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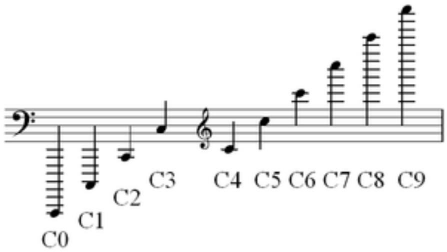
Scientific pitch notation

Scientific pitch notation (or **SPN**, also known as **American standard pitch notation** (**ASPN**) and **international pitch notation** (**IPN**))[1] is a method of specifying musical pitch by combining a musical note name (with accidental if needed) and a number identifying the pitch's octave.



Ten Cs in scientific pitch notation

Although scientific pitch notation was originally designed as a companion to scientific pitch (see below), the two are not synonymous. Scientific pitch is a pitch standard—a system that defines the specific frequencies of particular pitches (see below). Scientific pitch notation concerns only how pitch names are notated, that is, how they are designated in printed and written text, and does not inherently specify actual frequencies. Thus, the use of scientific pitch notation to distinguish octaves does not depend on the pitch standard used.

Contents

Nomenclature

The notation makes use of the traditional tone names (A to G) which are followed by numbers showing which octave they are part of.
The system begins at a frequency of 16.352 Hz, which is assigned the value $\mathbf{C_0}$.
The octave 0 of the scientific pitch notation is traditionally called the sub-contra octave, and the tone marked C_0 in SPN is written as *,,C* or *C,,* or *CCC* in traditional systems. Octave 0 of SPN marks the low end of what humans can actually perceive, with the average person being able to hear frequencies no lower than 20 Hz.
The octave number increases by 1 upon an ascension from B to C. Thus, A_0 refers to the first A *above* C_0 and middle C (the small octave's C or simply *c*) is denoted as C_4 in SPN.

Use

Scientific pitch notation is often used to specify the range of an instrument. It provides an unambiguous means of identifying a note in terms of textual notation rather than frequency, while at the same time avoiding the transposition conventions that are used in writing the music for instruments such as the clarinet and guitar. It is also easily translated into staff notation, as needed. While in describing musical pitches, enharmonic spellings can give rise to anomalies where $C\flat_4$ is a lower frequency than $B\sharp_3$; such paradoxes do not arise in a scientific context.

Scientific pitch notation avoids possible confusion between various derivatives of Helmholtz notation which use similar symbols to refer to different notes. For example, "c" in Helmholtz notation refers to the C below middle C, whereas "c" in ABC Notation refers to middle C itself. With scientific pitch notation, middle C is *always* $\mathbf{C_4}$, and $\mathbf{C_4}$ is never any note but middle C. This notation system also avoids the "fussiness" of having to visually distinguish between four and five primes, as well as the typographic issues involved in producing acceptable subscripts or substitutes for them. $\mathbf{C_7}$ is much easier to quickly distinguish visually from $\mathbf{C_8}$, than is, for example, **c**′′′′ from **c**′′′′′, and the use of simple integers makes subscripts unnecessary altogether.

Although pitch notation is intended to describe sounds audibly perceptible as pitches, it can also be used to specify the frequency of non-pitch phenomena. Notes below E_0 or higher than $E♭_{10}$ are outside most humans' hearing range, although notes slightly outside the hearing range on the low end may still be indirectly perceptible as pitches due to their overtones falling within the hearing range. For an example of truly inaudible frequencies, when the Chandra X-ray Observatory observed the waves of pressure fronts propagating away from a black hole, their one oscillation every 10 million years was described by NASA as corresponding to the B♭ fifty-seven octaves below middle C (or $B♭_{-53}$).[2]

Similar systems

There are pitch-octave notation conventions that appear similar to scientific pitch notation but are based on an alternative octave convention that differs from scientific pitch notation usually by one octave. For example, some MIDI software uses "C_5" to represent middle C (MIDI note 60).[3] This convention is probably related to a similar convention in sample-based trackers, where C_5 is the basic pitch at which a sample plays (8287.12 Hz in MOD), forcing the musician to treat samples at any other pitch as transposing instruments when using them in songs. Alternately, both Yamaha and the software MaxMSP define middle C as C_3.

Using scientific pitch notation consistently, the MIDI NoteOn message assigns MIDI note 0 to C_{-1} (five octaves below C_4 or Middle C; lowest note on the two largest organs of the world; about one octave below the human hearing threshold: its overtones, however, are audible), MIDI note 21 to A_0 (the bottom key of an 88-key piano), MIDI note 60 to C_4 (Middle C), MIDI note 69 to A_4 (A440), MIDI note 108 to C_8 (the top key of an 88-key piano), and MIDI note 127 to G_9 (beyond the piano; one octave above the highest note on some keyboard glockenspiels; some notes above the highest-pitched organ pipes).

This creates a linear pitch space in which an octave spans 12 semitones, where each semitone is the distance between adjacent keys of the piano keyboard. Distance in this space corresponds to musical pitch distance in an equal-tempered scale; 2 semitones being a whole step, 1 semitone being a half step. An equal-tempered semitone can also be subdivided further into 100 cents. Each cent is $^1⁄_{100}$ semitone or $^1⁄_{1200}$ octave. This measure of pitch allows the expression of *microtones* not found on standard piano keyboards.

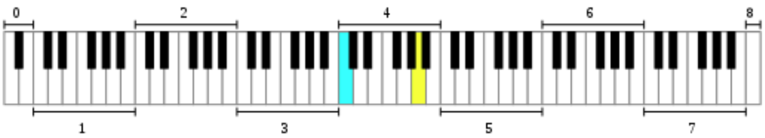
Meantone temperament

The notation is sometimes used in the context of meantone temperament, and does not always assume equal temperament nor the standard concert A_4 of 440 Hz; this is particularly the case in connection with earlier music.

The standard proposed to the Acoustical Society of America[4] explicitly states a logarithmic scale for frequency, which excludes meantone temperament, and the base frequency it uses gives A_4 a frequency of exactly 440 Hz. However, when dealing with earlier music that did not use equal temperament, it is understandably easier to simply refer to notes by their closest modern equivalent, as opposed to specifying the difference using cents every time.

Table of note frequencies

The table below gives notation for pitches based on standard piano key frequencies, in other words, standard concert pitch and twelve-tone equal temperament). When a piano is tuned to just intonation, C_4 refers to the same key on the keyboard, but a slightly different frequency.



An 88-key piano, with the octaves numbered and Middle C (cyan) and A440 (yellow) highlighted.

Fundamental frequency in hertz (MIDI note number)

Octave / Note	−1	0	1	2	3	4	5	6	7	8	9	10
C	8.1758 (0)	16.352 (12)	32.703 (24)	65.406 (36)	130.81 (48)	261.63 (60)	523.25 (72)	1046.5 (84)	2093.0 (96)	4186.0 (108)	8372.0 (120)	16744 ()
C♯/D♭	8.6620 (1)	17.324 (13)	34.648 (25)	69.296 (37)	138.59 (49)	277.18 (61)	554.37 (73)	1108.7 (85)	2217.5 (97)	4434.9 (109)	8869.8 (121)	17740 ()
D	9.1770 (2)	18.354 (14)	36.708 (26)	73.416 (38)	146.83 (50)	293.66 (62)	587.33 (74)	1174.7 (86)	2349.3 (98)	4698.6 (110)	9397.3 (122)	18795 ()
E♭/D♯	9.7227 (3)	19.445 (15)	38.891 (27)	77.782 (39)	155.56 (51)	311.13 (63)	622.25 (75)	1244.5 (87)	2489.0 (99)	4978.0 (111)	9956.1 (123)	19912 ()
E	10.301 (4)	20.602 (16)	41.203 (28)	82.407 (40)	164.81 (52)	329.63 (64)	659.26 (76)	1318.5 (88)	2637.0 (100)	5274.0 (112)	10548 (124)	21096 ()
F	10.914 (5)	21.827 (17)	43.654 (29)	87.307 (41)	174.61 (53)	349.23 (65)	698.46 (77)	1396.9 (89)	2793.8 (101)	5587.7 (113)	11175 (125)	22351 ()
F♯/G♭	11.563 (6)	23.125 (18)	46.249 (30)	92.499 (42)	185.00 (54)	369.99 (66)	739.99 (78)	1480.0 (90)	2960.0 (102)	5919.9 (114)	11840 (126)	23680 ()
G	12.250 (7)	24.500 (19)	48.999 (31)	97.999 (43)	196.00 (55)	392.00 (67)	783.99 (79)	1568.0 (91)	3136.0 (103)	6271.9 (115)	12544 (127)	25088 ()
A♭/G♯	12.979 (8)	25.957 (20)	51.913 (32)	103.83 (44)	207.65 (56)	415.30 (68)	830.61 (80)	1661.2 (92)	3322.4 (104)	6644.9 (116)	13290 ()	26580 ()
A	13.750 (9)	27.500 (21)	55.000 (33)	110.00 (45)	220.00 (57)	440.00 (69)	880.00 (81)	1760.0 (93)	3520.0 (105)	7040.0 (117)	14080 ()	28160 ()
B♭/A♯	14.568 (10)	29.135 (22)	58.270 (34)	116.54 (46)	233.08 (58)	466.16 (70)	932.33 (82)	1864.7 (94)	3729.3 (106)	7458.6 (118)	14917 ()	29834 ()
B	15.434 (11)	30.868 (23)	61.735 (35)	123.47 (47)	246.94 (59)	493.88 (71)	987.77 (83)	1975.5 (95)	3951.1 (107)	7902.1 (119)	15804 ()	31609 ()

Mathematically, given the number n of semitones above middle C, the fundamental frequency in hertz is given by $440 \cdot 2^{(n-9)/12}$ (see twelfth root of two). Given the MIDI NoteOn number m, the frequency of the note is normally $440 \cdot 2^{(m-69)/12}$ Hz, using standard tuning.

Scientific pitch versus scientific pitch *notation*

Scientific pitch (q.v.) is an absolute pitch *standard*, first proposed in 1713 by French physicist Joseph Sauveur. It was defined so that all Cs are integer powers of 2, with middle C (C_4) at 256 hertz. As already noted, it is not dependent upon, nor a part of scientific pitch *notation* described here. To avoid the confusion in names, scientific pitch is sometimes also called "Verdi tuning" or "philosophical pitch".

The current international pitch standard, using A_4 as exactly 440 Hz, had been informally adopted by the music industry as far back as 1926, and A440 became the official international pitch standard in 1955. SPN is routinely used to designate pitch in this system, and A_4 may be tuned to other frequencies under different tuning standards as well, and SPN octave designations still apply (ISO 16[5]).

With changes in concert pitch and the widespread adoption of A440 as a musical standard, new scientific frequency tables were published by the Acoustical Society of America in 1939, and adopted by the International Organization for Standardization in 1955. C_0, which was exactly 16 Hz under the scientific pitch standard, is now 16.352 Hz under the current international standard system.[4]

See also

- Mathematics of musical scales
- Helmholtz pitch notation
- MIDI
- MIDI tuning standard
- Piano key frequencies
- Keyboard tablature
- Letter notation

References

1. International Pitch Notation (http://www.flutopedia.com/octave_notation.htm)
2. Black Hole Sound Waves (https://science.nasa.gov/science-news/science-at-nasa/2003/09sep_blackholesounds/) “Sound waves 57 octaves lower than middle-C are rumbling away from a supermassive black hole in the Perseus cluster”
3. Guérin, Robert. *MIDI Power!*. ISBN 1-929685-66-1.
4. Young, Robert W. (1939). "Terminology for Logarithmic Frequency Units". *Journal of the Acoustical Society of America*. **11** (1): 134–000. Bibcode:1939ASAJ...11..134Y (https://ui.adsabs.harvard.edu/abs/1939ASAJ...11..134Y). doi:10.1121/1.1916017 (https://doi.org/10.1121%2F1.1916017).
5. *ISO 16:1975 Acoustics – Standard tuning frequency (Standard musical pitch)* (http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=3601). International Organization for Standardization. 1975.

External links

- English Octave-Naming Convention (http://www.dolmetsch.com/musictheory1.htm#uspitch) – Dolmetsch Music Theory Online
- Notefreqs (http://www.deimos.ca/notefreqs) – A complete table of note frequencies and ratios for midi, piano, guitar, bass, and violin. Includes fret measurements (in cm and inches) for building instruments.