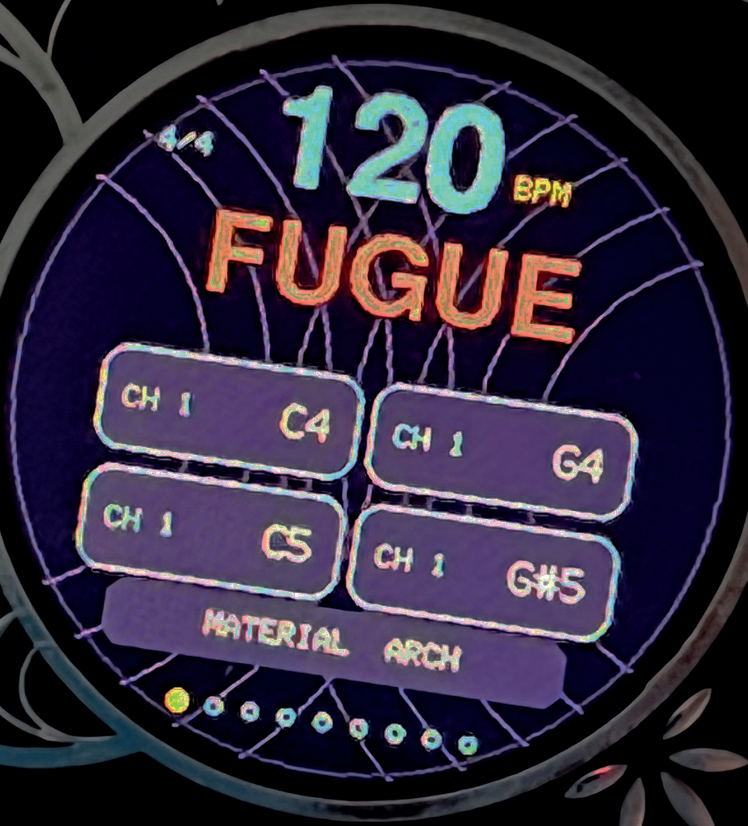
B.A.C.H.

Musical composition generator

User manual

version 1.037



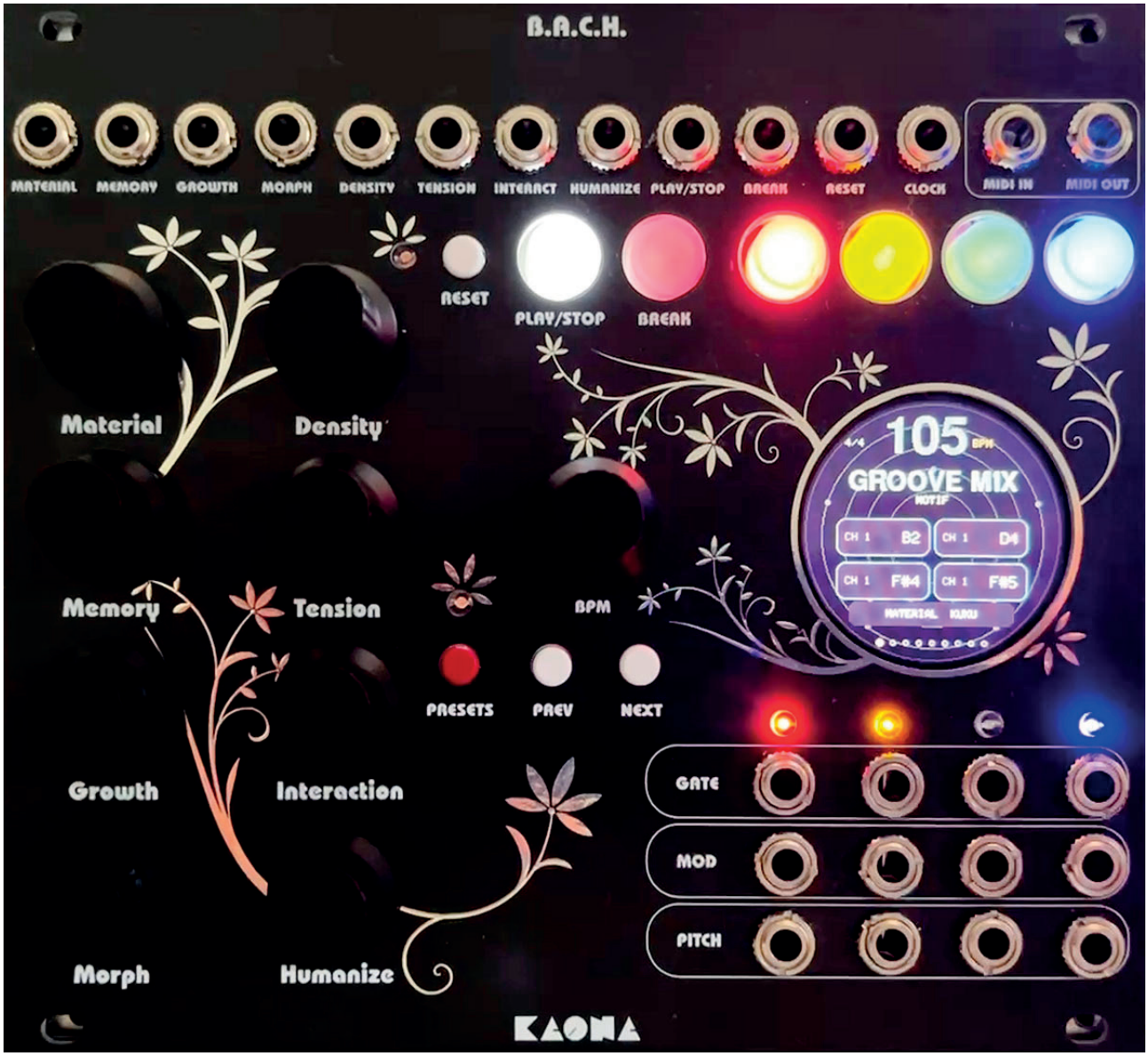
KAONA

Ingenious Instruments for Creative Minds

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Introduction



B.A.C.H. is a four-voice generative composition instrument. On every clock pulse (corresponding, depending on the setting, to a beat or to a rhythmic subdivision), it determines the activity of each voice: note or rest, pitch, duration and dynamics. This generation relies on one of the writing rules offered by the module.

These rules are conceived as so many languages, each with its own musical grammar and its own vocabulary. They thus make directly manipulable a set of notions that normally belong to the work of composition. B.A.C.H. does not seek

to reproduce a particular method or style, but offers an interface built on concepts general enough to accommodate very different musical approaches.

The available languages make it possible to explore various forms of counterpoint (fugue and canon), probability chains, tintinnabuli, repetitive music, cellular automata, walks through a growing tree (L-system), fractal structures and motif transformation. B.A.C.H. can also produce evolving rhythms, either independent of or tied to the melodic rules.

B.A.C.H. is not an artificial intelligence and does not produce a finished work from a simple request. It offers the musician an environment in which he or she defines constraints, introduces musical ideas, transforms the rules and steers the evolution of the composition.

Eight rotary controls, also drivable by CV, act in real time on the chosen language. They control the initial vocabulary, persistence, development, transformation, density, tension, the relationships between voices and expressive gesture. Other parameters determine the harmonic progression, the scales used and the playing dynamics.

B.A.C.H. is an instrument with many settings, allowing new ways of composing, improvising or accompanying to be explored. Although producing the first sequences is very simple and quick, B.A.C.H. may require a real learning period before all its subtleties are mastered. This manual should help you understand its concepts.

Specifications

B.A.C.H. is a module intended for the Eurorack environment. It is nevertheless perfectly possible to install it in a standalone case powered at ±12 V and to use it over MIDI.

Width: 28 HP

Current draw:

+ 12 V: 240 mA

– 12 V: 30 mA

+ 5 V: 0 mA

Depth: 28 mm

TRS MIDI (IN and OUT) : type B

An SD card is supplied and installed directly on the back of the module. The files are not directly usable and there is no need to provide access to this card. However, if the module is replaced, the card can be removed in order to keep the saved presets.

Installation

Connect B.A.C.H. to a Eurorack power supply using the cable provided. The module is protected against reverse polarity, and a key on the cable ensures it is inserted the right way round.

B.A.C.H. produces no sound: it must be connected to one or more VCOs, external synthesizers or any MIDI instrument. It is not limited to the modular synthesizer environment and can be installed in a powered host case and used outside the Eurorack standard thanks to the MIDI output.

Operation

B.A.C.H. is a four-voice composition generator. It does not play back recorded sequences: on every clock pulse (internal or external), it computes which notes are to be played, on which tracks, with what duration and with what dynamics. Twelve writing languages are available, each applying a specific musical logic: counterpoint, imitation, gradual process, automaton, growth grammar, mathematical sequence, rhythmic grid.

The four tracks are output as CV and as MIDI. Each track has a GATE output, a PITCH output at the 1 V/octave standard and a VELOCITY output, and in parallel on one of the configurable MIDI channels. The module produces no sound: it only supplies the notes and their dynamics, which are then produced by oscillators or MIDI instruments.

Eight encoders continuously adjust the current language. These controls have no defined positions, no start or end of travel. The values of the settings are readable on the screen. Whatever the chosen composition language, they always bear the same name and always keep the same general role: MATERIAL chooses the starting vocabulary, MEMORY persistence, GROWTH development, MORPH transformation, DENSITY filling, TENSION the distance from stability, INTERACTION the dependency between tracks, HUMANIZE gesture.

What each one means concretely, however, depends on the language: in a fugue, GROWTH sets the length of the sections; in a cellular automaton, the speed of the generations. The chapter devoted to each language in this manual specifies the framework in which every control operates.

All the controls have a CV input with its attenuator, which makes it possible to modulate the composition from the rest of a modular system.

The difference between B.A.C.H. and a sequencer

A sequencer requires every note to be entered. It gives total control over a sequence, shorter or longer, but always limited and looping.

B.A.C.H. is a generator: you no longer enter the notes but the conditions that produce them, and the length of the score played is no longer limited. In exchange, control over detail is lost: there is no provision for forcing a specific note at a given place.

The concept is therefore to give access to the parameters of recognizable rules. Each language applies a procedure that has a history and a documented theoretical framework, so that the eight controls act on parameters that are meaningful within that procedure.

The origins of generative music

Composing from a rule rather than note by note is an old practice. Around 1026, Guido of Arezzo described in *Micrologus* a method of melodic invention that associates the vowels of a text with the degrees of the scale: the text thus provides a framework from which a melody can be produced or improvised. In the early XIVth century, the innovations in rhythmic notation gathered under the name Ars nova (traditionally associated with Philippe de Vitry) allowed a more precise and more flexible organization of durations. In 1668 there appeared in London *Tintinnalogia, or the Art of Ringing,* attributed to Richard Duckworth, a work that describes, by means of figures, ordered chains of bell permutations: music produced by a procedure and performed without a musical score in the usual sense.

In the Baroque period, the rule does not necessarily produce the music directly, but it organizes the writing. Imitation, inversion, retrogradation, augmentation, diminution and canon are all formalizable operations, whose possibilities Johann Sebastian Bach explored systematically. In the *Musical Offering* of 1747, several canons are presented in a deliberately enigmatic form: it is up to the reader to discover the missing voices or transformations. The motto *Quaerendo invenietis* ("Seek and you shall find") sums up this game of deduction. *The Art of Fugue*, whose first posthumous edition appeared in 1751, sets out the elements of procedural thinking:

a subject, operations and successive states. It is not yet, however, an autonomous generative system.

The XVIIIth century also explored combinatorial composition. In 1757, Johann Philipp Kirnberger published a manual for assembling musical fragments by means of tables. The following year, Carl Philipp Emanuel Bach described a procedure for building six measures of double counterpoint without knowing its rules. One of these games is *the Anleitung zum Komponieren von Walzern,* attributed (perhaps falsely) to Mozart. Two dice are used to select pre-written measures from tables containing 176 entries. The system produces a sixteen-measure waltz; fourteen of the measures offer eleven possibilities, the eighth only one and the last two. The music is indeed obtained by a procedure, but that procedure does not create its material: it arranges fragments already composed.

In the early XXth century, the rule again bears on the organization of the material itself. Between 1921 and 1923, Arnold Schoenberg developed his "method of composing with twelve tones related only to one another." A row orders the twelve pitches of the chromatic scale and can be transposed, inverted, retrograded or subjected to a retrograde inversion. These operations, familiar from counterpoint, no longer apply only to a theme but to the general organization of pitches. The row does not by itself determine the entire work, however: rhythm, timbre, articulation, texture and form remain largely subject to the composer's decisions.

After 1945, generalized serialism extended this drive for organization to several parameters. In *Mode de valeurs et d'intensités* by Messiaen, composed in 1949, pitches, durations, intensities and modes of attack are associated according to determined modes. Boulez generalized this approach in the first book of *Structures pour deux pianos*.

Other composers entrusted certain decisions to chance or to calculation. John Cage used combinations from the Yi Jing to determine the score of *Music of Changes* in 1951. Lejaren Hiller and Leonard Isaacson then programmed the ILLIAC I computer at the University of Illinois to produce and select musical phrases. Their *Illiac Suite*, completed in 1956 for string quartet, can be regarded as the first large-scale score to come out of a computer-assisted composition process.

Iannis Xenakis applied laws of probability to sound masses in *Pithoprakta* in 1955–1956 and *Achorripsis* in 1956–1957, before setting out his stochastic methods in *Formalized Music* in 1963. In *the Poème symphonique pour 100 métronomes* of 1962, György Ligeti created a twenty-minute piece played solely by metronomes whose tempos and starting times are set. In 1965, Steve Reich used phasing by having the same loop played by two tape recorders running at slightly different speeds. He then adapted this principle to instrumentalists, notably in *Piano Phase* in 1967. Once prepared and set in motion, the process unfolds by itself and must remain perceptible throughout the listening.

The expression "generative music" was popularized by Brian Eno in the mid-1990s, during a lecture given in San Francisco on June 8, 1996. His research was nevertheless much earlier: in *Discreet Music* in 1975, a synthesizer feeds a delay and feedback setup whose behavior Eno largely lets develop on its own. For some pieces on *Ambient 1: Music for Airports* in 1978, long tape loops of differing lengths superimpose isolated notes and short fragments: their encounters keep renewing themselves over very long periods.

From 1981 onward, David Cope developed *Experiments in Musical Intelligence,* which analyzes musical corpora and recombines them. Arvo Pärt, for his part, devised, with *Für Alina* in 1976, the tintinnabuli system: a melodic voice is paired with a voice that draws its notes from a triad according to precise rules of position and proximity. This writing is highly formalizable, yet remains largely interpreted by Arvo Pärt in his compositions.

Modular synthesis followed its own path in parallel. In 1970, Donald Buchla introduced the 200 series, which developed a control of sound open to variable and random voltages. The 266 *Source of Uncertainty* module, designed in the mid-1970s, supplies fluctuating, quantized or stored random voltages, some of whose distributions can be controlled. Since the 2000s, the Eurorack ecosystem has multiplied shift registers, quantizers, probabilistic sequencers and Euclidean rhythm generators, turning these principles into everyday tools of modular composition.

B.A.C.H. belongs to this lineage, moving generation to the scale of musical writing. It offers not merely isolated sources of variation, but composition rules whose

internal state (subject, phrase, generation and section) persists from one measure to the next. It thus joins the family of Kaona instruments devoted to algorithmic and generative music, alongside Skippy, a generator of matrix or non-matrix, linear or logarithmic rhythms, and Zazou, which produces sequences, accompaniments, improvisations and melodies on four fully independent channels.

Controls and navigation

The eight encoders are contextual: on the main screen they shape the algorithm; on the dedicated pages they set the musical parameters, the sequence, the Breaks or the CVs.

The eight controllers

CONTROL	FUNCTION
MATERIAL	Chooses the starting vocabulary: motif, rule, family, language or rhythm.
MEMORY	Sets persistence, repetition or renewal speed depending on the algorithm.
GROWTH	Develops the form: length, depth, number of cells or voice entries.
MORPH	Transforms what exists: rotation, inversion, displacement, permutation or mutation.
DENSITY	Determines how many events and voices are audible.
TENSION	Moves the material away from its stability through syncopation, intervals or passing notes.
INTERACTION	Sets the dependency between the four tracks: unison, imitation, dialogue or independence.
HUMANIZE	Introduces a progressive notion of improvisation suited to each language.

Interface encoder and buttons

CONTROL	ACTION
Interface encoder	Sets the tempo expressed in BPM. Remains available on every screen.
Click on the interface encoder	Opens and confirms the choice of algorithm.
Click on the eight performance encoders	Normally returns the parameter to its reference value. That value is the last value saved in the chosen preset, or the factory default.
PREV / NEXT	Moves through the pages.
PRESETS	Opens the presets or the sequence bank depending on the context.
RESET	Restarts the form and returns SEQUENCE to its first position; it does not erase the current preset.
PLAY/STOP	Starts or stops the current progression. STOP acts as a pause: playback resumes on the quarter note where it stopped (at most three sixteenth notes back), so that the restart always falls on a beat. Under an external clock, the start is armed: the PLAY LED blinks and playback starts on the master's next quarter note. Pressing again cancels the wait. Stopping is always immediate. To start again from the beginning, press RESET.

CONTROL	ACTION
BREAK	Launches the BREAK function (see later in this manual).
Track buttons	Four buttons in four different colors mute or unmute each track individually. The LED of a muted track goes dark. The state of the four tracks is stored in presets. The same mutes can be controlled over MIDI (TRACK 1 to TRACK 4 rows on the MIDI IN page).

The four tracks

TRACK	GENERAL ROLE
1	Bass, cadence, or the LOW role in GROOVE.
2	Middle voice, support, or the BACKBEAT role in GROOVE.
3	Answer, countersubject, or the TIME role in GROOVE.
4	High voice, subject, main motif, or the tuned PERC role in GROOVE.

Inputs and outputs

All the CV inputs are grouped at the top of the module and the outputs at the bottom of the screen, except for the MIDI output (MIDI OUT) at the top right.

CV	USE
MATERIAL, MEMORY, GROWTH, MORPH, DENSITY, TENSION, INTERACTION, HUMANIZE	CV inputs for controlling the composition parameters externally.
PLAY/STOP	External control of start and pause.
BREAK	External control of the Break.
RESET	External control of the Reset.
CLOCK	External clock replacing the internal clock: 1, 2, 4, 24 or 48 pulses per quarter note, set by the CV CLOCK row on the MIDI IN page.
MIDI IN	Allows the ROOT note to be forced from a keyboard and the module to be controlled from a MIDI controller.
MIDI OUT	MIDI output for controlling external instruments.
GATE	Four buttons in four different colors mute or unmute each track individually. The LED of a muted track goes dark. The state of the four tracks is stored in presets. The same mutes can be controlled over MIDI (TRACK 1 to TRACK 4 rows on the MIDI IN page).
MOD	The four velocity outputs. 0 to 5 V.
PITCH	The four note outputs. 0 to 8 V, that is 8 octaves at the 1 V/octave standard

Clock

Internally, the interface encoder sets the BPM.

The CLOCK input accepts 1, 2, 4, 24 or 48 pulses per quarter note (PPQ). The value is selected on the CV CLOCK row of the MIDI IN page; the factory setting is 1 PPQ.

– At 1, 2 and 4 PPQ, the module measures the tempo over a full quarter note, then realigns its grid on every quarter note.

– At 24 and 48 PPQ, every pulse advances the grid, exactly like MIDI clock: the position within the bar cannot drift.

After a silence, the first edge received counts as a beat. A master that stops its clock when it stops will therefore restart B.A.C.H. on its first beat.

As soon as an external clock is active (CLOCK input or MIDI), a small padlock appears next to the BPM. After about 2.5 seconds without a pulse, the internal clock takes over again without skipping a step.

If MIDI clock and the CLOCK input (at 24 or 48 PPQ) arrive at the same time, MIDI clock drives the grid and steps are not doubled.

Note: the Gate output of a keyboard or sequencer is not a clock. It follows the notes played and stops during rests and tied notes. Use the device's Sync or Clock output.

CV inputs

Every control has a CV input. On the CV IN screen, the corresponding encoder sets its attenuation, which allows each modulation to be dosed separately. A zero calibration prevents a disconnected or centered input from making a parameter oscillate between two values (see the CALIBRATION chapter).

Factory reset

Hold down the HUMANIZE click, the MORPH click and the interface encoder click simultaneously for about 2.5 seconds. A bar confirms how long they have been held, then FACTORY RESET / DEFAULTS RESTORED appears.

RESET	KEPT
FUGUE algorithm, tempo 120 BPM and initial values of the eight controls.	All user presets and sequences present on the SD card.
MUSIC and BREAK settings, MIDI channels 1 to 4 and the GROOVE MIX partner CANON.	The 96 factory sequences and the library files.
Current progression emptied, MAIN screen and stored software state.	The electrical calibration (CV and pitch) specific to this unit, stored in EEPROM. System settings: MIDI IN page assignments (channels, CCs, ROOT NOTES, MIDI CLOCK, RESET ON STOP, CV CLOCK) and the EXPRESSION and MIDI CLOCK settings of the MIDI OUT page.

The factory reset should be used if an inconsistent state persists after a restart, or to return to the as-delivered configuration, or after a firmware update. It does not replace RESET, which merely restarts the musical form without changing the settings.

The screens

The PREV and NEXT buttons move through the normal pages. The PRESETS mode and the SEQUENCE bank are temporary views opened with PRESSETS.

SCREEN	WHAT IT DOES
MAIN	Displays the algorithm, the *Material*, the tempo and the activity of the four tracks.
VISUAL	Gives an animated representation of the activity and of the relationships between the voices.
CONTROLS	Shows the values of the eight algorithmic controls simultaneously.
MUSIC	Sets scale, root, velocity, duration, Swing, Ornaments, meter and Phrase.
SEQUENCE	Edits up to 64 chord positions, enables or disables the progression.
HARMONY	Displays the current chord while playing when VISUALISATION is selected.
BREAK	Chooses the character and the length of the next Break.
CV IN	Sets the gain (0 to 200%) of each of the eight CV inputs.
MIDI OUT	Assigns the MIDI channels of the four tracks.
MIDI IN	Allows most functions to be assigned to an external MIDI command.
MEMORY	Recalls or saves up to 128 presets on the SD card.

MAIN

Performance screen. It displays the active algorithm, the name of the current *Material*, the tempo and the activity of the four tracks. The name of the Material stays visible during playback. The eight encoders act on the algorithmic controls; a click returns a control to its reference value, that of the loaded preset or of the last save.

A click on the interface encoder opens the list of algorithms; rotation moves through the list, a second click confirms. When the algorithm changes, MATERIAL is placed back at the center of the nearest choice so that the control does not sit on a boundary between two *Materials*.

The tempo value is shown in white on every beat and in green at every new bar. When an external clock is active, a gold padlock is shown next to the tempo (it also appears on the VISUAL page).

The panel at the bottom of the screen shows the last control used. After a recall or a save, it confirms the operation for one and a half seconds (for example MEMORY 012 RECALLED).

VISUAL

Overall representation of the activity. The eight controls are laid out in a circle and the surface drawn between them deforms according to their values. The four track indicators follow the events actually emitted.

CONTROLS

The eight algorithmic values are displayed simultaneously as percentages, with the name of the parameter. The page is used to read a setting before writing it down or reproducing it, and to check the effect of a CV modulation, since the value shown is the effective value, control and CV added together.

MUSIC

The eight encoders leave their algorithmic function and set the parameters shared by all the languages: scale, root, duration, meter, velocity, swing, ornaments, and phrase length. The following chapter describes each of them.

SEQUENCE

Editing of a chord progression of up to 64 positions, superimposed on the logic of the algorithm. Six encoders are used; the other two remain inactive on this page (see the Sequence and harmony chapter).

HARMONY

Display of the current chord while playing, when VISUALISATION mode is selected on the SEQUENCE page. The page has no settings of its own.

BREAK

MATERIAL chooses the character of the break, MEMORY its length. It is triggered by the BREAK button (see the Break chapter).

CV IN

Each of the eight controls has a CV input whose gain can be set from 0 to 200%. A parameter's encoder sets the gain of its input.

At 100%, a ±10 V modulation is needed to sweep the full range of a parameter set to its center. At 200%, ±5 V is enough, which matches most Eurorack LFOs and envelopes. The gain is purely digital: the input stage and its protections are unchanged.

The effective value applied to the algorithm is the sum of the encoder position and the incoming voltage multiplied by the gain, limited to the 0–100% range: a CV that is too strong simply clips.

An unconnected input must be calibrated to zero so that a parameter does not start oscillating between two neighboring values. This calibration is carried out during the validation phase of each module; it can nevertheless be performed again (see the Calibration chapter).

MIDI OUT

Assignment of a MIDI channel, from 1 to 16, to each of the four tracks. The four encoders used are those of the left-hand column: MATERIAL for track 1, MEMORY for track 2, GROWTH for track 3, MORPH for track 4. Several tracks can share a channel; the CC11 expression used for the envelopes is then returned to full level only when the last voice on the channel is released (see the MIDI chapter).

MIDI IN

A MIDI channel and a CC can be assigned to any control, either by setting the values manually or by learning. A MIDI monitor makes it possible to track the values entering the module (see the MIDI chapter).

MEMORY

Recall and saving of 128 presets on the SD card. The page opens with the PRESET button (provided you are not on the SEQUENCE screen). The interface encoder chooses the slot, the PRESET button toggles between RECALL and WRITE, a click on the interface encoder confirms. A preset contains the algorithm, the eight controls, the CV attenuations, the MUSIC and BREAK settings, the MIDI channels, the GROOVE MIX partner and a complete copy of the SEQUENCE progression.

Musical settings

On the MUSIC screen, the eight encoders temporarily leave their algorithmic function and give access to the parameters shared by all the languages.

ENCODER	MUSIC PARAMETER
MATERIAL	SCALE: Chromatic, Major, Minors, modes, pentatonics, Blues, whole tone or diminished.
DENSITY	ROOT: root note; it can also be driven by MIDI Note On.
MEMORY	DURATION: overall length of the notes.
TENSION	METER: time signature.
GROWTH	VELOCITY: overall dynamic level of the four voices.
INTERACTION	SWING: eighth-note displacement.
MORPH	ORNAMENTS: amount of ornamentation.
HUMANIZE	PHRASE: formal length or INFINITE mode.

SCALE (MATERIAL encoder)

Chooses the scale in which the algorithms write. Fourteen values are available.

SCALE	DEGREES IN SEMITONES FROM THE ROOT
CHROMATIC	0 1 2 3 4 5 6 7 8 9 10 11 (can play every note)
MAJOR	0 2 4 5 7 9 11
NAT MINOR	0 2 3 5 7 8 10
HARM MINOR	0 2 3 5 7 8 11
MEL MINOR	0 2 3 5 7 9 11
DORIAN	0 2 3 5 7 9 10
PHRYGIAN	0 1 3 5 7 8 10
LYDIAN	0 2 4 6 7 9 11
MIXOLYDIAN	0 2 4 5 7 9 10
MAJ PENTA	0 2 4 7 9
MIN PENTA	0 3 5 7 10
BLUES	0 3 5 6 7 10
WHOLE TONE	0 2 4 6 8 10
DIMINISHED	0 2 3 5 6 8 9 11

The scale acts in two ways depending on the algorithm. Most produce free pitches, which are then brought back to the nearest degree of the scale. FUGUE and TINTINNABULI think directly in degrees of the chosen scale and decline this requantization. In TINTINNABULI, the triad of the T-voices is built on degrees 1, 3 and 5 of the active scale: the choice of scale therefore also determines the color of the accompaniment. Scales with five and six degrees (pentatonics, blues, whole tone) change the meaning of the words "adjacent degree": two neighboring degrees are sometimes three semitones apart. Processes described as stepwise remain so in the sense of the scale, not in the sense of the semitone (see Tintinnabuli).

DURATION (MEMORY encoder)

Defines the length of the notes. VARIABLE lets each algorithm decide according to its internal mechanism, which preserves, for example, the long values of a chorale. The other six positions impose a single value on all the voices: 1/32, 1/16, 1/8, 1/4, 1/2 and WHOLE.

The duration is then articulated according to metric position. A note on the first beat sounds at full length; on an intermediate group it loses about 3%, on a beat 6%, on an eighth note 12%, on a subdivision 18%. A value equal to or greater than the half note keeps its sustaining function and is never shortened by more than 6%.

VELOCITY (GROWTH encoder)

Several modes are possible:

– FULL sets all velocities to maximum: the dynamics composed by the algorithm are ignored, which suits an instrument whose envelope is set elsewhere.

– MODULATED keeps the dynamics computed by the language, then applies the metric hierarchy and the HUMANIZE gesture to them.

– HARD establishes strong dynamics.

– SOFT establishes generally soft dynamics.

– COOL establishes the modulated dynamics of calm playing.

– PROGRESS keeps the dynamics computed by the language, but introduces a progressive tension across the measures.

The MOD output in CV and the MIDI velocity follow the same setting.

ORNAMENTS (MORPH encoder)

Amount of ornamentation, from OFF to 100%. The gestures added depend on the context: appoggiatura, mordent, turn or trill according to the tempo, the length of the carrying note and its metric position. Only one ornamental gesture can begin on any given step, priority rotating among the voices. In GROOVE and GROOVE MIX, the setting produces flams rather than melodic ornaments.

The direction of the ornament follows the movement of the line: a rising line approaches its target from below. At high tempos or on short notes, only the appoggiatura remains possible.

ROOT (DENSITY encoder)

Reference root note, expressed as a note. The range runs from C1 (MIDI note 24) to C6 (MIDI note 84). FUGUE imposes a minimum of C2 (MIDI note 36), its lowest voice being placed two octaves below the reference. A note played through the MIDI input also defines ROOT, and its velocity contributes to the overall dynamics.

METER (TENSION encoder)

Time signature. Eight values: 2/4, 3/4, 4/4, 5/4, 6/8, 7/8, 9/8 and 12/8. The meter fixes the length of a measure in sixteenth notes (8, 12, 16, 20, 12, 14, 18 and 24 respectively) and the position of the stresses, which follow the usual grouping: 2+2+3 in 7/8, groups of three eighth notes in 6/8, 9/8 and 12/8, grouping 3+2 in 5/4.

The *Materials* whose cycle does not coincide with the chosen meter behave in two ways. Those whose cycle exceeds the measure, or which are marked as cyclic, continue their cycle from one measure to the next: a sixteen-position clave played in 2/4 occupies two measures. The others start again at each measure.

SWING (INTERACTION encoder)

SWING acts on the eighth note. In simple meters, the four internal intervals of a quarter note follow LONG, LONG, SHORT, SHORT: the offbeat is delayed and the following quarter note stays exactly on the clock. 0% is straight, 100% reaches a

ternary 2:1 ratio. The length of a beat is never changed: the time borrowed is given back before the next stress, and the BPM remains the one displayed.

The curve is softened at both ends. The first detents refine the placement in small amounts; the end of travel gradually approaches the ternary ratio without exceeding it.

In 6/8, 9/8 and 12/8, the pulse being already ternary, only the internal division of the eighth notes into sixteenth notes breathes, with half the amplitude. The natively ternary GROOVE Materials (ROCK SHUFFLE, SWING RIDE, BEMBE 6-8, GNAWA, BEBOP, JAZZ WALTZ, BRUSHES, ODD JAZZ 5, BELL 12, EUCLID 5-12, EUCLID 7-12, POLY 3-2, POLY 4-3 and INTERLOCK) are written on an exact triplet grid and are not deformed a second time.

PHRASE (HUMANIZE encoder)

The formal length of the composition. This length is set to the values 1, 2, 4, 8, 16 or 32 measures, and the INFINITE length never loops a sequence. At a fixed value, the step counter returns to zero at the end of the phrase: the algorithms that follow the step number detect this return and restart their architecture. The SEQUENCE progression is not affected and continues to advance.

INFINITE lets the internal forms unfold without any reset. This is the setting to choose in order to hear the long cycles of FUGUE, of MOTIF or of a cellular automaton, whose period often exceeds thirty-two measures.

SEQUENCE and HARMONY

The B.A.C.H. languages compose on their own. They draw all their material from ROOT and SCALE, and they stay there: an algorithm started in C minor will "speak" in C minor as long as it is not given another scale. SEQUENCE gives it a harmonic plan, that is a series of chords that the module runs through in a loop and to which the voices conform.

SEQUENCE touches neither the rhythm, nor the density, nor the ornaments, nor the form of the language: it moves only pitches, and only those that carry the harmony. The same configuration can thus become a twelve-bar blues, a rhythm-changes progression, a classical cadence, without a single algorithm setting being altered.

The progression advances on the common sixteenth-note grid, independently of the internal grid of the language. It exposes a current chord at every moment, and intervenes only when a note is emitted.

A structural note, that is one that falls on a beat of the measure, or that lasts at least a quarter note, is brought back to a note of the chord, chosen in the octave closest to the pitch the algorithm had planned.

All the other notes (passing notes, ornaments, fast subdivisions, and so on) are brought back to the nearest note belonging either to SCALE or to the current chord. They thus keep their linking role without contradicting the harmony.

This division allows the procedure to keep firm stresses while leaving freedom in the passing notes.

Rhythm, note length, velocity, ornaments, Breaks and the form of the algorithm are never modified by SEQUENCE.

Enabling and disabling the progression

On the SEQUENCE page, three elements determine whether the sequence can be heard. The band at the bottom of the screen always indicates which one applies.

WHAT DECIDES	HOW TO ACT
The content	The progression is read as long as position 1 carries a chord. If position 1 is EMPTY (shown by a hyphen "-"), SEQUENCE is inactive and the screen displays EMPTY AT STEP 1 at the bottom. Placing a chord at position 1 is enough to enable it; the band then displays EDIT MODE.
The page mode	The MORPH encoder alternates between EDITED, SEQUENCE OFF and VISUALISATION. SEQUENCE OFF suspends the progression without erasing anything: the 64 positions stay in memory and come back intact when you return to EDITED.
The algorithm	FUGUE and GROOVE ignore SEQUENCE. The progression nevertheless keeps advancing in the background and becomes audible again as soon as you return to a compatible language. The band at the bottom of the screen displays SEQUENCE BYPASSED.

The encoders on the page

On SEQUENCE, six of the eight encoders are used to set up the function.

ENCODER	FUNCTION ON THE SEQUENCE PAGE
MATERIAL	Root of the selected chord, expressed as a degree relative to ROOT. Thirteen values, including EMPTY (-).
DENSITY	Chord quality: DIATONIC, or one of the twenty-four chords.
MEMORY	Moves the editing cursor across the 64 positions.
GROWTH	Length of the chord, from a single beat to eight measures.
INTERACTION	Inversion 0 to 3 of the chords, or automatic VOICING.
MORPH	EDITED, SEQUENCE OFF or VISUALISATION.

The four chord encoders (MATERIAL, GROWTH, DENSITY, INTERACTION) act only in EDITED mode. In SEQUENCE OFF and in VISUALISATION they have no effect: only MEMORY and MORPH act.

Reading the SEQUENCE screen

The screen is read as three bands.

– **The band of eight cells**. Each cell carries its position number and the position of the chord relative to its ROOT (I, III, b3, V, and so on) or a hyphen (-) for EMPTY. An orange outline marks the cell being edited, a green outline marks the position being played.
– **The central band**. It indicates the actual chord corresponding to the chosen quality (7th, dim, major, and so on) according to the position relative to its root. For example, if ROOT is C and the position is "V" (fifth), then the chord will be on G, completed by its quality. This cartouche also indicates the length of the chord and its inversion.
– **The status band**. It can display EDIT MODE, SEQUENCE OFF, EMPTY AT STEP 1 or SEQUENCE BYPASSED.

The four parameters of a chord

A position is described by four values, edited separately. They are stored for all 64 positions, even those the progression never reaches.

Root (MATERIAL)

The root is not an absolute note but a degree counted in semitones from ROOT. The progression is therefore transposed as a block when ROOT is changed on the MUSIC page, or when an incoming MIDI note redefines the tonic.

FIGURE	POSITION FROM ROOT	FIGURE	POSITION FROM ROOT
I	the tonic itself	**#IV**	six semitones (tritone)
bII	one semitone (minor second)	**V**	seven semitones (perfect fifth)
II	two semitones (major second)	**bVI**	eight semitones (minor sixth)
bIII	three semitones (minor third)	**VI**	nine semitones (major sixth)
III	four semitones (major third)	**bVII**	ten semitones (minor seventh)
IV	five semitones (perfect fourth)	**VII**	eleven semitones (major seventh)
-	end-of-progression marker		

Quality (DENSITY)

With DIATONIC the chord is built by stacking thirds within SCALE from the root, then every other degree, giving three notes. In major, a DIATONIC "II" gives a minor chord, a DIATONIC "V" a major chord; in Dorian, the same "II" will sound different. This is the setting to use in order to keep a progression that must "stay" in the mode.

The other twenty-four qualities are explicit and take precedence over SCALE. They are displayed under their usual figuring.

DISPLAY	CHORD	DISPLAY	CHORD
MAJ	major	**ADD9**	major added ninth
MIN	minor	**mADD9**	minor added ninth
DIM	diminished	**7**	dominant seventh
AUG	augmented	**MAJ7**	major seventh
SUS2	suspended second	**m7**	minor seventh
SUS4	suspended fourth	**mMAJ7**	minor major seventh
5	power fifth	**m7b5**	half-diminished
6	major sixth	**DIM7**	diminished seventh
m6	minor sixth	**9**	dominant ninth
MAJ9	major ninth	**11**	dominant eleventh
m9	minor ninth	**m11**	minor eleventh
13	dominant thirteenth	**7SUS4**	suspended fourth seventh

The number of notes in the chord (two for power, three for a triad, up to seven for a thirteenth chord) determines the notes the four tracks receive and how far the inversion extends.

Length (GROWTH)

The length is counted in beats and measures of the time signature chosen on MUSIC; in 6/8, 9/8 and 12/8, a beat is a dotted quarter note. Eight values are possible: 1 BEAT, 2 BEATS, 1/2 BAR, 1 BAR, 2 BARS, 3 BARS, 4 BARS, 8 BARS.

Nothing requires a regular grid: four measures of tonic followed by half a beat of dominant are perfectly acceptable.

Inversion and Voicing (INTERACTION)

The inversion decides which note of the chord is placed in the bass, and therefore on track 1. The other tracks receive the following notes of the chord, in order, starting again from the beginning when the chord has fewer than four notes.

SELECTION	EFFECT
0	Root in the bass: root position.
1	Third in the bass: first inversion.
2	Fifth in the bass: second inversion.
3	Fourth note in the bass: seventh, sixth or ninth depending on the quality. On a triad, this value amounts to the root-position value.
VOICING	Automatic inversion: at every chord change, B.A.C.H. tries all the possible inversions, measures the total movement of the four voices relative to the notes they were playing just before, and keeps the shortest movement. The choice is then frozen for the whole length of the chord.

VOICING is the setting to prefer for a progression meant to be played quickly: it produces smooth voice leading and avoids octave leaps at every measure. A fixed inversion is justified when a specific bass note is wanted.

EMPTY: the end marker

EMPTY (-) indicates where the sequence stops. The progression is read from position 1 up to the first EMPTY position encountered, then starts again at position 1. A three-chord progression therefore occupies positions 1, 2 and 3, and leaves position 4 empty; there is no need to "clean" the remaining 60 positions by setting them to EMPTY.

EMPTY at position 1 is a special case: the entire progression is declared inactive. This is the default state, and it is also the quickest way to switch off the harmony, and therefore not to use the sequences.

Algorithm compatibility

ALGORITHM	BEHAVIOR
CANON, PROBA, MINIMAL, CELLULAR, TREE, FRACTAL, MOTIF, HYBRID	Follow the progression according to the rule described above.
GROOVE MIX	Also follows the progression: its four outputs carry melodic pitches supplied by the associated algorithm, and all of them conform to the chord.
TINTINNABULI	Receives the chord directly in its engine rather than by after-the-fact correction. The M-voice stays tied to SCALE and its local tonic moves with the root of the chord; the T-voices borrow the notes of the chord instead of the central triad; the bass follows the inversion, and VOICING makes it choose the chord note closest to the one it was holding.
FUGUE, GROOVE	Ignore SEQUENCE. FUGUE builds its own tonal plan and its own cadences; GROOVE plays a drum kit. The sequence progression nevertheless keeps advancing, but silently. It becomes audible again when the algorithm is changed.

The HARMONY screen

HARMONY is a specific page of the SEQUENCE mode. When MORPH is turned to VISUALISATION, the title of the screen becomes HARMONY and the band of eight cells gives way to a display showing the actual chord being played rather than the chord relative to the position of the root.

Sequence presets

Pressing the PRESET button from the SEQUENCE or HARMONY page gives access to the sequence presets. 96 presets are already stored and 128 slots are available to the user.

CONTROL	ACTION
Turn MATERIAL	Runs through FACTORY 01 to 96, then USER 001 to 128. The name of the factory sequence, or the state of the user slot (empty or occupied), is displayed under the number.
Click MATERIAL	Loads the displayed slot, or saves it in WRITE USER mode.
PRESETS button	Alternates between RECALL (loading a preset) and WRITE USER (writing a preset). In write mode, the selection jumps automatically to the first user slot; the factory sequences cannot be modified.

CONTROL	ACTION
PREV / NEXT buttons	Leaves the preset loading or writing mode.

The bottom band confirms the operation: TURN MATERIAL while waiting, then LOADED, SAVED, INVALID, VERSION, SD ERROR or NO SD CARD. Loading a sequence returns the cursor to position 1 and restarts the reading of the progression.

The 96 “factory” sequence presets

They are stored in ROM and are available even without an SD card. Thirty-two harmonic forms, each in three speeds: QUICK shortens each chord by one step, LONG lengthens it by one step, the variant without a suffix keeps the nominal length. The form and the order of the chords are identical in all three.

CIRCLE FIFTHS	II V I MAJOR	II V I MINOR
TURNAROUND	BACKDOOR	POP AXIS
POP MINOR	ROCK MIXOLYD	ANDALUSIAN
BLUES 12	QUICK BLUES	MINOR BLUES
RHYTHM A	RHYTHM BRIDGE	JAZZ AABA
MINOR FIFTHS	MAJOR THIRDS	COLTRANE CYCLE
BOSSA MAJOR	BOSSA MINOR	MONTUNO
LATIN 2 3	PACHELBEL	FOLIA
ROMANESCA	PASSAMEZZO	LAMENT
DORIAN VAMP	MIXOLYD VAMP	PHRYGIAN VAMP
AMBIENT THIRDS	CINEMATIC	

The 128 user slots

They are held on the SD card, in the /BACH/SEQUENCES folder, as files SEQ001.BSQ through SEQ128.BSQ. Every write goes through a temporary file and leaves a backup copy of the previous version: a power failure during saving cannot destroy the previous sequence. A check prevents an incomplete file from being loaded, reported as INVALID.

Each general preset on the MEMORY page also includes a complete copy of the sequence in use. Recalling a preset therefore restores its progression, and returns the page mode to EDITED or SEQUENCE OFF according to the state that was saved.

SEQUENCE, RESET and BREAK

RESET returns playback to position 1 and restarts the form of the algorithm. The chords are untouched.

BREAK does not suspend the progression: it keeps advancing during the break, so that the resumption falls at the right place in the grid. A break of the Silence type does, however, cut all notes, harmony included, for its duration.

Changing the algorithm does not modify the progression. Going from MOTIF to FUGUE makes it inaudible, going back makes it audible again, at the point it has reached.

BREAK

BREAK creates a temporary break, then hands control back to the current form. Choose its character with MATERIAL and its length with MEMORY: 1, 2, 4 or 8 bars, or LIVE. In LIVE mode the break has no set end and closes on a second press of BREAK.

Pressing the button arms the break: the BREAK LED blinks and the break starts on the first beat of the next bar. It ends on a bar line; on its last beat, the music comes back as an upbeat.

The break never invents pitches: it starts from the last bar played and reuses its notes. Key, meter and the SEQUENCE progression are preserved; texture, rhythm and the number of voices change. Most often the ensemble is reduced to a skeleton, usually the low voice on track 1. DENSITY shapes the result of each character.

TYPE	GENERAL EFFECT
AUTO	For each break, picks a character suited to its length and to the density of the playing, never repeating the previous one. AUTO never picks SILENCE.
SILENCE	Interrupts all notes for the chosen length.
AGITATION	Each note is replaced by two, three or four notes within its own duration. Depending on DENSITY, one to three voices also replay the last bar at double speed.
SUSPENSION	Keeps only the low voice, sustained, plus a little of the second voice depending on DENSITY. The two upper voices fall silent.
FRAGMENT	Replays the last bar unchanged, as many times as the break has bars.
PULSE	Makes the pulse heard in layers: track 1 marks every beat, track 2 double time, track 3 carries the piece's material in divided values, track 4 holds a multiple of the beat.
EROSION	The bass marks every beat, then every second, third and fourth beat; the other voices gradually fade out.
EXPANSION	The bass alone marks every beat for one bar, then the voices come back in one by one.

In GROOVE and GROOVE MIX, the Breaks adopt a behavior better suited to drum playing.

Loading and saving

B.A.C.H. automatically saves its state two seconds after the last change, when no note is playing. At power-up, this state is restored as it was saved.

While GROOVE and GROOVE MIX are playing, this save is suspended so as not to disturb the rhythm; it takes place after STOP. Before switching the module off, allow about two seconds after STOP and after the last change.

System settings (MIDI IN page, CV CLOCK, EXPRESSION, MIDI CLOCK) are saved separately, one second after the last adjustment.

The PRESETS function also makes it possible to make saves and to recall them at any time.

Pressing the PRESETS button opens the MEMORY screen. Pressing it again toggles between RECALL (load) and WRITE (save). Clicking the interface encoder confirms the operation.

If the operation succeeds, the MEMORY page closes and the main screen confirms it for one and a half seconds: MEMORY 012 RECALLED (load) or MEMORY 012 WRITTEN (save).

If it fails, the MEMORY page stays on screen and shows the reason: EMPTY (empty slot), NO SD CARD, CARD LOST, WRITE FAILED, INVALID (incomplete file) or VERSION (file from another version). MODIFIED indicates that the loaded preset has been changed since it was recalled.

The PREV or NEXT buttons close the page without doing anything. On the MIDI IN page, the PRESETS button does not open the memories: it arms MIDI learn.

Preset contents

The algorithm, the eight controls, the CV gains, the MUSIC and BREAK settings, the MIDI channels of the four tracks, the state of the four tracks (muted or active), the GROOVE MIX partner and a full copy of the SEQUENCE progression. System settings (MIDI IN page, EXPRESSION, MIDI CLOCK) are not part of presets.

Loading (RECALL)

When RECALL is displayed on the screen, the main encoder (BPM) can be turned to scroll through the save slot numbers. If the text EMPTY appears under a number, the slot is empty and no preset can be loaded.

Saving (WRITE)

When WRITE is displayed on the screen, the main encoder (BPM) can be turned to scroll through the save slot numbers. A preset can be saved to an empty slot (EMPTY) or written over a slot that already contains a save. In the latter case, the old preset is permanently erased.

ACTION	CONTROL
Open MEMORY	Press PRESETS outside the SEQUENCE bank.
Choose a slot	Turn the interface encoder among 128 slots.
Toggle the mode	PRESETS alternates between RECALL and WRITE.
Confirm	Click the interface encoder.

Description of the algorithms

FUGUE

Multi-voice writing based on a subject, its answers, a possible countersubject and episodes.

Origin and principle

The fugue is a type of writing in which several voices take up the same melodic line, called the subject, one after another. During the exposition, the first voice generally presents the subject in the main key. A second voice answers it, most often in the key of the dominant, while the first continues its own line. The other voices then enter in turn.

The fugue has its origins in the Renaissance, in imitation procedures. It gradually took its present form in the XVIth and XVIIth centuries, then met with very great success in the first half of the XVIIIth century, notably with Johann Sebastian Bach.

The name B.A.C.H. thus pays tribute to Johann Sebastian Bach, but also to the famous motif formed by the notes B–A–C–H. In German notation, B stands for B flat and H for B natural: the motif therefore corresponds to B flat, A, C, B natural (a sequence found here and there in this module).

The vocabulary used in B.A.C.H. takes up the main terms of fugal writing:

– The subject is the main melodic line.
– The answer is the restatement of the subject by a new voice, generally transposed. It is called real when it keeps the intervals of the subject exactly, and tonal when certain intervals are adjusted in order to maintain the stability of the key.
– The countersubject is a recognizable melodic line that regularly accompanies the subject or the answer. When it can be placed either above or below the subject, it uses what is called invertible counterpoint. The other accompanying

lines belong to free counterpoint. Counterpoint consists in sounding several melodies at the same time. Each voice follows its own path while remaining coherent with the others.

– The episode, also called divertissement, is a passage in which the subject does not appear in full. It is often built from a fragment of the subject or of the countersubject, repeated and transposed.

– The stretto brings the entries of the subject closer together: a new voice begins before the previous one has finished its statement.

In B.A.C.H., the FUGUE algorithm builds an exposition with four entries, generally alternating subject and tonal answer. It can then use a countersubject designed to work above or below the subject, an episode based on a progression of descending fifths, a new transposed entry after the exposition, and a stretto.

To complete the voices, the program examines nine possible notes around the previous note and chooses the one that best respects several musical principles. In particular it favors consonances on strong beats and contrary motion between voices. It avoids parallel fifths and octaves, as well as certain direct fifths or octaves. After a large melodic leap, it prefers stepwise movement in the opposite direction, and it also seeks to prevent the voices from crossing.

This method nevertheless has its limits. B.A.C.H. does not carry out a complete harmonic analysis and does not build true modulations as a composer writing a classical fugue would. Its tonal plan rests on a reference chord for each half measure. The eight subject families are not borrowed from existing works: they are original melodic contours, designed to allow a coherent tonal answer.

Like the other B.A.C.H. algorithms, FUGUE copies no score and does not seek to reproduce a work by Bach. Resemblances or reminiscences may naturally appear, but they result from coincidences and from shared musical rules. These rules remain adjustable so that the musician can integrate the result into his or her own composition.

FUGUE organizes the four voices along its own tonal trajectory. In order to preserve this architecture, it does not use the SEQUENCE progression.

Settings

CONTROL	ACTION IN THIS ALGORITHM
MATERIAL	Chooses the subject family: see the table below.
MEMORY	Fidelity of the subject. At maximum, each section restates the original subject; going down, it drifts by a degree or swaps two rhythmic values at each statement, and the mutation accumulates.
GROWTH	Speed of the discourse: length of the current section, recalculated continuously, and the succession of sections.
MORPH	Pitch range of the contour and rhythmic stretching of the subject, then inversion and retrograde.
DENSITY	Number of free counterpoint voices added. The subject, the answer, the countersubject and the episode motif are always played in full.
TENSION	Suspensions, tolerance to dissonance, distance from the tonal plan and the call for the stretto. Beyond 45% of travel, a chromatic passing note can appear on a weak beat.
INTERACTION	Sets the way the other voices follow the main voice. At a low value, they move freely and avoid copying it. As the value increases, they take up its melody more and more, up to imitating it as in a canon.
HUMANIZE	Share of improvisation, at most one gesture per measure: the balance of the measure, a passing note, a short phrase, an unplayed note or a one-beat rupture.

Materials

MATERIAL	MUSICAL CHARACTER
ARCH	A subject rises toward a central peak then returns to the tonic, favorable to very legible entries.
FIFTHS	The subject articulates dominant, octave and returns of the fifth.
SCALAR	A stepwise line runs up the scale then comes back down, with continuous movement.
SYNCOPATED	Asymmetrical durations shift the stresses of the subject and give more propulsion to the counterpoint.
TURN	An ornamental turn around the tonic becomes the signature of the subject before it widens.
PEDAL	The tonic returns as a regular pivot while the other degrees are freer.
WEDGE	The intervals spread alternately above and below the center.
CHORALE	Long values and a chordal contour produce relatively stable material.

CANON

The Canon is an imitation of a single melody by several voices, with an adjustable delay and interval.

Origin and principle

The canon is a strict form of imitation. A first voice, called the leading voice, plays a melody. One or more voices then take it up according to a precise rule: after a certain delay, at the same pitch or transposed.

In its simplest form, the melody is reproduced identically. It can also be transformed: its movements can be inverted, its notes played in reverse order or its durations lengthened. Once the starting melody and the rules have been chosen, the other voices are produced automatically. An independent accompaniment can nevertheless be added to them.

This practice is attested as early as the XIIIth century, but Bach produced some of its most elaborate realizations. In the *Goldberg Variations* (1741), every third variation is a canon: first at the unison, then at the second, at the third, and so on up to the ninth. The *Musical Offering* (1747) contains several canons presented as riddles. In the *Canon per tonos*, the music rises by a tone at each repetition and returns to an equivalent pitch after six cycles.

In B.A.C.H., canons are defined by four main characteristics:

– The interval of imitation gives the distance between the leading voice and the voices that follow it: unison, second, third, fourth, fifth or octave.

– The delay gives the time separating the entries of the voices. A short delay produces close entries and a denser texture; a long delay spaces the voices out further.

– The transformation modifies the copy. In contrary motion, every rising movement becomes falling, and vice versa. In retrograde motion, the melody is traversed from the last note to the first.

– The speed can also be modified. Augmentation lengthens the durations of the copy; diminution shortens them. In B.A.C.H., augmentation produces a copy that is twice as slow.

The engine first builds the starting melody, then derives the other voices from it. MATERIAL combines one of the four melodic shapes with one of the seven imitation intervals, that is twenty-eight combinations.

A strict four-voice canon imposes many constraints, since every note of the melody must be able to be superimposed correctly on its various copies. The engine does not examine every possible melody: it builds a line whose shape favors clear and balanced superpositions for the intervals and delays offered. DENSITY finally makes it possible to lighten the texture when the four voices produce too crowded a result.

Settings

CONTROL	ACTION IN THIS ALGORITHM
MEMORY	Lifetime of the leading voice. A new statement is built every 1 to 16 measures; fully clockwise, the same melody is kept the longest.
GROWTH	Length of the leading voice, from 6 to 16 events. Beyond 60%, every other voice plays its copy in augmentation; beyond 72%, some of the rhythmic values are doubled.
MORPH	Transformation of the copies. Beyond 42%, every other voice switches to contrary motion; beyond 72%, the two upper voices read the melody in retrograde.
DENSITY	Proportion of the leading voice's events actually played, from 55 to 98%. Also acts on the overall velocity.
TENSION	Chromatic inflections: up to 16% of the notes are displaced by a semitone. Also increases the velocity.
INTERACTION	Distance between the entries, from wide canon to close canon. Beyond 80%, the notes are shortened by half. Also increases the probability of ornamentation.
HUMANIZE	Share of improvisation, at most one gesture per measure: the balance of the measure, a passing note, a short phrase, an unplayed note or a one-beat rupture.

Materials

MATERIAL	MUSICAL CHARACTER
DIATONIC 8VE	A calm stepwise motif is imitated at the octave.
DIATONIC 5TH	A calm stepwise motif is imitated at the fifth.
DIATONIC 4TH	A calm stepwise motif is imitated at the fourth.
DIATONIC M3	A calm stepwise motif is imitated at the major third.
DIATONIC m3	A calm stepwise motif is imitated at the minor third.
DIATONIC 2ND	A calm stepwise motif is imitated at the second.
DIATONIC UNI	A calm stepwise motif is imitated at the unison.
TRIADIC 8VE	A lively, consonant arpeggio figure is imitated at the octave.
TRIADIC 5TH	A lively, consonant arpeggio figure is imitated at the fifth.
TRIADIC 4TH	A lively, consonant arpeggio figure is imitated at the fourth.
TRIADIC M3	A lively, consonant arpeggio figure is imitated at the major third.
TRIADIC m3	A lively, consonant arpeggio figure is imitated at the minor third.
TRIADIC 2ND	A lively, consonant arpeggio figure is imitated at the second.
TRIADIC UNI	A lively, consonant arpeggio figure is imitated at the unison.
SINUOUS 8VE	An undulating line with small contrary movements is imitated at the octave.
SINUOUS 5TH	An undulating line with small contrary movements is imitated at the fifth.
SINUOUS 4TH	An undulating line with small contrary movements is imitated at the fourth.
SINUOUS M3	An undulating line with small contrary movements is imitated at the major third.
SINUOUS m3	An undulating line with small contrary movements is imitated at the minor third.
SINUOUS 2ND	An undulating line with small contrary movements is imitated at the second.
SINUOUS UNI	An undulating line with small contrary movements is imitated at the unison.
DISJUNCT 8VE	A broad contour, made of wider leaps, is imitated at the octave.
DISJUNCT 5TH	A broad contour, made of wider leaps, is imitated at the fifth.
DISJUNCT 4TH	A broad contour, made of wider leaps, is imitated at the fourth.
DISJUNCT M3	A broad contour, made of wider leaps, is imitated at the major third.
DISJUNCT m3	A broad contour, made of wider leaps, is imitated at the minor third.
DISJUNCT 2ND	A broad contour, made of wider leaps, is imitated at the second.
DISJUNCT UNI	A broad contour, made of wider leaps, is imitated at the unison.

PROBA

PROBA remains the language of chance... but of a directed chance. MATERIAL defines what is allowed to happen; the other controls set frequency, memory and dependency between the voices. Probabilities are at the heart of the language.

Origin and principle

Composing through the calculus of probabilities consists in describing not a series of notes, but the law that governs the passage from one note to the next. The result is never twice the same, while the character remains identifiable, because it is the transition preferences that carry the style.

The basic tool is the Markov chain, introduced by Andrey Markov in 1906 and applied by him to the statistics of letters in a text. A first-order Markov chain decides the next event from the current event alone; a higher order takes several past events into account.

The musical application is one of the first uses of the computer in composition. Lejaren Hiller and Leonard Isaacson programmed the ILLIAC at the University of Illinois and published in 1957 the Illiac Suite for string quartet, whose fourth movement rests on Markov chains. Iannis Xenakis developed in parallel a different approach, based on continuous distribution laws rather than on discrete transitions, set out in *Formalized Music* (1963).

The implementation in B.A.C.H. follows a melodic walk per voice, whose transitions are drawn from a style matrix chosen by MATERIAL.

The eight MATERIAL vocabularies correspond to pitch collections and not to historical styles. TONAL, PENTATONIC, BLUES and OCTATONIC describe the set of permitted pitches and their weighting; STEPWISE and FOURTHS describe an interval preference; PEDAL introduces a frequently recurring return note.

A Markov chain has no long memory: it decides the next note without knowing the phrase in progress. It therefore produces a set that is locally coherent but without overall direction. The global form comes from a slow drift of the tonal center or from a chord progression imposed by SEQUENCE.

Settings

CONTROL	ACTION IN THIS ALGORITHM
MATERIAL	Chooses the transition matrix among the eight vocabularies described below.
MEMORY	Inertia of the walk: probability of continuing the direction of the previous movement rather than changing it.
GROWTH	Slow drift of the tonal center, over four semitones either way; the speed of this drift increases with the value. Beyond 72%, the durations are doubled every other measure.
MORPH	Beyond 50%, the walk can reverse abruptly, with a probability that rises to 35%. Also increases the probability of ornamentation.
DENSITY	Probability that a voice emits a note at each step. Also acts on the velocity.
TENSION	Amplitude of the leaps, multiplied by 1 to 4 and capped at twelve semitones. Beyond 52%, the duration table shifts from calm playing to tense playing.
INTERACTION	Probability that a voice adopts the direction of its neighbor, from independence to homophony.
HUMANIZE	Share of improvisation, at most one gesture per measure: the balance of the measure, a passing note, a short phrase, an unplayed note or a one-beat rupture.

Materials

MATERIAL	MUSICAL CHARACTER
TONAL	Favors the stable degrees of the key and quickly produces consonant lines.
ATONAL	Distributes the pitches more freely.
PENTATONIC	Limits the vocabulary to five open tones, easy to superimpose.
BLUES	Brings out the inflections and degrees characteristic of blues phrasing.
STEPWISE	Favors stepwise movement in order to keep a connected line despite the probabilities.
FOURTHS	Builds contours in fourths.
OCTATONIC	Alternates tones and semitones for a symmetrical and mobile tension.
PEDAL	Frequently anchors a pivot note while the other voices move around it.

TINTINNABULI

TINTINNABULI pairs a melodic voice, called the M-voice, with one or more T-voices, built from the notes of a chord.

The M-voice, played on track 1, moves by adjacent degrees along the path chosen by MATERIAL. Tracks 2 and 3 play only notes belonging to the triad and are computed from each note of the M-voice.

SCALE determines both the notes available to the M-voice and the major or minor quality of the triad. MATERIAL therefore chooses the shape of the melodic path, but not the mode. When SEQUENCE is enabled, the T-voices use the notes of the current chord in the progression.

Origin and principle

Tintinnabuli is a composition system devised by Arvo Pärt from 1976 onward. His first work written in this style is *Für Alina*, for piano.

In its simple form the system sets two types of voice in dialogue. The M-voice carries the melody and generally moves by adjacent degrees around a central note. Its path can follow a rule defined in advance: moving away from the center, moving toward it, or alternating the two movements.

The T-voice, or tintinnabuli voice, plays only the three notes of a triad. For each note of the M-voice, a rule determines the chord note to be associated with it. The two lines thus form a counterpoint: two different melodies heard simultaneously and completing one another.

To build this algorithm we used the indications given by Paul Hillier, who in his book *Arvo Pärt* (Oxford University Press, 1997) describes the position of the T-voice by means of two indications:

– The side specifies whether the chord note is sought above or below the M-voice. In certain works, the two sides may alternate according to a fixed rule.

– The rank specifies which chord note is kept: the closest one, the next one or the one after that.

This rule can remain the same throughout a phrase or a section. It makes it possible to compute each note of the T-voice without writing out a second melody separately.

The procedure produces a characteristic effect. While the M-voice advances step by step, the T-voice may keep the same note, then move abruptly to another note of the triad. One moves continuously while the other alternates held notes and leaps. This relationship contributes to the clear, bell-like sonority that gave the system its name.

In B.A.C.H., these principles are handled directly by the engine. The eight MATERIAL paths move the M-voice one degree at a time. The T-voices play at the same time as it does, without producing a unison, and use only the notes allowed by the triad.

Since SCALE determines both the scale of the M-voice and the triad of the T-voices, the two elements remain compatible. TENSION chooses whether the T-voice uses the closest chord note, the next one or a more distant one. It thus increases the distance between the voices without adding any note foreign to the chord.

In the original system, the T-voice is most often tied to a central triad. SEQUENCE extends this principle by allowing it to follow the various chords of a progression.

Silence and space also play an important role in Pärt's music, notably in *Tabula rasa* (1977) and *Spiegel im Spiegel* (1978). In B.A.C.H., DENSITY determines how many voices take part and introduces rests. The path of the M-voice keeps evolving according to the chosen rule, even when some of its notes are not played.

Settings

CONTROL	ACTION IN THIS ALGORITHM
MATERIAL	Chooses the process of the M-voice among the eight described below. All of them move by adjacent degrees.
GROWTH	Breadth of the arc, and therefore the range covered by the M-voice.
MEMORY	Slowness of the process: lifetime of each M-note and holding of the note.
INTERACTION	Position of the T-voices. Up to mid-travel, track 2 stays above and track 3 below; beyond that, the two alternate their side. Also sets the attack density of the T-voices.
TENSION	Moves the T-voices further out within the triad: they go from the first to the second and then to the third rank. No foreign note is added.

CONTROL	ACTION IN THIS ALGORITHM
DENSITY	Thinning of the texture, up to silence.
MORPH	Reverses the process and moves track 3 to the upper rank of the triad.
HUMANIZE	Share of improvisation, at most one gesture per measure: the balance of the measure, a passing note, a short phrase, an unplayed note or a one-beat rupture.

Materials

MATERIAL	MUSICAL CHARACTER
ARC UP	The M-voice rises one degree at a time to the top of the arc, then comes back down to the center. This is the most direct process.
ARC DOWN	The same arc mirrored: the M-voice first descends below the center before returning to it.
MIRROR UP	The arc crosses the center and continues symmetrically below before rising again, which doubles the length of the cycle.
MIRROR DOWN	The same symmetrical path, started toward the low register.
WAVE UP	The M-voice covers the whole range from low to high then returns, without passing through the center twice.
WAVE DOWN	The same complete sweep of the range, started from the high register.
ALINA UP	The MIRROR UP figure held twice as long: each degree lasts two notes of the process, in the stripped-down spirit of *Für Alina*.
ALINA DOWN	The same slowness, oriented toward the low register.

MINIMAL

MINIMAL explores process music. The starting structure is made of short, deliberately repetitive cells, transformed gradually. The music can thus be heard evolving slowly, step by step.

Origin and principle

Process music occupies an important place in the American minimalism that appeared during the 1960s. A simple rule is applied to a short repeated cell and gradually transforms its melody, its rhythm, its density or its distribution among the voices.

Steve Reich described the process in *Music as a Gradual Process* (1968): it must be slow and audible enough for the listener to be able to follow its evolution. Once the rule is in place, it determines how the music unfolds.

MINIMAL uses four procedures:

– Phasing: two voices play the same cell, but one moves slightly ahead of the other. They therefore shift apart gradually, producing new combinations, but may end up back in unison.

– The additive process: the cell lengthens gradually through the addition of one or more notes. The reverse movement is also possible: the cell shortens little by little. Philip Glass uses this procedure in *Two Pages* (1968), where a single line lengthens then contracts.

– Hocket: the notes of a single figure are distributed among several voices. Each plays only part of it, but their combination lets the complete figure be heard. This technique was already used in medieval music of the XIIIth century under the name hoquetus.

– Substitution: a cell contains both notes and rests. At each repetition, a note gradually replaces a rest, or a rest replaces a note, without the total length of the cell changing. Steve Reich uses this procedure notably in *Drumming* (1970-1971).

Settings

CONTROL	ACTION IN THIS ALGORITHM
MATERIAL	Chooses the starting cell and, with it, the procedure applied: phasing, additive process, hocket or substitution.
MEMORY	Slowness of the process: one step every 1 to 13 measures. Beyond 72%, the durations are doubled.
GROWTH	Length of the cell, from 4 to 8 positions, and speed of the slow transposition that accompanies the process.
MORPH	Beyond 55%, the intervals of the cell are inverted, on every other voice and every other step.
DENSITY	Proportion of the cell's notes actually played, from 35 to 100%.
TENSION	Beyond 58%, a semitone of tension can be added to about 14% of the notes. Beyond 60%, the pulse doubles in speed and the durations tighten.

CONTROL	ACTION IN THIS ALGORITHM
INTERACTION	Its effect depends on the procedure. In phasing, it multiplies the phase gap between the voices; in hocket, beyond 70%, each position is doubled by the neighboring voice. No effect on the additive and substitution procedures.
HUMANIZE	Share of improvisation, at most one gesture per measure: the balance of the measure, a passing note, a short phrase, an unplayed note or a one-beat rupture.

Materials

MATERIAL	MUSICAL CHARACTER
PHASE STEPS	A stepwise cell shifts gradually between the voices to create phase beating.
ADD FIFTHS	An arpeggio of fifths grows note by note in the manner of an additive process.
HOCKET MODAL	A modal figure is shared between the tracks in interlocking hocket.
SUBSTITUTION	Rests are gradually replaced by notes within a broad modal cell.
PHASE CHORD	A minor-seventh chord cell phases between the four voices.
ADD WAVE	A curve of open intervals is built up by successive additions.
HOCKET MAJ7	The notes of a major-seventh color circulate from voice to voice.
SUBST WIDE	A wide-interval cell fills in gradually for a very spacious result.

CELLULAR

CELLULAR is a cellular automaton made of 32 positions arranged in a ring. Each cell can be active or off. The last cell is adjacent to the first, so that activity can circulate in a loop.

At each generation, the state of every cell is recomputed from three pieces of information: its own state, that of its left-hand neighbor and that of its right-hand neighbor. All the cells are updated simultaneously from the previous generation.

Depending on the rule and on the starting arrangement, activity can die out, stabilize, oscillate, travel around the ring or produce a more complex evolution. The system is deterministic: with the same rule and the same initial state, it always reproduces the same evolution, even though that evolution may seem unpredictable.

Origin and principle

The concept was formulated by John von Neumann and Stanisław Ulam in the 1940s, as part of research into self-reproduction. *The Game of Life* by John Conway popularized the idea with a wide audience.

The classification used here comes from Stephen Wolfram in *Statistical Mechanics of Cellular Automata* (*Reviews of Modern Physics*, 1983). A line of two-state cells is used, each looking at its two neighbors. The neighborhood counts three cells, hence eight possible configurations; a rule assigns a state to each of these eight configurations, which gives 256 rules.

The number of the rule determines neither its density, nor its difficulty, nor its complexity. Two neighboring numbers can therefore produce very different evolutions.

The result also depends on the initial arrangement of the cells. The same rule can die out quickly with one starting state and produce a long evolution with another. On the 32-cell ring of B.A.C.H., patterns can also travel around the ring and meet their own trace.

Materials

MATERIAL runs through rules R001 to R254, that is 254 possibilities. R000 and R255 are set aside because they lead immediately to the two simplest states: all cells off or all cells active.

Each rule is associated with a harmonic indication (OPEN, MIN7, TENSE or MAJ7). This indication guides the conversion of active cells into musical pitches, but it does not describe the behavior: a rule does not represent a guaranteed musical pattern, it defines a small dynamic system whose result is discovered over the course of the loops.

The most useful approach is therefore to listen to each rule for several measures. A high number does not indicate denser or more chaotic activity: R230 is not necessarily more complex than R030.

Settings

CONTROL	EFFECT IN CELLULAR
MATERIAL	Chooses the rule (from R001 to R254) and its harmonic translation color.
GROWTH	Speeds up the evolution: low, several musical steps between two generations; high, a new generation at almost every step.
MEMORY	Increases inertia and can freeze more cells, thus stabilizing or prolonging patterns.
INTERACTION	Widens the neighborhood relationships and brings closer the positions observed by the four voices, which become more connected.
MORPH	At successive thresholds, rotates the ring, complements its state or reflects certain intervals.
DENSITY	Sets the proportion of living cells actually made audible; its curve is progressive.
TENSION	Accentuates cell births and sometimes adds a semitone of tension to the new events.
HUMANIZE	Share of improvisation, at most one gesture per measure: the balance of the measure, a passing note, a short phrase, an unplayed note or a one-beat rupture.

It can sometimes happen that the texture “dies out”; MATERIAL must then be changed or RESET used to start again from a new state.

TREE

TREE uses growth rules drawn from research in biology, turned into melodic lines.

Origin and principle

L-systems were devised in 1968 by the biologist Aristid Lindenmayer to represent the growth of simple organisms. They were then widely used to describe plants and branching structures.

An L-system is a growth rule based on symbol replacement. One starts from a short string called the axiom. At each step, all its symbols are replaced simultaneously according to predefined rules. By repeating the operation, one obtains an

increasingly long and branched structure, in which certain shapes can reappear at several levels.

TREE interprets this structure as a musical path: the branches, the directions and the repetitions become melodic movements. The Kaona modules *Strange Garden* and *Fractaos* likewise explore principles of growth and repetition at different scales.

The size of the structure can grow very quickly, sometimes exponentially. After a few steps, it can exceed the available memory or produce a phrase too long to remain musically useful. B.A.C.H. therefore limits the length of the structure. The tree can thus be truncated instead of being developed in full.

The system used in B.A.C.H. is a deliberately simplified interpretation of a formalism that has many variants. The eight species offered are deterministic: a symbol is always replaced in the same way, whatever the symbols surrounding it. With identical settings, TREE therefore rebuilds the same tree and the same melodic line.

Settings

CONTROL	ACTION IN THIS ALGORITHM
MATERIAL	Chooses the "species," that is the rewriting rule applied to the axiom.
MEMORY	Beyond 60%, slows the path through the structure by one step.
GROWTH	Rewriting depth, from 2 to 6 steps; every change rebuilds the tree. Beyond 78%, all the notes are reduced to the sixteenth note.
MORPH	Beyond 50%, the intervals are inverted on every other voice.
DENSITY	Proportion of events actually played, from 40 to 98%. Beyond 60%, the path advances by one note at every step instead of every other step.
TENSION	Beyond 55%, a semitone of tension can be added to about 16% of the notes. Also increases the velocity.
INTERACTION	Reading gap between the voices: fully clockwise they read the same position of the structure, to the left they move away from it. Also sets the spread of the registers.
HUMANIZE	Share of improvisation, at most one gesture per measure: the balance of the measure, a passing note, a short phrase, an unplayed note or a one-beat rupture.

Materials

MATERIAL	MUSICAL CHARACTER
CANOPY	A heavily branching rule builds a dense canopy with many branch returns.
TENDRIL	Growth alternates between extensions and small ascending branches.
ZIGZAG	The line changes direction regularly and forms a very clear angular figure.
FERN	An asymmetrical system brings out offset branches.
CORAL	Repeated bifurcations and numerous doublings.
VINE	Loop and lateral branchings.
FORK	Symmetrical paths.
ROOTS	Descending branches, favoring the low register.

FRACTAL

FRACTAL creates long polyphonic musical structures from mathematical sequences and processes.

Origin and principle

The name FRACTAL is used here in a broad sense. The generators offered in B.A.C.H. have different mathematical origins: some rest on recursive sequences, such as Thue-Morse or the dragon sequence; others, such as the logistic map, come from the study of chaotic systems. All produce series of values that can be translated into musical events.

These sequences have no musical meaning in themselves. Everything depends on the way B.A.C.H. interprets their values. The same binary sequence can serve to build a rhythm, to alternate between two pitches, to choose a register or to distribute notes among several voices.

The result depends heavily on the reading scale. If the sequence evolves too quickly, the notes can seem disordered or unrelated. If it evolves too slowly, the repetitions may on the contrary seem monotonous.

FRACTAL is therefore probably one of the trickiest languages to master in B.A.C.H. MEMORY sets this compromise by determining the time scale over which the mathematical structure unfolds.

Settings

CONTROL	ACTION IN THIS ALGORITHM
MATERIAL	Chooses the generator among the eight described below.
MEMORY	Reading scale: the sequence advances progressively by one step.
GROWTH	Number of superimposed levels, from 1 to 5. For LOGISTIC, sets the range of pitches produced, from six to eighteen semitones.
MORPH	Acts on BASE-4: beyond 44%, the digits are complemented; beyond 76%, every other level is inverted. Also increases the probability of ornamentation.
DENSITY	Probability that a voice emits a note at each step.
TENSION	For LOGISTIC, sets the parameter of the map, from the stable cycle to deterministic chaos. For the other generators, beyond 56%, a semitone of tension can be added to about 16% of the notes.
INTERACTION	Reading gap between the voices: fully clockwise the four voices read the same position.
HUMANIZE	Share of improvisation, at most one gesture per measure: the balance of the measure, a passing note, a short phrase, an unplayed note or a one-beat rupture.

Materials

MATERIAL	MUSICAL CHARACTER
THUE-MORSE	A self-similar binary sequence sets figures against one another at several scales without systematic repetition.
LOGISTIC	A logistic map evolves from stable cycles toward deterministic chaos according to the tension.
BASE-4	The digits of the position in base four superimpose similar figures at several depths.
1/F ADDITIVE	Binary layers of decreasing amplitude produce a balanced variation between order and disorder.
RULER	The divisibility of the steps by powers of two creates a hierarchy of accent and interval breaks.
SIERPINSKI	A recursive triangular pattern brings out self-similar gaps and groupings.
FIBONACCI	The ratios of the Fibonacci sequence organize irregular but strongly coherent returns.
DRAGON	A paper-folding sequence alternates directions and generates a recursive contour with substantial breaks.

MOTIF

MOTIF assembles a chain of melodic and rhythmic cells. The starting cell depends on the genre chosen with MATERIAL.

Each cell lasts from 8 to 32 sixteenth notes, and a chain contains from 2 to 10 of them. The complete phrase can thus develop over several measures before returning to its starting point. In the longest configurations, it can exceed ten measures.

For each genre, the first cell stays the same. The following cells introduce answers, variations and digressions. Some can also add a counterpoint, that is one or more secondary lines played at the same time as the main line. The last cell prepares the cadence and the return to the beginning of the chain.

There is no note-by-note random draw. With the same settings and the same starting conditions, B.A.C.H. reproduces the same succession of phrases and transformations. The result evolves when the musician acts on the eight controls, on the SEQUENCE chords or on the BREAKS.

Origin and principle

A motif is a short melodic or rhythmic phrase distinctive enough to be recognized when it returns. Composing with motifs consists in developing this idea by repeating it, transposing it, fragmenting it or modifying its rhythm. The same element can thus be recognized in different forms.

This way of building music occupies an important place in the Western tradition, particularly from the Classical period onward. Arnold Schoenberg offered a detailed description of it under the name “developing variation”: the new elements are not independent, but derive gradually from an initial motif. Composers belonging to very different aesthetics, from Boulez to Philip Glass, then used their own forms of repetition and transformation.

In MOTIF, the first cell and the final cadence stay fixed in order to give the musician landmarks. If every element changed at each cycle, the chain might be perceived as a succession of unrelated events rather than as the transformation of

a single phrase. MEMORY is therefore an important control, since it determines the degree of reorganization of the inner cells, without modifying the starting point or the final cadence.

Settings

CONTROL	ACTION IN THIS ALGORITHM
MATERIAL	Chooses one of the 32 cell repertoires.
GROWTH	Progressively opens a chain of 2 to 10 cells.
MEMORY	Keeps or reorganizes the inner cells; the start and the cadence stay fixed.
MORPH	Applies displacement, augmentation, fragment, inversion or retrograde.
DENSITY	Progressively reveals motif, answer, support and bass.
TENSION	Moves the digressions further out or strengthens their passing notes.
INTERACTION	Runs through solo, accompaniment, call-and-response and counterpoint.
HUMANIZE	Share of improvisation, at most one gesture per measure: the balance of the measure, a passing note, a short phrase, an unplayed note or a one-beat rupture.

Materials

MATERIAL	MUSICAL CHARACTER
CANTABILE	A stepwise phrase lengthens into cadenced answers.
ARCH	A rising then falling contour serves as a landmark for the successive digressions.
STEPWISE	Stepwise motion, producing a relatively even result.
FOLK	Simple, modal and memorable cells.
ARPEGGIO	Chord notes in arpeggios.
CHORALE	Solemn harmonic structure.
LAMENT	Descending movement and minor stresses.
PEDAL	A pivot note that returns between the fragments.
RIFF	A short, accented cell.
OSTINATO	Deliberate repetition of a cell, the other voices making the texture evolve.
SYNCOPATED	Off-beat attacks.
WALTZ	Ternary organization with impulse, answer and cadence over the measure.
CALL RESPONSE	The first track receives contrasting answers from the other voices.
MODAL	Characteristic modal degrees.
DANCE	Regular, accented and repeated cells.
WIDE	Large intervals.
NOCTURNE	A spaced-out line, favoring rests and late answers.

MATERIAL	MUSICAL CHARACTER
HYMN	Diatonic movements and long durations.
BAROQUE	Ornaments, harmonic sequences and sequential answers.
ROMANTIC	Delayed resolutions and more expansive expressiveness.
MINIMAL LINE	A reduced cell that transforms itself through small differences and displacements.
JAZZ LINE	Mobile stresses and passing notes.
BLUES LINE	Inflections characteristic of the blues.
LATIN LINE	Generic Latin phrasing.
BOSSA LINE	Bossa syncopation.
ROCK LINE	Substantial repetitions and clear cadences.
AFRO LINE	Interlocking, cyclic cells, potentially polyrhythmic.
BALKAN LINE	Asymmetry and irregular accents.
CELTIC LINE	Stepwise motifs and varied restatements.
EASTERN	Tight seconds and ornaments.
IMPRESSIONIST	Ambiguous intervals.
CINEMATIC	Register progression and clear cadence.

HYBRID

HYBRID occupies a special place in B.A.C.H. It does not rest on a precise historical musical procedure, but combines several of the generative languages available in the module. Each voice can thus follow a different engine.

Origin and principle

HYBRID can be compared to works that superimpose several independent musical planes. Charles Ives frequently used this technique, letting materials coexist that do not necessarily share the same tempo, the same rhythm or the same key. In *The Unanswered Question* (around 1906–1908), three planes are superimposed: strings, solo trumpet and woodwinds. The procedure questions the listener's degree of divergence: at what moment does one stop hearing an ensemble and start hearing separate layers.

In a generative system, running several engines simultaneously means deciding which one controls each voice and when this distribution should change. B.A.C.H. uses three forms of distribution:

– The common engine: the four voices use the same language.

– Distribution in pairs: two groups of two voices use different languages.

– Individual distribution: each voice can use its own language.

INTERACTION determines this distribution. At a high value, the four voices share the language designated by MATERIAL. At intermediate values, they are grouped in pairs. At low values, each track can use a different language.

MATERIAL chooses the reference language around which the combination is built. TRANSFORMATION and BREAK rotate the assignment of the engines, so that a given voice does not stay indefinitely tied to the same language.

The other controls are passed directly to the engines in use. The same setting can therefore produce different effects depending on which language is controlling a voice at that moment.

HYBRID can thus give results that are hard to predict, without resting on permanent chance. Its use is more exploratory than that of the other languages and may require some time to become familiar with.

Settings

CONTROL	ACTION IN THIS ALGORITHM
MATERIAL	Chooses the reference language among the nine in the list below.
MEMORY	Passed unchanged to the language assigned to each voice; its effect therefore depends on that language.
GROWTH	Passed unchanged to the language assigned to each voice; its effect therefore depends on that language.
MORPH	Beyond 66%, the assignment of the languages rotates by one step at the halfway point of each measure. Below that, the control is passed on to the languages.
DENSITY	Passed unchanged to the language assigned to each voice; its effect therefore depends on that language.

CONTROL	ACTION IN THIS ALGORITHM
TENSION	Passed unchanged to the language assigned to each voice; its effect therefore depends on that language.
INTERACTION	Distribution of the languages. Beyond 66%, the four voices follow the MATERIAL language; between 33 and 66%, two languages share the voices in pairs; below that, each voice receives its own language.
HUMANIZE	Share of improvisation, at most one gesture per measure: the balance of the measure, a passing note, a short phrase, an unplayed note or a one-beat rupture.

Materials

MATERIAL	MUSICAL CHARACTER
FUGUE	Takes FUGUE as the base language before distributing or mixing other engines among the voices.
CANON	Takes CANON as the starting point of a mixture based on imitation.
PROBA	Takes PROBA as the center and keeps greater freedom of events.
TINTINA	Takes TINTINNABULI as the center for a clear mixture of melodic and chordal voices.
MINIMAL	Takes MINIMAL as the center and brings cells and gradual processes to the fore.
CELLULAR	Takes CELLULAR as the center to spread an emergent evolution among the tracks.
TREE	Takes TREE as the center and combines several growth logics.
FRACTAL	Takes FRACTAL as the center to superimpose different mathematical hierarchies.
MOTIF	Takes MOTIF as the center and mixes its long cells with the other languages.

GROOVE

GROOVE does not compose a melodic line in the usual sense: it is a generative drum machine organized in four roles and offering 64 starting structures.

The roles are fixed: track 1 LOW (kick, low drum, and so on), track 2 BACKBEAT (snare, clap, and so on), track 3 TIME (hi-hat, ride, shaker, and so on) and track 4 PERC (toms and tuned percussion). The first three tracks keep stable drum pitches. PERC follows ROOT and SCALE to produce tuned percussion, notably toms. These variations are available only on the PITCH outputs. To drive a standalone *Drum* module, the GATE outputs can be used instead.

Origin and principle

A traditional drum machine chains fixed patterns or ones programmed step by step. GROOVE follows another approach: each MATERIAL value defines a structure capable of varying. It indicates when each role intervenes, independently of the sounds used.

The engine works at 24 pulses per quarter note. This resolution makes it possible to combine eighth notes, sixteenth notes and triplets precisely, without any offset due to rounding.

The traditions mentioned in the MATERIAL list designate families of rhythmic placement, not faithful transcriptions. A traditional rhythm is also defined by its instruments, its timbres, its performance, its regional variants and its social function. These dimensions are not reproduced here.

Settings

CONTROL	ACTION IN THIS ALGORITHM
MATERIAL	Chooses one of the 64 rhythmic models.
MEMORY	Keeps the variations from one measure to the next for a longer or shorter time.
GROWTH	Builds layer entries, phrases and short sequences.
MORPH	Rotates, displaces or inverts certain cells.
DENSITY	Runs from the skeleton to ghost notes and subdivisions.
TENSION	Moves the stresses toward syncopations and intermediate positions.
INTERACTION	Goes from superimposition to interlocking and call-and-response.
HUMANIZE	Shades velocity and microtiming according to each role.

Materials

MATERIAL			
TECHNO DRIVE	**SWING RIDE**	**BOSSA NOVA**	**AKSAK 5**
TECHNO DUB	**BEBOP**	**SAMBA**	**AKSAK 7**
HOUSE CLASSIC	**JAZZ WALTZ**	**SAMBA REGGAE**	**AKSAK 9**
HOUSE DEEP	**JAZZ FUNK**	**BAIAO**	**BALKAN 11**
ELECTRO	**LATIN JAZZ**	**MARACATU**	**KARSILAMA**
TRANCE	**BRUSHES**	**FREVO**	**MALFUF**

MATERIAL			
DNB HALF	ODD JAZZ 5	IJEXA	MAQSUM
INDUSTRIAL	ODD JAZZ 7	PARTIDO ALTO	DABKE
ROCK BASIC	SON 3-2	AFROBEAT	EUCLID 3-8
ROCK SHUFFLE	SON 2-3	HIGHLIFE	EUCLID 5-8
FUNK POCKET	RUMBA 3-2	BEMBE 6-8	EUCLID 5-12
FUNK SYNC	RUMBA 2-3	BELL 12	EUCLID 7-12
SOUL	MAMBO	KUKU	POLY 3-2
MOTOWN	SONGO	GNAWA	POLY 4-3
HIP HOP	REGGAE ONE	GUMBE	ROTATING
NEW ORLEANS	CALYPSO	KWAITO	INTERLOCK

The names of styles and traditions are evocative landmarks for exploring a family of placements. The *Materials* do not claim to replace the study, the instruments or the regional variants of a traditional rhythm.

So as never to break the rhythm, GROOVE and GROOVE MIX do not apply every setting immediately during playback:

– MATERIAL, MEMORY, GROWTH, TENSION and INTERACTION are applied together on the first beat of the next bar. Only the last requested position is kept, and the new Material starts at the beginning of its cycle. The displayed name follows the encoder immediately.

– MORPH moves gradually to its new value over four quarter notes, regardless of the bar line.

– DENSITY and HUMANIZE change gradually, in small steps on every sixteenth note; the full range takes at most one bar.

This rule applies to the encoders, the CV inputs and MIDI CCs. When stopped, all settings take effect immediately. In GROOVE MIX, the melodic partner receives the changes at the same moment as the rhythm. The other languages apply their settings immediately.

GROOVE MIX

GROOVE MIX takes up exactly the 64 Materials described in the previous chapter, but the rhythmic events drive a melodic partner. It thus makes it possible to produce harmonized playing with a rock, bossa, Latin, jazz or electronic feel without giving up the composition controls.

Principle

GROOVE MIX separates two decisions that most generators take together: when a note occurs, and what pitch it carries. The rhythmic grid comes from GROOVE, the pitches from a second language, the partner.

The arrangement imposes a constraint: the melodic partner must supply an available pitch at the moment the grid calls for a note. The choice of permitted partners follows from this constraint. CANON, PROBA, CELLULAR, TREE, FRACTAL, MOTIF and HYBRID produce pitches at a compatible rate. FUGUE, TINTINNABULI and MINIMAL are excluded: their rhythmic architecture is part of their definition and would be replaced by the drum grid.

Choosing the partner

When GROOVE MIX is selected, the screen presents the available partners. Only after this choice is GROOVE MIX operational.

Behavior

MATERIAL, DENSITY, GROWTH, MORPH, TENSION, INTERACTION, MEMORY and HUMANIZE first shape the rhythmic grid, then its melodic articulation, as in GROOVE.

GROOVE MIX follows SEQUENCE and VOICING; it can therefore move through a chord progression.

SWING and ORNAMENTS remain active.

BREAK acts on the virtual drum kit and the melodic material together: SILENCE is truly silent and FRAGMENT produces an audible rupture.

Materials

The 64 names and their descriptions are those of the GROOVE chapter. The partner does not change the reference placement; it changes the way that placement becomes pitch, chord, motif or counterpoint.

MIDI

The two MIDI sockets are TRS type-B. Adapters are supplied with B.A.C.H., but any adapter meeting the standard will work. Note that type-A adapters will not work: no note will be produced. The monitor on the MIDI IN page will tell you whether MIDI is being received correctly or not.

MIDI OUT

A MIDI channel, from 1 to 16, can be assigned to each of the four tracks. The four encoders used are those of the left-hand column: MATERIAL for track 1, MEMORY for track 2, GROWTH for track 3, MORPH for track 4. Several tracks can share a channel; the CC11 expression used for the envelopes is then returned to full level only when the last voice on the channel is released.

- To use B.A.C.H. with a synthesizer or a polyphonic module, set the four tracks to the same MIDI channel.

- To use B.A.C.H. with several synthesizers, several modules or multitimbral synthesizers and modules, set the four tracks to different MIDI channels.

When B.A.C.H. is the master (internal clock), it generates the clock from the displayed tempo, aligned with its own grid. When it is itself following an external clock, it passes the received clock through unchanged, together with Start, Continue and Stop messages.

Before each Start or Continue, the module sends a Song Position Pointer: devices that understand it restart at the same bar and beat. Others simply ignore it.

Switching from OFF to TRANSP or CLOCK during playback sends a Continue; switching back to OFF during playback sends a Stop. When stopping, the module sends an All Notes Off on every channel in use.

When two tracks share a channel, that channel is shown in terracotta on the MIDI OUT page and on the main page. EXPRESSION and MIDI CLOCK are system settings: recalling a preset does not change them.

MIDI IN

A MIDI channel and a CC can be assigned to any control, either by setting the values manually or by learning. The upper box displays the command being set.

The page has twenty rows: the eight controls, ALGORITHM, RESET, BREAK, PLAY / STOP, TRACK 1 to TRACK 4, ROOT NOTES, MIDI CLOCK, RESET ON STOP and CV CLOCK.

Settings

CONTROL	ACTION
MATERIAL	Selects the row to set.
MATERIAL (click)	Clears the row's assignment.
MEMORY	Selects the channel: OMNI, then 1 to 16. On MIDI CLOCK and RESET ON STOP: ON or OFF. On CV CLOCK: 1, 2, 4, 24 or 48 PPQ.
GROWTH	Sets the CC number: OFF, then 0 to 127.
PRESETS button	Labeled ALT on screen, arms MIDI learn. The frame turns terracotta while learning.

Learning

Learning makes it possible to assign any control to the CC chosen on the external MIDI controller.

– Choose the command to be controlled (MATERIAL encoder)

– Press the PRESET button (ALT)

– Turn the knob or press the PAD on the controller

– The channel and the CC are captured together and assigned directly to the chosen command. A click on the MATERIAL encoder clears this assignment.

Learning makes the CC exclusive: the command that was already using that CC loses it.

Share CC

Two commands can listen to the same CC on the same channel: both of them then respond. The MIDI IN page flags this in terracotta, in place of the row's help text, for example CC ALSO DRIVES DENSITY. The OMNI channel overlaps every channel; two different channels do not overlap.

Choosing a CC with the encoder does not clear any other assignment: only MIDI learn makes a CC exclusive. A click on MATERIAL clears an assignment that gets in the way.

Tracks and Transport

The TRACK 1 to TRACK 4 rows (CC 28 to 31 on channel 1 by default) mute or unmute each track, exactly like the track buttons: same LED, same storage in presets.

RESET, BREAK, PLAY / STOP and TRACK 1 to 4 act when the message is received, whatever its value: many MIDI switches send 127 on every press. The only exception: a zero value following a non-zero value (release of a momentary pedal) is ignored. A momentary pedal therefore mutes a track on one press and unmutes it on the next. PLAY / STOP and TRACK toggle the current state.

Change of tonic note

An incoming MIDI note redefines ROOT, in order to change a sequence manually, for example. The ROOT NOTES line on the MIDI IN page chooses which channel these notes are listened to on. By default the setting is OMNI, which means that any note on any channel will change the ROOT note. If FUGUE is the language in use, the tonic does not go below C2, the engine needing at least one octave below the bass.

The clock

MIDI clock can be used. Note, however, that some MIDI clocks do not produce a steady enough tempo.

Clock and transport reception is set on the MIDI CLOCK row (help text: CLOCK AND TRANSPORT IN): select the row with MATERIAL, then ON or OFF with MEMORY. It is on by default. Turning it off still lets CCs and notes through.

– Clock (F8): 24 pulses per quarter note. Each pulse advances the module's grid, which therefore cannot drift; the displayed BPM is measured over a full quarter note.

– Start (FA): returns the form to the beginning and starts playback on the next pulse.

– Continue (FB): resumes playback without returning the form to the beginning.

– Stop (FC): stops playback. If RESET ON STOP is ON, the form is also returned to the beginning, as with the RESET button (OFF by default).

– Song Position Pointer (F2): when the master sends its position before a Continue, the B.A.C.H. grid locks to the master's. Only the grid locks: the bar number remains the module's own. The monitor displays the received position (for example SONG POS 84).

A padlock appears next to the BPM value as soon as an external clock is active. The tempo is limited to the 40–240 BPM range. Pressing PLAY under MIDI clock is armed and takes effect on the master's next quarter note (the PLAY LED blinks).

CV CLOCK

The CV CLOCK row sets the number of pulses per quarter note expected on the panel's CLOCK input:

– 1 PPQ (factory): one pulse per quarter note;

– 2 PPQ: per exemple Korg Volca or KeyStep "1 PULSE" output;

– 4 PPQ: one pulse per sixteenth note;

– 24 PPQ: DIN Sync, per exemple TR-808 or KeyStep Sync output;

– 48 PPQ: some Linn machines and the KeyStep.

This setting is stored with the system settings: it does not follow presets and is not changed by a factory reset.

At 24 and 48 PPQ, the module corrects the flaws of an imperfect signal: a spurious edge (bounce, noisy cable) is discarded, a missed edge is counted back in. As soon as a correction has occurred, the CV CLOCK row shows EXTRA n MISSED n in gold: the number of spurious edges discarded and missed edges recovered since power-up. If these counters keep rising, the incoming signal is not clean: check the cable and the source.

The monitor

The lower panel shows the last message received, as the module understood it (for example CH 3 CC 16 = 64 or CH 1 NOTE 60 = 100). It stays bright for one second, then dims.

The second line shows what the module did with that message:

- -> DENSITY 75 %: the control took the value;
- -> BREAK: the command was triggered;
- -> BREAK RELEASE: release, intentionally ignored;
- -> ROOT NOTE: the note redefined ROOT;
- -> LEARNED BREAK: MIDI learn captured the message;
- -> NOT ASSIGNED: no command listens to this CC on this channel.

One second later, this line gives way to two counters: MSG (channel messages received since power-up) and CLK (clock pulses received). If MSG and CLK stay at zero, nothing is coming in: check the cable, the jack or the source's transmit channel. If CLK rises but MSG does not, the clock is getting through and the assignment needs checking.

Default assignment

By default, B.A.C.H. uses the settings below. Modified assignments are stored in the system settings: neither recalling a preset nor a factory reset changes them.

The default channel is 1. Since the CC 16–31 range is undefined in the MIDI standard, it is available as is on most control surfaces.

COMMAND	CC	EFFECT
MATERIAL	16	0-127 -> 0-100%
MEMORY	17	0-127 -> 0-100%
GROWTH	18	0-127 -> 0-100%
MORPH	19	0-127 -> 0-100%
DENSITY	20	0-127 -> 0-100%
TENSION	21	0-127 -> 0-100%
INTERACTION	22	0-127 -> 0-100%
HUMANIZE	23	0-127 -> 0-100%
ALGORITHM	24	0-10 -> FUGUE,| 64-74 -> TREE, 11-21-> CANON 75-85 -> FRACTAL, 22-31 -> PROBA, 86-95 -> MOTIF 32-42 -> TINTINNABULI, 96-106 -> HYBRID 43-53 -> MINIMAL, 107-117 -> GROOVE 54-63 -> CELLULAR, 118-127 -> GROOVE MIX
RESET	25	triggers on every message received.
BREAK	26	triggers on every message received.
PLAY / STOP	27	toggles on every message received.
ROOT NOTES		Note on sets root
TRACK 1 to TRACK 4	28 to 31	mutes or unmutes the track on every message received.
MIDI CLOCK		ON/OFF : Clock and transport in
RESET ON STOP		ON/OFF: a received Stop also returns the form to the beginning (OFF by default).
CV CLOCK		1, 2, 4, 24 or 48 pulses per quarter note on the CLOCK input (1 by default).

CALIBRATION

Calibration corrects individually the zero point of the eight CV inputs and the conversion to volts of each DAC output. It is independent of the presets and of the last musical state.

Every module is calibrated individually before shipping. It is therefore not necessary to carry out this operation. However, should a calibration drift appear for any reason, the procedure below makes it possible to perform it again.

Access and saving

1. Switch the module off.
2. Hold PREV and NEXT together while powering up.
3. Release the buttons when CALIBRATION appears.
4. PREV and NEXT to move from one view to the next: CV INPUT ZERO, DAC ZERO READ, DAC HALF-SCALE and PITCH CHECK.
5. When finished, hold PREV and NEXT together for about one second: B.A.C.H. saves the corrections in EEPROM, then starts normally.

What the PITCH output must produce

PITCH covers eight octaves at 1 V per octave, from C1 (MIDI note 24) to C9 (MIDI note 120): C1 is 0.000 V, C4 is 3.000 V, C7 is 6.000 V and C9 is 8.000 V. A semitone is therefore 83.3 mV. Keep that figure in mind throughout the procedure: a 100 mV reading error on the DAC HALF-SCALE page already moves middle C by a full semitone.

CV INPUT ZERO

1. Set the eight CV inputs to 0 V, preferably with no cable connected.
2. Press RESET. Each zero is averaged over 32 acquisitions and applied immediately.
3. If necessary, turn each physical encoder to fine-tune the zero of the corresponding input individually.

A capture more than 1.28 V away from the theoretical center is refused, so that a modulation is not accidentally recorded as zero.

DAC ZERO READ

The DAC used in B.A.C.H. is a high-end component with very low noise and very high precision. It must be calibrated carefully, with an accurate, calibrated multimeter.

The eight outputs receive raw code 0. Measure the residual voltage of each one and enter that value, in volts and with its sign, using the corresponding encoder; one detent equals 1 mV. RESET returns the eight measurements to 0.000 V.

A negative residual is fully compensated by the computation. A positive one cannot be, since the DAC is unipolar: the lowest note, C1, then stays too high by that same residual, while all the others remain correct. Only the analog stage can remove it.

DAC HALF-SCALE

All eight outputs receive the raw code, set exactly at mid-scale. Measure each output and enter the measured value using the corresponding encoder; one encoder step equals 1 mV, while a fast turn changes the value by 10 mV. The default values are 2.500 V for VELOCITY and 4.000 V for PITCH, but each channel must be measured individually. RESET restores these default values.

This is the most critical calibration page: the entered value determines the output slope, and therefore the volts-per-octave scaling, so any error increases with pitch. For PITCH, a 10 mV error shifts middle C by 9 cents, 50 mV by a quarter tone, and 100 mV by a semitone. Use the finest measurement range that can accommodate 4 V, and allow the reading to stabilize.

PITCH CHECK

This page checks the tuning and lets you adjust it. The four PITCH outputs carry the calibrated voltage of four real notes, spread across the range: OUT 1 plays C2, that is 1.000 V, OUT 2 plays C4, 3.000 V, OUT 3 plays C5, 4.000 V, and OUT 4 plays C7, 6.000 V. A single set of four measurements therefore gives the whole slope. The VELOCITY outputs are at zero and are not displayed.

The page has a single adjustment: the DETUNE counter, from -100 to +100 cents. Any encoder moves it, one detent per cent and ten cents on a brisk turn. It shifts the four outputs by the same amount without touching the volt per octave, which serves both to finish the tuning and to detune deliberately in order to match an instrument that is not at 440 Hz. RESET returns it to zero.

If the discrepancy grows with pitch (correct at C2, wrong at C7) the slope is at fault: go back to DAC HALF-SCALE. If it is the same everywhere, it is a simple offset: correct it with DETUNE.

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These books and articles were valuable assets in designing B.A.C.H.

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Acknowledgments

B.A.C.H. is an important step in the experiments I have long been conducting around generative music, chance and chaos. I designed this instrument in order to share my experiments with these procedures while making them manipulable by the musician.

My thanks go first of all to Bach, who makes life less absurd for me every day; to Mademoiselle Huvet, my organ and piano teacher at the conservatory, who did not manage to put me off Bach despite the willow-cane raps on the fingers; to Monsieur Delanos, the mathematics teacher who did a great deal to make "all that" meaningful; and finally and above all to Jutta and Maëlle, the suns of my life.

Many thanks as well to all the testers and supporters of Kaona, you do so much for me: Yi–Jill for her music; Gildas, of course, who is so good at digging out the tiniest detail and on whom the excuse "it's not a bug, it's a feature" does not work; Brian, Erme, Bryce, Max, Rudi: you are wonderful! Thanks also to the whole community of French electronic instrument makers for welcoming me into their family!

Gilles from Kaona