a patch. See also **interface**.

PCM

See **pulse code modulation**.

perception

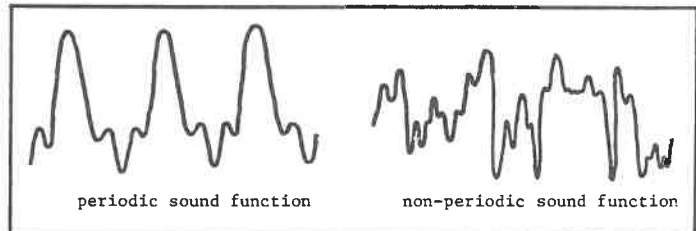
The process by which sensations are mentally interpreted. (American National Standards Institute, Psychoacoustical Terminology, S3.20 (1973) p. 36)

period

The elapsed time between the beginning and end of a single **cycle** of a **periodic waveform**. The period of a sound is inversely proportional to its frequency.

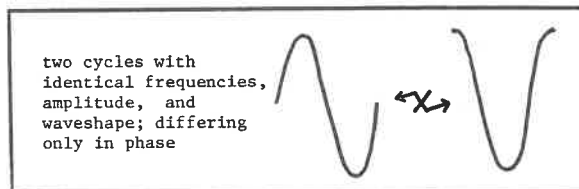
periodic

Any simple or complex function is described as periodic if and only if it has an identifiable cycle of identical repetition. When the rate of recurrence or **frequency** of repetition lies within the range of human hearing, the resulting sound will convey a sense of **pitch**. (NOTE: All pitched sounds are not necessarily periodic, and only periodic sounds which lie in the audible range are pitched.) Complex periodic functions may be analyzed into simple periodic components by the process of **Fourier analysis**. Functions which are not periodic are referred to as aperiodic or non-periodic. See also **pseudo-periodic**, **cycle**, **complex tone**, **waveform frequency**.



phase

Two **periodic** functions may be identical in all respects except that corresponding points of their **cycles** are offset in time. The amount of offset may be measured in seconds or **milliseconds**, however phase offsets are more commonly measured in radians or **degrees**, where 2 radians or 360 degrees is considered one full cycle. (Specifying phase in degrees or radians provides an offset measure which is independent of frequency). When the phase offset of two identical functions is 180 degrees, they are said to be "out of phase". Their summation will result in total cancellation of the sound function.



phase register

A register or computer **word** used in **computer sound synthesis**, the contents of which are used to **address** a table containing values corresponding to a single period of a particular waveform (often a **sine wave**). The register is incremented with the calculation of each new sound function sample. The value of the increment is an inverse function of the desired frequency. The width of the

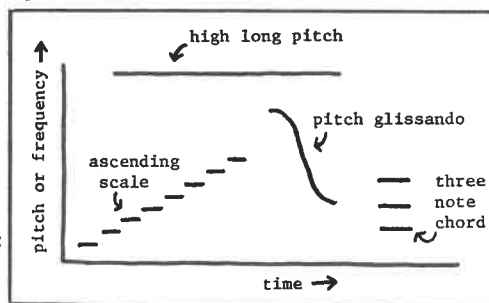
register in bits, generally corresponds to the number of elements in the wave-form table. Modulus arithmetic is performed automatically by ignoring the register overflow. The initial phase of the signal may be specified by loading some particular initial value into the register. See **table lookup oscillator**, **sampling increment**.

phototypesetter

A computer controlled photo-optical text setter commonly used in the production of books and newspapers. When supplied with an image disk containing musical symbols, musical scores may be typeset. See also **music setting**. (Bauer-Mengelberg, Computers and the Humanities, Vol. 6, No. 2 (1971) p. 110)

piano-roll notation

(also called **mod notation**) A method of musical notation analogous to piano-rolls used in player-pianos. Piano-roll notation employs a two dimensional graphical plan in which the ordinate (Y-axis) represents pitch or frequency, and the abscissa (X-axis) represents time, (strictly speaking, the reverse of piano-rolls). Single horizontal lines represent tones of stable pitch, with line length indicating duration, and horizontal placement indicating the time of occurrence within a score. A simple scale will appear as an ascending or descending set of steps while **glissandi** appear as oblique lines or curves. Similar to a **sonogram** in layout, piano-roll notation differs from a sonogram in its omission of **timbral** information -- preferring instead to only portray fundamental pitches or regions of pitch complexes. See also **tendency mask**.



piecewise-linear additive synthesis

A **time-variant additive sound synthesis** technique which employs linear approximations of pairs of functions describing changes of **amplitude** and **frequency** for each **partial** component of a single complex sound. Each line segment is described through the specification of x- and y-coordinates locating several **breakpoints**

-- fewer breakpoints indicating a greater degree of **data reduction**. See also **additive synthesis**, **breakpoint**, **data reduction**, **Fourier analysis**, **Fourier synthesis**, **time-variant**. (J. Grey, "An Exploration of Musical Timbre", PhD dissertation Stanford University -1975; distributed as Dept. of Music Report No. Stan-M-2)

FILE

A **computer sound synthesis** program written by Paul Berg. (Berg, Computer Music Journ., Vol. 3, No. 1 (1979) pp. 30-37)

pink noise

A type of broad-band non-periodic signal. Pink noise may be considered a unique sort of **white noise**. Like white noise, pink noise contains all frequencies within a specified bandwidth (usually the whole audible spectrum), however the noise within each musical interval (for example, within the interval of an **octave**) is present in equal amplitudes -- hence the total amplitude for the range 100Hz-200Hz is the same as for the range 800Hz-1600Hz. Pink noise is, therefore, biased toward greater power in the lower frequency range. Contrast with **white noise**).

pitch

The mental sensation of 'highness' or 'lowness' of a tone; a psychological/musical term denoting the mental correlate of frequency. Although the perception of pitch is purely a psychological phenomenon, pitch is usually measured in its physical relative -- **frequency** (expressed hertz - Hz). (A proposed psychological unit for pitch named the mel has failed to be widely adopted.)

pitch extraction

The analysis of sound signals to determine the **fundamental frequency** or perceived pitch present. Although several workable pitch extraction **algorithms** exist, there is no known algorithm for accurately determining the pitch of a wide variety of signals.

PL/1

An extensive high level structured programming language. PL/1 is frequently used in musicological processing and analysis applications.

Plaine and Easie Code System for Musicke

A music **encoding language** for translating music incipits into a computer-readable format, developed by B. Brook and M. Gould. See also **SPEC**. (Brook, Fontes Artis Musicae, Vol. 12, Nos. 2-3 (1965) pp. 156-160)

PLATO

Programmed Logic for Automatic Teaching Operation; one of the most extensive and well-known computer-aided instruction (CAI) systems, invented by Donald Bitzer and Peter Braunfeld of the University of Illinois. Several music instruction programs have been implemented on PLATO, notably Fred Hofstetter's **GUIDO**.

POD

An integrated computer music-composition/sound-synthesis system developed by Barry Truax. POD is an acronym for POisson Distribution. (Truax, Computer Music Journ., Vol. 1, No. 3 (1977) pp. 30-39.

pointer

An element of data that serves no other purpose than to refer to the location or **address** of another piece of data. Pointers are useful in permitting the construction of complex **data structures** in which elements of data are related to each other. See **data structures**; see also **phase register**, **thematic catalogue**.

polyphonic

A musical term signifying the presence of two or more simultaneous lines or voices in a passage of music. In computer music applications polyphonic is used more specifically to refer to the capability of a system to process two or more sounds or voices simultaneously. The term polyphonic is used in contrast to **monophonic** and is often employed in reference to the properties of keyboard **interfaces**.

portability

The ease with which computer software may be transferred from one computing machine to another. The portability of software may be enhanced through the avoidance of machine-dependent features, and by using popular standardized programming languages and library routines.

process music

A type of canonic or deterministic composition in which sounds or scores are produced through the repeated application of a cyclic permutation or other process to some initial musical materials. (Steve Reich "Music as a gradual process" in Writings about Music Nova Scotia College of Art and Design -1974)

processing

See **signal processing**.

protocol analysis

The analysis by behavioral scientists (or artificial intelligence engineers) of a complex human activity (such as puzzle solving or musical composition) through direct observation and subject query, in order to establish a step by step procedural description or model of that activity. Protocol analysis is sometimes performed as a first step in attempting to automate a specified task. (O. Laske, Interface, Vol. 1, No. 2 (1972) pp. 111-125)

pseudo-harmonic

Overtones for many naturally occurring sounds are often not exactly harmonic, but nearly so. For example, a **fundamental frequency** of 100 Hz might have overtone components pitched at (say) 202Hz, 298Hz, 406 Hz, etc. -- these overtones are referred to as "pseudo-harmonically related", or as "pseudo-harmonics". (Compare **harmonic**, **inharmonic**.)

psychoacoustics

The study of the perceptual and cognitive aspects of audition. There are many acoustical features to which the human auditory system is insensitive and conversely there are several acoustical factors to which humans are critically attuned. Psychoacoustic research is considered an important companion to computer sound generation and music synthesis in that it defines the framework of auditory/perceptual significance and thereby suggests areas of effective system design. See also **critical band**, **loudness**, **masking**, **pitch**, **Shepard's tone**.

punctuation

See **music setting**.

pure tone

See **sine tone**.

Push-Button Bertha

A work by Martin Klein and Douglas Bolitho, that shares the distinction of being one of the first computer-composed works of music (along with Hiller & Isaacson's Illiac Suite for String Quartet).

Push-Button Bertha was broadcast on a KABC-TV (Los Angeles) science programme called "Adventure Tomorrow" on July 15, 1956. Klein and Bolitho never continued further in this work. It is due to Hiller and Isaacson's protracted interest, experimentation, and documentation, for which they are generally acclaimed as the pioneers of computer music composition. ("Brain' Computes New Tune for TV", New York Times, July 3, 1956, p. 51 (late ed.))

quantizing error

Small errors due to the finite representation of **continuous analog signals**. Quantizing error is closely analogous to round-off error in arithmetic; it can be decreased substantially by increasing the resolution of representation through an increase in **word size**. Quantizing error occurs in both **digital sound synthesis** and **digital sound reproduction**. See also **analog**, **analog-to-digital converter**, **digital**, **digital-to-analog converter**, **continuous**, **discrete**, **Blessner's equation**.

quantizing noise

(also known as quantization noise) **Noise** produced as a result of **quantizing error**. Quantizing noise occurs in both **digital sound reproduction** and **computer sound synthesis**.

RANDHIND

A FORTRAN program written by Michael Hunt to generate two-voiced exercises according to the rules formulated by Paul Hindemith in his The Craft of Musical Composition. (Hunt, PhD dissertation, Washington Univ. -1974)

real-time

Time as it passes; time which is treated neither slower nor faster than the time of the real world. Real-time specifies a temporal frame in which a time-dependent operation or signal is executed or evaluated as it is needed or required. (Contrast with **non-real-time**.) See also **time-scale**, **real-time control**, **real-time sound synthesis**.

recursion

A procedure, function or routine which refers to itself -- that is, a procedure may "call" a copy of itself to carry out a calculation before it is, itself, finished. Such a self-referencing procedure may be repeated many times before the original task is completed. Not all computer programming languages permit the use of recursion. Recursion is frequently useful in the design of algorithms.

release

See (decay (3)).

resonance

The acoustic disposition of physical bodies and enclosures to promote energy at one or more frequencies or bands of frequencies. The resonance characteristics of bodies (for example violins or oboes) are important features by which listeners are able to identify these instruments. Resonances may be emulated through the use of filters; the simulation of complex resonances is usually achieved through filter networks -- that is, interconnected banks of simple filters.

reverberation

A type of continuing aura surrounding acoustic events -- in nature due to the "reservoir-like" properties of enclosures or partial enclosures with respect to acoustic energy. Multiple echoes which coexist in a single acoustic environment are perceptually fused and heard as reverberation. In natural acoustic environments, single echoes are not exact repetitions of the incident sounds but are modified timbrally due to the peculiarities of the absorptive properties of the exposed structural materials and furnishings. Computers are in principle capable of simulating the complex reverberation patterns of both real and imaginary acoustical environments. Depending upon the degree of accuracy sought, computer simulation may employ the use of digital filters to approximate the timbral modifications caused by the reflective materials. When the simulation includes the manipulation of timbres, it is called coloured reverberation; when the simulation does not include the manipulation of timbres, it is called colourless reverberation. A popular but comparatively crude method of colourless computer reverberation is the digital delay line, in which artificial reverberation is produced by the summation of periodic echoes of progressively diminishing amplitudes (of some sound input). See also comb filter digital delay, intimacy.

reverberation mix

The ratio of sound energies of the reflected sound components to the direct-path sound. Decreasing the reverberation mix gives the impression of approaching a sound source in an environment with fixed reverberation characteristics.

reverberation time

The time, measured in seconds, for the sound pressure level in a reverberant environment to decrease by 60 **decibels** from the instant a sound source ceases. Highly reverberant environments may have reverberation times of five seconds or more. In natural acoustic environments, the reverberation time is proportional to the volume of the space and inversely proportional to the sound-absorbitive properties of the surface materials. (W. C. Sabine, Collected Papers Harvard U.P. (1922) pp.3-68)

rhythmic justification

The rearrangement of performed timing impulses in order to align them with the musical beat (or appropriate subdivision of the beat). Rhythmic justification may be required to coordinate multi-tracked performances, or to rationalize or simplify rhythmic notation in amenuensis programs. First coined by New England Digital, manufacturers of the Synclavier computer music instrument.

RILM

Repertoire Internationale de la Littérature Musicale; a computer-assisted international index of abstracts of current music literature. RILM was initiated in 1967 under the joint sponsorship of the International Musicological Society and the International Association of Music Libraries and is centred in Flushing, New York. In periodically issued volumes, RILM attempts to keep abreast of the recent periodical literature, as well as books, dissertations, monographs, collected volumes and other musical scholarship. RILM relies heavily upon author-prepared abstracts -- mostly in English. RILM has also attempted the compilation of retrospective indexes and abstracts. See also **RISM**.

ring modulation

A complex form of **amplitude modulation** also known as balanced modulation. Ring modulation may be performed digitally by multiplying together the respective sample points for two discrete sound functions to create a third composite signal. Ring modulation produces complex timbres due to the colouring of numerous **sidebands**; the number of sidebands produced depends upon the timbral complexity of the initial signals. Ring modulated sounds are usually clangorous-sounding due to a high degree of **inharmonic**ity.

RISM

Repertoire International des Sources Musicales or International Inventory of Musical Sources: a reference catalogue of musical works (published and unpublished manuscripts) as well as writings about music, music textbooks, etc., in all languages from ancient times to the year 1800. RISM was initiated in 1955 under the joint sponsorship of the International Musicological Society and the International Association of Music Libraries. The RISM project is centred in Kassel, West Germany. See also RILM. (Brook, "Music Bibliography and the Computer" in Lefkoff, Computer Applications in Music McClain (Parsons, Virginia) -1967)

RUMBA

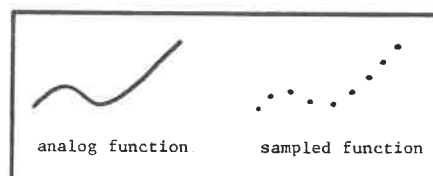
An initialism for Representations Utilizing Music Braille Alphamericis. RUMBA is a system for the printing of Braille music. See also SAMBA. (American Printing House for the Blind, Louisville, Kentucky; several reports between May 1971 and Aug. 1975)

SAMBA

An initialism for Systems Activated for Music Braille Automation. SAMBA is a system for the printing of Braille music. See also RUMBA. (American Printing House for the Blind, Louisville, Kentucky; several reports between May 1971 and Aug. 1975)

sampling

The process of taking a sequence of digital "snapshots" of a continuous analog signal (usually a sound function) for the purpose of producing a computer-compatible representation. Sampling is usually performed at a consistent rate; the frequency of sampling is referred to as the **sampling rate** (abbreviated SR). Sampling of incoming sound functions is performed by a device called an **analog-to-digital converter**.

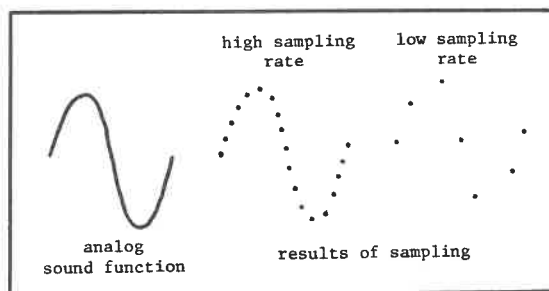


sampling increment

(abbreviated SI) A number stored in the **phase register** and used as the address increment to a table of numbers as used in a **table lookup oscillator**. The sampling increment is proportional to the desired frequency of a sound output -- that is, the sampling increment is inversely proportional to the period. See also **phase register**.

sampling rate

(abbreviated SR) The rate at which an **analog-to-digital converter** converts an input analog signal. Sampling rates are usually fixed and so are expressed in **hertz** or **samples-per-second**. Higher sampling rates provide more accurate representations of



analog signals than lower sampling rates as can be seen in the illustration. Sampling rate is synonymous with **conversion rate** when speaking of **analog-to-digital conversion**, however when speaking of **digital-to-analog conversion**, conversion rate is the preferred term. Both sampling rate and conversion rate are analogous to 'frames-per-second' as used in film. See also **sampling**, **Nyquist criterion**.

scale

A musical term applied to distinguish repertoire-sets of pitches from which a composer selects the pitches employed in a musical work. An early attraction of electronic and computer music was a desire by some composers to experiment with various non-traditional scales and methods of tuning.

SCHENKER

An interactive programming language developed by Stephen Smoliar for formulating and verifying analyses of tonal music compositions. SCHENKER is based on the theoretical formulations developed by Heinrich Schenker (1867-1935). Schenker posited the existence of prototypical music structures which expand hierarchically into tonal music compositions through a system of well-defined rewriting rules. See also **data structures**. (Smoliar, Technical Report CHS-76-8 (1976) Univ. of Pennsylvania)

scope

The extent or range over which an operation has effect. The scope of an operator is particularly important in editing environments where modifications are too numerous to easily permit specific or local changes, but where global operations are not sufficiently discriminating.

score

1. A paper manuscript on which are placed symbols used to either describe a musical composition, or direct a musical performer in the generation of a sound output.
 2. A computer file which either "describes" a musical composition, or directs software or hardware processors in sound synthesis or execution.
 3. A computer file consisting of **note-records** or note-cards. See also **score file**.
-

SCORE

A **computer music composition** program devised by Leland Smith. (Smith, Journ. Audio Engineering Soc., Vol. 20, No. 1 (1972) pp. 7-14)

score file

1. A computer file containing music notational information analogous to traditional musical scores.
 2. A collection of note-cards or **note-records** ordered in time; a type of data file to be used by an **orchestra**. See also **score** (def'ns 2 & 3)
-

semitone

The smallest pitch distance separating two scale degrees in traditional western-European music. One-twelfth division of an **octave**; the pitch distance between neighboring keys on a piano (such as C# to D). A pitch distance corresponding to a frequency ratio of the twelfth-root of 2 (approximately 1.059463). See also **pitch**, **frequency**, **octave**, **equal temperament**.

serial

The process of transmitting **data** one **bit** at a time. See also **parallel**.

setting

See **music setting**.

Shepard's tone

A single musical tone of gradually rising or falling pitch which may be generated in perpetuity without the tone becoming either too high or too low to hear. The Shepard's tone was devised as a demonstration of the breakdown of transitivity in judgments of relative pitch in the human auditory system. That is, if tone A is judged lower in pitch than tone B, and tone B is judged lower in pitch than tone C, it does not necessarily follow that tone A will be judged lower in pitch than tone C. To-date Shepard's tones have only been successfully constructed through the use of **computer sound synthesis** techniques. Shepard's tones have appeared in several contemporary music compositions, notably Jean-Claude Risset's "Mutations" (1969). (R.N. Shepard, "Circularity in Judgments of Relative Pitch", Journ. Acoustical Society of America, Vol. 36, No. 12 (1964) pp. 2346-2353)

SI

See **sampling increment**.

sideband

A sideband is an audible frequency component produced by a fast modulation of some sound signal. For both **amplitude modulation** and **frequency modulation**, sidebands appear in pairs above and below the original sound signal (called the carrier frequency). The presense of sidebands may be mathematically predicted and hence purposely exploited in the production of complex timbres. See also **ring modulation**.

signal

A message or sign of importance. In computer sound applications the most common signals are **discrete time-variant** functions represented numerically. (Contrast with **noise**.)

signal deconvolution

Any signal can be thought of as composed of two parts: the programme (wanted), and noise (unwanted). Perceptually the distinction between programme and noise is obvious, however from a physical standpoint the distinction is arbitrary. For example, if a recording consisted of a duet between a flute and clarinet, depending upon the musical objective it may, for example, be desirable to consider the clarinet **voice** as programme and the flute as noise. By using sophisticated techniques based on signal predictability (see **information theory**) it is more or less crudely possible to partially separate, or deconvolve, the two parts. In the well-known work of Thomas Stockham, old acoustic recordings of operatic tenor Enrico Caruso were subjected to enhancement through the use of signal deconvolution techniques. See also **echo removal**. (Stockham, Proc. I.E.E.E., Vol. 63, No. 4 (1975) pp. 678-692)

signal processing

Any manipulation of a **signal**. In digital sound processing, the discrete sound function is processed by arithmetic operations to obtain the desired manipulation. Examples of sound signal processing include: metering, mixing, editing, compression, expansion, limiting, gating, impulse noise reduction, **signal deconvolution**, **filtering**, **reverberation** and **echo removal**. Signal processes may be categorized as either manipulative processes (in which the original signal is modified before being outputted), and detective processes (in which features of the signal are passively monitored without changing the original signal, nor is any modified form of the input ever outputted). (Moorer (?) "Signal processing aspects of computer music" Computer Music Journ.)

signal-to-noise ratio

A number which expresses the difference between a signal level and the concurrent or idle noise in an electroacoustic system. The signal-to-noise ration (S/N) is often confused with **dynamic range**. For fixed- or floating-point digital sound systems, the signal-to-noise ratio is given by **Blessner's equation**.

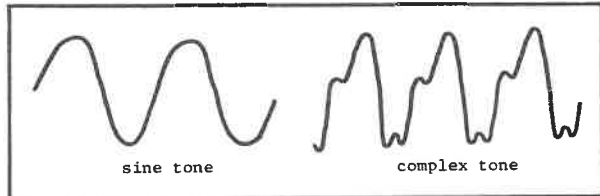
simple tone

See **sine tone**.

sine tone

A single audible **frequency**, also known as a "pure tone" or "simple tone" in contrast to **complex tone**. The sine tone takes its name from its distinctive waveform which may be derived

from sinusoidal trigonometry (sinus is Latin for 'fold' or 'curve'). While sine tones are simple single frequencies, they are characteristically "dull" sounding rather than "simple" or "pure" sounding as might be expected. Whether or not an individual judges a tone to be a pure sine tone or a complex tone is dependent upon ability, experience, and listening attitude. (American National Standards Institute, Psychoacoustical Terminology, S3.20 (1973) p. 12)



sinusoidal

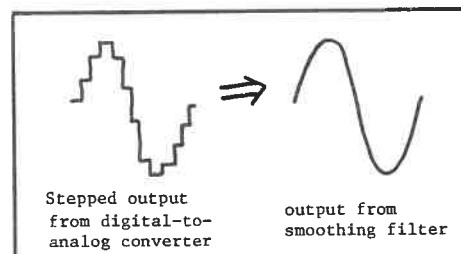
Pertaining to, or of, sine curves or **sine tones**.

slewing

The inability of an electronic component or circuit to produce abrupt changes in voltage or current (rate-limiting distortion). Slewing is a problem common to both analog and digital circuitry, however these problems are often compounded in digital/analog interfaces.

smoothing filter

A **low-pass filter** which is connected to the output of a **digital-to-analog converter** in order to smooth the stepped-function output and prevent the transmission of frequencies above the **Nyquist frequency**.



SNOBOL

A programming language with powerful text processing capabilities. Because of its flexibility, particularly with respect to the matching of patterns of character strings, it has been widely used in musical analysis applications. (Griswold, et al, The SNOBOL 4 Programming Language, Prentice-Hall (Englewood Cliffs), -1971)

software

1. Computer languages, systems and programs. Contrasts with **hardware**.
2. Tools that exist only conceptually (non-physically).

sonic object

A term coined in the early 1950s by the French writer/musician, Pierre Schaeffer ("objet sonore") denoting the concrete sound itself rather than an abstract representation of it -- an idea loosely analogous to the "note" concept of traditional western music, although less restrictive. (Schaeffer, P. Traité des objets musicaux (Paris) -1966)

sonology

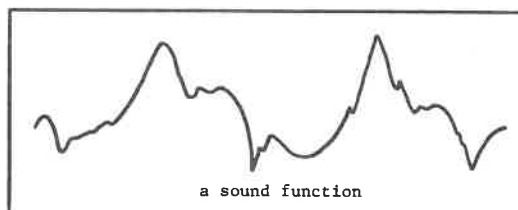
The study of the 'phenomenon of music', with particular emphasis on the examination of musical structure and musical creativity by the development of models and descriptive techniques. The active centre for sonological research is the Institute for Sonologie in Utrecht, Netherlands.

sound editor

1. A program used to rearrange digitally represented sound functions -- analogous to the cutting and splicing of analog magnetic tape; also called digital sound editor, tape-recorder-like (TRL) editor, or simply editor.
2. A program used to define or redefine computer synthesized **sonic objects**.

sound function

A generic term used as an abbreviation for "sound pressure function", or "sound particle displacement function", or "sound particle velocity function", or any other physical or graphic representation of the phenomenon of sound.



sound generation

The production of sound by any means, usually implying electronic sound generation or **computer sound generation**. A phonograph system, a piano, and an electronic **oscillator** are all methods of sound generation. Contrast with **sound synthesis**.

sound synthesis

Any process of **sound generation** employing "artificial" methods of sound construction (invariably by electrical or electronic means). The word synthesis, in **sound synthesis** implies the building-up of sounds through the assembly of simple components, however it is generally agreed that the process of breaking down complex electronically generated kernels to arrive at a final sound is also a form of sound synthesis. (See **synthesis**.) The former method is commonly called additive sound synthesis (or simply **additive synthesis**) and the latter method is commonly called subtractive sound synthesis (of simply **subtractive synthesis**). **Computer sound synthesis** denotes any sound synthesis technique which employs a computer -- usually through digital-to-analog methods. Contrast with **sound generation**. See also **hybrid synthesis**, **fixed-waveform synthesis**, **piecewise-linear additive synthesis**, **linear prediction**, **waveshaping**, **IRMA**, **MUSIC I-V**, **MUSIC7**, **MUSIC-11**, **MUSIC 65**, **MUSIC 360**, **MUSIC 3150**, **MUSIGOL**.

SPEC

Simplified Plaine & Easy Code; see also **Plaine and Easie Code System for Musicke**. A music **encoding language** for translating musical scores into a computer-readable format, developed by Barry

Brook and Murray Gould. SPEC was developed primarily for the restricted role of encoding thematic incipits for bibliographic purposes. It was proposed as the standard encoding language for RISM but was never adopted. The initialism SPEC was coined by Charles Boody. (Boody, PhD dissertation, Univ. of Minnesota, -1975)

spectral aliasing

The transmutation of one frequency into another frequency. The most common cause of spectral aliasing in computer music applications is **foldover** -- a condition caused when frequencies greater than or equal to the **Nyquist frequency** are synthesized or digitally recorded. In general, any frequency f will alias to the frequency f' such that $f' = SR - f$ if and only if f is greater than or equal to $SR/2$ (SR - **sampling rate**). In the process of digital recording, spectral aliasing may be prevented through the use of an **anti-aliasing filter**. Spectral aliasing in **computer sound snthesis** may be avoided only through careful programming and/or informed program use.

spectrum

A graphic display or other representation of the **frequency** content of a **signal**. Two-dimensional graphic spectrums usually plot **amplitude** (ordinate axis) versus frequency (abcissa). There are two general types of spectrums. A partial spectrum portrays **discrete** frequencies and is suitable for graphic descriptions of **harmonics**. A **continuous** spectrum portrays **bands** of contiguous frequencies and is suitable for graphic descriptions of noise bands. See also **frequency domain**, **frequency distribution**, **Fourier analysis**, **timbre**, **noise**.

SPIRAL

A **real-time computer sound synthesis** system developed by John Amuedo which utilizes an array processor. (Amuedo, Paper presented at the First International Conference on Computer Music, M.I.T. Oct. 28-31 -1976)

SR

See **sampling rate**.

SSP

Sound Synthesis Program; **computer sound synthesis** and composition tool developed by G. M. Koenig. The SSP system is distinctive in its pervasive use of amplitude and time as the sole descriptors for both sonic **objects** and musical structures. (Berg et al, "SSP and Sound Description", Computer Music Journ., Vol. 4, No. 1 (1980) pp. 25-35)

SSSP

Structured Sound Synthesis Project; computer music synthesis research and development group at the University of Toronto. (Buxton & Fedorkow, SSSP: An Introduction, Technical Report CSRG-92, Univ. of Toronto (1978) - Toronto)

stochastic

The Greek roots for this adjective connote a target, or a person who forecasts a future event in the sense of aiming at the truth. A stochastic model or process contains at least one random variable and so, unlike the exact forecasts of **deterministic** systems, future states of stochastic systems are only probabilistically known. Although specific details are unpredictable, the general behaviour of a stochastic process is predictable. Composer Iannis Xenakis is well-known for his use of stochastic methods in composition. (Contrast with **deterministic**.) See also **tendency mask**, **computer music composition**

stochastic music

Music composed by **stochastic** means.

stored sound synthesis

A **sound generation** or **sound synthesis** technique in which short recordings of prerecorded sounds are outputted on demand. Digital drum machines often employ stored sound synthesis -- using studio recordings of individual real drum sounds.

strength/generalizity

Based on the work of Allen Newell, it has been observed that computer music systems and programs may be characterized by their degrees of strength and generalizity -- where strength is loosely defined as the computational efficiency or productivity, and generalizity is the breadth of tasks to which a program can be applied. There appears to be an inverse or reciprocal relation between strength and generalizity, that is, programs with high strength tend to be narrow or specific while programs with high generalizity tend to be inefficient. In **computer sound synthesis** for example, the most general program would require the specification of each and every point in the sound function -- this method would not restrict the range of output in any way but would obviously be a tedious method of sound synthesis. (Truax, "The inverse relation between generalizity and strength in computer music programs", unpub. ms. 1976)

string manipulation

A string is a linear sequence of alphabet and/or numeric characters of some length. Many applications of computers require tools suitable for manipulating strings -- specifically searching for occurrences of particular "substrings", recognizing patterns or matching patterns of strings, substituting, removing, and inserting strings, etc. In music theory applications, character strings are often used to represent various musical notations (see **encoding language**) and consequently flexible string manipulation techniques are needed to perform specialized transformations of music theoretic significance. See also **ICON**, **LISP**, **PL1**, **SNOBOL**

structure

See **form**; see also **data structure**.

structural isomorphism

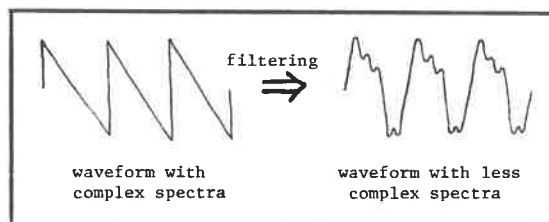
The design criterion of an **encoding language** which demands that the representation not force the presence of structural complications which do not exist in the original musical notation itself.

subharmonic

A simple **sine wave** component which exists below a **fundamental frequency** or fundamental pitch, and which fuses with other components to comprise a single **complex tone**. The frequency of a subharmonic is an integer divisor of the fundamental frequency. Subharmonics are **partials** which occur below the perceived pitch of a complex tone, and so are types of **undertones**.

subtractive synthesis

A **sound synthesis** technique in which **waveforms** containing complex spectra are filtered to achieve the desired sound signal. In a manner analogous to stone sculpture, new sound objects are created by removing features from an already existing signal. Subtractive synthesis is not frequently used in computer sound synthesis due to the computational inefficiency of digital filtering. Contrast with **additive synthesis**.



SYCOM

A **hybrid synthesis** facility at the University of South Florida employing a PDP11/10 minicomputer with Moog and Buchla analog synthesizers. (Austin, Numus West, Vol. 1, No. 5 (1974) pp. 57-59)

syntax

The arrangement of symbols in an orderly and permissible (but not necessarily meaningful) way; or the set of rules governing the arrangement of such symbols. See also **encoding language**, **assembler**, **compiler**, **context-dependency**.

Syntax Checker

A program for the proof-reading and error identification of **DARMS** input strings, written by Raymond Erickson.

synthesis

The artificial construction of **sonic objects**; any method of sound generation by electrical or electronic means.

The combining or assembling of parts or elements so as to form a whole. In the domain of electronic music, the term is usually restricted to indicate the assembly of individual sounds or **sonic objects** (see also **sound synthesis**, **computer sound synthesis**), but the term has also been occasionally applied to the assembly of musical aspects other than elemental sounds -- for example, the assembling of a composition from prepared phrases, motives, cells, etc.

In recent times, the word synthesis has acquired another popular connotation -- that of "artificial imitation". This alternate meaning can be traced, notably from the widespread displacement of natural fabrics by the production of "synthetic fibers". The result has been a conflating of the natural-artificial dichotome with the synthetic-analytic dichotome in musical circles -- for example, R.S. Brindle's statement that it "implies that the synthesizer's objective is to imitate" (The New Music (1975), p. 110). On the other hand, electronic music's use of the term is not entirely true to the meaning outlined in the first paragraph either, since many of the standard "synthesis" methods involve the breaking down or removal of components from an existing whole, rather than a building up from elements ('Subtractive synthesis' appears to be a contradiction in terms). In this regard, along with chemical engineering, electronic and computer music share an ambiguous use of the words "synthesis" and "synthetic". See also **Theory of Analysis/Synthesis**.

SYTER

A digital system developed by the Groupe de Recherches Musicales at the Institut National de l'Audio-visuel (Paris) which permits the real-time manipulation of live acoustic signals, (Allouis, Cahiers recherche/musique, Vol. 1, No. 3 (1976) pp. 62-91)

table lookup noise

The accompanying noise caused by finite binary representation of real-number values in **digital oscillators** and programs which use table lookup methods in sound generation. (Moore, "Table Lookup Noise for Sinusoidal Digital Oscillators," Computer Music Journ. Vol. 1, No. 2 (1977) pp. 26-35)

table lookup oscillator

A simple **sine wave** may be constructed by employing **algorithms** for the calculation of trigonometric sines, however this method is computationally inefficient. A much more efficient method is to create a table of numerical values corresponding to the **waveform** of a single **cycle** of a **periodic** sound. Values in the table are **sampled** according to an **addressing** increment called the **sampling increment** (SI). Tables generally contain exactly one cycle of the particular waveform of interest, however multiple or even partial i.e. half or quarter) cycles may be represented by the table instead. When the table contains a single cycle, the addressing or sampling increment may be calculated according to the formula:

$$SI = \frac{f \times TS}{SR}$$

where SI is sampling increment, f is the desired frequency, TS is the table size, and SR is the **sampling rate**. Thus, for example, if we wished to generate a 200 Hz pitch, where a 512-value table contains a single cycle -- at a sampling rate of 40,000 Hz:

$$SI = \frac{200 \times 512}{40,000} = 2.56$$

The address or **phase register** would be incremented by 2.56 for each sample to be calculated. The running value in the phase register would be truncated or rounded-off in order to provide a specific table address. In this manner, an oscillator routine skips through the table copying values into an output file and thereby constructs the required **sound function**. See also **interpolating oscillator**.

tempo

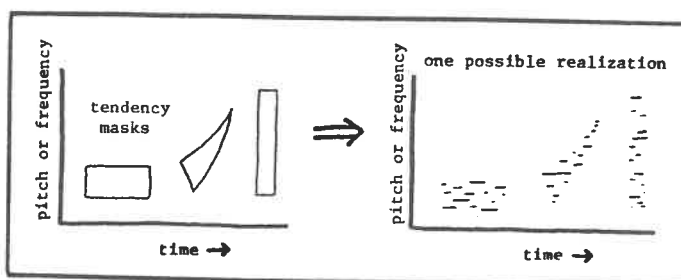
The musical speed or 'beat rate' of a musical passage. Tempo is sometimes specified in metronomic beats per minute.

TEMPO

Initialism for Transformational Electronic Music Process Organizer -- a programming language for **sound synthesis**, developed by John Clough. (Clough, Perspectives of New Music, Vol. 9, No. 1 (1970) pp. 113-125)

tendency mask

A notational device commonly used in **stochastic** music to identify clusters or clouds of notes: a tendency mask is often a simple closed curve superimposed on a **piano-roll** notation score used to define a region of pitch-time.



Since a tendency mask relies on random processes to fill in details, it serves only as a template for possible musical activities rather than defining explicit events. The musical value of tendency masks is partially based on the higher level perceptual "chunking" of complex superficial events into cognitively simpler "deep" structures.

thematic catalogue

A data-base catalogue of musical themes extracted from the repertoire of musical compositions. Musical themes have traditionally resisted any ordering analogous to the alphabetizing of words for the purpose of quick referral. Computer-based thematic catalogues may readily employ several concurrent orderings (including rhythm, pitch, composer's name, opus number, etc.) based on **thematic incipits**. Thematic catalogues are fast and convenient methods of accessing information on musical works, although no large computer-based thematic catalogues have as yet been developed for reasons of cost. (Brook, in Letkoff (ed.) Computer Applications in Music, West Virginia Univ. Press -1967, pp. 9-27)

thematic incipit

(pronounced: in-chip-it) A short fragment or extract from the score of a musical composition. Incipits are usually extracted from the most predominant motif or theme of a composition, and are chosen such that they are uniquely referential to the specific work considered. (The opening four notes of Beethoven's Symphony No. 5 is a good example.) Incipits may include both rhythmic and pitch information and are convenient ways of tagging entries in catalogues of musical compositions. See also **thematic catalogue**, **data structure**, **pointer**.

Theory of analysis/synthesis

A general theory of knowledge acquisition and use which has been applied to the synthesis of natural sounds and machine generation of musical compositions. The theory may be described as a four-part process:

1. A sample of objects is selected from the population of objects under consideration (e.g. trumpet tones, hymn tunes, the works of Beethoven).
2. A method of analysis is applied to the members of this sample. For sound objects, **Fourier analysis** may be appropriate; for musical compositions, **Markovian analysis** might be performed.
3. Through the examination of analytical results, common features from the sample members are identified and a generalization of distinctive or characteristic features of the class constructed.
4. Through some elected method of generation, new objects are generated such that they are constrained by or exhibit the features embodied in the previously constructed generalization. The newly created objects will be of the same class as the original population within the errors due to false assumptions introduced in the sampling, analysis, generalization, and generation stages.

NOTE: Each of the above processes employ certain techniques which are the choice of the experimenter. For example, an experimenter may choose (in order) 1) sampling theory, 2) Schenkerian analysis, 3) pattern recognition (or **discriminatory analysis**), 4) **Monte Carlo method** or some other set of techniques. (ref. Brooks, et al)

timbre

(pronounced tam-bur) Timbre, "tone colour" or "tone quality" are catch-all terms intended to denote all those properties of a sound, other than pitch and loudness, which combine to produce an overall auditory identity or character. The notion of timbre is closely associated with the "identifiability" or "distinguishability" of a sound or class of sounds; musicians will thus speak of the timbre of a violin, or the class of "brassy" timbres. See also **waveform**, **time-variant**, **voice**.

time domain

Sound may be regarded as an audible fluctuation of some physical attribute with respect to time. When discussing variations of the sound pressure function one is said to be conceptualizing sound within the time domain. Since many musical sounds are periodic or partially periodic, it is alternatively useful to regard sound in the **frequency domain**. Frequency domain representations may be constructed from time domain representations through the use of the **Fourier transform**; conversely, time domain representations may be reconstructed from their frequency domain counterparts through **Fourier synthesis**. Contrast with **frequency domain**.

time scale

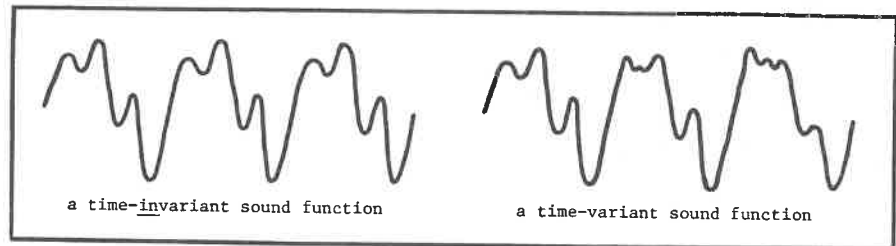
Time scale is defined as the time needed to compute samples of a sound -- divided by -- the duration of the sound. If the time scale is less than or equal to 1, then output data may be taken directly from the computer's central processor and sound can be synthesized in **real-time** -- this may permit performing on the computer (that is, hearing the sounds as one directly manipulates the musical parameters). When the time scale is greater than 1, real-time synthesis is not possible and so the computed sound samples must be temporarily kept on an intermediate storage medium for later playback in real-time. The time to compute samples of a sound is directly proportional to the number of independent simultaneous voices and to the complexity of the algorithms used in the generation of the timbres; the time to compute samples of a sound is inversely proportional to the speed of the computer processor. (Mathews et al, The Technology of Computer Music, (1969) p. 34)

time-sharing

The property of a computer system which permits multiprogramming or multiprocessing capabilities. To each user, it appears that the computer is dedicated to his or her self. In reality, the computer is slicing its time into very small segments, a segment for each user, and hence is able to do all of the work of the many users.

time-variant

Time-variant (also known as "dynamic") is a general term used to denote



aspects of the evolutionary changes a sound undergoes through time. In particular, time-variant commonly refers to the change of a sound's **waveform** with respect to time. Up until the middle part of this century, it was widely thought that **timbre** or toe quality was determined solely by the **waveshape** of a **periodic** signal. It is now recognized that the waveshape of a sound (or the ratio of the amplitudes of various harmonic components) is much less perceptually important than the manner in which these aspects change with respect to time. See also **timbre**, **inharmonic**, **pseudo-harmonic**.

time-variant spectra

(Also called **dynamic spectra**).

TLO

See **table lookup oscillator**

tonal density

That aspect of audition by which sounds may be ordered on a scale from diffuse to compact. A tone is said to increase in tonal density (i.e. become more compact) when its frequency and intensity are increased. Low frequency tones will appear to be less compact (or less dense) than high frequency tones. (American National Standards Institute, Psychoacoustical Terminology, S3.20, (1973) p. 12)

tone

1. A pitched sound.
2. The **timbre** or sonic quality of a particular sound or class of sounds (as the class of sounds produced by a musical instrument).

transitional probability

See **conditional probability**.

tremolo

A small **periodic** fluctuation of amplitude within a note or voice; a type of **amplitude modulation**. Contrast with **vibrato**.

undertone

Any simple **sine wave** component which exists below a **fundamental frequency** or fundamental pitch and which fuses with other components to comprise a single **complex tone**. Undertones are **partials** which occur below the perceived pitch of a complex tone. An undertone whose frequency is an integer divisor of the fundamental pitch is called a **subharmonic**. Contrast with **overtone**.

unison

The close but not exact coordination of pitch of two or more **voices**. The coordination must be close enough such that the voices are perceived as being "together", but not so coordinated as to fuse into a single voice.

unit generator

A **software** "device" used in **computer sound synthesis** programs which are fashioned after the modular design of analog synthesizers. Processors are designed and used as subroutines which are **patched** together through the use of variables or passed

values. Examples of unit generators are software oscillators, filters, reverberators, ring modulators, etc. Since unit generators are software processes, many replications of specific unit generators can be spawned as demanded by the user. (Mathews et al, The Technology of Computer Music, (1969) p. 34)

UNIX

A popular time-sharing operating system developed by Bell Telephone Labs. UNIX is noted for its device-independent input/output, (BTL) its hierarchical file system, its powerful software tools, and such innovative features as pipes and filters. The UNIX operating system is employed at several prominent computer music installations. (Thomas & Yates. A User Guide to the Unix System, McGraw-Hill -1982)

user

Any person who makes use of a computer or a particular computer system or computer program.

velocity-sensitive

Refers to a particular property of some clavier/keyboards or other manual controllers. A velocity-sensitive keyboard, for example, is a keyboard which supplies information regarding the speed of key depression -- such information is admirably suited to controlling loudness and/or **timbre** information in **real-time computer sound synthesis**.

vibrato

A small **periodic** rising and falling of pitch, within a note or voice which is perceived as adding 'character' or 'richness'. A type of **frequency modulation**. Contrast with **tremolo**.

vocoder

A device or the synthetic superimposition of voice upon some other sound. A vocoder extracts **formant** information corresponding to the **time-variant** changes of **resonances** of a speaking or singing vocal input. The sound function of the voice itself is discarded and

only the extracted formant information is retained, plus information regarding whether the vocal sounds are 'voiced' or 'unvoiced' (that is, whether or not the primary energy source is the vocal chords). This extracted information is then applied to frequency domain processors (a **filter network**) which modify a usually unrelated complex sound. Vocoder may be used to produce such effects as 'talking traffic' or 'singing clarinet'. Vocoder may be emulated in computer **software**.

voice

A sequence of similar sound events which are perceived by a listener as issuing from a single acoustic source.

volume

The overall "bigness" of a sound field including the **loudness**, duration, **timbre**, spatial distribution, **reverberation**, and number of simultaneous sound activities or **voices**.

VOSIM

A **computer sound synthesis** technique. The VOSIM technique is based on the modulation of sine-squared pulses, where the pulse frequency, pulse width, and duty cycle are controlled parameters. The manipulation of these parameters often produces sound outputs superficially similar to human vocal sounds. VOSIM is an acronym for VOcal SIMulation. (Tempelaars, "VOSIM Sound Synthesis", Institute for Sonologie, Utrecht, Netherlands (1976, Oct.))

waveform

The specific shape or contour of a single cycle of a **periodic sound function** as represented by a two-dimensional graph. Waveforms other than **sine waves** are considered complex, since they contain more than one simple frequency component (see **Fourier analysis**). The shape of the waveform is partly dependent upon the **harmonic** content of the sound -- hence, waveform is sometimes

erroneously used synonymously with **timbre**. See also **cycle**, **periodic**, **sine wave**, **harmonic**, **timbre**, **Fourier analysis**.

two functions of identical RMS amplitude and fundamental frequency; differing in waveform or waveshape



waveform sequencing synthesis

A **sound synthesis** technique in which sounds are produced by outputting values stored in a series of sound segments. Each segment may be repeated one or more times before proceeding to the next segment, and segments may sometimes be "nested" within one-another. Segments typically contain a single **waveform** or **waveshape**. Waveform sequencing is a useful means of synthesizing **harmonic** and **pseudo-harmonic timbres**. See also **table lookup oscillator**, **stored sound synthesis**.

waveshape

Synonymous with **waveform**.

waveshaping

A **sound synthesis** technique in which varied **waveforms** are derived from a single standard waveform (usually a **sine wave**) through the use of controlled distortion. Waveshaping may be accomplished in **hardware** through the use of nonlinear circuits. In **software**, the waveshape distortion may be achieved by simple arithmetic manipulation of the **discrete sound function**. When the waveshaping input is **sinusoidal**, it is easy to control the **harmonic** or **timbral** richness of the resulting output. (R. Schaeffer "Electronic Musical Tone Production by Nonlinear Waveshaping", Journ. Audio Engineering Soc. Vol. 18, No. 4 (1970) pp. 4113-417)

WEMUREP

Acronym for Western European MUsic REPresentation; a music **encoding language** for translating musical scores into a computer-readable format.

white noise

Analogous to 'white light', white noise (also called Johnson noise) consists of all frequencies within a specified bandwidth (usually the whole audible spectrum). Each frequency is present in equal amplitude -- for example, the total amplitude for the range 100 Hz - 200 Hz is the same as the range 5100 Hz - 5200 Hz, hence white noise is richer in high frequency components. Contrast with **pink noise**.

word

The basic unit of addressable computer storage. A single word commonly can store a single numerical value or store a couple of alphabetic/numeric characters. The only property of a word is its size -- measured in **bits** or bytes (characters). Typically words are 8, 16, or 32-bits in size (occasionally larger). The word-size of a computer is determined by the width of its data bus. See also **data representation**.

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