

CCOMP

Computer COMposition Program

**COMPUTER PROGRAM FOR COMPOSITION AND AUTOMATIC NOTATION
OF INSTRUMENTAL AND VOCAL PIECES OF CONTEMPORARY MUSIC**

1. INTRODUCTION

The universal program for contemporary serious music composition together with programs for automatic notation and traditional notation output are intended for use by students of composition as well as by professional composers of different orientations. The program is one of the examples of the wide use of computer in the field of art in general and in the very specific field of composition in particular.

The program can also be used in the field of research on human thinking, as it is a model of human brain activity in that it uses random operations, with certain limits given by the composer as well as the computer, which are transformed into creative works of art.

Wide knowledge is necessary for discovering all the relations between individual elements constituting a piece of music as well as for their description in the form of algorithms or programs. The program is able to show whether the defined attributes and laws of a certain musical style, period or composer are really typical of the particular phenomenon or not. The composer can have a part of his composition generated to compare the result with his original idea and to add some more details if required.

The element of chance or random choice, enabling different variants of a traditionally written piece to come into existence, is represented here by the random generator. Primary generation is controlled by a number of limiting conditions, which only let through a small part of the musical material produced by the computer.

The system described in great detail on the following pages is just one of the many systems for contemporary serious music composition written during nearly 30 years of the existence of computer-assisted composition, research and teaching, and resulting in a number of different kinds of compositions (chamber, instrumental and vocal pieces, concertos, symphonies, operas, cantatas, and electroacoustic pieces).

The basic composition principle of the program is the use of pseudorandom numbers within defined limits. Random numbers are intended to simulate random processes typical of the activity of the nature and human brain. The result is a specific and self-contained composition style. The basic tool producing random processes in computer is the random generator, which is able to output a succession of numbers within the range 0 - 1 which is repeated after several millions of members.

The program includes rules restricting the composition process, similar to those used by human composers of contemporary serious music. These rules include elimination of traditional harmony, i.e. of traditional chords and their combinations, elimination of classical polyphony with harmonic basis, limitation of traditional rhythmical structures connected with the division into bars (accented and non - accented tones) and elimination of traditional methods of work with melody, phrasing, composition structure and form etc. As to the notation, contemporary music composers write each note with its accidental, simplify rhythmical structures and melodic ornament indications etc.

There is therefore a new concept of melodic line, rhythmical structure, harmony and polyphony involved. The composer, however, is still allowed to use traditional scales and imitations of traditional melodic ornaments, irregular rhythms, elements of instrumental or vocal character of melody (accents, glissando, legato, staccato etc.) and traditional notation (division into bars, clefs, transpositions of instruments, scores etc.).

Every classically educated composer will be able to prepare data for the program, which means that even a beginner in the field of computer music will be able to work with the program and achieve good results. As there is a practically unlimited number of variants of the input data for the program and an unlimited number of possible results (thanks to random processes), every composer can show his individual abilities and original approach. The possibility of changing the percentage tables of distribution of the results according to the demands of each composer (especially in the field of rhythmical structures, harmonic and melodic intervals, modes and polyphony) is another great advantage of the program. With the help of appropriate parameters for pseudorandom numbers generation it is possible to create melodic and rhythmical structures similar to traditional variations.

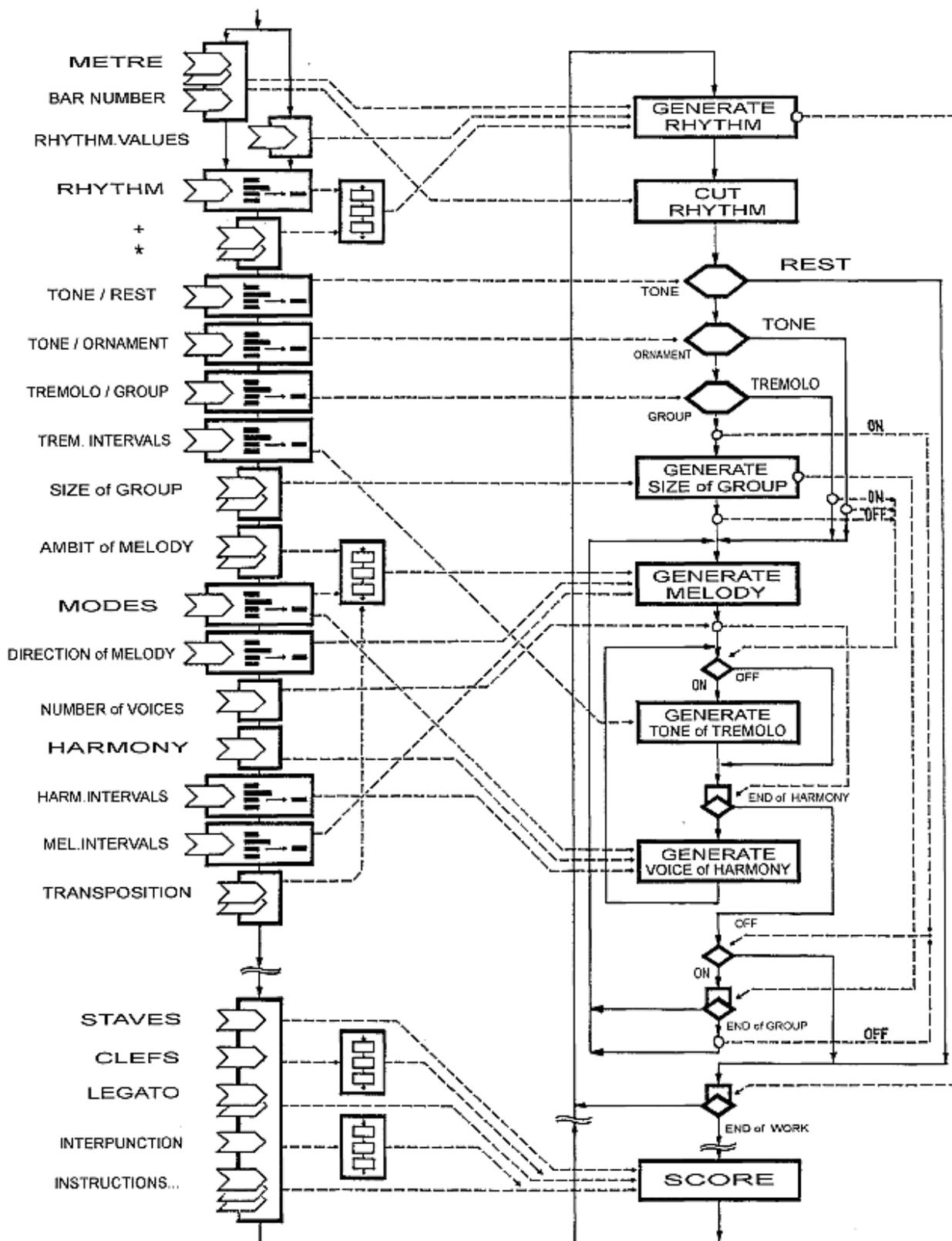
There are two written forms of music composed with the help of computer: automatic notation, which is a modified version of the transcribed music language in a form easily decipherable by performers, and traditional notation in the form of a score with the possibility of extracting any individual part. The latter can be printed either on plotter or on adapted printer.

The most important feature of the program is the fact that it does not substitute the composer's creative work. It only helps him to realize his intentions more quickly and eliminates a lot of routine work, such as dividing the score into bars, transposing instruments and voices, the use of different clefs, forming the score and writing down each individual part.

2. DESCRIPTION OF THE PROGRAM (Fig. 1.)

The length of each composition is determined by the number of bars or tones and rests. It is necessary to define the proportion of tones and rests, ornamented and normal notes, the proportion of tremolos (trills, rollings, frullatos etc.) and groups (leaning notes, grouplets, arpeggios etc.). The range of melody is determined by the lowest and the highest pitches, the selection of tones that should be used is defined by the type of mode. The selection of rhythmic values, melodic intervals and intervals between tones in chords is based on chosen distribution functions. Tremolo is defined by the interval between the two tones, the number of tones in ornaments by the minimum and maximum number, polyphony by the number of parts. Two types of transposition (modal and instrumental) allow modifications of the basic modes and automatic corrections of the parts for transposing instruments. The selection of tones, rhythms and some other elements is done through pseudorandom number generation according to a defined discrete distribution. Separate utility programs extract individual parts from the score using for each instrument a suitable clef and signs and allowing the use of traditional notation.

Fig. 1. Flow chart of main program and utility programs for automatic notation



3. NOTATION CODE

The notation code included in this program is based on the "ALMA" language (Alphanumeric Language for Musical Analysis) in a partly adapted form suitable for this program. The notation is supposed to be produced by computer peripheries. The basic feature of the code is understandability for musicians accustomed to traditional notation and legibility for the computer at the same time.

3.1.

rhythmic values (Fig. 2.A.) :

- 1 semibreve (whole note) or semibreve rest
- 2 minim (half note)
- 4 crotchet (quarter note)
- 8 quaver (eighth note)
- 16 semiquaver (sixteenth note)
- . dot after a note or a rest
- .. two dots

Fig. 2.A.



- P rest
- () irregular rhythm (triplet, quintuplet)
- / bar-line
- 2:4 two-fourth time

tone names: C, D, E, F, G, A, H

accidentals:

- X sharp
- B flat
- N natural

tone systems:

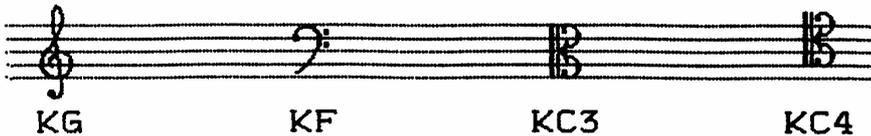
- A-3 ...H-3 subcontraoctave
- C-2 ...H-2 contraoctave
- C-1 ...H-1 great octave
- C0 ...H0 small octave
- C1 ...H1 one-line octave
- C2 ...H2 two-line octave
- C3 ...H3 three-line octave
- C4 ...H4 four-line octave
- C5 five-line octave

- Q** melodic ornament (grouplet, acciacatura, turn, mordent, arpeggio etc.)
- +** other tones of melodic ornament
- W** tremolo, trill, roll, frullato etc.
- &** other tremolo or trill tones
- *** next harmonic tone
- =** tied notes
- < >** beginning and end of legato
- ,** separation of clefs, metre signs or rhythmic values

clefs (Fig. 2.B.):

- KG** treble clef (G clef)
- KF** bass clef (F clef)
- KC3** alto C clef
- KC4** tenor C clef

Fig. 2.B.



3.2.

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clef ::= { KG | KC3 | KC4 | KF }
measure ::= { 1 | 2 | 3 | ... } : { 1 | 2 | 4 | 8 | 16 }
rhythm ::= { 1 | 2.. | 2. | 2 | 4.. | 4. | 4 | 8. | 8 | 16 }
irregular_rhythm ::= { 1 | 2 | 4 | 8 } ( { 2 | 4 | 8 | 16 } ... )
rest ::= { rhythm | irregular_rhythm } P

```

```

tone == basic_tone ::= { C | D | E | F | G | A | H }
accidental ::= { X | B | N }
octave ::= { -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 }
pitch ::= [ accidental ] tone octave
set == set_of_pitches ::= pitch [ * pitch ] ...

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note ::= { rhythm | irregular_rhythm } set
tremolo == trill ::= rhythm W set & set
ornament == melodic_ornament ::= Q set [ + set ] ... + note
notation ::= { note | tremolo | ornament }
tie == tied_tones ::= notation { = [ bar-line ] notation } ...

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```

element == basic_element_of_composition_structure ::= { notation | tie | rest }
{ separator | bar-line } legato ::= < element ... >
sector == sector_of_composition ::= clef separator [ measure separator ] { element | legato } ...
composition ::= sector ...

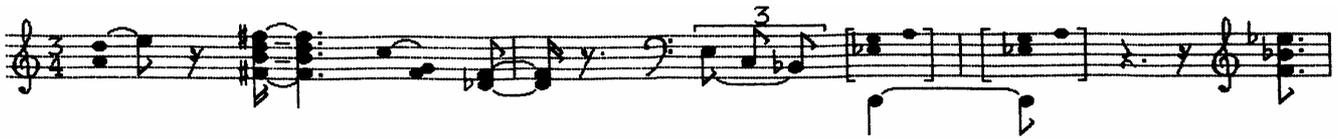
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3.3. Example of transcribed notation output on the printer (Fig. 3.A., Fig. 3.B.)

Fig. 3.A.

KG,3:4,<QA1*D2+8E2>,16P,16XF1*H1*D2*XF2=4.XF1*H1*D2*XF2,
<QC2+F1*G1>+8BD1*F1=/16BD1*F1,8.P,KF,4(<8E0,8C0,8BH-1>),
4WBE0*G0&A0=/8WBE0*G0&A0,4.P,16P,KG,8.F1*BH1*BE2/

Fig. 3.B.



4. SETTING UP PARAMETERS IN THE PROCESS OF COMPOSITION

Parameters can be set either by writing the values on the terminal screen or by preparing them beforehand and storing them in the data file. The program is intended for the PDP 11/34 and ADT 4500 (HP 1000) computers and the FORTRAN IV-VO2.2-5 and FORTRAN 4X rev.2340 programming languages. There is also a version compatible with IBM PC.

4.1. Name

4.1.1. HEADING - general details about the composition or its part - the maximum number of characters - 20, positions <01-20> in the data file

Values in parentheses are placed above the staff in the score or part; values in square brackets are situated in front of the staff; values separated by slashes are put one below the other; values that are not in brackets are not written in the score.

4.2. Tone length

4.2.1. METRE - (example 2,4 - two-four time) - 2 times 2 characters <21-22><23-24>

4.2.2. BAR NUMBER - (only when metre is defined in 4.2.1.) - 3 characters <25-27>

4.2.3. NUMBER OF RHYTHMIC VALUES - determines tone and rest lengths, only when no metre is defined by 4.2.1. - 3 characters <25-27>

4.2.4. RHYTHM - selection of rhythmic values based on percentage tables of pseudorandom process distribution; the tables can be changed and amended to meet the requirements of each individual composer; irregular rhythms can only be required if 4.2.3. has been set - 2 characters <28-29>

4.2.5. " * " - multiple of basic rhythmic values (if not set then the basic rhythmic values do not change) - 2 characters <30-31>

4.2.6. " + " - a defined rhythmic value added to the set values (if not set then the basic rhythmic values do not change) - 2 characters <32-33>

Example (Fig. 5.A., Fig. 5.B.) :

Fig. 5.A.

2	3	4	
...012345678901234567890...			- positions
5 2 2			- parameters

the RHYTHM percentage table 5 shows the following distribution of individual tone lengths :

16 - 50%, 8 - 25%, 8. - 10%, 4 - 15%;

the required conversion gives the following structure :

4 - 50%, 4. - 25%, 2 - 10%, 2=8 - 15%

Fig. 5.B.

random:	0--- --- --- --- --- --- --- --- --- ---1
RHYTHM	16----->8----->8.->4---->
conversion:	4----->4.->2-->2=8-->

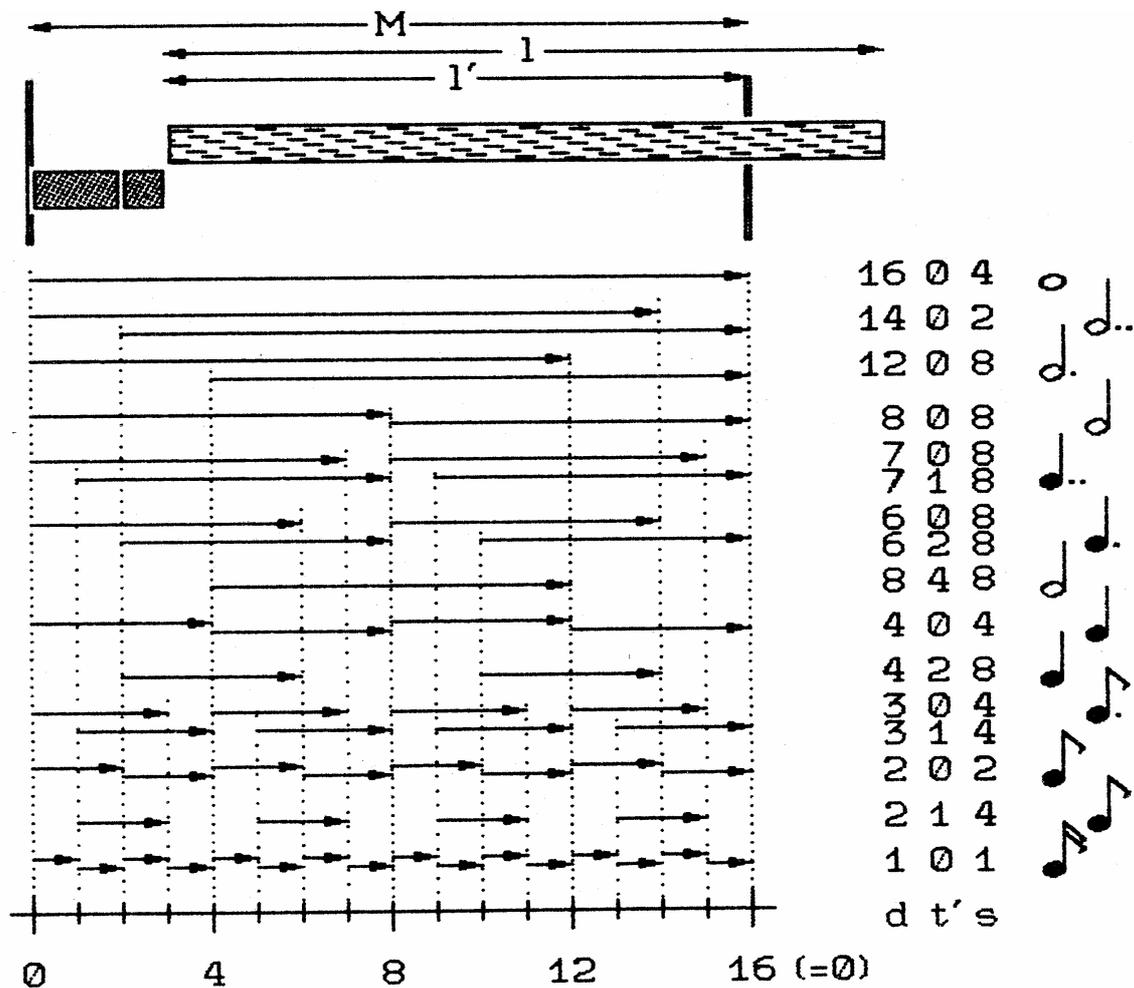
Rhythmic values in the form of a single note or rest are often difficult for the performer to read; notations b) and c) from the three examples given below are written in a much more comprehensible way than a). The notation shown in c) shows the most clearly presented rhythmical structure; in b) and c) the rhythmic structure is presented according to the metre. (Fig. 6.)

Fig. 6.



A special algorithm has been developed for automatic arrangement of rhythmical notation into bars in a logic and easily decipherable way. (Fig. 7.)

Fig. 7. The automatic rhythmical notation algorithm



- t** ... the moment of a new rhythmic value appearance ($t = 0$ - the beginning of a bar)
- M** ... the length of a bare
- l** ... a new rhythmic value input
- l'** ... a section of "l" that is going to be processed
- d** ... a section of "l'" that is to be output in the form of a single note
- t'** ... the moment of a new note appearance
- s** ... a step on the time axis ($t' := t + s$)

A. if a new value is longer than the remaining part of the particular bar ($t + l > M$), then a shorter value will be used in the moment: $l' := M - t$, otherwise $l' := l$

B. the first "d" value that can be used within "l'" is found in the table of selected values for the allowed positions within the bar (into "t" moment)

B1. if the appearance of the "d" note corresponds to the "t" time then the "d" value is output, the original "l" value is shortened ($l := l - d$) and if the result is non-zero, then another step A. is applied and the next note is tied to the first one; the algorithm is terminated when $l = 0$

B2. if the "t'" moment of the "d" note appearance does not correspond to "t", the $l' := t' - t$ section that has been left out will be created first, beginning with step B.

4.2.7. TONE/REST - ratio of tone and rest occurrences determined by pseudorandom occurrence tables alterable by each individual composer; two and more successive rests are joined together (this should always be set) - 1 character <34>

4.2.8. TONE/ORNAMENT - ratio of tone and ornament occurrences determined by pseudorandom occurrence tables (this should always be set) - 1 character <35>

4.2.9. TREMOLO/GROUP - ratio of tremolos, trills, rolls and frullatos (from now on referred to as "tremolos" for short) and other ornaments (grouplets, leaning notes, turns, mordents, arpeggios etc.) - from now on referred to as "groups" for short - which are not taken as rhythmic values (set only if ORNAMENT required by 4.2.8) - 1 character <36>

Example (Fig. 8.A., Fig. 8.B.) :

Fig. 8.A.

3	4	5	
...012345678901234567890...			- positions
345			- parameters

the ratio of tone and rest occurrences (**75% - tones, 25% - rests**) determined by the percentage occurrence table 3 (TONE/REST);

the ratio of tone and ornament occurrences (**50% - tones, 50% - ornaments**) determined by the percentage occurrence table 4 (TONE/ORNAMENT);

the ratio of tremolo and group occurrences (**25% - tremolos, 75% - groups**) determined by the percentage occurrence table 5 (TREMOLO/GROUP)

Fig. 8.B.

random:	0--- --- --- --- --- --- --- --- --- ---1
TONE/REST	T----->R----->
TONE/ORNAMENT	T----->Q----->
TREMOLO/GROUP	W----->G----->

4.2.10. TREMOLO INTERVALS - determines the intervals of tremolos according to the percentage given in the tables; the size of the intervals is defined by the number of semitones (interval 1 - minor 2nd, 2 - major 2nd, 3 - minor 3rd, 4 - major 3rd etc.); (set only if TREMOLO required by 4.2.9.) - 2 characters <37-38>

4.2.11. SIZE OF GROUP - the smallest and largest number of tones within a group (based on random choice and even distribution) including the nearest rhythmic tone following the group, in the case the same number is set for all groups it is sufficient to input one value only (set only if GROUP required by 4.2.9.) - 2 times 2 characters <39-40><41-42>

Example (Fig. 9.A., Fig. 9.B.) :

Fig. 9.A.

3	4	5	
...012345678901234567890...			- positions
116 10			- parameters

the choice of melodic intervals in tremolos is determined by the percentage table 11 (TREM.INTERVALS) approximate occurrences: 1 - 25%, 2 - 35%, 3 - 20%, 4 - 20%;

in SIZE OF GROUP the groups of 6 to 10 are evenly distributed, each forming 20%

Fig. 9.B.

random:	0--- --- --- --- --- --- --- --- --- ---1
TREM. INTERVALS	1----->2----->3----->4----->
SIZE OF GROUP	6----->7----->8----->9----->10----->

4.3. Tone pitch

4.3.1. AMBIT OF MELODY - allowed range of pitches; the lowest and the highest tone that can be used in a composition or its part and that falls within the basic, non-transposed sound of the instrument (this should always be set) - 2 times 4 characters <43-46><47-50>

Example (Fig. 10.) :

Fig. 10.

4	5	6	
...012345678901234567890...			- positions
BH-1XF3			- parameters

the setting BH-1,XF3 defines the range by the limits of B flat in great octave and F sharp in three-line octave

4.3.2. MODES - the enumeration of tones that can be used in the composition - can be altered and augmented by the composer; if the mode is not repeated after an octave is completed, then C1 is the beginning (this should always be set) - 2 characters <51-52>

Survey of the modes used (includes definitions of all common 5 to 12-tone modes beginning with the oldest historic pentatonic mode and including the whole-tone and diatonic modes, Messiaen's modes, chromatic scale and all modes with the period other than octave and the interval combinations 1,2,3,4 and the maximum number of 3 intervals of the same or different size). (Fig. 11.)

Fig. 11. Modes table

	CODE	MODE TONES
1	101010010100/22323	five-tone (pentatonic) C D E G A
2	111000110000/11415	five-tone C XC D XF G
3	111000011000/11514	five-tone C XC D G BA
4	10/2	six-tone (whole-tone) C D E XF XG XA
5	1100/13	six-tone C XC E F XG A
6	110100/123	six-tone C XC XD XF G A
7	110010/132	six-tone C XC E XF G BH
8	111000/114	six-tone (Messiaen) C XC D XF G BA
9	101011010101/2212221	seven-tone (diatonic) C D E F G A H
10	111100111000/1113114	seven-tone C XC D XD XF G BA
11	111100011100/1114113	seven-tone C XC D BE G XG A
12	110/12	eight-tone (Messiaen) C XC XD E XF G A BH
13	111100/1113	eight-tone (Messiaen) C XC D XD XF G XG A
14	111010/1122	eight-tone (Messiaen) C XC D E XF G BA BH
15	1110/112	nine-tone (Messiaen) C XC D E F XF XG A BH
16	111110/11112	ten-tone (Messiaen) C XC D XD E XF G XG A BH
17	1/1	twelve-tone (chromatic) C XC D XD E F XF G XG A XA H
18	11010/122	twelve-tone A-3 H-3 XC-2 D-2 E-2 XF-2 G-2 A-2 H-2 C-1 D-1 E-1 F-1 G-1 A-1 BH-1 C0 D0 BE0 F0 G0 BA0 BH0 C1 BD1 BE1 F1 XF1 XG1 XA1 H1 XC2 XD2 E2 XF2 XG2 A2 H2 XC3 D3 E3 XF3 G3 A3 H3 C4 D4 E4 F4 G4 A4 BH4 C5
19	11100/113	twelve-tone A-3 XA-3 XC-2 D-2 XD-2 XF-2 G-2 XG-2 H-2 C-1 XC-1 E-1 F-1 XF-1 A-1 XA-1 H-1 D0 XD0 E0 G0 XG0 A0 C1 XC1 D1 F1 XF1 G1 XA1 H1 C2 XD2 E2 F2 XG2 A2 XA2 XC3 D3 XD3 XF3 G3 XG3 H3 C4 XC4 E4 F4 XF4 A4 XA4 H4
20	1100100/133	twelve-tone XA-3 XC-2 D-2 F-2 XG-2 A-2 C-1 XD-1 E-1 G-1 XA-1 H-1 D0 F0 XF0 A0 C1 XC1 E1 G1 XG1 H1 D2 XD2 XF2 A2 XA2 XC3 E3 F3 XG3 H3 C4 XD4 XF4 G4 BH4
21	11000/14	twelve-tone A-3 XC-2 D-2 XF-2 G-2 H-2 C-1 E-1 F-1 A-1 BH-1 D0 BE0 G0 BA0 C1 BD1 F1 XF1 XA1 H1 XD2 E2 XG2 A2 XC3 D3 XF3 G3 H3 C4 E4 F4 A4 BH4
22	1101000/124	twelve-tone A-3 XC-2 D-2 E-2 XG-2 A-2 H-2 XD-1 E-1 XF-1 XA-1 H-1 BD0 F0 BG0 BA0 C1 BD1 BE1 G1 BA1 BH1 D2 BE2 F2 A2 BH2 C3 E3 F3 G3 H3 C4 D4 XF4 G4 A4
23	1100010/142	twelve-tone H-3 XC-2 D-2 XF-2 XG-2 A-2 XC-1 XD-1 E-1 XG-1 XA-1 H-1 BE0 F0 BG0 BH0 C1 BD1 F1 G1 BA1 C2 D2 BE2 G2 A2 BH2 D3 E3 F3 A3 H3 C4 E4 XF4 G4 H4
24	11001000/134	six-tone A-3 C-2 E-2 F-2 BA-2 C-1 XC-1 E-1 XG-1 A-1 C0 E0 F0 BA0 C1 XC1 E1 XG1 A1 C2 E2 F2 BA2 C3 XC3 E3 XG3 A3 C4 E4 F4 BA4 C5
25	11000100/143	six-tone A-3 XC-2 E-2 F-2 A-2 C-1 BD-1 F-1 XG-1 A-1 XC0 E0 F0 A0 C1 BD1 F1 XG1 A1 XC2 E2 F2 A2 C3 BD3 F3 XG3 A3 XC4 E4 F4 A4 C5
26	110001000/144	twelve-tone C-2 BD-2 F-2 A-2 BH-2 D-1 XF-1 G-1 H-1 XD0 E0 BA0 C1 BD1 F1 A1 BH1 D2 XF2 G2 H2 XD3 E3 BA3 C4 BD4 F4 A4 BH4
27	10100/23	twelve-tone XA-3 XC-2 XD-2 XF-2 XG-2 H-2 XC-1 E-1 XF-1 A-1 H-1 D0 E0 G0 A0 C1 D1 F1 G1 BH1 C2 BE2 F2 XG2 XA2 XC3 XD3 XF3 XG3 H3 XC4 E4 XF4 A4 H4
28	1010100/223	twelve-tone BH-3 BD-2 BE-2 F-2 BA-2 BH-2 C-1 BE-1 F-1 G-1 BH-1 C0 D0 F0 G0 A0 C1 D1 E1 G1 A1 H1 D2 E2 XF2 A2 H2 XC3 E3 XF3 XG3 H3 XC4 XD4 XF4 XG4 XA4
29	10100100/233	nine-tone XA-3 XC-2 E-2 XF-2 A-2 C-1 D-1 F-1 XG-1 XA-1 XC0 E0 XF0 A0 C1 D1 F1 XG1 XA1 XC2 E2 XF2 A2 C3 D3 F3 XG3 XA3 XC4 E4 XF4 A4 C5
30	101001000/234	eight-tone C-2 D-2 F-2 A-2 H-2 D-1 XF-1 XG-1 H-1 BE0 F0 BA0 C1 D1 F1 A1 H1 D2 XF2 XG2 H2 BE3 F3 BA3 C4 D4 F4 A4 H4
31	101000100/243	eight-tone A-3 C-2 D-2 XF-2 A-2 H-2 BE-1 BG-1 BA-1 C0 BE0 F0 A0 C1 D1 XF1 A1 H1 BE2 BG2 BA2 C3 BE3 F3 A3 C4 D4 XF4 A4 H4
32	1010001000/244	six-tone BH-3 D-2 BG-2 BA-2 C-1 E-1 BG-1 BH-1 D0 E0 BA0 C1 D1 XF1 BH1 C2 E2 BA2 BH2 D3 BG3 BA3 C4 E4 XF4 XA4
33	1001000/34	twelve-tone A-3 XC-2 E-2 XG-2 H-2 BE-1 BG-1 BH-1 BD0 F0 BA0 C1 BE1 G1 BH1 D2 F2 A2 C3 E3 G3 H3 D4 XF4 A4
34	1001001000/334	twelve-tone H-3 D-2 XF-2 A-2 C-1 E-1 G-1 BH-1 D0 F0 BA0 C1 XD1 XF1 XA1 XC2 E2 XG2 H2 D3 XF3 A3 C4 E4 G4 BH4
35	10010001000/344	twelve-tone H-3 BE-2 BG-2 BH-2 D-1 F-1 A-1 XC0 E0 BA0 C1 BE1 G1 H1 D2 BG2 BH2 BD3 F3 A3 C4 E4 XG4 H4

Mode definition is based on ascribing 0 or 1 to each tone of the tone system (0 - tone will not be used in the mode, 1 - tone will be used); the first value defining the period of the mode is denoted C1 (or transposed C1) and the other values then correspond to the successive semitones. After the defined period is completed the values are repeated automatically in both up and down directions from the basic period.

Example (Fig. 12.A., Fig. 12.B.) :

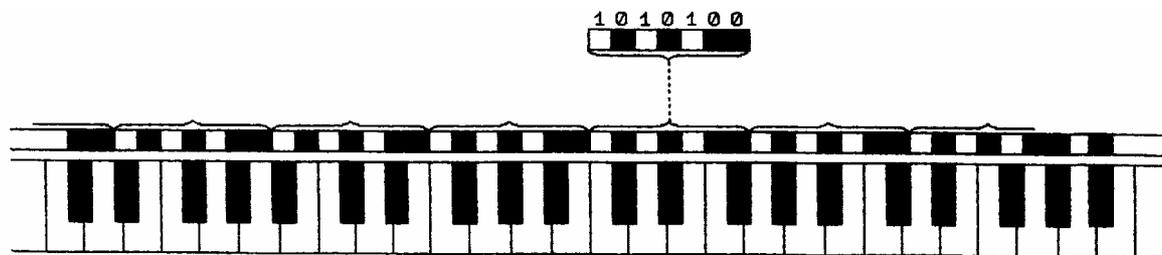
Fig. 12.A.

```

      4           5           6
...012345678901234567890...   - positions
                        28       - parameters
  
```

Fig. 12.B. Graphic presentation of mode 28 with the help of keyboard

*28 : BH-3 | BD-2 BE-2 F-2 | BA-2 BH-2 C-1 | BE-1 F-1 G-1 | BH-1 C0 D0 | F0 G0 A0 | C1 D1 E1 | G1 A1 H1 | D2 E2 XF2 | A2 H2 XC3 | E3 XF3 XG3 | H3 XC4 XD4 | XF4 XG4 XA4 |



4.3.3. DIRECTION OF MELODY - forced melody direction (up or down) based on percentage limitation chosen by the composer; if a next tone in the defined direction exceeds the allowed range, it is not accepted and another suitable tone is generated; the result is that melody runs within the defined part of the range - to realize this intention the first 50 tones of the melody are ignored (this should always be set) - 1 character <53>

Example (Fig. 13.A., Fig. 13.B.) :

Fig. 13.A.

```

      4           5           6
...012345678901234567890...   - positions
                        6       - parameters
  
```

the ratio of rising and falling intervals of the melody is determined by the percentage table 6 (DIRECTION):
 rising intervals - 75%, falling intervals - 25%

Fig. 13.B.

```

random:      0---|---|---|---|---|---|---|---|---|---1
DIRECTION   rising----->falling-->|
  
```

4.3.4. NUMBER OF VOICES - maximum number of voices that are to form a many-part harmony; the lowest part - melody - is generated according to the parameters set by 4.2.1. to 4.2.11., 4.3.1. to 4.3.3. and 4.3.7.; when any of the other harmonic parts exceeds the range defined by 4.3.1. the tone is not realized (if the number of parts is not set to be 2 or more then no polyphony is generated) - 2 characters <54-55>

4.3.5. HARMONY - the character of harmony and tremolos within and outside the limits of the defined mode and range of melody; when a required harmonic or tremolo tone is not found within the defined mode after 1000 attempts have been made, the tone is not realized (this is only set when TREMOLO is required by 4.2.9. or when the number of voices is set do be 2 or more by 4.3.4.) - 1 character <56>

The character of harmony and tremolos is defined with the help of code numbers 1 to 4 :

- 1 generation of tones is controlled by a defined mode and range of melody
- 2 generation of tones is controlled by a defined mode
- 3 generation of tones is controlled by a defined range
- 4 generation of tones is not limited

4.3.6. HARMONIC INTERVALS - pseudorandom percentage tables limit the occurrences of intervals in the many-part structure (this is only set when the number of parts is set to be 2 or more by 4.3.4.) - 2 characters <57-58>

4.3.7. MELODIC INTERVALS - pseudorandom percentage tables limit the occurrences of melodic intervals (this should always be set) - 2 characters <59-60>

Example (Fig. 14.A., Fig. 14.B.) :

Fig. 14.A.

```

      5           6           7
...012345678901234567890...   - positions
      6 3                               - parameters

```

percentage table 6 (HARM.INTERVALS) determines the ratio of intervals in the many-part structure:

interval 3 - 50%, interval 4 - 50%;

percentage table 3 (MEL.INTERVALS) determines the ratio of melodic intervals :

interval 0 - 20%, 1 - 17.1%, 2 - 14.5%, 3 - 12%, 4 - 9.9%, 5 - 7.9%, 6 - 6.15%, 7 - 4.6%, etc.

Fig. 14.B.

```

random:           0---|---|---|---|---|---|---|---|---|---1
HARM. INTERVALS  3----->4----->|
MEL. INTERVALS   0----->1----->2----->3--->4-->5->6>7...

```

4.3.8. TRANSPOSITION - the first value determines the number of semitones by which the mode is to be transposed without changing the melody range; the second value determines instrument transposition resulting in the change in the melody range set by 4.3.1. - 2 times 3 characters <61-63><64-66>

Example (Fig. 15.) :

Fig. 15.

```

      5           6           7
...012345678901234567890...   - positions
      -8 14                       - parameters

```

the setting -8,14 defines mode transposition by minor 6th in the downward direction and instrument transposition by major 9th in the upward direction (for example with the B flat bass clarinet)

4.4. Initialization

Initial parameters for the pseudorandom generator (the first of each pair of numbers should be set, the second number always being 0) should be set separately for tone lengths and tone pitches, the advantage of this is the possibility of generating classical variation sections of the compositions; to achieve even distribution of pseudorandom numbers the first 50 numbers are eliminated.

4.4.1. RHYTHM-RANDOM - initial parameters of pseudorandom data for 4.2.4., 4.2.7 to 4.2.11. (these should always be set) - 4 characters <67-70>

4.4.2. MELODY-RANDOM - initial parameters of pseudorandom data for 4.3.3., 4.3.6., 4.3.7. (these should always be set) - 4 characters <71-74>