REVISED EDITION 1988

by Tamas Ungvary

INTERACTIVE

MUSIC

PERFORMANCE

AND

COMPOSITION

designed and programmed by

MICHAEL HINTON

Acknowledgements

Many thanks to ...

Erik Nyberg, the inventor of real-time control at EMS, who, apart from writing special versions of his direct-play and TV-handler programs (DIP1 and TVEMS) for IMPAC, sacrificed a great deal of time in order to instruct me in the mysterious ways of the PDP-15/XVM;

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Ann, who was patient.

CONTENTS

1 Introducing IMPAC

1.1 Principles

IMPAC is a computer-based system for musical performance and composition. Its design is based on three fundamental principles.

1.1.1 The music is created primarily by direct control over compositional parameters such as pitch and amplitude range, and density; from these the program calculates the actual instrumental activity on frequency generators.

1.1.2 The system is easy to use, requiring no previous knowledge of computers or programming; it can be mastered within a matter of hours. The only requirement is that the user has basic knowledge of the functions and operation of the EMS studio; this includes the computer **peripherals such as DEC-tape units, line-printer, and the Tektronix display terminal. Baisc knowledge of two of the system supplied programs, PIP and EDIT, are also required.**

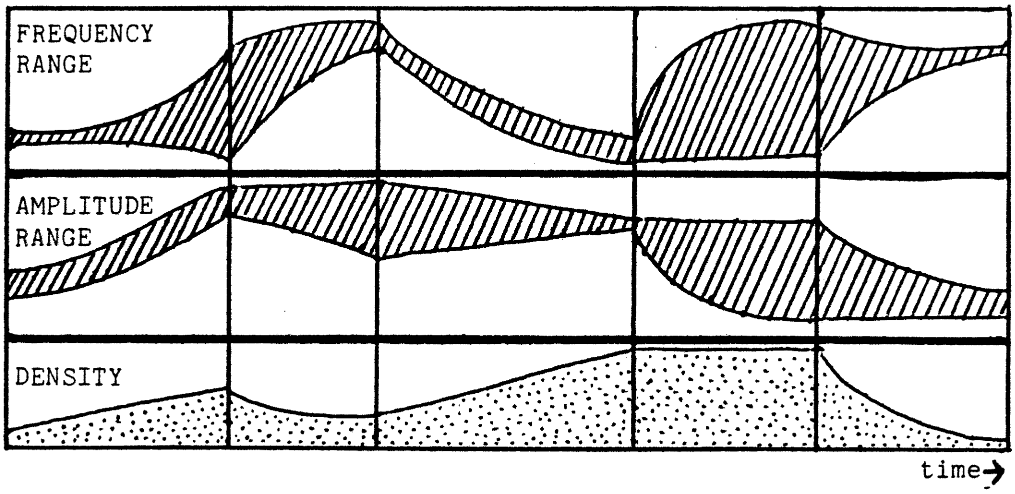
1.1.3 A fast interactive approach is adopted to allow the user to respond immediately to what he hears; this extends to real-time manual control over the compositional parameters.

1.2 Working with the program

IMPAC has two interdependent parts, the composition program and the real-time program. It is possible to work with one of these elements without reference to the other: the user can, for example, choose to work with compositional structures only, exercising no real-time control whatsoever; or he can use the real-time facilities alone, in which case the system functions purely as a musical instrument. But the most powerful feature of the system is that these two methods can be combined: composed structures can be played and modified in real-time.

1.2.1 **In the composition program the user creates compositional BLOCKS (BLOCK TABLES) or complex structures composed of many BLOCKS which has been saved on BLOCK-FILES previously.**

The score for a compositional BLOCK would typically look like this:



Frequency and amplitude are to lie within the limits described by their respective curves; density means "number of notes per second" - so a low value gives a sparse texture with few notes sounding.

Working procedure would typically follow this pattern:

1) Define parameters for one BLOCK.
2) Listen to the BLOCK - it is automatically stored as a file which can be retrieved at any time.
3) Make necessary alterations to any of the parameters. Each time an alteration is made a new file is created and stored. Go back to (2) and repeat until a satisfactory result is achieved.
4) Listen to all of the files so far created as a further check, and note the number of the file(s) to be used in the final composition.
5) Repeat (1) - (4) for all compositional BLOCKS.
6) When all BLOCKS have been thus defined and tested, define the sequence in which the selected files are to be played, together with their start-times if they are to be mixed vertically.
7) Listen to the final result.

For the example on p.1, this whole procedure should not take longer than a few minutes. It is therefore possible to realize and test quite long and complicated structures in one 2-3 hour session with IMPAC. Moreover, BLOCKS and combinations of BLOCKS can be stored on dec-tape for future working sessions with the program.

1.2.2 In the real-time program these parameters, and others which define timbre, vibrato, attack-time, and so on, can be controlled manually with the help of the Joystick, the Digitizer and one of the manuals on the Tektronix terminal, which functions as a twelve-key keyboard. Or they can be controlled by four programmed pseudo-generators, producing random, sinus, triangle and square-wave oscillations; these can, in turn, be controlled manually by the user. So, for example, at the same time the user might be changing frequency limits with the Joystick X and Y axes respectively, amplitude with the sine-wave generator (whose frequency is being controlled by the Tektronix keyboard), attack-time with a combination of random generator and the digitizer´s X-axis, reverberation with the triangular wave generator, and so on.

And finally, it is possible to exercise a more structured control over some of the parameters with BLOCK-definitions made with the composition program, while at the same time controlling other parameters manually.

1.3 System development

IMPAC has been developed, modified and expanded over a period of a few years. At first it was nothing but a primitive version of the composition program, which wrote music information for the twenty-four frequency generators to magnetic tape; the studio facilities allowed for no real-time control, and feedback from composition to composer was unbearably slow. But gradually it was realized at EMS that most composers require a direct contact with their music, and recently several advances have been made in that direction. These include Erik Nyberg´s program DIP1, which allows the computer to control the studio devices at the same time as it calculates music, and, on the hardware side, the installation of a manually controlled Joystick, a Digitizer, and a number of FM generators. IMPAC has all the time been expanded to include the new facilities, and it is expected that it will continue to develop in the future at the same pace as the studio itself.

2 Formalities

2.1 The disks

IMPAC reads information from two disk areas:
1) DK <IMP>, which is a pre-defined area containing all the files belonging to the IMPAC system;
2) A user-defined disk area.

2.1.1 The following files are on DK <IMP>:

```
IMPAC XCT
IMPAC XCU
IMPAC BAT
0     BIN
0     CON
1     CON
2     CON
3     CON
4     CON
```

IMPAC XCT and IMPAC XCU are the EXECUTE files which contain the IMPAC system.

IMPAC BAT is a BATCH file which performs some necessary operations at the beginning of a run.

0 BIN is an OBJECT or BLOCK file, containing default values for the music parameters; if the user plays music with IMPAC before he has defined any parameters, the musical result is governed by the information in this file. BLOCK files are described in more detail in §§4.2 ff, 0 BIN in §5.1.2.

0 CON - 4 CON are connection files: they contain the information needed to make various device/amplifier connections in the studio. They are described in detail in §2.4.

2.1.2 As with all other programs and systems, the user must define part of the computer´s disk as his own working-area. (Note that "$" is never written by the user - it is written by the computer to show that the system monitor is ready to receive commands.)

```
$LOGIN USE
```

where USE can be any combination of three letters except SCR, EMS, or IMP.

N.B.

All user information files created during a run will be on DK <USE> when the run is complete.

If the user has files created on previous runs which are to be used during the current run, he must ensure that they are on the defined working-area, not DK <IMP>.

2.2 Starting the program

To start IMPAC
a) write on the decwriter (TT) after the monitor´s $-sign:

```
B DK <IMP> IMPAC
```

b) turn on the main studio switch and the Tektronix.

2.2.1 When the command in (a) above is written, the computer reads in a series of instructions from the BATCH file "IMPAC BAT" on DK <IMP>. The following text is then printed automatically on TT:

```
$B DK <IMP> IMPAC            your command line which starts a batch-file

XVM/DOS V1A000               written by the computer:

$$JOB
$PIP
PIP XVM V1A000                                             (1)

>T DK_DK <IMP> 0 BIN

>
XVM/DOS V1A000

$$JOB                                                      (2)
$BUFFS 4

$A DK 14,15,16,17/DK <IMP> -4,1/TW1 4,11,20                (3)

$A NON 2,3,5,6,12,13                                       (4)

$E IMPAC
EXECUTE XVM V1A000
```

(1) PIP is called, in order to transfer the default BLOCK file from DK <IMP> to DK <USE>. Note that if there is already a file called 0 BIN on DK <USE>, it will be destroyed.

(2) The command "BUFFS 4" increases the amount of core available to IMPAC.

(3) Assignments are made here to instruct the system monitor that:
   a) DK <IMP> contains the required EXECUTE files (-4), and the CONNECTION files (1).
   b) DK <USE> will be used for reading and writing all user files (14, 15, 16, and 17).
   c) TW1 (Tektronix) will be used for user commands, interactive data input, error messages, etc. (4, 11) and for printing user files with the WR command (20).

(4) .DAT slots not used by IMPAC are assigned to NON; this is another way of ensuring that IMPAC has sufficient core for buffers and data.

2.2.2 It may occasionally be desirable or necessary to alter the above assignments. In that case the following commands and assignments must be written by the user:

a) If interactive input/output is to take place at the DEC-Writer instead of the Tektronix, TT must be assigned to 4,11 instead of TW1 :

```
$BUFFS 4
$A TT 4,11
$A DK 14,15,16,17/DK <IMP> -4,1/TW1 20
$A NON 2,3,5,6,12,13
$E IMPAC
```

b) If the WR command is to print BLOCK FILES on the LINE-PRINTER instead of the Tektronix (TW1), LP must be assigned to 20 :

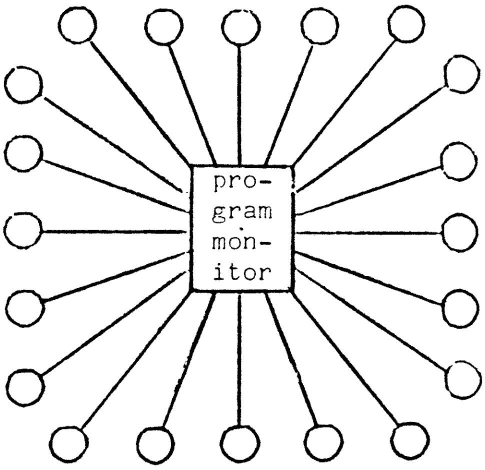
```
$BUFFS 4
$A LP 20
$A DK 14,15,16,17/DK <IMP> -4,1/TW1 4,11
$A NON 2,3,5,6,12,13
$E IMPAC
```

If you run IMPAC on TT (decwriter), the functions of EOT are performed by CTRL D.

If has been stated that interactive input/output takes place on .DAT slots 4 and 11, and that these units can be assigned to either TW1 or TT. Note, however, that the input/output referred to here does not include the functions that can be controlled in real-time; this control can be exercised only from the Tektronix (TW1).

2.2.3 The clock switch on the computer console must be UP (off) all the time during an IMPAC run. If the switch is on, the run will probably be interrupted at unexpected moments by IOPS error messages on the DEC-Writer. A list of IOPS messages and their explanations is obtainable from the System Manager.

2.3 The IMPAC program monitor



This is the part of the IMPAC system that reads user commands, checking their validity and issuing error messages when required; when a legal command is given, this monitor invokes the appropriate subprogram which is to carry out the command.

2.3.1 Input commands are written in one of the following formats:

1) >XX

2) >XX n1

3) >XX n1 n2

where:
>	is printed by the computer to show that the program is ready to receive a command;
XX	is a mnemonic consisting of two letters, or one letter and a number (e.g. F1, A2), or one letter only.
n1 and n2 are numbers defining the command more closely.

Examples of the three types:

1) >EX "Exit" from IMPAC; this is the instruction written at the end of a run.

2) >WF 4 frequency generators are to have wave-form 4 (sawtooth).

3) >FG 1 12 music is to be played by generators 1 to 12 inclusive.

Commands are closed with carriage return (**CR**).

N.B.

- If no value is given to n1, it is assumed to have the value 0. Thus:
  >WF
  and:
  >WF 0
  are from the program's point of view identical.
  The command
  >FG
  is therefore illegal, since no generator has the number 0.

- The only characters that may appear in n1 and n2 are: 0123456789-; if any characters other than these are written, the number is put to zero.
  Thus:
  >FG X
  is interpreted as:
  >FG 0
  which is illegal. However:
  >WF X
  is interpreted as
  >WF 0
  which is allowed. There is therefore no error message.

2.3.2 In some cases, a command to the program monitor is answered with

:

instead of

>

This indicates that a SUBMONITOR has temporary control; each submonitor has its own set of instructions and formats, and will keep control until the command "return to program monitor" is given. "ED", for instance, which is used to edit compositional blocks, has fifteen instructions, some of them similar to the program monitor commands - e.g. A2, which alters definitions of the A2 curve - while others are used only in ED; "AB", for example, means "abort", and is used to cancel any alterations made, i.e. to retain the original block definitions.

>ED 10	**Edit block-file number 10**
:A2 -8	**A2 "curve" is to be 2 dB (-8 * 0.25 dB) less then it was originally**
: (CR.)	**Empty line terminated with carriage return means " complete editing and return to the program monitor ".**
>	**Program monitor has control, i.e. waits for your command**

The mnemonics and instruction formats for each submonitor are described in the relevant sections of chapter 4.

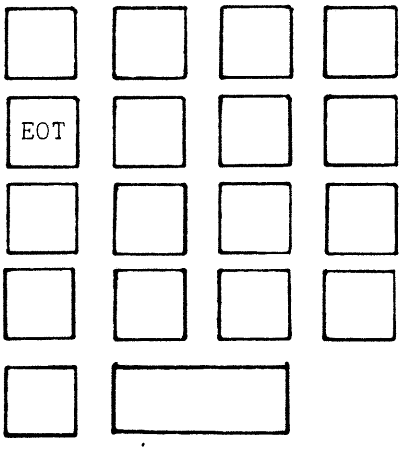
2.3.3 The function key EOT on the Tektronix has a number of special uses; it always:

1) cancels everything that has been written in the current line;

2) clears the screen;

3) moves the cursor to the top left hand corner of the screen.

If conversation takes place on TT instead of TW1, the place of this function is taken by **CTRL D** in this case only (1) above is performed.



When the submonitors have control, EOT has various uses in addition to the three already mentioned. In "ED", for example, it performs the same function as AB (see above); after the "SC" command (scale definition) it signals "end of definition and return to program monitor".

Explanations of the special uses of EOT are given in the individual descriptions of commands in chapter 4.

2.3.4 Comments can be written on any line that begins with the program-monitor´s >-sign.

1) If an instruction is written first in the line, the comment must be preceded by at least one space. For example:

```
>FG 1 40 USE ALL GENERATORS
```

2) If no instruction is written, the comment must be preceded by at least two spaces.

```
>  THIS IS A COMMENT
```

Note that the program ignores comments completely.

2.3.5 The command "PL" (PLAY, cf §4. 4) hands over control to the real-time submonitor. Here the keys on the Tektronix have completely different functions from the characters normally associated with them; consequently, when a key is pressed, the character is not echoed on the screen. Instructions are given by pressing sequences of one, two or three keys. Return to program monitor is achieved by pressing the SPACE key.

The real-time program and its command set are discussed in detail in chapter 5.

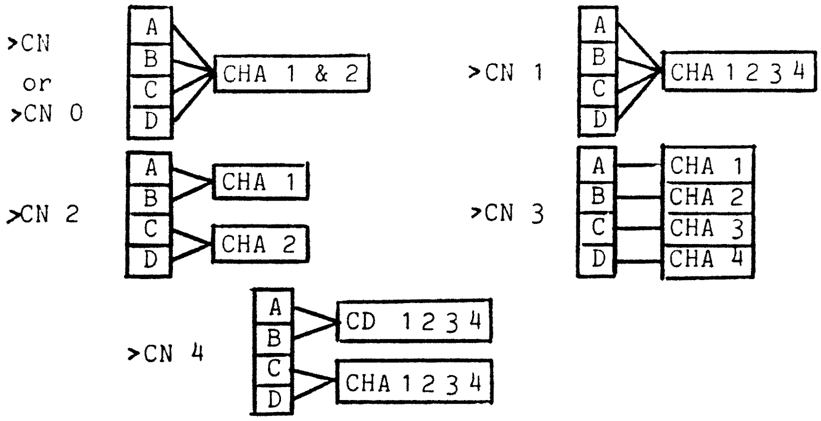
2.4 Studio connections

The command "CN" makes connections in the studio.

2.4.1 The forty generators can be thought of as being divided into four groups:

A: FGs 1 to 6 and FM oscillators 25 to 28.
B: FGs 7 to 12 and FM oscillators 29 to 32.
C: FGs 13 to 18 and FM oscillators 33 to 36.
D: FGs 19 to 24 and FM oscillators 37 to 40.

"CN" can be used to connect these groups of generators as follows:



Here CHA stands for "channel output amplifier", and CD stands for "channel distributor".

Note that connections to appropriate reverberation units are made at the same time as the channel output connections; intensities of 100 dB are also set on the channel output amplifiers.

2.4.2 Information about the different ways of connecting generators to studio outputs is contained in the CON files on DK <IMP>; the number written after the command "CN" refers to the numbers (0-4) of these files.

It is possible for the user who can write FORTRAN programs to create his own connection files. These are given names of type "n CON", where n is a whole number in the range 5 to 99999; and they can be called with the "CN" command in exactly the same manner as the standard connection files.

The techniques used in creating "CON" files are described in §6. 3

2.4.3 Intensities and decay times can be set on the reverberation units with the command "RV". Format:

```
>RV n1 n2
```

where n1 is the decay time, from 0 to 15;
n2 is the intensity, from 0 to 400 (1 unit = $\frac{1}{4}$ dB).

These values are set immediately on all four reverberation units.

2.4.4 All connections and amplifier intensities, as well as generator frequencies and amplitudes, are cleared with the command:

```
>CL
```

To change connections which have been set before, write:

```
>CL

>CN n
```

where n is the number of the new connection file to be read in.

The studio can also be cleared manually with the "nollställ" button; similarly, connections and amplifier intensities can be set in the studio by hand.

3 The Music Parameters

Music parameters in IMPAC are of three main types: primary, note-defining, and spacial.

3.1 Primary parameters are those which define frequency range, amplitude range, and density.

3.1.1 DENSITY - DE - represents the statistical probability of a given number of new notes being started per second. Thus, if DE = 1, a new note will be started roughly once every second; if DE = 100, there will be about a hundred new notes every second. However, these notes will not start at regular time intervals, since density is by definition a random process.

Legal values for DE: 0 to 2000

N.B. 1) A density of zero (DE = 0) means that no new notes are started; however, notes started before density is set to zero continue sounding for their full duration.

2) It is unlikely that a density as high as 2000 can ever be achieved when music is played directly in the studio; the time required for calculating the music will in practice always restrict the density to about 700 or 800 notes per second.

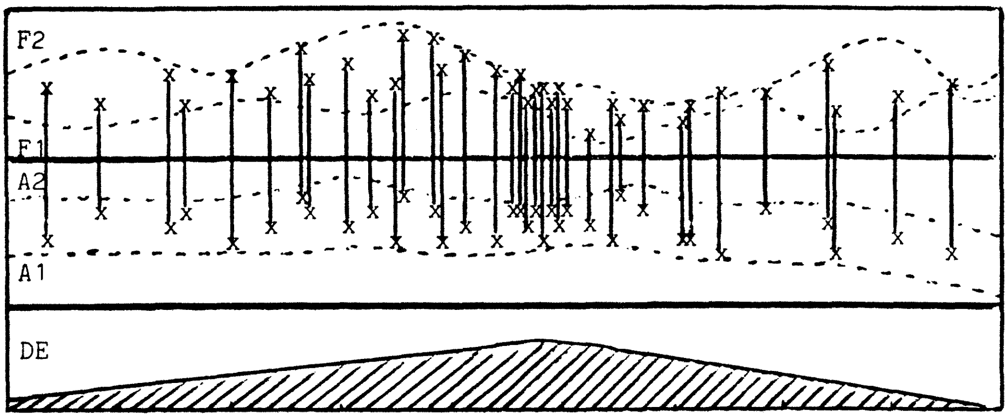
3.1.2 FREQUENCY RANGE is defined by two values, F1 and F2, which determine the limits within which frequencies are to be chosen. Exact choice of pitch is made by a random number generator, but the user can determine the random distribution - rectangular or exponential - and the type of interval relationships (scales) to be used.

Legal values for F1 and F2: 0 to 15999 Hz

3.1.3 AMPLITUDE RANGE is defined by A1 and A2; amplitudes on individual notes are chosen by the random number generator between these two limits.

Legal values for A1 and A2: 0 to 400, where each unit is equivalent to $\frac{1}{4}$dB. Thus 100 = 25dB, 400 = 100dB, and so on.

3.1.4 The main structural principle of IMPAC is thus that timing of notes is controlled by DE on a probability basis; pitch and intensity are set at random between limits defined by the user.



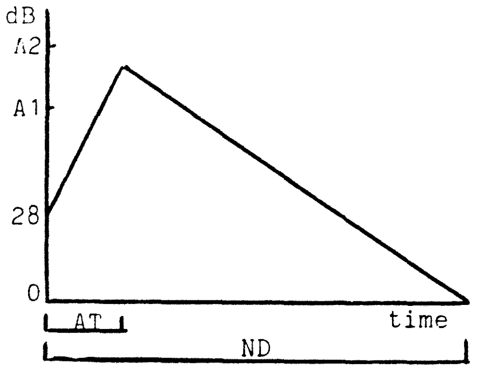
3.2 Note-defining parameters

Once DE, F1, F2, A1 and A2 have determined that a note is to start at a particular time and with a given pitch and intensity, the character of the note is formed by the note-defining parameters.

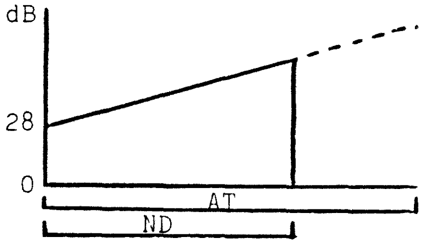
3.2.1 NOTE-DURATION (ND) defines the length in milliseconds of each note.

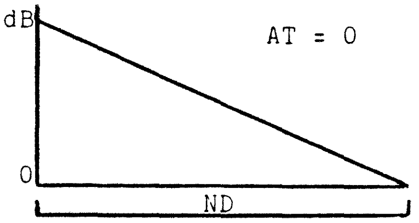
Legal values: 10 to 131000 ms.

3.2.2 ATTACK TIME (AT) is an amplitude envelope factor; it defines the time in milliseconds that it takes for a note to reach its maximum amplitude, which is the value chosen at random between A1 and A2.



N.B.
1) If AT is longer than ND, the note will stop before it reaches maximum intensity. And if AT is zero, the note will start at maximum amplitude.





2) The amplitude at the beginning of a note is 28dB unless:
   a) the generator in question already has an amplitude greater than 28dB; in this case the start amplitude will be 4dB less than the generator´s current amplitude.
   b) AT is zero (see point (1) above).

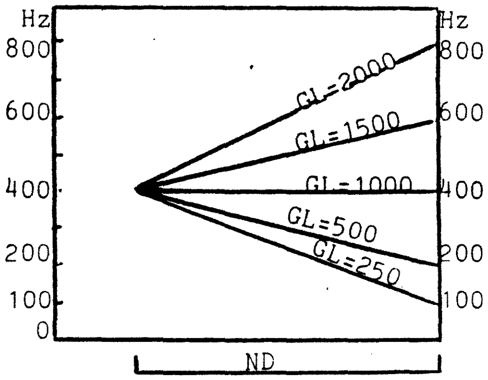
3) Envelopes are calculated on a linear basis. Amplitude decay is such that it reaches zero at the end of ND; this means that a note may become inaudible before it has sounded for its full duration.

Legal values for AT: 0 to 131000 milliseconds.

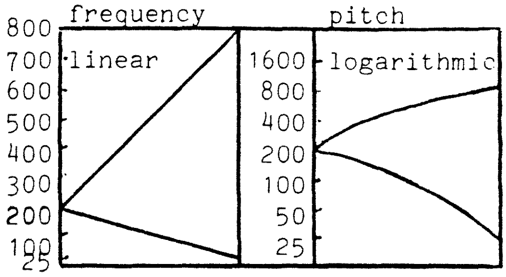
3.2.3 GLISSANDO (GL) defines the relationship between the frequencies at the beginning and end of a note. Values are given "per mille", in such a way that:

1000 = no glissando
2000 = glissando up one octave (start freq. x 2.0)
8000 = gliss. up three octaves (start freq. x 8.0)
500 = gliss. down one octave (start freq. x 0.5)
250 = gliss. down two octaves (start freq. x 0.25)

Legal values for GL: 0 to 8192.

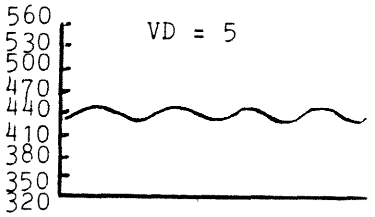


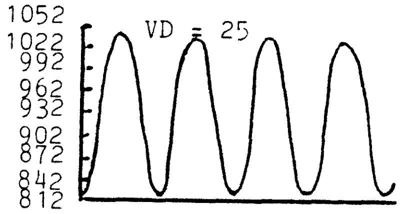
N.B.
GL is calculated on a linear basis, which means that rising glissando seems to move faster at the beginning of the note, while descending glissando is faster at the end of the note.



3.2.4 VIBRATO is defined by VD and VS (vibrato depth and vibrato speed).
1) Values for VD are given in percent, such that the difference between the vibrato's highest and lowest points is "VD"-percent of each note's basic frequency. For example:

- If VD = 5 and a note's frequency is 440, then the depth (amplitude) of the vibrato will be: 5/100 x 440, that is, 22 Hz. Vibrato will therefore be between 429 Hz and 451 Hz, 11 Hz on each side of the basic frequency.
- If VD = 25 and frequency is 932, then vibrato depth will be 25/100x932 (= 233 Hz). Vibrato will be between 815.5 Hz and 1048.5 Hz.

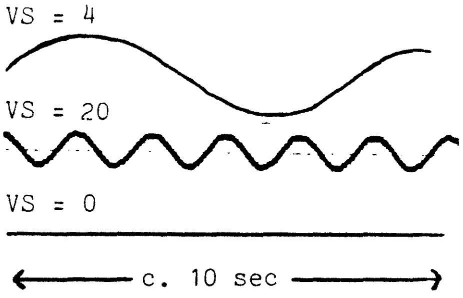




Legal values for VD: 0 to 1000.

2) Vibrato is calculated by looking up values in the SINE-WAVE table (cf §6.5). VS determines the speed at which a pointer is to go through this table; thus

- if VS = 4, this pointer is moved in turn to every fourth value;
- if VS = 100, every hundredth value is taken;
- if VS = 0, the pointer, and thus vibrato too, come to a halt.



Legal values for VS: 0 to 2880.
(see also 5.6.1)

3.2.5 TIMBRE is defined by:
1) WF for analogue frequency generators;
2) MI and MF for digital frequency-modulating generators.

WF stands for WAVE-FORM; the values which can be set on the frequency generators are:

0 & 1	sinus	2	parabolic
3	triangular	4	saw-tooth
5	square	6	single pulse
7	double pulse		

WF has no effect on the FM oscillators.
Legal values: 0 to 7.

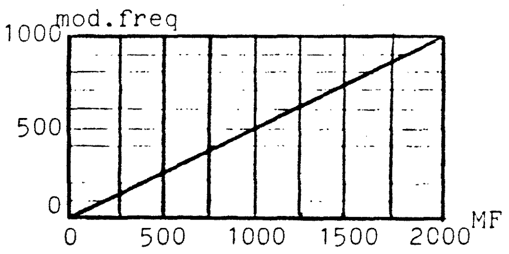
MI and MF stand for modulation index and modulation frequency.

The user defines MI as modulation-index x 100 (e.g. to get an index of 1.5, the user gives MI the value 150.

MF represents, not the actual modulation frequency, but the ratio between carrier and modulation frequencies. Values are assigned "per mille"; for example:

1000: mod freq = carrier freq
2000: mod freq = car freq x 2
500 : mod freq = 0.5 x car freq
100 : mod freq = 0.1 x car freq

Legal values for MI: 0 to 4095
Legal values for MF: 0 to 2000



carrier freq at 500 Hz

3.3 The spacial, or room-defining parameters are moving-sound and reverberation.

3.3.1 The "moving-sound" is controlled in real-time only, by the parameters SX and SY. They control the amplitude of the sound on the 4 output channels.

For stereo paning on channels 1 & 2 set SY=1000, connect SX to e.g. the joystick and alter the values of SX.

If you set SY=0, by altering SX you will be able to pan between channel 3 & 4.

3.3.2 REVERBERATION (RV) also has various functions:

1) By giving the command RV from the program monitor, the user can set both times and levels on the reverberation units. See §2.4.3.

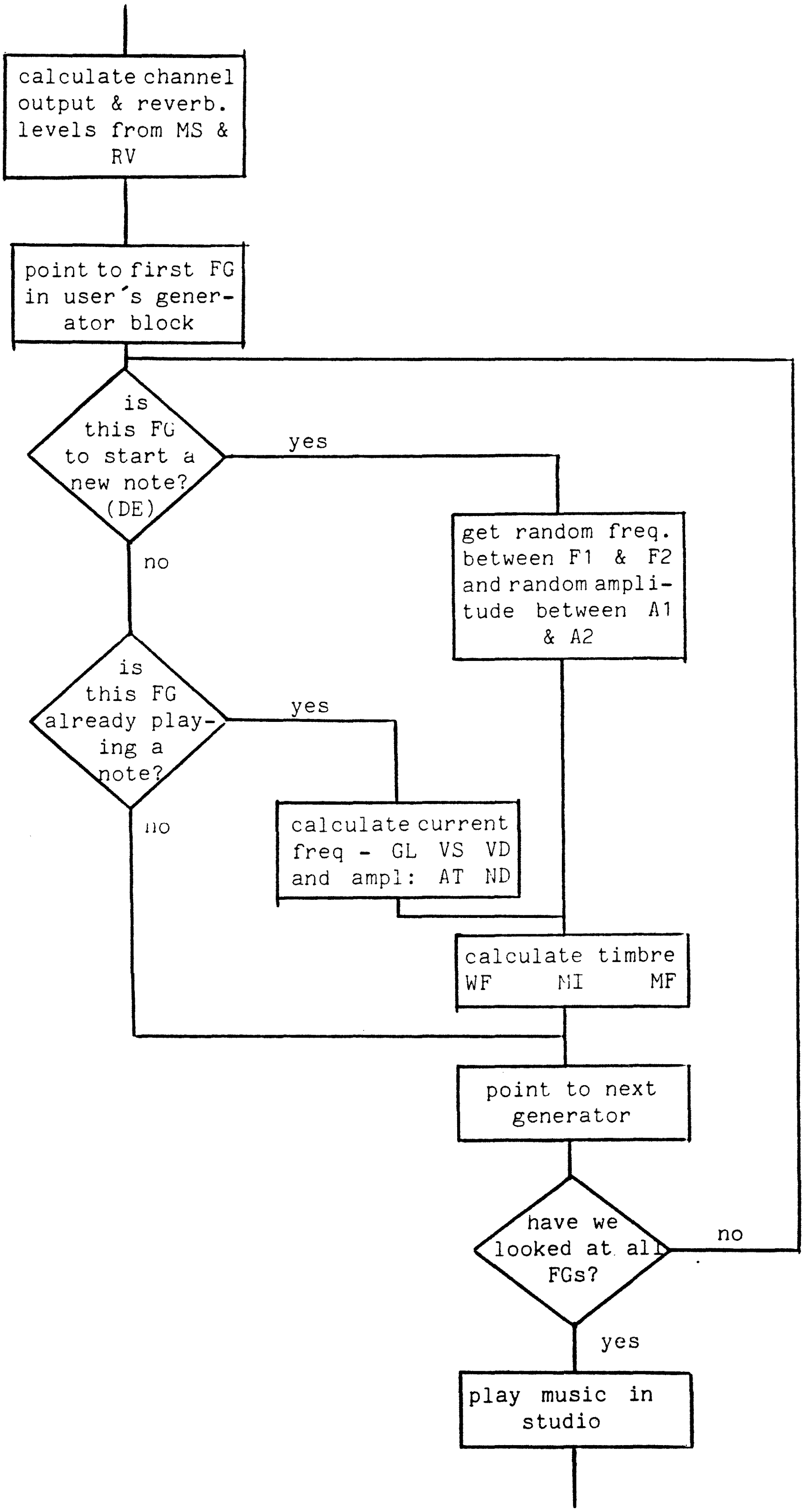
2) In the real-time program RV controls reverberation levels only. Legal values: 0 to 400, where each unit is equivalent to $\frac{1}{4}$ dB - 100 = 25 dB, 400 = 100 dB, etc.

3) It is also possible to set reverberation levels with connection files - see §2.4. 1.

3.4 Miscellaneous parameters

There are a number of other parameters which do not easily fit into the above categories.

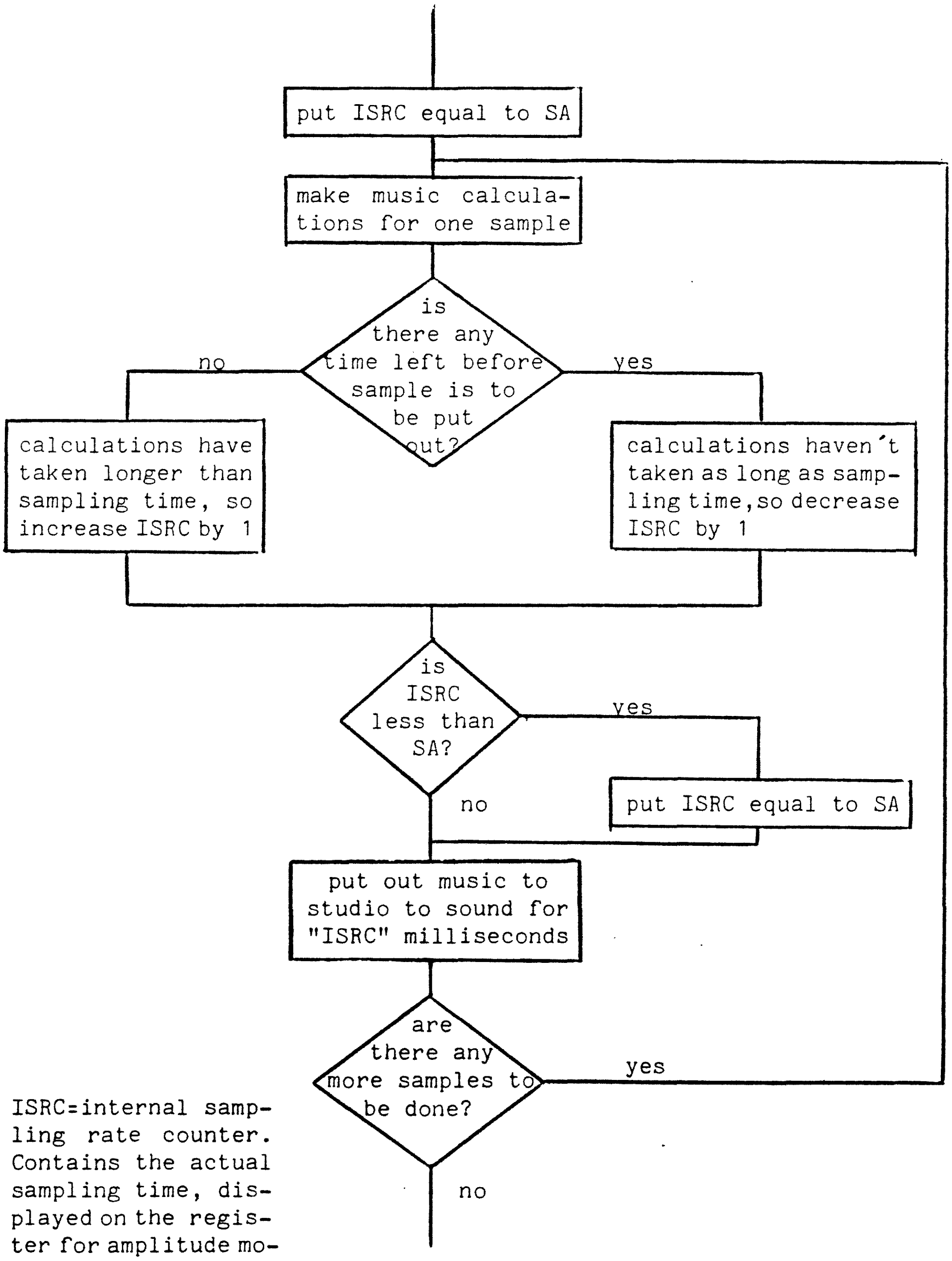
3.4.1 FG (FREQUENCY GENERATORS) defines the number and type of generators to be used: the analogue frequency generators are numbered 1 to 24, while the digital FM oscillators are numbered 25 to 40. Normally the user defines a block of generators, e.g. 1 - 12, or 7 - 10, or 25 - 36, or 20 - 30. The last example means that frequency generators 20 - 24 and the first six FM generators will be used. Allocation of individual notes to generators is then automatic and random, depending entirely on the current value of DE (density). The program does not look for free generators; notes can therefore be interrupted before they have sounded for their full duration.


calculate channel output & reverb. levels from MS & RV
point to first FG in user's generator block
is this FG to start a new note? (DE)
yes
no
get random freq. between F1 & F2 and random amplitude between A1 & A2
is this FG already playing a note?
yes
no
calculate current freq - GL VS VD and ampl: AT ND
calculate timbre WF MI MF
point to next generator
have we looked at all FGs?
no
yes
play music in studio

Flow-chart showing music calculations for one sample, using primary, note-defining, and spacial parameters.

3.4.2 SA (SAMPLING) determines the rate in milliseconds at which music information is output to the studio; e.g. if SA = 10, new information is sent to the studio every ten milliseconds. However, if calculations take longer than the time defined by SA, then SA is ignored; in other words, SA defines only the minimum sampling rate.

The program maintains an internal sampling rate counter, independent of SA; when the necessary calculations for a sample have been made, this counter is adjusted to take into account the actual time it took to calculate the sample. The logic of this is illustrated in the following flow-chart.


put ISRC equal to SA
make music calculations for one sample
is there any time left before sample is to be put out?
no
yes
calculations have taken longer than sampling time, so increase ISRC by 1
calculations haven't taken as long as sampling time, so decrease ISRC by 1
is ISRC less than SA?
yes
no
put ISRC equal to SA
put out music to studio to sound for "ISRC" milliseconds
are there any more samples to be done?
yes
no

ISRC=internal sampling rate counter. Contains the actual sampling time, displayed on the register for amplitude modulator 1.

Legal values for SA: 1 to 65536 milliseconds.

3.4.3 SE (SEGMENTS) and DU (DURATION) are structural parameters used only in the "composition" part of the program. SE defines the number of segments a compositional BLOCK is divided into, while DU defines the duration in milliseconds of each segment. For details of these parameters, see §4.1.1 and §4.1.3.

Legal values for SE: 1 to 50 (i.e. a maximum of 50 segments per block is allowed).

Legal values for DU: 10 to 131000 ms.

3.4.4 DS LF HF LA HA
These parameters are related to DE, F1, F2, A1, and A2 respectively, and are used in the "composition" program only. They define values for the primary parameters <u>at the start of a compositional block.</u> They are described in detail in §4. 2.2.

3.5 The scale patterns

3.4.5 SC (SCALE) defines the scale-patterns (interval relations within one octave) which govern the random choice of frequency between F1 and F2.

IMPAC contains a table of quarter-tones from 12 Hz to 19345 Hz (a little more than $10\frac{1}{2}$ octaves); a scale is defined by signalling which of the 24 $\frac{1}{4}$-tones within an octave are to be allowed; thus a whole-tone scale can be defined by taking every fourth $\frac{1}{4}$-tone: 1 5 9 13 17 21.

The program´s procedure for finding a frequency for a new note is:
1) Calculate a random frequency between F1 and F2.
2) Look in the $\frac{1}{4}$-tone table to find the pitch which lies nearest below this random frequency.
3) See if this particular $\frac{1}{4}$-tone is contained in the current scale-pattern; if it is, then use it. If not, then go upwards through the table until a pitch is found which <u>is</u> allowed.

There are 18 pre-defined scales, each of which can be accessed instantaneously in the real-time program (cf "pitch mode" §5.7.2). These scales are:

1:	1 5 9 11 15 19 23	................major
2:	1 5 7 11 15 17 23	................minor harmonic
3:	1 5 7 11 15 17 21	................minor melodic
4:	1 5 9 15 19	......................pentatonic
5:	1 5 7 11 13 17 19 23	.............alternating $\frac{1}{2}$/whole-tones
6:	1 5 9 13 17 21	...................whole tones
7:	1 4 7 10 13 16 19 22	.............3/4-tones
8:	1 3 5 7 9 11 13 15 17 19 21 23	..semitones (12-tone scale)
9:	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	..quarter-tones

**10-18: single notes (octaves) ; when untransposed : 10 = G , 11 = A, 12 = B^b
13 = B, 14 = C, 15 = D^b, 16 = D, 17 = E^b, 18 = F**

During real-time performance scales can be transposed a given number of quarter tone steps (see 5.7.2) . <u>When they are NOT transposed, position 1 is the note G.</u>

The user can replace any or all of the scales by giving the SC command from the program monitor. Command format:

```
>SC n
```

where n is the number (from 1 to18) of the scale to be defined. The program answers

```
:
```

and waits for the user to define the ¼-tone positions which are included in the scale. This is done by writing not more than 24 numbers from 1 to 24 with one space or one carriage return between each number; after every carriage return the program writes

```
:
```

and waits for further numbers. The user indicates that input is complete by pressing EOT immediately after the program´s ":".

```
>SC 2
:3 7 11 13 17 21 1
:EOT
>SC 3
:2 6 8 12 14 20
:22 24
:EOT
```

Numbers less than 1 or greater than 24 are ignored; i.e. there is no error message. However, if all the numbers are illegal or if no numbers are written, the program writes

```
TRY AGAIN
```

followed by

```
:
```

and waits for the user to redefine the scale.

```
>SC 6
:EOT
TRY AGAIN
:
```

Scales on file

The scale table can be stored on file with the command

```
>PT name 1
```

The scale files stored on disk are automatically given extension SCA and can be accessed by:

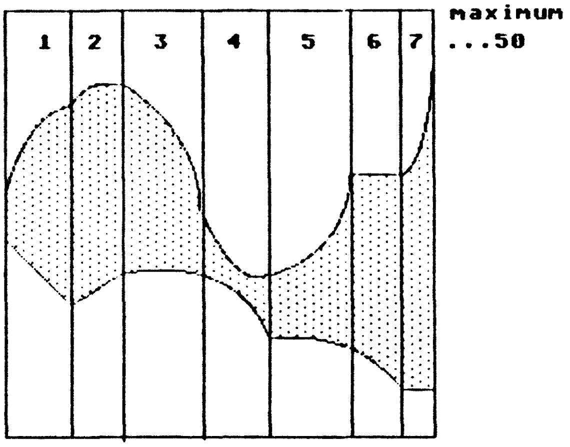
```
>GT name 1
```

4 The Composition Program

In the composition program the user **defines, tests** and **modifies** compositional **Blocks;** these Blocks can be combined with one another horisontally, i.e. appended to each other, while all the time the user has complete control : he can **listen, interrupt,** and **alter** at will.

4.1. BLOCK TABLE defining parameters.

The main structural element in IMPAC is the **compositional BLOCK.** It stored in the memory, i.e. within the so called **BLOCK TABLE.** within which the curse of the **primary** (or dynamic) parameters **(DE, F1, F2, A1 and A2)** may be defined as curves in time, with up to **fifty segments.**



Within a segment a parameter curve can go in one direction only : up, down or staright. To define the curves in the example, seven segments are used. The segemnt deviding lines mark the points at which at least one of the curves changes direction.

A simple compositional Block is defined primary by **redefinition** of the **default** parameter values which are established at the start of IMPAC (0 BIN , i.e. the Block-file-zero also contain them). The redefinition will be called however **definition** throughout of this manual. It may occur in two ways :

a.) definition of a certain parameter in a way which will effect the course of the parameter throughout of the whole Block

b.) change of one (or more) individual values of a choosen segment

NOTE ! The expressions "compositional Block" and "Block Table" are synonyms.

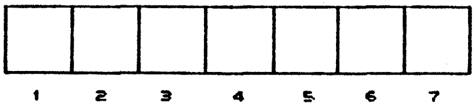
4.1.1. Basic time—frame definition.

The time frame of a compositional BLOCK is defined by the number of segments it will contain and of the durations of those segments.

SE defines the number of segments in a BLOCK. Format : >SE N
where N is a number between 1 and 50 (default: 50)

DU defines the duration of the segments in milliseconds. Format : >DU N
where N is minimum 10ms and maximum 131000ms.
This form of the command assignes the same value
to all of the segments defined previously.

Thus the commands : >SE 7
>DU 1000 define the following Block frame :



segment no.	1	2	3	4	5	6	7
duration	1000	1000	1000	1000	1000	1000	1000

Within a Block curves will be defined, each of them assigned either to the lower or to the upper limit of the "dynamic" parameters, frequency, amplitude or density. (See 1.2.1.) Thus, the composer will be able to control the bandwidth of a "dynamic" parameter at every moment.

Within a segment, a parameter curve can go in **one direction only** : up, down, or straight. It means that the user can change the direction of a curve only when a new segment starts.

4.1.2. Definition of dynamic parameters.

One may assign values, i.e. curves, to the "dynamic" parameters, after the definition of a Block frame. The "dynamic" parameters are :

DU	duration (detailed description in 4.1.3)
DE	density
F1 and F2	lower and upper limit of frequency
A1 and A2	lower and upper limit of amplitude

The assignements may occur in four different ways. The definition or **DE is given below as an example**; the others are defined in exactly the same way.

4.1.2.1. The same value throughout the Block.

To assign one and the same value throughout a Block, write :

›XX N

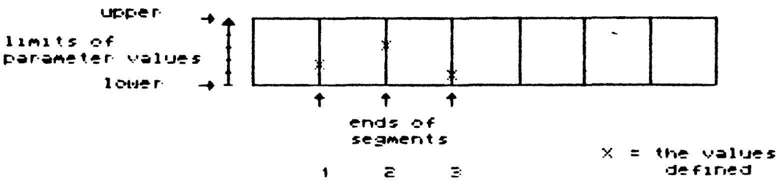
where

XX denotes one of the parameters

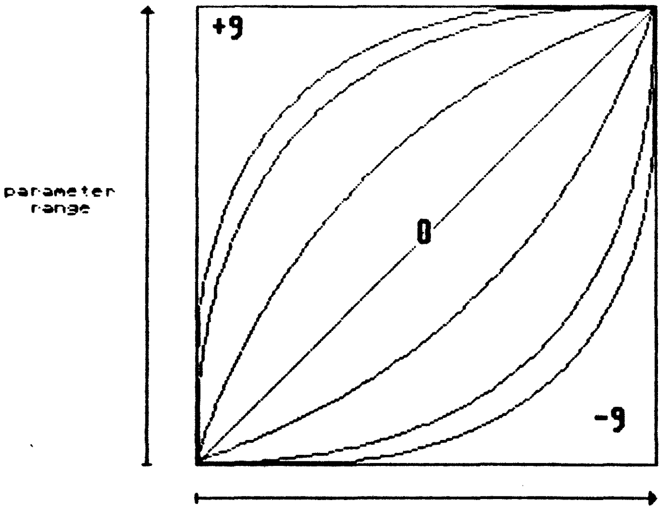
N is a legal value (from 1 to legal maximum).

4.1.2.2. Individual curves for each segment and STARTING PARAMETERS.

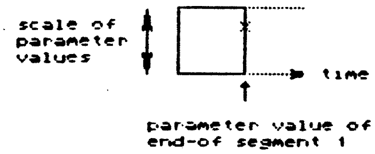
The user may define a specific, individual value to the **end of each segement**



and a value for the **curve shape** parameter which will define the character of interpolation between the **foregoing** value and of the defined end-of-segment-value. There are CONVEX (1 to 9), CONCAVE (-1 to -9) and STRAIGHT (0) shapes.



As an example we will define the desity of the first segment as a curve with a shape of zero. We define first the value of end-of-segment 1 .



The question : which is the foregoing value to compute an interpolation from ? There is obviously non. In order to be able to define the every first foregoing value, so called STARTING PARAMETERS has been established within IMPAC. Each of the dynamic parameters have its corresponding starting parameter. They are :

>DS N	density start	for DE	curve
>LF N	low frequency	for F1	curve
>HF N	high frequency	for F2	curve
>LA N	low amplitude	for A1	curve
>HA N	high amplitude	for A2	curve

In all cases **N** must be a legal value for the parameter concerned. If the user does not explicitely defines the value of a starting parameter, its value will be ZERO. Thus, to be able to define an individual curve for the first segment, we have to define the starting parameter **first** (e.g.: >DS 10).

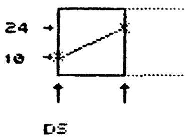
To assign specific, **individual** parameter and curve-shape values in each segment, write :
>XX O

where XX denotes one of the dynamic parameters (DE, F1, F2, A1, A2)
O is the command for the procedure

: the submonitor waits for the user to give **two** values for each segment. These pairs of values are:

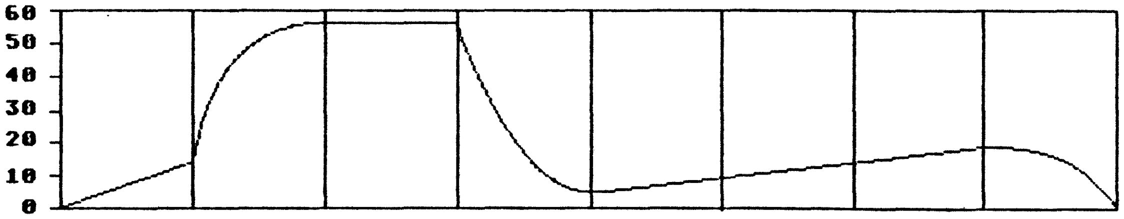
value A : the point reached at the **end** of the segment;
value B : the shape of the curve during the segment (see above).

1. Example :
Supposed, the value at the end of segment 1 is 24, and the defined shape is 0 (straight-line), our curve is as followes.



>DS 10 definition of starting parameter
>DE 0
:24 0

2. Example (full)
Suppose that the following density curve is to be described :



values	15	57	57	5	10	15	20	0
shapes	0	6	0	-5	0	0	0	4

The whole BLOCK is defined as followes :

```
>SE 8
>DU 1000
>DE 0
:15 0 57 6 57 0 5 -5 10 0 15 0 20 0 0 4
>
```

IMPORTANT REMARKS !

Between each number there is either one SPACE **or** carriage RETURN (CR.). If CR. is written before values for ALL segments (the current value of SE) have been defined the program writes

```
                    :                      and waits for further values.
```

To avoid mistakes, it is favorable to write the parameter and curve-shape values in pairs, like :

```
>DE 0
:15 0
:57 6
:57 0    etc.
```

N.B. Two consecutive spaces, to consecutive CR.'s , and one space followed immediately by CR., must never be written within these curve definitions; they will cause values to be assigned to the wrong segments, and may occasionally give rise to error messages.

Input is terminated when either all values for the BLOCK have been written, or the key **EOT** is pressed . If EOT is pressed before all segments have been defines, then the values previously defined for the remaining segments are kept; if no values have been given previously, the defaul values are kept.

When input is terminated, the program checks the values. **FIRST** it looks at the numbers which define the parameter points at the end of the segments ; if one is found to be illegal, a message is written together with the offending value.

```
                                 For example :    ILLEGALVALUE
                                                  123456
                                                  :
```

The user must then give one new value to replace this number; if the new number is illegal or if **EOT** is pressed, the error message is repeated, untill a legal value is given. **AFTER** the values have been checked, the shape values will be inspected. Suppose, that the density curve on the previous example is wrongly defined; conversation with the program might look like this :

```
                    >DE 0
                    :15 -10 57 6 5757 0 -5 -5 10 0 15 0 20 20 0 4
                    ILLEGALVALUE
                      557            maximum legal density is 2000
         parameter  :57              the new value typed in
         values
         checked    ILLEGALVALUE
                      -5             minimum legal density is zero
                    :0               the new value typed in
                    ILLEGALVALUE
                      -10            the lowest legal shape value is -9
         shapes     :0               the new value typed in
         checked
                    ILLEGALVALUE
                      20             the highest legal shape value is 9
                    :0               the new value typed in
                    >         now everything is legal and the program waits for
                              new command
```

MORE ON STARTING PARAMETERS !

Note that if a primary parameter is defined by thwe method **same value throughout the Block**, (e.g. >F1 220), the equivalent starting parameter is automatically given the **same value** (>F1 220 automatically assigns 220 to LF).

4.1.2.3. Random values and periodic functions

Before using periodic/ autamatic functions define first (always) duration of segments. SEE 4.1.3 too.

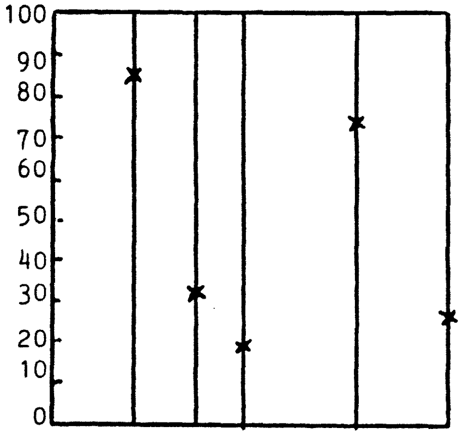
It is also possible to assign values for each segment with random and periodic functions. Format:

```
>DE n
```

where n is a negative whole number from -1 to -6.

-1	random	-2	sinus
-3	triangle	-4	sawtooth
-5	square	-6	curve

-1 RANDOM



random values 10-100

a) The program asks:

```
RANDOM LIMITS:
```

and waits for two numbers, specifying the limits of variation. For example:

```
RANDOM LIMITS:10 100
```

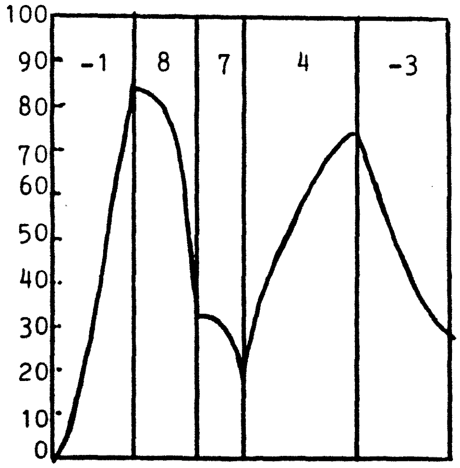
Both numbers must be legal values for the parameter in question; if either or both of them are illegal the program writes:

```
ILLEGAL VALUE
```

and asks again:

```
RANDOM LIMITS:
```

EOT returns control to the program monitor without altering the existing curve definitions.



as above plus random shapes -9 to 9

b) The program then asks:

```
SHAPE LIMITS:
```

and waits for two more numbers, defining the limits of variation for the curve shapes (-9 to 9). Shape values are then chosen at random between these two numbers. For example:

```
SHAPE LIMITS:-9 9
```

allows all possible curve shapes. If either number is illegal, the program writes:

```
ILLEGAL VALUE
```

and asks again:

```
SHAPE LIMITS:
```

EOT returns control to the program monitor without altering the existing shape values.

To define the example in (b), write:

```
(>SE 5)
 >DE -1
 RANDOM LIMITS:10 100
 SHAPE LIMITS:-9 9
```

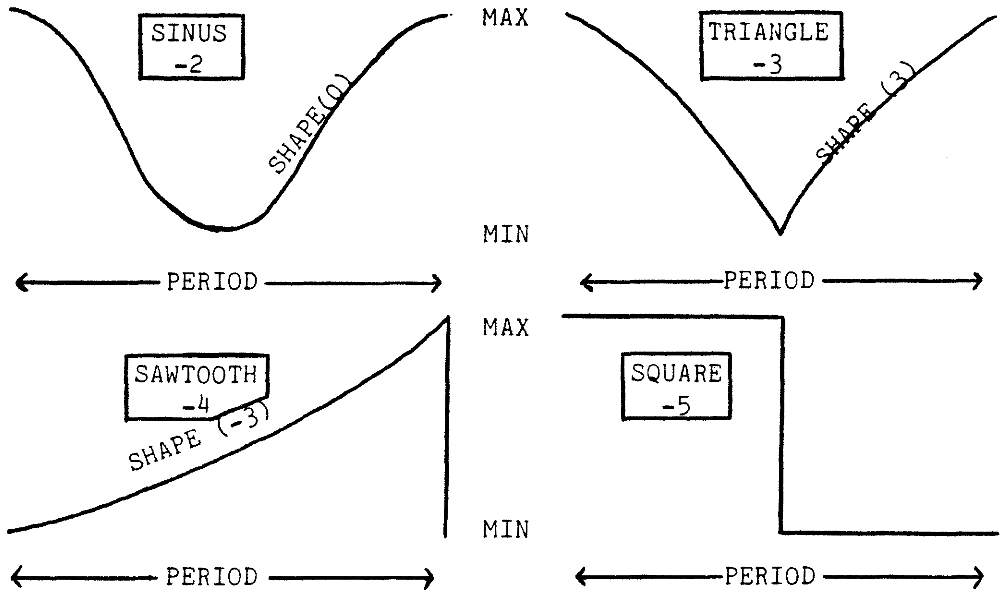
-2 to -5 SINUS TRIANGLE SAWTOOTH SQUARE

If DE is followed by one of the numbers -2, -3, -4, or -5, the program asks:

MIN,MAX,PERIOD,SHAPE:

and waits for four numbers to be written, defining the structure of a periodic oscillation.

MIN and MAX define the lower and upper limits of the oscillation.
PERIOD defines the period length in milliseconds.
SHAPE defines the curve form deviation (-9 to 9); this is not valid for -5 (square).



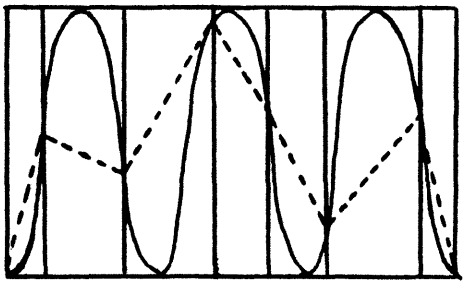
MIN and MAX are checked for illegal values; if either of them is outside the parameter limits, the message:

ILLEGAL VALUE

is written, and the program asks again:

MIN,MAX,PERIOD,SHAPE:

PERIOD should be in the range 10 to 131000 milliseconds, and SHAPE should be in the range -9 to 9. If either of these values lies outside its prescribed range, it will be difficult to predict the structure of the resulting curve.



When these values are defined, the program creates an imaginary oscillation, from which it takes values for the end of each segment. Note that the parameter does not in fact get a smooth oscillation: instead it gets straight lines between the points where the segments and oscillation intersect.

Note also that the durations of each segment must be defined first (see §4.1.3 below). If they are defined afterwards, the values calculated for oscillations are not adjusted, which means that the oscillations become distorted.

EOT returns control to the program monitor.

-6 CURVE

The program asks:

```
          MIN,MAX,PERIOD,SHAPE:
```

and waits for four numbers.

```
          MIN    is the starting point.
          MAX    is the end point.
          PERIOD is the duration in milliseconds of the curve
                 (10 to 131000).
          SHAPE  is the curve-form deviation (-9 to 9).
```

MIN and MAX must be legal values for the parameter being defined. If either of them is illegal, the program writes:

```
          ILLEGAL VALUE
```

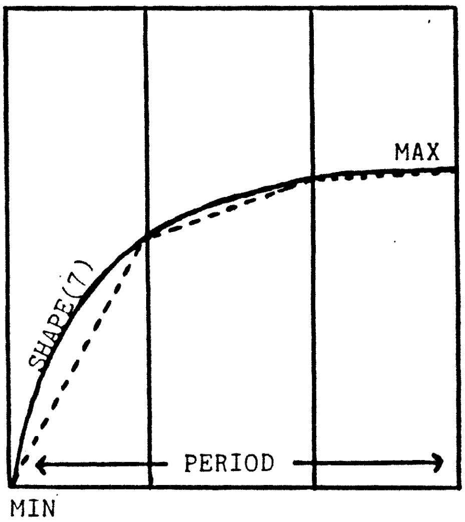
and asks again:

```
          MIN,MAX,PERIOD,SHAPE:
```

EOT returns control to the program monitor without altering the existing curve definition.

If PERIOD is shorter than the total duration of the BLOCK, the value MAX is kept from the point where it is first reached until the end of the BLOCK.

If PERIOD is longer than the BLOCK duration, MAX is never reached.



As with the periodic functions, the program creates an imaginary curve from the data given (including segment durations); values for each segment are then calculated at the curve intersections.

4.1.2.4. Definition by relationship.

The command to define "dynamic" parameters by relationship is :

>P1 P2 N

where

P1 and P2 are parameter names (DU, DE, F1, F2, A1, A2)

N is an integer number

This command means : P1 is to follow P2 with a relationship defined by **N.**

The value of the relationship serves as **multiplication factor** expressed "per mille" (1000=1., 500=0.5) **except** of amplitude, where the value of **N** is an **increment.**

Examples :

a.) >F1 -1
RANDOM LIMITS : 100 800
SHAPELIMITS : -9 9
>F2 F1 2000

F2 will be one octave higher (F1*2000/1000=F1*2) than F1 throughout the BLOCK.

b.) >A2 -2
MIN, MAX, PERIOD, SHAPE :240 330 6000 -1
>A1 A2 -20

A1 will be 20 ampl. units (5dB) lower than A2 throughout the whole BLOCK.

N.B. N is added to the original value if **both** P1 and P2 are amplitude parameters, i.e. A1 or A2 . Otherwise N is taken as a multiplication factor.

Note also that P1 and P2 may be the **same** parameter name. E.g. :

>DU DU 750 Here the existing duration values in the Block Table are multiplied by 0.75

4.1.3 DURATION DETAILED.

DU (duration) the length in milliseconds of each segment. As with the dynamic parameters, there are four methods of giving values to DU :

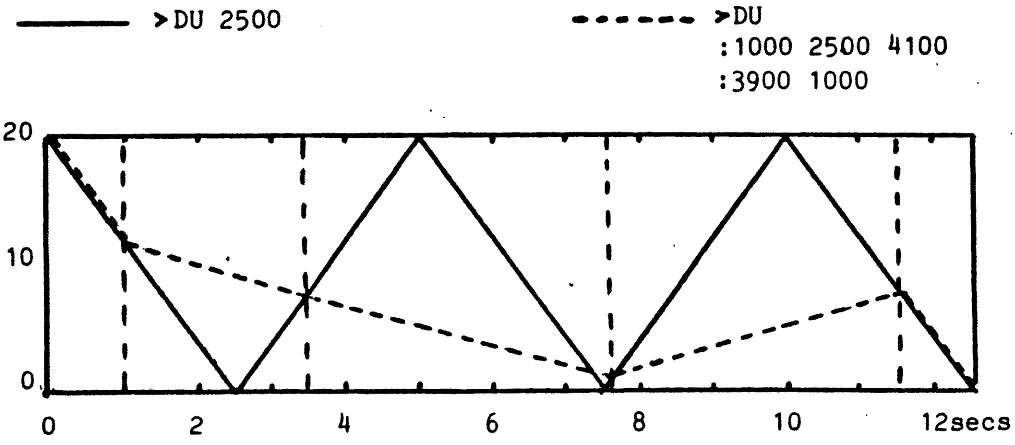
>DU N	>DU	>DU -N	>DU m1000
same value throughout the BLOCK, e.g. >DU 1000 if all segments are to be 1000 ms long	individual values for every segment e.g. : (>SE 5) >DU :1000 500 5200 :750 2500	periodic, i.e. automatic functions: -1 random -2 sinus -3 triangle -4 sawtooth -5 square -6 curve questions and answers as in 4.1.2.3	where n1000 is a multiplication factor "per mille" expressing a relationship see 4.1.2.4

N.B.

1.) Values assigned to Du are always rounded down to the nearest multiple of ten. Thus 1317 becomes 1310, etc. 2.) The current values of DU are always inspected when preiodic/automatic functions are calculated for the dynamic parameters; it is therefor **essential** that <u>DU be **defined before** such functions are used</u>. Suppos, for example, that density is defined as followes :

```
>DE -3
MIN,MAX,PERIOD,SHAPE:0 20 5000 0
>DS 20

>
```

The shape of the resultant curve will depend on the current values of DU.



4.1.4. STATIC PARAMETERS and the Command SP.

All of the rest of the definable parameters are callled "static" . It means that they can only be controlled by single values. However, depending on wheather these values control a parameter

- during the whole compositional BLOCK, or
- during one segment only,

they may be gathered into two groups.

4.1.4.1 GROUP1

The value assigned to a parameters belonging to this group will be constant throughout the whole compositional BLOCK (Note ! It does not effect real-time control.) These are :

SS	starting scale number (see 3.5)
MI	modulation index (expressed as index*100 ; see 3.2.5)
MF	modulation frequency, i.e. the relation between carrier(s) and modulation frequency (see 3.2.5)

1) Single values can be set on these parameters with the command :

```
>SP  pname  n                         ( SET PARAMETER )
```

where

pname	is the parameter name to be set
n	is the value to be assigned

2) The current values of these parameters can be obtained with :

```
>SP pname
```

where **pname** is the parameter name. The program prints the value, followed by ":", and wait for the user to give a new value. If the old value is to be kept, press EOT For exanple :

```
>SP MS        inspect MS
MS 500        program prints current value
: EOT         keep it
>SP VS        inspect VS
VS 0          program prints current value
:175          type in a new value
>             main program monitor waits for command
```

4.1.4.2 GROUP 2

There are two ways to assign values for the parameters

FG	frequency generators
ND	note duration
GL	glissando
WF	wave forms of analog generators

1) to write the mnemonic followed by a number, indicating that there is to be a constant value throughout the BLOCK. THUS:

```
>ND 1000      note duration is 1000 milliseconds
>GL 2000      glissando goes up one octave
>WF 2         wave-form 2 (parabolic) on all generators
>FG 6 13      use generators 6 to 13 inclusive
```

Note that two numbers are required for FG; if only one is given, only one generator will be used. Thus:

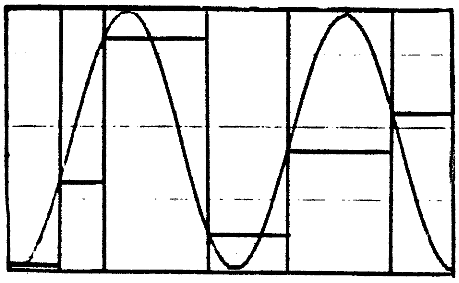
```
>FG 8
```

gives exactly the same result as

```
>FG 8 8
```

If no number is written after the mnemonic, zero is assumed.

2) It is also possible to assign automatic functions to the static parameters. Definition and question / answer formats are the same as those for the dynamic parameters, with the exception that function -1 (random) has <u>no</u> question about "SHAPE LIMITS".

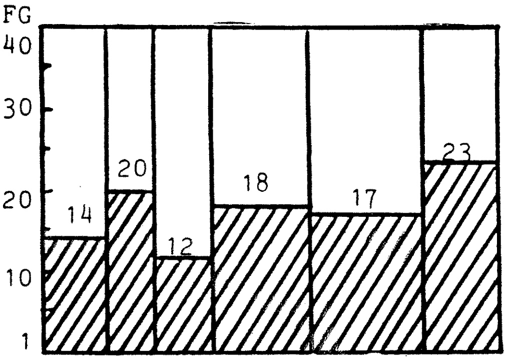


-1	random	-2	sinus
-3	triangle	-4	sawtooth
-5	square	-6	curve

One value is calculated for each segment, and kept throughout the segment.

Note that when FG is defined by an automatic function, the user gives values denoting the total number of generators to be used; thus the sequence

```
>FG -1

RANDOM LIMITS:12 24

>
```



means that a minimum of 12 and a maximum of 24 generators will be in operation; the program chooses generators starting at number one.

N.B.

Automatic functions on static parameters are calculated when the music is played, <u>not</u> at the time of definition; it is therefore <u>not</u> necessary to define DU before these functions are used. (see 4.3 notes)

4.1.4.3. <u>The command SET PARAMETER (>SP)</u>

The command SP can also put values on the Dynamic Parameters DE, F1, F2, A1, A2 besides the Static Parameters. However the user should be warned, since SP has the effect of "freezing" a parameter, so that it is no longer controlled by curves or other values assigned in a BLOCK definition.

This means that <u>whatever</u> file you play next

```
> PL n
  or
> PL
```

the sounds will have <u>the last specified</u> MF and MI values, not the ones which are defined in the file being played, until you <u>unfreeze</u> MF and MI in one of the following ways:

```
1) >AD 0
   :MF
   :MI
   :

2) >AD -1                    unfreeze all parameters
3) in real-time program
   >PL anything              to start
```

shift—MI + shift—MF

and leave real-time program: SPACE

4.1.5 SUMMARY of the composition-program parameters and a complete example :

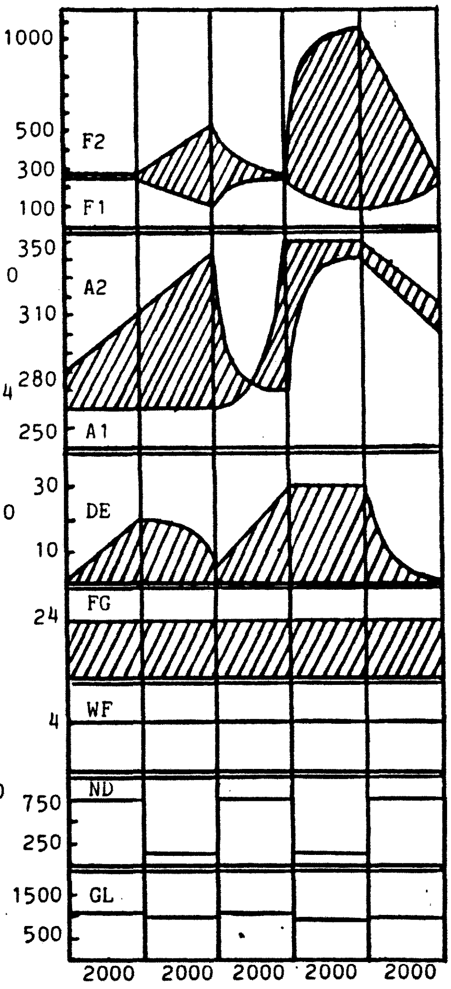
Structural :	SE	DU			
Dynamic :	DE	F1	F2	A1	A2
Curve starting:	DS	LF	HF	LA	HA
Static Group 1 :	MI	MF	SS		
Group 2:	FG	ND	GL	WF	

These parameters constitue the BLOCK definition, and values assigned to them are associated absolutely with a particular BLOCK ; so they remain unchanged every time a block is changed.

Here is an example of a graphic score for a compositional Block, together with the definitions needed to create the BLOCK, and of the commands to set up the program and of the studio hardware for listening the result.

Supposed you started IMPAC , set up the Studio and the terminal.

```
>SE 5
>DU 2000
>FG 1 24
>WF 4
>GL -1
RANDOM LIMITS:990 1012
>ND -5
MIN,MAX,PERIOD,SHAPE:50 750 4000 0
>LF 247
>F1
:247 0 123 0 247 5 110 -4 220 -4
>HF 262
>F2
:262 0 523 0 262 -4 1046 7 262 0
>LA 260
>A1
:260 0 260 0 350 -5
:350 0 315 0
>HA 280
>A2
:310 0 340 0 270 -7 340 6 300 0
>DS 1
>DE
:20 0 5 7 30 0 30 0 1 -5
>
```



4.1.6 Changing values in the BLOCK TABLE.

The normal way to change values in the Block Table is to redefine the parameters. Remember that all of the definitions described in Chapter 4 , are actually redefinitions. Thus, changing values means to define them again, to redefine them. Thus

```
>WF 2                defines wave-form
>WF 4                gives wave-form a new value
```

The dynamic parameters are redefined in much the same way :

```
>DE -1               define density curve (random)
RANDOM LIMITS :0 25
SHAPE LIMITS :-2 3
>DE -2               redefine curve (sinus)
MIN,MAX,PERIOD,SHAPE :0 25 15000 -2
> etc.
```

4.1.7 Alter values of individual SEGMENTS only.

Values of individual segments may be altered with the CHANGE SEGMENT (>CS) command. Format :

>CS n

where **n** is the **number of the segment** to be altered. The program then displays the values and shapes of Dynamic Parameters for this segment, waiting after each one for the user to accept or alter the value.

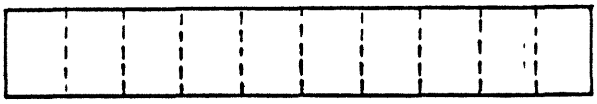
- to keep old values press EOT
- to assign new values, type them after the programs " : "

4.1.8 How to use automatic functions to create complex curves.

1) define max. no. of segments and durations

>SE 10

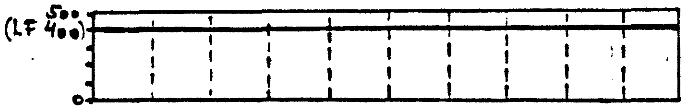
>DU 1000



2) start to fill with curve, first with curve for the last segment.

>F1 400

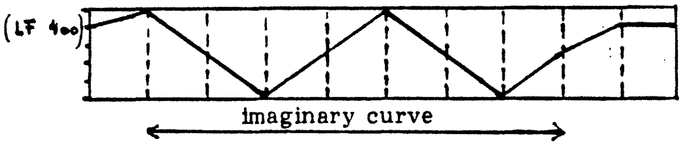
(also sets LF)



3) redefine curve, keeping current value for segments 9 & 10.

>SE 8

>F1 -3



MIN, MAX, PERIOD, SHAPE: 0, 500, 4000, 0

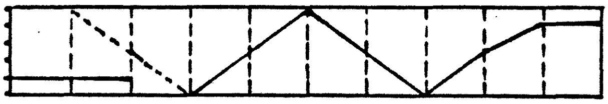
(LF is kept)

4) redefine curve keeping current values for segment 3 - 10.

>SE 2

>F1 100

(also sets LF)



>L

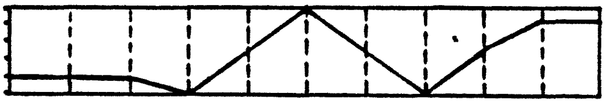
if you list the BLOCK-TABLE you will see only the first two segments, but the values you have already defined are intact in the memory.

5) the final resultant curve is

>SE 10

>L

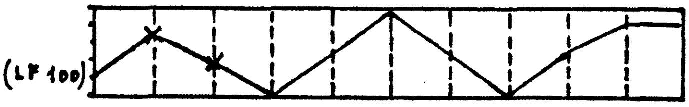
you can see the values of all 10 segments.



6) redefine segment 1 & 2 with random values:

>SE 2

>F1 -1



RANDOM LIMITS: 100, 400

SAMPLE LIMITS: 0,0

NOTE! LF is unchanged: it retains the value assigned in 4) above.

4.2 PARAMETERS wich does NOT belong to the BLOCK TABLE

There are several other parameters which cannot be controlled from within the BLOCK TABLE. Practically it means that they may be set, however the setting cannot be saved to a file for future use. They can be altered in real - time .

VS	vibrato speed (see 3.2.4)
VD	vibrato depth (see 3.2.4)
AT	attack time (see 3.2.2)
SX	4 channel sound distribution X axis
SY	------ " ------ " ------ Y axis
RV	reverberation time (see 3.3.2)
SA	sampling step time

SA , the sampling step time may be freely change without effecting BLOCK structures. It controls the hardware clock of the studio only (see 3.4.2). Format :

```
>SA n
```

where **n** is a whole number from 1 to 65536.

SX and **SY** . Both of them control the positioning of the sound between two loudspeakers (0 - 1000). See also 3.3.1

4.3 Listing of the BLOCK TABLE.

Values assigned to the BLOCK-definig parameters are stored in the BLOCK TABLE; This table can be listed with the command :

```
>L
```

The BLOCK definition in 4.1.5 , for example, would be listed as followes :

```
SE     5
FG   124
SA     5
WF     4
GL    -1
ND    -5
LF   247
HF   262
LA   260
HA   280
DS     1
F1
    247      0    123      0    247      5    110     -4    220     -4
F2
    262      0    523      0    262     -4   1046      7    262      0
A1
    260      0    260      0    350     -5    350      0    315      0
A2
    310      0    340      0    270     -7    340      6    300      0
DE
     20      0      5      7     30      0     30      0      1     -5
DU
   2000   2000   2000   2000   2000
```

Note

1) FG 124

Values for "FG" are defined by the user as

```
>FG n1 n2
```

They are stored in the BLOCK table as one value: (n1 x 100) + n2; "FG 124" in the table means, therefore, "FG 1 24".

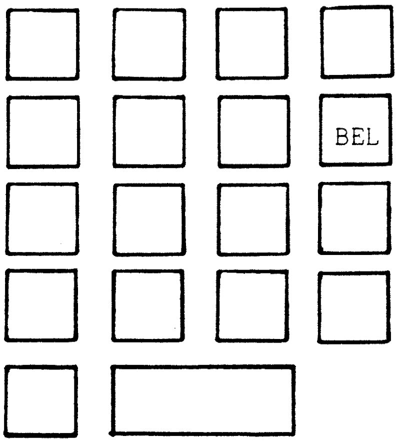
2) SA 5

SA is listed in the BLOCK table even though it is not part of a BLOCK definition.

3) GL -1   ND -5

When static parameters are controlled by automatic functions, only the function number is stored in the table; the values for each segment are calculated when the music is played. However, when dynamic parameters are assigned automatic functions, the segment values are calculated immediately and stored in the BLOCK table; so they can be checked at once with "L".

4) The BLOCK table has room for values for 50 segments; the "L" command lists as many segments as are specified by "SE". Thus if SE = 30, values for 30 segments are listed, and so on. If a BLOCK contains a large number of segments, the values will not all fit on to the Tektronix screen. When the screen is full, the program waits for the user to press the function button BEL; this clears the screen, and allows listing to continue.



The BLOCK table can also be inspected parameter by parameter:

```
>L PARNAM
```

where PARNAM is a parameter name according to the following list:

SE
FG
SA
WF
GL
ND
LF
HF
LA
HA
DS
F1
F2
A1
A2
DE
DU

For example:

```
>L  DE

DE

    20    0    5    7    30    0    30    0    1    -5
```

4.4 Playing a BLOCK (-file)

N.B. — BLOCK will be used as synonym for BLOCK FILE.
— The parantheses [n] indicates here and later that it is an optional part of the command; the parantheses must not be written by the user.

4.4.1 To play a whole block : PL

>PL

When this command is given **a check is made first to see if any values in the BLOCK TABLE have been changed since the last time PL or PP was done.**

— IF changes have been made, then this is assumed to be a **new BLOCK TABLE definition**, and accordingly
- the BLOCK TABLE is **saved on a BLOCK FILE** .
- it automatically receives a number, such that the first file created during the run is called " 1 BIN " , the second " 2 BIN " and so on.
- the program then reads from the newly created BLOCK FILE to play the the music in the studio. - the number of the most recently created BLOCK FILE is displayed at all times on the studio register for the **Noise Generator**.

— If no changes have been made
- the most recently created BLOCK FILE is played ; and **if no file has been created, the default file " 0 BIN " will be palyed.**

>PL n

This command plays a BLOCK FILE number " n ", where "n" is a positive . number from 0 (0 BIN = default file) to 998. If "n" is negative, it is interpreted as beeing undefined and plays the last created Block File.

>PL name

Since IMPAC produces files with the same numbering at each run, it is necessery to rename the numbered files at the end of each run in order to be able to use them during the next run (See 4.4.7). This command plays the renamed BLOCK FILES . " name " is the name of the file withouth extension.

4.4.2 To play part of a BLOCK, write:

```
        >PP[ n]              ( = PLAY PART)
```

where n is a positive whole number indicating a BLOCK-file number.

- If n is undefined, zero or negative, the most recently created BLOCK-file is read from.

The program asks:

```
        SEGMENTS:
```

and waits for the user to give two values stating which segments in the named BLOCK file are to be played. For example:

```
        SEGMENTS:10 20
```

indicates that segments 10 to 20 inclusive are to be played.

- If the file contains fewer than 10 segments, the program writes:

  ```
        SEG     10 NOT FOUND
  ```

  and control is returned to the program monitor.
- If the second number is greater than the total number of segments in the BLOCK, the BLOCK is played to the end; there is no error message.

4.4.3 Playing is completed either when the last segment in the BLOCK has been played, or when the SPACE key is pressed. In the latter case, the program prints:

```
        STOPPED IN SEG     n
```

where n is the number of the segment being played at the time of the interruption; and control reverts to the program monitor.

4.4.4 BLOCK files can also be created (but not played) with the commands F and PF.

1) >F (= FILE)

creates a file from the current values in the BLOCK table; this file is numbered in the normal way (see §4.4.1).

2) >PF[n] (= PART FILE)

creates a new BLOCK file from a section of an already existing one. The program asks:

```
        SEGMENTS:
```

and waits for the user to give two numbers stating which segments in the named file are to be included in the new file.

For example:

```
>PF 5                                create a new file from
                                     part of BLOCK file no.5
SEGMENTS:4 8                         it will consist of seg-
                                     ments 4 to 8 inclusive
17    BIN OK                         program answers that a
                                     new file has been cre-
>                                    ated called "17 BIN".
```

Files created with "PF" are numbered automatically in the same way as all BLOCK files.
- If n is undefined, negative or zero, the most recently created BLOCK-file is read from.

4.4.5 Suppose that the BLOCK definitions in §4.1.5 have been made at the beginning of a run. This BLOCK might then be tested and adjusted in the following way.

```
>CN 2                                make studio connections
                                     first
>PL                                  play the BLOCK - a file
                                     is created: "1 BIN"
>WF 2                                see what it sounds like
                                     with wave-form 2
>PL                                  "2 BIN" is created and
                                     played
STOPPED IN SEG       3               playing is interrupted
                                     with SPACE key
>WF 3                                try it with wave-form 3

>GL 1000                             and without glissando

>PL                                  "3 BIN" is created and
                                     played
>ND 10000                            try it with very long
                                     notes
>DE                                  and with density half
                                     of what it was before
:10 0 2 7 15 0 15 0 1 -5

>PL                                  "4 BIN" is created and
                                     played
>SP 15                               have a look at vibrato
                                     depth (VD)
VD     5                             it's 5%

:12                                  make it 12%

>SP 14 220                           and make vibrato speed
                                     (VS) a bit faster
>PL                                  no change to BLOCK table
                                     so "4 BIN" again
>PL 1                                play "1 BIN" - with new
                                     vibrato
>PF 1                                make a file of segments
                                     4 & 5 from BLOCK no. 1
SEGMENTS:4 5

5     BIN OK                         this file gets name "5
                                     BIN"
>PL                                  new file no.5 is played
```

4.4.6 Normally BLOCK files are numbered automatically in the order in which they are created. The numbering can, however, be controlled with:

```
>FP n1 n2                (= File pointer)
```

where n1 must be ZERO in order to point to a Block File.
n2 is a positive whole number defining the number which is to be given as a file-name to the next BLOCK-file created.

Suppose for example that ten BLOCKS, numbered 1 to 10, are created during a run; in the next run it is desired to keep these ten files on the disk, and to start numbering new BLOCKS from 11 onwards. Write:

```
>FP 0 11
```

See also 4.6.2 and 5.9.2.

4.4.7 Renaming of BLOCK FILES.

Block Files may be renamed

- **from numbered file to a named file where the name constitutes of letters. This must be done outside of IMPAC, from the system monitor of the PDP 15, using the program PIP.**
- **from numbered file to numbered file within IMPAC using the following command :**

```
>RN n1 n2                ( = RENAME)
```

where n1 is the number of an existing BLOCK file;
n2 is a positive whole number, stating the new number that the file is to receive.

1) If file "n1 BIN" is not found on DK <USE>, the program writes:

```
n1 BIN NOT FOUND
```

and control reverts to the program monitor.

2) If n2 is undefined, negative or zero, the program writes:

```
ILLEGAL VALUE
```

and control reverts to the program monitor.

3) If there is already a file on DK <USE> called "n2 BIN", the program writes:

```
FILE ALREADY ON DK. ARE YOU SURE?Y/N
```

The user can answer "Y" or "N".
Y: The existing file "n2 BIN" is deleted, and "n1" becomes "n2".
N (or any character other than Y): Control is returned to the program monitor without the re-numbering taking place.

When the operation is complete, the program writes:

```
n2    BIN OK
```

(see also 5.9.1)

4.4.8 BLOCK files can be inspected with the command:

```
>WR[ n]                  ( = WRITE)
```

where n is the number of the BLOCK file to be listed; if n is undefined, zero or negative, the most recently created BLOCK file is listed. Listing with "WR" is performed on .DAT slot 20 (usually assigned to TW1); if there is too much information in the file to fit on to the screen, the BEL key must be pressed to clear the screen and allow listing to continue.

The format of these files is discussed in detail in §6.9.1.

4.4.9 Summary of BLOCK-file manipulations

Play	PL (PLAY)	PP (PLAY PART)
Create	F (FILE)	PF (PART-FILE)
Name	RN (RENAME)	FP (FILE-POINTER)
List	WR (WRITE)	

4.5 BLOCK FILE EDITING

IMPAC has an internal EDIT facility which can be used to alter parameter values in previously created BLOCK files.

4.5.1 EDIT is a subprogram with its own submonitor and set of commands. To enter EDIT, write:

```
>ED[ n]
```

where n specifies the BLOCK file which is to be edited; if n is undefined, negative or zero, the most recently created BLOCK file is opened for editing.

4.5.2 When the submonitor is ready to receive a command, it prints:

```
:
```

Commands are of two types:
1) parameters: DU DE F1 F2 A1 A2 FG WF GL ND
2) file-manipulation: D G AB $\boxed{\text{EOT}}$ SE

4.5.3 The parameters are changed as follows

1) Multiplication

```
:DU n        (0 ≤ n)
:DE n        (0 ≤ n)
:F1 n        (0 ≤ n ≤ 8192)
:F2 n        (0 ≤ n ≤ 8192)
```

Here n represents a multiplication factor, such that the new value equals the old value times n / 1000.
For example:

```
:DE 2000
```

indicates that density values are to be multiplied by 2000 / 1000 , which means that they are to be doubled.
Similarly:

```
:F1 1059
```

indicates that values for F1 are to be multiplied by 1.059, which has the effect of raising them by a semitone. See also the table on the next page.

2) Addition

```
:A1 n
:A2 n
```

Here n is to be added to the old values in the file. Thus:

```
:A1 16
```

adds 16 to values for A1, i.e. they are increased by 4 dB. Similarly:

```
:A2 -10
```

has the effect of lowering A2 values by 2½ dB.

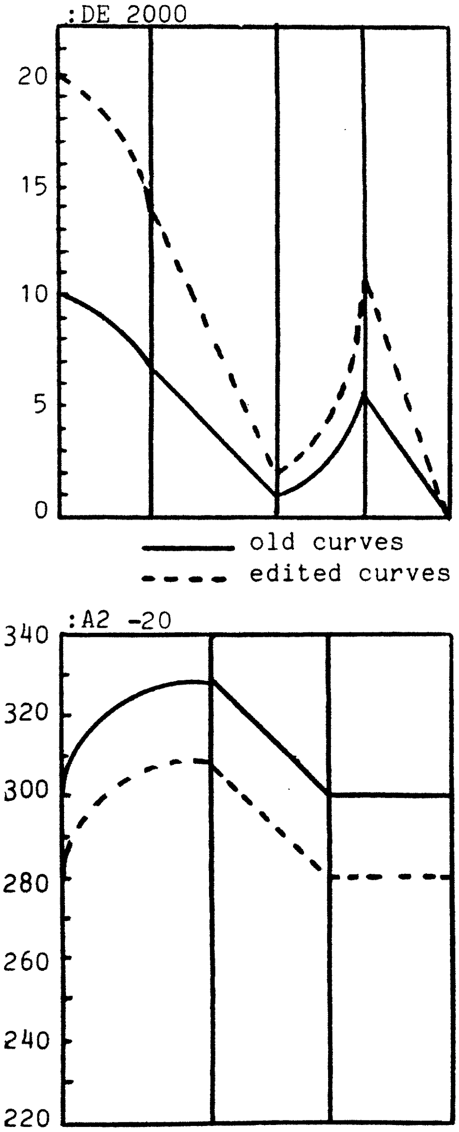


Table of multiplication factors for raising and lowering pitches (unit = 1000)

Interval	Raise	Lower
Unison	1000	1000
Minor second	1059	944
Major second	1122	891
Minor third	1189	841
Major third	1260	794
Perfect fourth	1335	749
Aug. fourth	1414	707
Perfect fifth	1498	667
Minor sixth	1587	630
Major sixth	1682	595
Minor seventh	1782	561
Major seventh	1888	530
Octave	2000	500
Minor 9th	2119	472
Major 9th	2245	445
Minor 10th	2378	420
Major 10th	2520	397
Perfect 11th	2670	375
Augmented 11th	2828	354
Perfect 12th	2997	334
Minor 13th	3175	315
Major 13th	3363	297
Minor 14th	3563	281
Major 14th	3775	265
Two octaves	4000	250

3) <u>New values</u>

```
:FG n1 n2  (1 ≤ n1 ≤ n2 ≤ 40)
:WF n      (0 ≤ n ≤ 7)
:GL n      (0 ≤ n ≤ 8192)
:ND n      (0 ≤ n ≤ 131000)
```

The values given with these parameters are new values which are to replace the old ones. For example:

```
:WF 4
```

means that wave-form no.4 is used instead of the old value.

N.B.

Definitions given with multiplication and addition factors may result in values outside the legal limits being calculated. If this happens, the program automatically puts the parameter to the legal minimum or maximum.

For example, after the command:

```
:F1 2000
```

(raising all values by an octave) frequencies of 8000 Hz or more are edited to 15999 Hz exactly.

4.5.4 When one of the parameter-commands above is given, its value is checked and then stored; the actual editing takes place when an extra carriage return is done immediately after the program´s ":". For example:

```
>ED 2                              edit BLOCK file 2

:DU 500                            halve segment durations

:GL 2000                           put GL to 2000

:                                  carriage return to com-
                                   plete editing
2     BIN OK                       editing done & all well

>
```

In this case all the segments are changed. Note however that no changes are made until the extra carriage return is done; so the sequence:

```
:DU 500

:DU 800
```

is quite legitimate: 800 <u>replaces</u> 500 as multiplication factor.

4.5.5 It is also possible to edit individual segments, by writing:

```
:SE n                ( = SEGMENT)
```

where n is a positive whole number denoting which segment is to be altered. The "SE" command can be given at any time before the extra carriage return is done; thus:

```
>ED 2

:SE 5                                alter segment 5 only

:DU 200

:A1 8

:                                    carriage return to per-
                                     form editing
:                                    program waits for more
                                     commands
```

In this example the first four segments remain unchanged; segment 5 is altered (:DU 200 and :A1 8) and the program waits for more instructions. In other words "SE" followed at some stage by an extra carriage return moves a "pointer" to the named segment, performs editing there, and then leaves the pointer immediately after the named segment.

EDIT always counts segments from the beginning of the file; so the number given in any further "SE" command must be higher than those given previously. Thus:

```
>ED 2

:SE 5                                in segment 5 ...

:DE 4000                             multiply density by 4

:                                    carriage return to per-
                                     form this
:SE 1                                pointer is between seg-
                                     ments 5 and 6: it can't
ILLEGAL VALUE                        go backwards

:SE 6

:ND 50                               50 ms on ND for seg 6

:                                    do it

:DE 500                              density x 0.5 for rest
                                     of file (seg 7 onwards)
:                                    do it

2     BIN OK
```

If the file does not contain as many segments as are defined after "SE", the file is closed and a message is output:

```
SEG   n NOT FOUND
```

4.5.6 Single segments can be <u>deleted</u> with:

```
:D                    ( = DELETE)
```

SE must be defined before "D" can function. For example:

```
>ED 10

:SE 5

:D

:SE 10

:D

:

10    BIN OK
```

<u>original file</u>

1 Axxxxxxxxxxxxxxxxxx
2 Bxxxxxxxxxxxxxxxxxx
3 Cxxxxxxxxxxxxxxxxxx
4 Dxxxxxxxxxxxxxxxxxx
~~5 Exxxxxxxxxxxxxxxxxx~~
6 Fxxxxxxxxxxxxxxxxxx

after :SE 5
:D

<u>edited file</u>

1 Axxxxxxxxxxxxxxxxxx
2 Bxxxxxxxxxxxxxxxxxx
3 Cxxxxxxxxxxxxxxxxxx
4 Dxxxxxxxxxxxxxxxxxx
5 Fxxxxxxxxxxxxxxxxxx

If SE is not defined, the program prints an error message, and the submonitor waits for further commands:

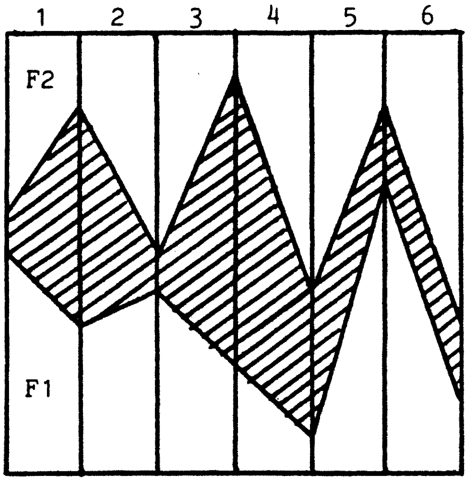
```
'D' ONLY AFTER 'SE'

:
```

After "D" the pointer is positioned between the deleted segment and the next one; note that following segments retain their original numbering until the file is closed.

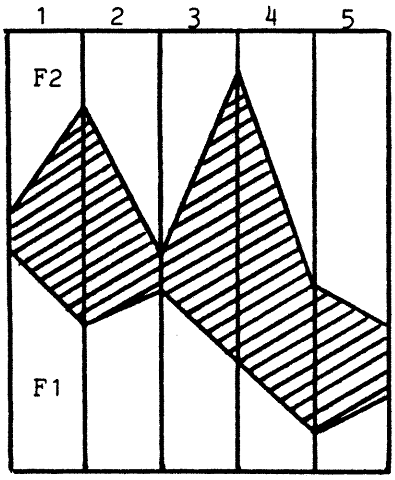
N.B.

For the dynamic parameters, a segment contains information about the final value reached by the curve and the shape of the curve; so when "D" is used the effect is usually a compromise between the deleted segment and the one following it. In the following figure, for example, the diagram on the left represents the frequency curve in an unedited BLOCK-file. The diagram on the right shows what the curve looks like after the EDIT commands:

```
:SE 5

:D
```



original file



edited file

4.5.7 To combine BLOCK FILES

Block Files can be combined with

```
    :G n1 n2
        where  G means GET
               n1   is the number of BLOCK FILE which is to
                    be combined with the currently edited file
               n2   is either any non-zero whole number to indi-
                           cate NO TRANSITION
                        or    zero, indicating SMOOTH TRANSITION
```

alternately

```
    :G name n2
        may be used, where "name" is a  non-numerical file name.
```

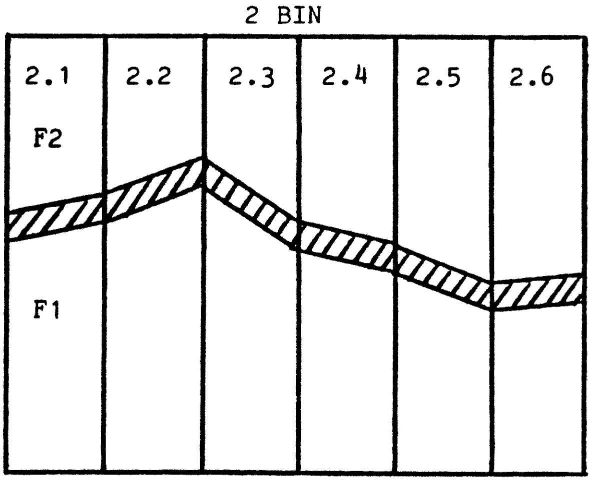
Thus :

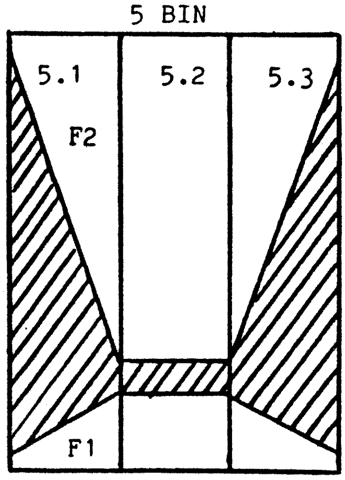
```
        >ED 2       open Block File " 2 BIN " for editing
        :G 5 0      read in " 5 BIN " and compute smooth transition
                    to " 2 BIN ". The pointer is now after last seg-
                    ment of "5" and before first segment of "2".
                    The following changes effect " 2 BIN " only
        :DU 2000
        :GL 8192
        :           CR.  performs editing
        2 BIN OK
        >
```

The file read in with "G" is copied withouth alteration into the place where the pointer is. In the example above, before " 2 BIN " . It is thus possible to place an outside BLOCK FILE anywhere within the currently edited BLOCK FILE. For example :

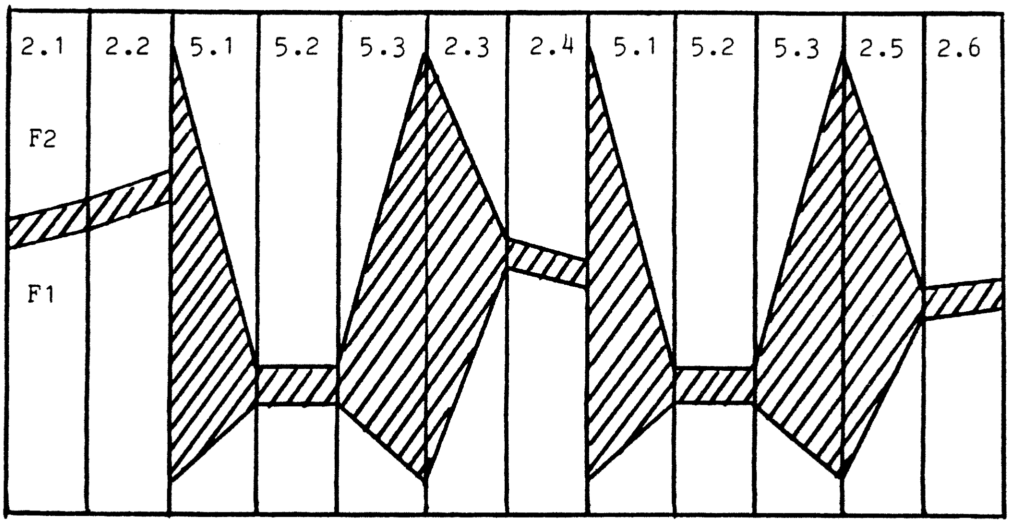
```
        >ED 2       open Block File " 2 BIN " for editing
        :SE 2       pointer should be placed after segment 2
        :          CR.   performs pointer replacement
        :G 5 1       read in " 5 BIN " . No transition.
        :SE 4
        :          CR.   move pointer after segment 4
        :G 5         read in " 5 BIN " again
        : etc
```

Suppose that the frequency curves in the original BLOCKS "2 BIN" and "5 BIN" looked like this:





In the combined file the frequency curves will be as follows:



It will be noticed that segments 2.3 and 2.5, which come immediately after the inserted BLOCK, are adjusted automatically to achieve a smooth transition; however, the first segment of the inserted BLOCK, 5.1, is <u>not</u> normally adjusted.

A smooth transition can be obtained here with

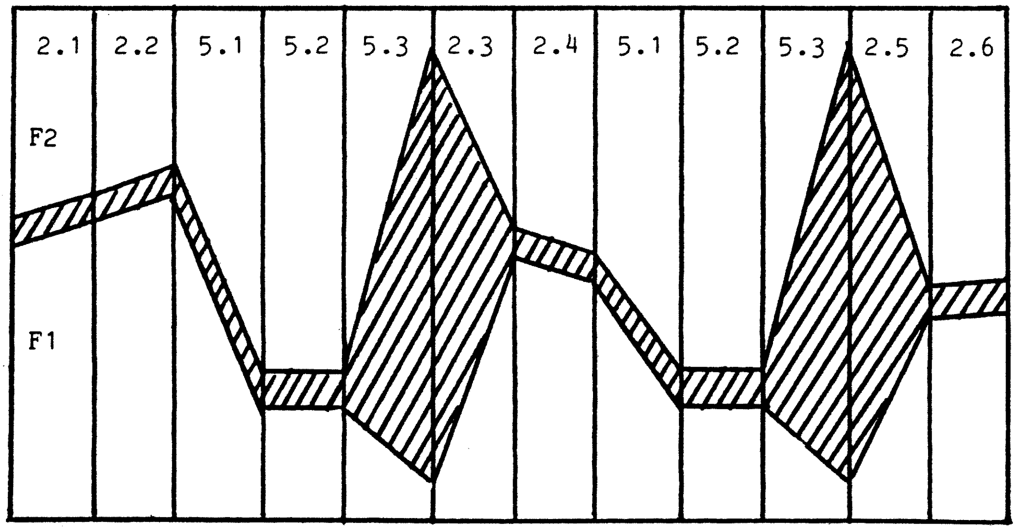
```
        :G n1 n2
```

where n1 is the number of the BLOCK;
n2 is any non-zero whole number.

Written in this format, the command has the effect of ignoring the curve start-values at the beginning of segment 1. For example:

```
        :G 5 1
instead of
        :G 5 0
```

in the sequence of instructions on the previous page would give the following result:



4.5.8 If at any time the user should regret the alterations made with EDIT, one of the commands:

```
          :AB                    ( = ABORT)
or
          : EOT
```

will restore the BLOCK to its pre-edit form. This can be done, of course, only if the file is still open for editing. For example:

```
>ED 2                              open BLOCK "2" for ed-
                                   iting
:SE 1

:                                  point after segment 1

:G 10                              get BLOCK "10 BIN"

:AB                                it should have been "9"
                                   so abort from this ed-
ORIGINAL FILE KEPT                 iting and ...

>ED 2                              start again

:etc
```

4.5.9 Summary of the ED-submonitor commands

PARAMETERS			OTHER
multiplication	addition	new values	OPERATIONS
DU DE F1 F2	A1 A2	FG WF GL ND	SE D G AB EOT

4.5.10 A word of warning!

It is vital that the user distinguish between the following commands:

```
(1)     >GL 2000              (2)     >ED
        >etc.                         :GL 2000
                                      :etc.
```

(1) Here a change is made to one of the parameters in the BLOCK table. The next time "PL" is done a new BLOCK file will be created, containing this parameter value.

(2) Here the most recently created BLOCK file is altered, but the BLOCK table remains unchanged. So the next "PL" will not cause a new file to be created; it will instead play the old one in its edited version.

This means that the next time a new BLOCK file is created it will still have the <u>old</u> value for GL, <u>not</u> the one given in the EDIT command.

```
-After
:SE n
: some edit command affecting only segment "in"
: a carriage return causes the editing to be executed and the
  program writes
: awaiting further commands. It also advances the segment pointer
  to "n+1". If you do not write any further SE, then all subsequent
  editing commands (except :D) will change all segments from and
  including the "n+1"-th one, to the end of the file.
```

- If you fail to do an extra carriage return (empty line) after any command except D (delate segment), the command will not be executed.

- In the case of

```
:SE n
:D  the deletion is already executed after one CR, the segment
    pointer moves automatically to "n+1", and another
:D  delete command will delete segment "n+1"
:   One extra CR after :D will exit from the EDIT program.
```

4.5.11 Command to input BLOCK FILE into BLOCK TABLE

```
>I fn [iseg]                    = INPUT
```

Reads in file 'fn BIN' to BLOCK table, starting at segment 'iseg'.

Note:

a) reads in max 50 segments - no error message if file contains more than 50 segments.

b) FG, WF, GL & ND are set from first segment (iseg) only.

c) Start values are set from activity 48 if there is one in segment 'iseg'; otherwise they are calculated from the values reached at the end of segment 'iseg-1'. (see 6.1)

d) If a record with activity 48 is found after segment 'iseg' it signals the end of the BLOCK; i.e. no more records are read into the Block table. (see 6.1)

e) 'fn' may naturally be a non-numeric file-name.

4.5.12 Understanding the difference between editing a BLOCK TABLE and a BLOCK FILE.

Remember!

1) When commands PL or PP are given, a check is made first to see if any values in the BLOCK TABLE have been changed since the last time PL or PP was done. If anything have been changed a new BLOCK FILE is created.

2) >ED edits last created file unless file name is specified.

Monitor commands	BLOCK TABLE		BLOCK FILE	
>PL 0	default values (no glissando)		default values 0 BIN (no gliss)	→ played in the studio
>FG 1 24 >PL	redefined FG range (no gliss)	PL creates - - →	1 BIN	- - →
>ED :GL 2000 : >PL	no change		1 BIN redefined glissando	- - →
>FG 1 12 >PL	redefined FG range (no gliss)	PL creates - - →	N.B 2 BIN no glissando	- →
>I 1 >PL	reads in 1 BIN (with glissando)	PL creates - - →	3 BIN (identical with 1 BIN	- - →
>FG 1 12 >PL	redefine FG range (with gliss)	PL creates - - →	4 BIN with gliss. and redefined range	- →

4.6 Horizontal / sequential mixing

KP (KEEP) is used to mix BLOCK-files sequentially.

4.6.1 Format:

```
>KP n1 n2        or        >KP fn n2
```

where n1 is the number of the BLOCK which is to be "kept" (mixed); if n1 is zero, negative or undefined, the most recently created BLOCK file is kept; (or fn is the Block-file name).
n2 is an optional "transition-switch"; if it is non-zero there will be a smooth transition into this BLOCK (in other words the start-values of this BLOCK will be ignored - cf §4.5.7 :G n1 n2); if it is zero or undefined, this BLOCK will be mixed without alteration.

KP copies the contents of "n1 BIN" to a special-purpose BLOCK called "999 BIN". Successive KEEP commands copy the named files to "999 BIN" in the order in which the commands are given. For example, after these commands: file 999 BIN looks like this:

```
>KP 2
>KP 4
>KP 1
>KP 3
```

2 BIN	4 BIN	1 BIN	3 BIN

→

The KEEP-file is open (new BLOCKs can be copied on to it) until "999" is referenced with one of the commands:

```
>PL 999     >PP 999
>PF 999     >WR 999        >KP 999
>ED 999     >TM 999        is ILLEGAL!
```

These commands go through the following operations:

1) Close "999 BIN" and rename it, in such a way that the first KEEP-file becomes "1000 BIN", the second becomes "1001 BIN", and so on; this leaves "999" free to be used with any further KEEP files.
2) Perform the desired task on the renamed file.
3) Output message to show what number this KEEP-file has received. For example:

```
>KP                          KEEP the latest BLOCK
>FG -1                       redefine generators
RANDOM LIMITS:1 40
>PL                          create & play a new BLOCK
>KP                          KEEP this new one
>PL 2                        play BLOCK "2"
>KP 2                        and KEEP it
>PL 999                      play the KEEP file
1000  BIN OK                 it gets name "1000 BIN"
>
```

Note that files created with "KP" are identical in format to all BLOCK files; they can therefore be manipulated in exactly the same ways. Thus:

```
>PL 1000
>ED 1000
>KP 1000
>etc
```

are all legal commands.

4.6.2 The numbering of KEEP-files can be directed with:

```
>FP 1 n              ( = FILE-POINTER)
```

where n is a positive whole number defining the name which is to be given to the next KEEP-file created. See also § 4.4.6 and 5.9.2.

4.6.3 About some mysteries of Horizontal Mixning

To understand some of the "mysteries" of IMPAC, one has to understand the roles of the different records on the BLOCK FILE, especially of the record which contains code 48, which will be called simply activity 48 or header.

Study 6. 1 before reading this explanation:

Every BLOCK FILE starts with a header, with activity 48. Even the BLOCK TABLE starts with it. A BLOCK FILE may contain several activity 48 records but the BLOCK TABLE may NOT. That is why you cannot read into BLOCK TABLE (the command >I fname) a file which has been created by appending several files to each other (e.g. with the command >KP) , however you can play them. There is a possibility however to circumvent this limitation as explained below.

Supposed, you have two files each of them 2 segments long. You want append file BB to file AA withouth to have the header of BB in the resulting file.

```
>ED AA          open file AA to edit
:SE 2           set segment pointer to segment 2
:               type one extra CR to move pointer after segment 2
:G BB 1         GET file BB with transition type 1
:               CR to accomplish editing
AA BIN OK       the program signals the result
>I AA           read it into BLOCK TABLE
>L              look at it to see the result
>PL AA          play if you wish...
```

What is important within this scheme above is the TYPE of transition of order >G . It must be 1. If it is zero, the header of file BB will be kept within the resulting file. (It is obvious that the program interpreting 1 as smooth transition , opposed to the manual).
It is perhaps obvious, that in the above case the parameters of the header of file BB (MI (modulation index), MF (modulation frequency) and SS (start scale)) disappear. Thus if you absolutely need them, you must plan your horizontal mixing carefully .

We have another mystery, with files which has been created with the order >PF (Part file). The problem (IOPS 0 , PDP15 stop) occurs only if you extracted a part from segment 1 to segment X. Do not do that. If you want extract the first 3 segments of a file, there is another methods to use :

```
>I CC           reads in CC BIN into BLOCK TABLE
>SE 3
>PL             the new file which will be created automatically
                will contain 3 segments only
```

It is good to know also, that in case you want to expand your file which contains 5 segments to 10 segments, the following happens.

```
>I DD           reads in DD containing 5 segments
>SE 10
>PL             the new file which will be created automatically
                will contain 10 segments, however the values of
                segment 6-10 will get the default values of the
                program, i.s : DUration =131000 / DEnsity = 1 /
                F1= 16 / F2 = 3000 / A1 = 280 / A2 = 320
```

4.6.4 Working scheme with KEEP files and Starting Parameters

Suppose you have 3 files to mix horizontally, FIL1, FIL2 and FIL3. You "Keep" the files

```
>KP FIL1
>KP FIL2
>KP FIL3
>AD 0              unfreeze parameters if you have set
:MF                them before.
:MI
:
>SS 0              set starting scale
>PL 999
'KP' FILE: 1000 BIN
```

"keep file" 999 is played in the studio, whereupon it becomes "keep file" 1000.

Suppose you are not satisfied with MI (mod.index stored as starting parameter in activity 48) in FIL2. Call FIL2 into BLOCK-TABLE (i.e. into memory)

```
>I FIL2       give new value
>SP MI 1111   change modulation index (if frozen)
>F            create new file
n BIN OK      new file with name n BIN is created
>RN n FIL2    rename it
>KP FIL1      mix the three files again
>KP FIL2
>KP FIL3
>AD 0         unfreeze modulation index
:MI
:
>PL 999
```

"Keep file" 999 is played in the studio, whereupon it becomes "keepfile" 1001'

NOTE! If you write >FP 1 1000 FILE POINTER

```
>PL 999
```

"Keepfile" 999 is played whereupon it becomes 1000 BIN (as before). In this way you save diskspace.

A word of warning!

Rename your keepfiles before starting work again!
When terminating a run, rather then saving (to DEC-tape) your KEEP files, it is better to save the individual component files from which you made them. Next time you start work, you can very quickly reassemble KEEP files from them, AND you can call any of these component files into BLOCK-TABLE for unlimited further modification.

4.7 Miscellaneous commands

4.7.1 >TM[n] (= TIME)

where n is the number of a BLOCK-file.

1) If n is undefined, negative or zero, the program prints the duration of the music that was last played in the studio.

2) If n is a positive whole number, the program prints the duration of BLOCK-file "n BIN".

4.7.2 >IN (= INITIALIZE)

returns the composition program to its state at the start of the run.

1) All BLOCK-files, from "1 BIN" to the latest defined BLOCK-file inclusive, are deleted, except those that have been created with KP; the file-pointer (set with >FP 0 n) is put to 1.

2) If the KEEP-file 999 is active, it is closed and numbered in the normal fashion.

3) All parameters in the BLOCK table are put to default values:

SE 50	DE and DS 1	FG 25 40
DU 131000	F1 and LF 16	ND 10000
	F2 and HF 3000	GL 1000
	A1 and LA 280	WF 0
SA 10	A2 and HA 320	

4) The tables and stores used in the real-time program are cleared and put to default values.

5) The Tektronix screen is cleared, as are all studio registers.

6) The program writes:

IMPAC Vnn

where nn specifies which version of IMPAC this is.

5 The Real-time Program

5.1 Introduction

In the real-time program the user controls the music parameters while the music is being played; he can connect the parameters to various analogue or programmed devices, or choose to control them from a BLOCK file.

5.1.1 The real - time program is entered with:

```
>PL                        ( = PLAY)
```

Control is returned to the program monitor when

1) the SPACE key is pressed; or
2) the end of the BLOCK file being played is reached.

5.1.2 The normal working procedure at the beginning of a run is:

```
>CN  2                               make stereo studio connections
                                     (see §2.4.1)
>RV  8 360                           set reverberation time
                                     and level (see §2.4.3)
>PL
```

The program reads information about parameters from the default file "0 BIN"; or, if a BLOCK number has been given in the "PL" command, a file with this number is read from instead.

"0 BIN" contains the same values as the default values in the BLOCK-table. This file will play for 1 hr 49 min 10 sec, unless the SPACE key is pressed.

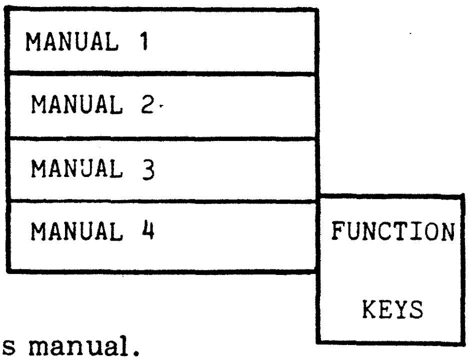
SE	50	DU	131000
F1	16	F2	3000
A1	280	A2	320
DE	1		
FG	25 40	WF	0
GL	1000	ND	10000

5.1.3 Instructions are given by pressing the keys on the Tektronix in certain special ways; the characters printed on the keys are of no significance!

Instructions are of five types:

Parameters
Devices
Multiple-key functions
Single-key functions
Keyboard

A full plan of the Tektronix as it is used in the real-time program is to be found on the last page of this manual.



Note that groups of keys will be referred to as MANUALS 1 to 4 and FUNCTION KEYS, as in the diagram above.

5.2 The parameters and devices

There are sixteen parameters, represented by the sixteen function keys on the right-hand side of the Tektronix.

5.2.1 The music parameters are: ND, GL, MI, MF, F1, F2, A1, A2, DE, AT, SX, SY, RV, VS and VD; these are described fully in ch 3. SI is discussed in 5.6.1.

To reference a parameter, press the key associated with it; when this is done, the current value of the parameter is written on the screen. Thus:

ND	GL	MI	MF
F1	F2	A1	A2
DE	AT	SX	SY
SI	VS	VD	RV
(SX)	(VS)		

```
ND


10000.000
```

5.2.2 The devices used to control the parameters are:

1) JOYSTICK X-axis
2) JOYSTICK Y-axis
3) DIGITIZER X-axis
4) DIGITIZER Y-axis
5) KEYBOARD (MANUAL 3)
6) RANDOM GENERATOR
7) SINE-WAVE GENERATOR
8) SQUARE-WAVE GENERATOR
9) TRIANGULAR WAVE GENERATOR
0) FILE

1 - 5 are controlled manually.
6 - 9 are software devices. See §§5.6ff for control facilities.
0 is not, strictly speaking, a device - it represents the information on the BLOCK file being played.

For the sake of convenience, all the devices - analogue and programmed - are referred to as ANALOGUE DEVICES (AD).

The devices are represented on the Tektronix by the corresponding numbers in Manual 1.

JOYSTICK		DIGITIZER										
X	Y	X	Y	KB	RAN	SINE	SQUA	TRI	FILE			
1	2	3	4	5	6	7	8	9	0	= -	{ [	}]

(KB = KEYBOARD)

5.2.3 A parameter is connected to a device by pressing the parameter key followed by the device key.

$$\boxed{\text{PAR}} \longrightarrow \boxed{\text{AD}}$$

If, for example, DE is to be controlled by the JOYSTICK X-axis, press:

$$\boxed{\text{DE}} \longrightarrow \boxed{1}$$

If F1 is to be controlled by information in the BLOCK file, press:

$$\boxed{\text{F1}} \longrightarrow \boxed{0}$$

There is no limit to the number of parameters which may be controlled by a given device at any one time. Thus the sequence:

$$\boxed{\text{A1}} \longrightarrow \boxed{3}$$

$$\boxed{\text{A2}} \longrightarrow \boxed{3}$$

means that the amplitude limits A1 and A2 are controlled in parallel by the digitizer X-axis.

5.2.4 Parameters can also be controlled by combinations of devices:

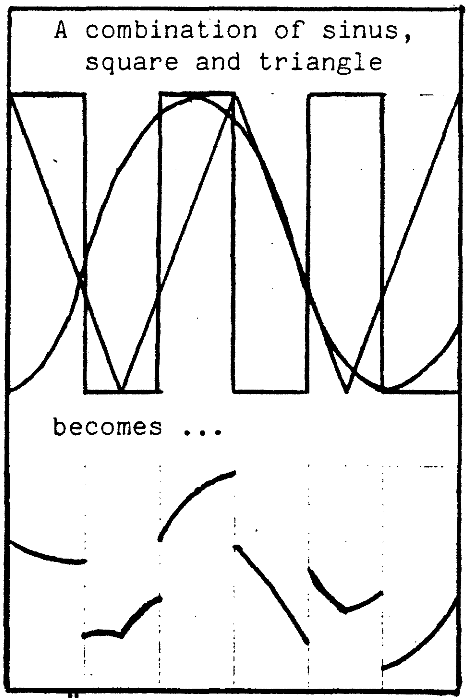
$$\boxed{\text{PAR}} \rightarrow \boxed{\text{AD}} \rightarrow \boxed{\text{AD}} \rightarrow \boxed{\text{AD}}$$

Control is then divided in equal proportions between these devices; so if F2 is connected thus:

$$\boxed{\text{F2}} \rightarrow \boxed{7} \rightarrow \boxed{8} \rightarrow \boxed{9}$$

each of the devices contributes 1/3 towards the result.

The exception to this multiple-connection facility is device 0 (FILE), which cannot be combined with any other device; as soon as the FILE key is pressed, the relevant parameter is controlled from file only. If the parameter is not controlled from the file, it will be "frozen".



5.2.5 It is often desirable to find a suitable value for a parameter with one of the analogue devices, and then freeze the parameter there; i.e. leave it at that value while the device is freed to control other parameters. This is done by pressing:

shift and $\boxed{\text{PAR}}$

at the same time. The parameter can be unfrozen at a later stage by repeating the action - it functions therefore as an on/off switch.

When a parameter is frozen, its value will not change until
a) it is unfrozen; or
b) it is connected to a device.

For example, to find a suitable value for MI with JOYSTICK Y-axis:

1) $\boxed{\text{MI}} \longrightarrow \boxed{2}$

2) Move the JOYSTICK until the right value is found.

3) shift and $\boxed{\text{MI}}$

to freeze the parameter.

4) When the parameter is to be changed again:

shift and $\boxed{\text{MI}}$

5) To control MI with another device, e.g. the random generator, press:

$\boxed{\text{MI}} \longrightarrow \boxed{6}$

5.2.6 Exact values can be put on the parameters by giving the command:

>SP

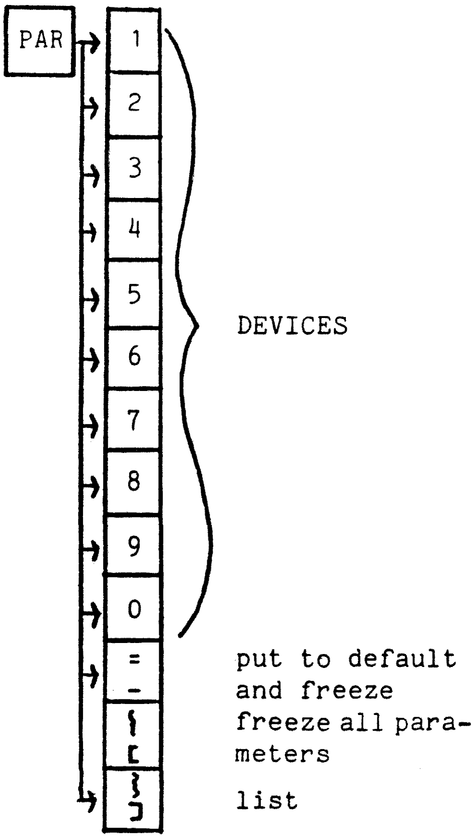
from the program monitor (SET PARAMETER. See 4.1.4).
Note that when this is written the parameter in question is automatically frozen.

5.2.7 All the keys in MANUAL 1 except $\boxed{\{[}$, which freezes all parameters, have varying functions depending on which key is pressed immediately before them. Keys 1 to 9 and 0, if preceded by a parameter key, make connections to the analogue devices; their functions with other keys are discussed later.

After a parameter key:
$\boxed{=-}$ puts one parameter to its default value and freezes it;

ND	10000	GL	1000
MI	0	MF	1000
F1	16	F2	3000
A1	280	A2	320
DE	10	AT	20
SX	500	SY	500
SI	4	VS	100
VD	0	RV	240

$\boxed{\}]}$ writes the value of the latest parameter pressed.



5.3 The AD table

The program maintains a table containing information about parameter/device connections and parameter ranges. This is called the AD (ANALOGUE DEVICE) TABLE.

5.3.1 The AD-table is referenced with two keys in MANUAL 2.

	SAVE AD	GET AD											

For example, the table can be listed by pressing either of these keys followed by the LIST key in MANUAL 1.

```
ND  789    100  10000
GL *2689     0   8192
MI   1       0   1000
MF   2      25   4000
F1   0      16   3000
F2   0      16   3000
A1   57    200    320
A2   57    240    340
DE *1        0    200
AT   3       0   2000
SX   0       0   1000
SY *0        0   1000
SI   0       0   2880
VS   6      30   1000
VD   6      20     10
RV   0     240    380
```

Column 1 contains the names of the parameters.

Column 2 contains the numbers of the devices to which the parameters are connected; for example, 789 indicates that the parameter is connected to devices 7, 8 and 9. An asterisk immediately before the device number shows that the parameter is frozen.

Columns 3 and 4 show the limits of the parameter range - from column 3 when the device has a low value (left or bottom) to column 4 when it has a high value (right or top). Note that in the example VD´s left limit is higher than the right one; this means that when the random generator produces a low number, VD gets a high value, and vice versa. Vibrato depth is thus made inversely proportional to vibrato speed.

5.3.2 It has already been shown how parameter/device connections can be made in real-time. Connections and parameter ranges can also be altered from the program monitor with the command:

```
>AD n                    ( = ANALOGUE DEVICE)
```

where n is the number of a device (0 to 9) to which parameters are to be connected.

"AD" is a subprogram with its own submonitor; it prints:

```
:
```

and waits for the user to give one of the following commands:

Parameters				Other functions
:ND n1 n2 :F1 n1 n2 :DE n1 n2 :SI n1 n2	:GL n1 n2 :F2 n1 n2 :AT n1 n2 :VS n1 n2	:MI n1 n2 :A1 n1 n2 :MS n1 n2 :VD n1 n2	:MF n1 n2 :A2 n1 n2 :RV n1 n2	:L (= LIST) :S n (= SAVE) :G n (= GET) :AD n (= ANALOGUE DEVICE)

Control reverts to the program monitor when EOT or carriage return is done immediately after ":".

1) PARAMETER COMMANDS

n1 and n2 specify the new parameter range. Thus:

```
:F1 220 440
```

gives "F1" a range between 220 and 440 Hz. At the same time it is connected to the device stated in the AD-command. For example:

```
>AD 5                                we're connecting to de-
                                     vice 5
:A2 300 350                          A2 with these limits...

:RV 400 200                          and reverb from 400 down
                                     to 200
:                                    empty line to return to
                                     program monitor
>etc.
```

Note the following special cases:

a) Parameter ranges cannot be altered after:

```
>AD 0
```

which connects parameters to BLOCK-file information; this is because ranges have no significance when a file has control.

b) To put all parameter/device connections to zero, write:

```
>AD -1
```

c) To alter parameter ranges without defining parameter/device connections, write:

```
>AD 10
```

and then parameter commands as usual; the connections in the table remain unchanged.

N.B.
All parameters can theoretically be connected to BLOCK-files; however, files have information for ND, GL, F1, F2, A1, A2 and DE only. If the other parameters are connected to "0", they are, in effect, frozen.

2) To list the AD-table, write:

:L

This is also done automatically when the AD-subprogram is entered.

3) To choose a new device for connection to parameters, write:

:AD n

This performs the same function as the program-monitor command "AD". For example:

>AD 6		connect random generator
:MI 0 250		to modulation index
:AD 7	new device!	connect sine-wave generator to ...
:MF 500 750		MF-ratio
:AD 10		no device! (i.e. range)
:F1 16 100		so change range only
:etc.		

4) The values in the AD-table can be stored with:

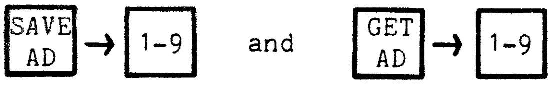
:S n

where n is a whole number from 1 to 9 specifying which of the nine AD-store positions this table is to go into. Values which have been saved in this way can be retrieved with:

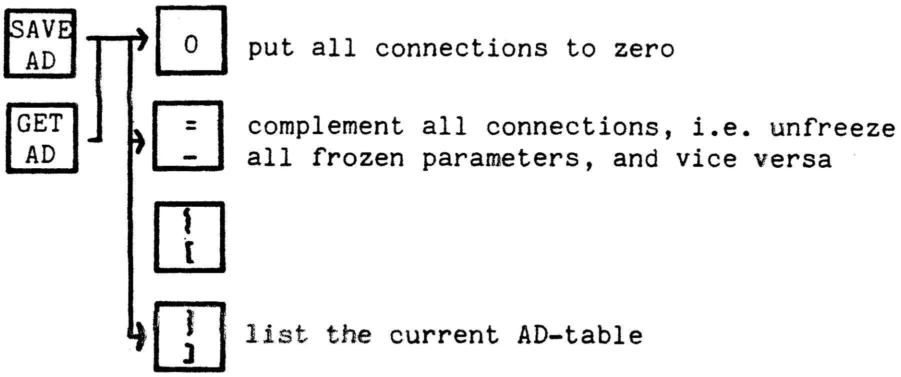
:G n

where n specifies which of the nine AD-stores is to be referenced. Both of these commands cause the Tektronix screen to be cleared and the AD-table to be listed.

5.3.3 In the real-time program the AD-stores are referenced with:



With the other keys in MANUAL 1, SAVE and GET have the following functions:

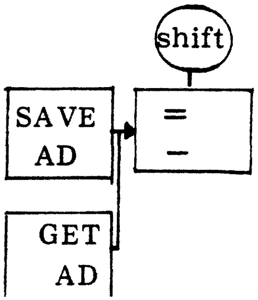


put all connections to zero

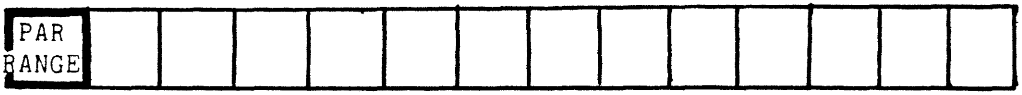
complement all connections, i.e. unfreeze all frozen parameters, and vice versa

list the current AD-table

If lost, the default AD table can be restored. Press



5.3.4 A certain amount of control can be exercised over parameter ranges with the key PAR RANGE in MANUAL 2.



Three keys are pressed in this operation:

1) the parameter whose range is to be modified;

2) PAR RANGE

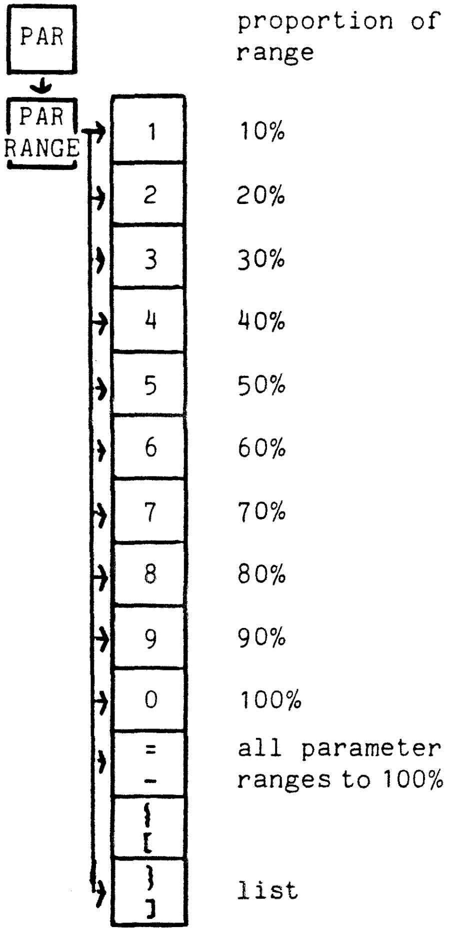
3) one of the keys in MANUAL 1.

The actual range then becomes a given percentage of the original range in the AD-table. This is done by lowering the upper limit; the lower limit is not changed. For example, suppose that in the AD-table F1 is to lie between 100 and 900 Hz - a range of 800 Hz. After:

F1 → PAR RANGE → 6

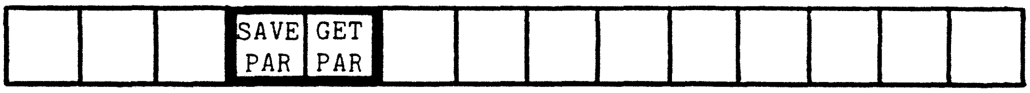
the range becomes 60% of 800, which is 480; so the upper limit is decreased to (480 + the lower limit), which is 580 Hz. But note that the original range limits always appear when the AD-table is listed. All the parameter ranges are restored to their original 100% values with:

PAR RANGE → =/-



5.4 The Parameter table

The PAR (parameter) TABLE contains the current values of all 16 parameters. It is updated each sample by any analogue devices and BLOCK-file information that may be controlling parameters; and it is from this table that music is calculated.



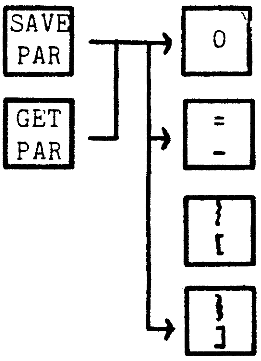
5.4.1 There are nine positions in memory reserved for storing the PAR table. These are accessed with:

SAVE PAR → 1-9 and GET PAR → 1-9

which saves the whole of the current PAR table (i.e. the values of all the parameters at the moment the number key is pressed) to one of the positions in the PAR store.

which retrieves values that have been stored with SAVE PAR, and puts them in the PAR table; then it freezes all connections in the AD-table.

The other keys in Manual 1 have the same functions for both SAVE PAR and GET PAR.

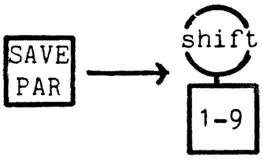


put all parameters to legal minimum and freeze them.

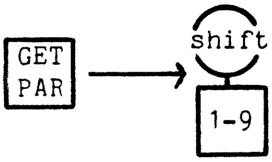
all parameters to default and freeze; see §5.2.7 for default values.

list PAR table.

5.4.2 The AD and PAR stores can be accessed simultaneously with:



and



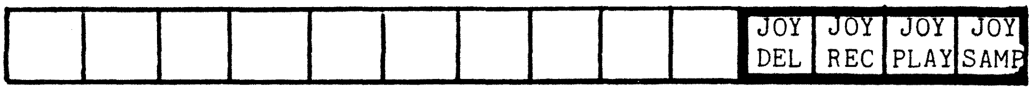
which stores the current AD-table in position "n" of the AD-store, and the current PAR-table in position "n" of the PAR-store.

which fetches values from position "n" of the AD-store and position "n" of the PAR-store and puts them in the AD and PAR tables respectively.

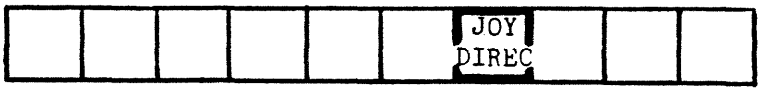
5.5 The Joystick Store

Movements with the Joystick can be stored in the JOYSTICK-store, and then recalled later to reproduce exactly the same, or slightly modified, sequences. Two keys in Manual 2 - JOY REC and JOY PLAY (Joystick Record and Joystick Playback) - are used to start storage and retrieval of Joystick information, while three keys are used to exercise control over playback - JOY DEL (Joystick Delay) and JOY SAMP (Joystick Sampling) in Manual 2, and JOY DIREC (Joystick Direction) in Manual 4.

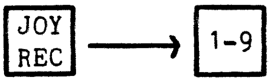
Manual 2



Manual 4



5.5.1 There are nine memory banks in the Joystick store, each with room for 1023 pairs of coordinates; during recording, one pair of joystick coordinates is stored every sample. To start recording, press:

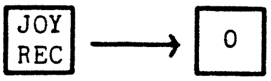


where the number specifies one of the nine memory banks

Recording is completed:

1) after 1023 samples;

2) after



3) when recording is re-initialized.

4) when playback is started.

5.5.2 To play back Joystick movements, press:

$\boxed{\text{JOY PLAY}} \longrightarrow \boxed{1\text{-}9}$ where the number specifies one of the nine memory banks.

Each sample, one pair of coordinates is fetched from the store, and these coordinates replace information coming from the actual joystick; so parameters connected to the joystick (devices 1 and 2) are controlled by the store information instead.

Playback is completed:

1) when another playback is started;

2) when joystick recording is started;

3) after

$\boxed{\text{JOY PLAY}} \longrightarrow \boxed{0}$

Otherwise, each memory bank is treated as if it were <u>circular</u> - the last pair of coordinates is followed by the first.

Note also:

$$\begin{tikzcd}\boxed{\text{JOY PLAY}} \arrow[r] & \boxed{\substack{\}\\ ]}} \\ \boxed{\text{JOY REC}} \arrow[ur] & \end{tikzcd}$$

writes the number of the current memory bank being played back.

5.5.3 Playback from Joystick store can be manipulated in a number of ways. Normally, a new pair of coordinates is retrieved each sample; with:

$\boxed{\text{JOY DEL}} \longrightarrow \boxed{n}$ where n is a number: 1 - 9 or 0

the user can control the <u>rate</u> at which information is fetched, such that each pair is valid for n + 1 samples. For example:

$\boxed{\text{JOY DEL}} \longrightarrow \boxed{9}$

means that new coordinates are fetched every tenth sample; playback speed is therefore one tenth of the speed during recording.

$\boxed{\text{JOY DEL}} \longrightarrow \boxed{0}$ restores the <u>original speed</u>.

$\boxed{\text{JOY DEL}} \longrightarrow \boxed{\substack{\}\\ ]}}$ writes the current delay factor.

SLOW DOWN

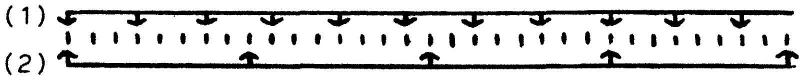
5.5.4 With the function:

$\boxed{\text{JOY SAMP}} \longrightarrow \boxed{n}$ where n is a number: 1 - 9 or 0,

the user controls the playback sampling rate, in such a way that n pairs of coordinates are skipped each time new values are fetched. For example:

(1) $\boxed{\text{JOY SAMP}} \longrightarrow \boxed{2}$ (2) $\boxed{\text{JOY SAMP}} \longrightarrow \boxed{7}$

The following information is fetched:



SPEED UP

JOY SAMP → 0 restores the original sampling rate.

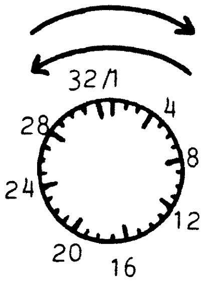
JOY SAMP → }] writes the current sampling rate.

The difference between JOY DEL and JOY SAMP is thus that JOY SAMP determines which coordinate-pairs are to be fetched, while JOY DEL determines how long each pair is to be valid.

5.5.5 The direction of playback can be changed with:

JOY DIREC

This is a single-key switch - each time it is pressed, the direction changes. A memory bank that is read backwards is still circular; the last coordinate-pair follows the first.



5.5.6 Summary of the Joystick-store functions.

JOY REC →	1-9	start recording to memory bank "n".
→	0	stop recording
	= -	
	{ [	
→	}]	write memory-bank number

JOY PLAY →	1-9	start playback from memory bank "n"
→	0	stop playback
	= -	
	{ [	
→	}]	write memory- bank number

JOY DEL →	1-9	set delay factor n
→	0	no delay
	= -	
	{ [	
→	}]	write delay factor

JOY SAMP →	1-9	skip n points each sample
→	0	no skip
	= -	
	{ [	
→	}]	write sampling factor

5.6 Controlling the devices

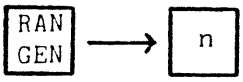
Four of the "analogue devices" - the sinus, triangle, square and random generators - are program-controlled.

5.6.1 The sine-wave generator is controlled by the parameter SI (SINE-WAVE INCREMENT), which determines the number of values in the sine-wave table that are to be skipped each sample. If SI = 10, the generator takes every tenth value from the table; if SI = 200, it takes every two-hundredth value; if SI = 0, the generator stops, and so on.

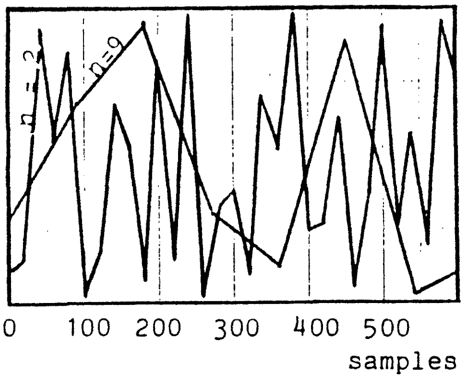
The maximum value for SI is 2880 (see §6. 5 for more information about the sine-wave table.

SI can be connected, listed, frozen, etc. in exactly the same way as every other parameter.

5.6.2 The random generator is controlled with:



where n is a number: 1 - 9 or 0, such that a new random number is chosen every (n x 10) samples. For the other samples, values are calculated on a linear-interpolation basis between the random numbers before and after.



$\boxed{\text{RAN GEN}} \longrightarrow \boxed{0}$

ensures that a new random number is chosen every sample.

5.6.3 The triangular-wave generator is controlled with:

$\boxed{\text{TRI GEN}} \longrightarrow \boxed{n}$ where n is a number: 1 - 9 or 0,

such that the period of the generator is (n + 1) x 20 samples.

5.6.4 The square-wave generator is controlled with:

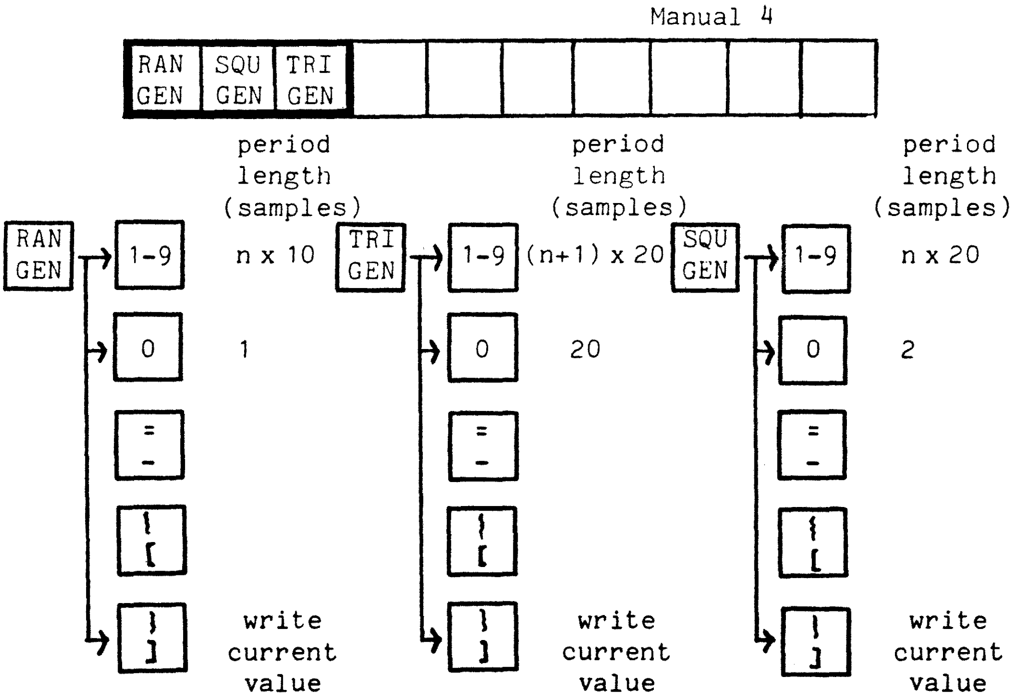
$\boxed{\text{SQU GEN}} \longrightarrow \boxed{n}$ where n is a number: 1 - 9 or 0,

such that the period of the generator is n x 20 samples.

$\boxed{\text{SQU GEN}} \longrightarrow \boxed{0}$

gives the shortest possible period: 2 samples.

5.6.5 Summary of the periodic devices

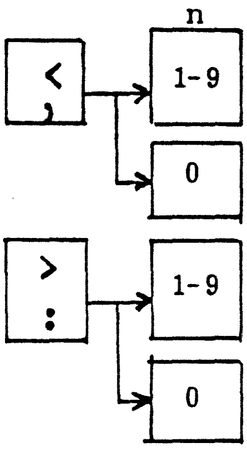


5.6.6 Control of the Joystick, Digitizer and Tektronix Keyboard (device 5) is manual, and should present no problems. Note however that only the region 0 to 1100 of the Digitizer is used; coordinates below or above these limits are adjusted to 0 or 1100 respectively.

5.6.7 Key store

The pressing of every key on the whole keyboard can be stored in nine memory banks. Each memory bank can store 63 key pressings. Together with the time (i.e. number of studio samples) between each pressing.

The time between successive key pressings should not exceed 1023 samples.



record key pressings in store "n"

stop recording

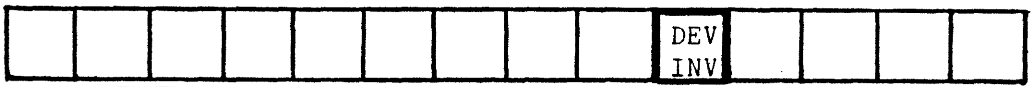
play-back keypressings stored in "n"

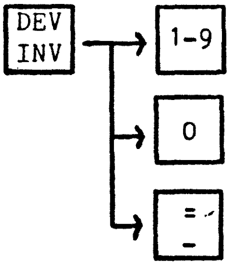
stop play-back

The memory banks of the keystore function are stored on IMP files (with the command PT).

5.7 Miscellaneous multiple-key functions

5.7.1 The control exercised by the analogue devices can be inverted with the DEVICE INVERSION key in Manual 2.



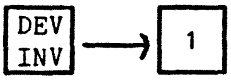


invert device "n".

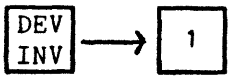
restore all devices to normal.

put all devices to inversion of normal state.

For example:

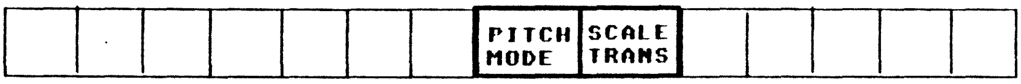


means that the Joystick X-axis will give high values to the left and low values to the right; values read from the Joystick-store are inverted in the same way. Pressing:



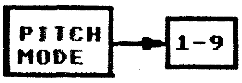
again restores the device to its original state; DEV INV functions therefore as an on / off switch.

5.7.2 Interval relations and scale patterns are controlled with PITCH MODE and SCALE TRANSPOSITION in Manual 2.

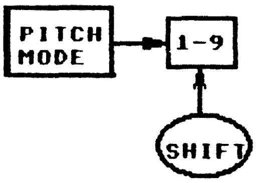


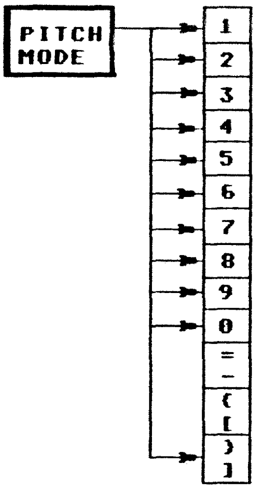
With PITCH MODE the user chooses between eighteen different scales, which are pre-defined. They can be accessed as followes.

Scales 1-9 :



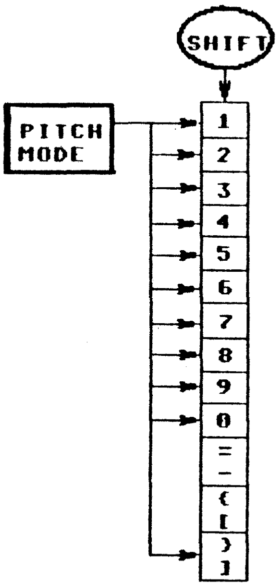
Scales 10-18 :





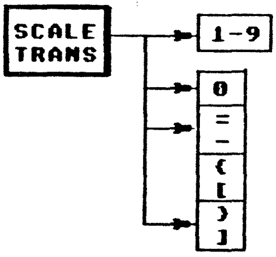
major
minor harmonic
minor melodic
pentatonic
1/2 whole tones
whole tones
3/4 tones
1/2 tones
1/4 tones
random

number of current
scale displayed



G
A
B^b
B
C
D^b
D
E^b
F

Any or all of the scales can be replaced by scales of the user's own definition – see 3.4.5

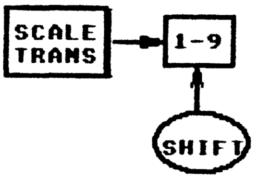


transposes all scales **down** n 1/4 tone steps

transposes all scales **down 10 1/4** tone steps

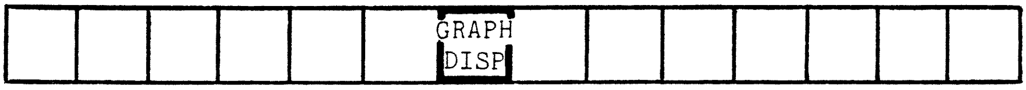
restores all scales to original position

current number of transposition steps displayed



trasposes cale patterns **upwards** n steps

5.7.3 The GRAPHIC DISPLAY key in Manual 2 is used to plot parameters and devices.



Format:

GRAPH DISP → n1 → n2

where n1 and n2 are devices (1 - 9) or parameter keys.

1) When n1 is pressed, that parameter or device is plotted on the Y-axis, against time on the X-axis.

2) When n2 is pressed, the first parameter or device is moved over to the X-axis, and the second is plotted on Y.

N.B.
After stage 1 above, the program will interpret the next pressing of a parameter key as a GRAPH instruction, even if the user intends it to be part of a device connection. If it is desired to plot one parameter or device against time, the user is recommended to press any key in Manual 2 except GRAPHIC DISPLAY immediately after

GRAPH DISP → n1

Examples:

a) To plot Joystick-X against Joystick-Y:

GRAPH DISP → 1 → 2

b) To plot the sine-wave generator alone:

GRAPH DISP → 7 → JOY SAMP (or any other key in Manual 2)

c) To plot F1 against the random generator:

GRAPH DISP → F1 → 6

d) To stop GRAPHIC DISPLAY:

GRAPH DISP → 0

e) To see which parameters and devices are being plotted:

GRAPH DISP → {]

This information is written as "X Y": parameters are represented by their two-character mnemonics, devices by the numbers 1 to 9; time on the X-axis is represented by T. The above examples give:

a)	1	2	b)	T	7
c)	F1	6	d)	0	

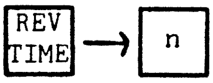
Graph information is drawn on the screen at a rate of one point per sample, except that the program does not allow text messages and graphs to be output at the same time. Text messages have priority; so graphic display is temporarily disenabled while messages are being written.

Clear screen with B in Manual 4.

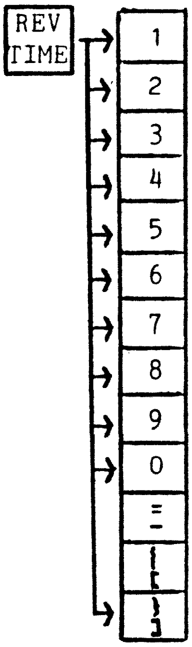
Scaling with GRAPHIC DISPLAY:

- Devices are scaled so that the minimum value is drawn at the lower or left edge of the screen while maximum is drawn at the upper or right edge.
- Parameters that are connected to 0 (file-information) are scaled from zero to legal maximum.
- Parameters connected to devices (1 - 9, frozen or unfrozen) are scaled between the minimum and maximum values in the AD table.

5.7.4 Reverberation time is controlled with:



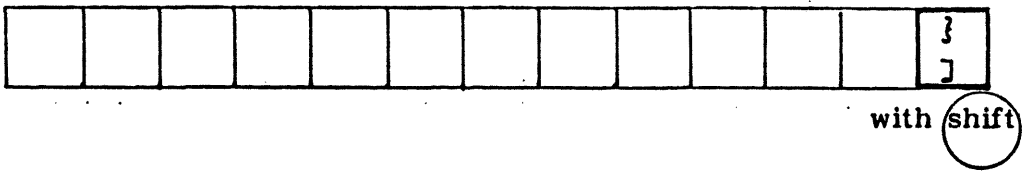
where n is a number (1 - 9 or 0) giving reverberation times as in the diagram.

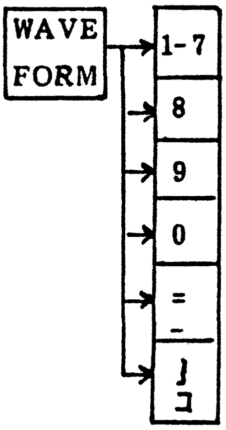


	reverb time
1	2
2	4
3	6
4	8
5	10
6	12
7	14
8	15
9	15
0	0
= -	
{ [	
}]	write rev time

5.7.5 Wave-form control

Wave-form controllable in real-time. On manual 1





1-7	wave form n
8	wave-form 0
9	random wave-forms
0	wave-form 0
= -	controlled by file
}]	write wave-form control (-1 = controlled by file)

5.8 Single-key functions

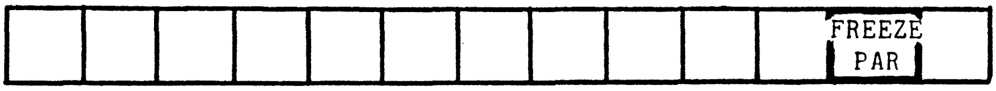
There are nine functions which are operated by pressing a single key.

5.8.1 All parameters are frozen with:

FREEZE
PAR

Note that this is the only key in Manual 1 with a fixed function; it does not matter which key was pressed before.

Manual 1



FREEZE PAR is now an on/off switch.

First pressing saves current AD connections & then freezes them.

Second pressing restores former AD connections.

Other key-pressings which cause all parameters to be frozen are interpreted as first pressings of FREEZE PAR.

E.g. SAVE PAR → = – (all parameters to default & freeze)

FREEZE PAR will then restore the connections which were frozen.

N.B. When playing is started, the first FREEZE PAR functions always as a first pressing.

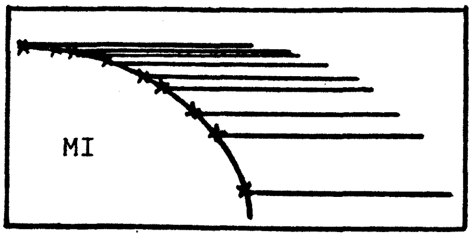
5.8.2 The RIGID/FLUID key is an on/off switch which allows parameters two completely different modes of operation.

In RIGID-mode the parameter values valid at the beginning of a note are kept throughout the duration of the note.

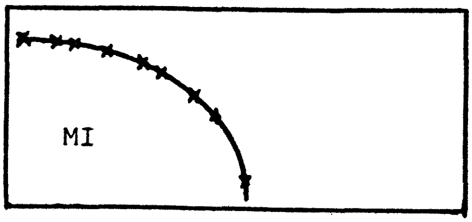
In FLUID-mode, every note follows changes made in the parameters; so all generators that are playing notes at a given moment have exactly the same values for ND, GL, MI, MF, AT, VS, and VD.

N.B.

1) Wave-form is always rigid.
2) At the start of a run, this switch is set to "FLUID".



RIGID - start-values follow the curves, but each note keeps its own value.

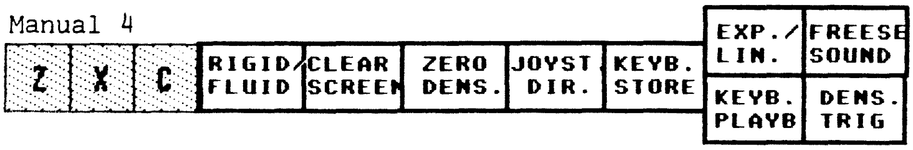


FLUID - new notes, starting at x, follow the MI curve.

5.8.3 The CLEAR SCREEN key clears the screen, stops any message that is in the process of being written, and sets a program flag to ensure that the next message is written at the top of the screen. Graphic display is not affected.

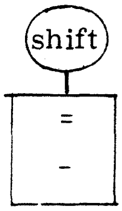
5.8.4 ZERO DENSITY puts density to zero no matter what the actual value on the parameter DE; no new notes can start, though all old notes will complete their envelopes as usual. It is an on / off switch: pressing it a second time returns control to DE.

Every time playing is started in the studio, this switch is automatically put to the non-zero position.



5.8.5 JOY DIREC changes the direction in which data is fetched from the Joystick store. See §5.5.5.

5.8.6 In order to establish possibilities for rhytmical structures the EVEN/RANDOM density distribution switch has been established. It is accessed by

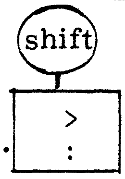


Manual 1

5.8.7 The switch EXP/LIN controls the distribution of random frequencies between F1 and F2.

EXP = exponential (logarithmic)
LIN = linear (rectangular)

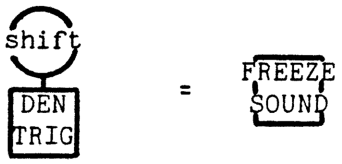
At the start of a run this switch is set to EXP.



5.8.8 When DENSITY TRIGGER is pressed, all the generators which are being used - those defined with ›FG n1 n2 - start a new note simultaneously; in other words, density is put to its maximum legal value for one sample only.

5.8.9 FREEZE SOUND is an on/off switch which is operated by pressing SHIFT and the DENSITY TRIGGER key at the same time. As long as it is on, all studio functions are frozen; no changes are made on any of the generators, reverberation units or amplifiers.

This switch is automatically "off" every time playing is started in the studio.



5.9 Program-monitor commands and real-time

There are a number of program-monitor commands which exercise control over the music played with the real-time program.

Non-numeric arguments are now possible in fields 2 and 3 of monitor commands. Used with the following commands:

```
>KP NAME  >WR NAME  >RN NAME 1  NAME 2
>PL NAME  >TM NAME  >PF  NAME  >CN NAME
>PP NAME  >ED NAME  >GT  NAME  >PT NAME

          (&  :G NAME)
```

5.9.1 Some of these commands have already been discussed:

>SP (SET PARAMETER) sets single values on parameters, and freezes them (see §4.1.4).

>AD (ANALOGUE DEVICE) controls the AD table, with information about parameter/device connections and parameter ranges (see §§5.3 ff).

>SA (SAMPLING TIME) controls the rate at which information is sent to the studio (see §§3.4.2 and 4.2.

>ED (EDIT) makes changes to previously created BLOCK-files (see §§4.5ff); it can also be used to alter the default file 0 BIN, which is played if no definitions have been made with the composition program. In fact, this is the only way to control the number of generators and the wave-forms to be set on them.

Suppose, for example, that at the beginning of a run the user wishes to play music on generators 1 to 12 with wave-form 5; but in all other respects, the default file is to be used:

```
>ED                                use EDIT to change gen-
                                   erator and wave-form de-
:FG 1 12                           finitions

:WF 5

:

0     BIN OK

>PL                                play the result , with
                                   real-time control.
STOPPED IN SEG      1

>ED                                now try it with genera-
                                   tors 25 to 40.
:FG 25 40

:

0     BIN OK

>PL                                and play this.
```

N.B.

1) The commands:

```
>ED
```

and

```
>PL
```

always mean "Edit (or Play) the latest BLOCK-file created"; they refer to "0 BIN" only when no definitions for composition-program BLOCKS have been made. However:

```
>FP 0 1
```

restores the file-pointer to its position at the beginning of the run: the next BLOCK-file to be created will be "1 BIN", and therefore the latest file is "0 BIN", which is thus referenced by >ED and >PL.

Similarly, "0 BIN" can be accessed by renaming it:

```
>RN 0 7777                          "0 BIN" gets new name
                                    "7777 BIN".
>PL 7777                            play this
>ED 7777                            and edit it.
:etc.
```

2) At the start of a run file "0 BIN" on DK <IMP> is transferred to the user-defined disk-area, destroying any file "0" that may previously have been on this disk. If, therefore, a version of "0 BIN" which has been edited during one run is to be used in the next run too, it must be renamed before the start of the second run. For example:

```
$PIP
>R DK 777 BIN_DK 0 BIN
>etc.
```

>WR (WRITE) is used to inspect BLOCK-files, including default-file "0 BIN". See also §4.2.8.

5.9.2 Some of the operations performed in real-time can be saved for use in future runs with:

```
>PT n              ( = PUT)
>PT name
```

which creates a file "n IMP" on the user-defined disk area; the first such file created during a run is "1 IMP", the second is "2 IMP", and so on. Alternately, "name" may be used as file name.

"IMP" files contain:

1) the AD-store, i.e. the nine versions of the AD-table which have been saved with:

$\boxed{\begin{matrix}\text{SAVE}\\ \text{AD}\end{matrix}} \longrightarrow \boxed{1-9}$ or

```
>AD
:S n
```

2) the PAR-store, i.e. the nine versions of the Parameter-table which have been saved with:

$\boxed{\begin{matrix}\text{SAVE}\\ \text{PAR}\end{matrix}} \longrightarrow \boxed{1-9}$

3) the Joystick-store, i.e. the nine memory banks where Joystick movements and XX wave-structures have been stored with:

$\boxed{\begin{matrix}\text{JOY}\\ \text{REC}\end{matrix}} \longrightarrow \boxed{1-9}$

4) the Key(board)-store, i.e. nine memory banks where the pressings are stored (63 pressings in each bank)

$\boxed{\begin{matrix}\text{KEY}\\ \text{STORE}\end{matrix}} \longrightarrow \boxed{1-9}$

The numbering of these files can be directed with:

```
>FP 4 n
>FP 4 name
```

where "n" is a possible whole number specifying the name of <u>next</u> "IMP" file to be created, "name" if a file name (without extension).

5.9.3 Files created with PT can be accessed with:

```
>GT n              ( = GET)
```

where n is a positive whole number stating which "IMP" file is to be read in. The previous contents of the AD, PAR, and Joystick stores are destroyed and replaced with the information in the file.

If there is no file called "n IMP" on the user-defined disk, the program writes:

```
n IMP NOT FOUND
```

and control reverts to the program monitor.

5.10 Combining real-time facilities with the composition program

BLOCKS created with the composition-program can always be modified in real-time by the operations described in this chapter. Such modifications are not permanent: but each time a BLOCK is played, the same real-time control must be exercised if the musical result is to be the same.

Note the following points when combining real-time functions and BLOCK-files created with the composition program:

1) Make sure that any parameters which are to be controlled from a BLOCK-file are connected to zero in the AD-table.

2) All functions, switches and connections valid when PLAY is completed are also valid for the next PLAY. The only exceptions are FREEZE SOUND and ZERO DENSITY, which are off when PLAY begins.

5.11 To the definition of various scales.

Values are given in IMPAC input format.

acoustical	1	5	9	13	15	19	21	
golden mean	1	7	11	17				
gipsy 1	1	5	7	13	15	17	23	
gipsy 2	1	3	9	11	15	17	23	
super locrian	1	3	7	9	13	17	21	
neapolitan minor	1	3	7	11	15	17	23	
neapolitan major	1	3	7	11	15	19	23	
oriental	1	3	9	11	13	19	21	
enigmatic	1	3	9	13	17	21	23	
major locrian	1	5	9	11	13	17	21	
lydian minor	1	5	9	13	15	17	21	
leading whole	1	5	9	11	17	21	23	
hungarian major	1	7	9	13	15	19	21	
eight tone spanish	1	3	7	9	11	13	17	21
symmetrical	1	3	7	9	13	15	19	21

6 Survey of IMPAC files

6.1 BIN files are those which contain the information for user-defined blocks.

A BIN file consists of any number of binary records, each containing eleven data words:

word	contents
1 - 2	a single-precision floating-point number defining the start time in seconds of this activity - e.g. 1.5 denotes that this activity is to start 1.5" after the beginning of the block.
3	activity number - 40, 41, or 48.
4 - 11	information - type depends on activity number.

time act information

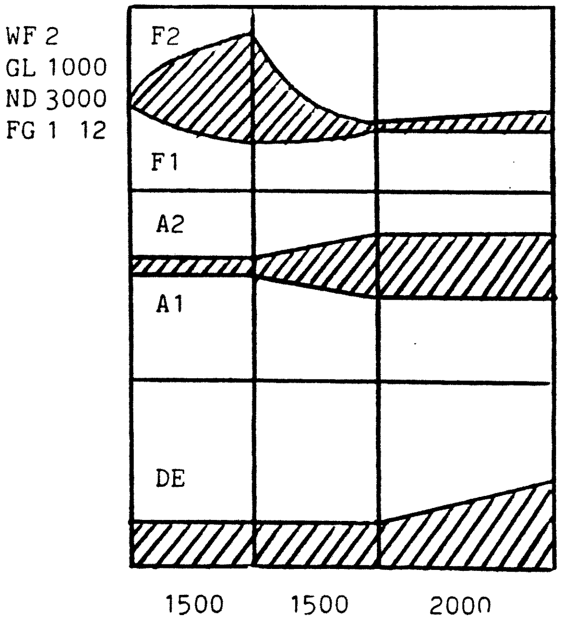
1 2	3	4	5	6	7	8	9	10	11	
TIME	48	LF	HF	LA	HA	DS	MI	MF	SS	start values
TIME	41	F1 to shape		F2 to shape		A1 to shape		A2 to shape		curve information
TIME	40	DE to shape		DU	FG1	FG2	WF	GL	ND	parameters & music

Activities 41 and 48 provide information for activity 40. Activity 40 causes music to be calculated and played in the studio. Each segment contains therefore one record of activity 40, optionally preceded by one record of activity 48 and/or one record of activity 41.

Within each segment, curves for primary parameters are calculated FROM either previous activity 41 or activity 48, TO current activity 41.

Here is an example of an IMPAC score and the instructions required to describe it:

```
>SE 3
>FG 1 12
>WF 2
>GL 1000
>ND 3000
>LF 400
>HF 440
>LA 300
>HA 320
>DS 10
>DU
:1500 1500 2000
>F1
:220 -1 296 -2 296 0
>F2
:700 2 315 -4 392 0
>A1
:300 0 280 0 280 0
>A2
:320 0 340 0 340 0
>DE
:10 0 10 0 20 0
```



The BIN file created when this is played looks like this:

```
0.0   48   400   440    300   320    10   0     0     0
0.0   41   220    -1    700     2   300   0   320     0
0.0   40    10     0   1500     1    12   2  1000  3000
1.5   41   296    -2    315    -4   280   0   340     0
1.5   40    10     0   1500     1    12   2  1000  3000
3.0   41   296     0    392     0   280   0   340     0
3.0   40    20     0   2000     1    12   2  1000  3000
```

N.B.
When BIN files are inspected with the WR command, the segment number is written at the beginning of each record; this is only for the convenience of the user - the segment number is not contained in the file.

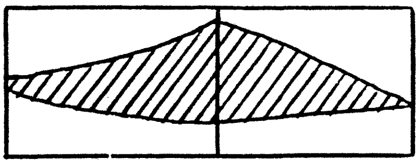
6. 2 It is possible for the user proficient in FORTRAN to create IMPAC block files externally. The following points should be noted:
1) IMPAC reads BIN files with FORTRAN unformatted READ statements.

```
DIMENSION IARRAY(9)
...
READ(12,END=999)TIME,IARRAY
```

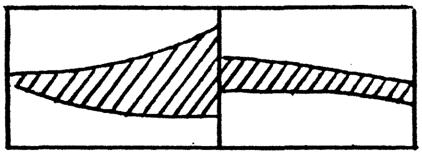
No checks are made to see if
  a) the file is in the correct mode (alphanumeric, binary, etc.)
  b) the records are of the correct length
  c) the parameter values are legal.
If the records are not of exactly the type required by IMPAC, the results will be unpredictable.

2) Activity 48 is not restricted to the beginning of a block; it can be used whenever a primary-parameter curve is to start at a point different from the one reached at the end of the previous activity 40. For example:

Here we need activities 48, 41 and 40 for the first segment, but only 41 and 40 for the second, since it starts with the values reached at the end of the first.



In this example, both segments require activities 48, 41 and 40, as the starting-point of segment 2 is not the end point of segment 1.



3) When music is played with the commands PL or PP, the start-time given in each record is ignored; each segment follows on as soon as the previous segment has been played. Only in conjunction with the MX facility are start-times of importance.

6.3 CON files contain data for studio connections, disconnections, amplifier intensities and reverberation time; they are executed with the command:

```
>CN n
```

where n is the number of the file to be performed. The five predefined CON files are discussed in §2.4.1.

A CON file consists of any number of binary records, each containing twenty-five data words.

word	contents
1 - 2	not used
3 - 25	function numbers (3,4,5 or 6) and data; a function number indicates that all following data is of that type, until another function number is given.

function	data
3	amplifier intensities; format in each word is AAIII, where AA is amplifier number (as in EMSDEV and DIP1) and III is the intensity in $\frac{1}{4}$-dB. For example: 20400: 100 dB on channel 2. 1360: 90 dB on reverberation unit 1.
4	studio connections; format in each word is FFTT, where FF is the number of the device which is to be connected to TT. For example: 7172: FG3 connected to FG6. 219: reverberation unit 2 connected to channel 1.
5	studio disconnections; format and numbering as for connections.
6	reverberation time; format of the data word: NNT, where N is the reverberation unit number and TT is time (0-15). E.g. 6,112 sets time 12 on rev. unit 1.
<3	there is no more data in this record.

For example, the following record connects four groups of generators to channels, 1,2,3 and 4 and reverberation units 1,2,3 and 4 respectively, and puts 100 dB on all of the channel output amplifiers:

0, 0, 3, 19400, 20400, 21400, 22400, 4, 7172, 7219, 7201, 7374, 7420, 7402, 7576, 7621, 7612, 7977, 8077, 7778, 8178, 8278, 8378, 7822, 7813.

Example of program to create IMPAC connection file :

```
          DIMENSION J(25),F(2)
          DATA F /2H99,4H CON/
C         obligatory :
          DATA J/0,0,
C         connections = function 4 followed by data words:
          9         4,7119,7220,7321,7422,7519,7620,7721,7822,
          9         7977,8077,8178,8278,8378,7201,7402,7613,7814,
C         intensities  = function 3 followed by data words:
          9         3,19400,20400,21400,22400
          CALL ENTER(2,F)
          WRITE(2)J
          CALL CLOSE(2)
          END
```

If the 25 data words are not enough to write your connection definitions, you have to declare a new array dimensioned to 25 again and write its content to the file, e.g.:

```
          DIMENSION J(25),F(2),K(25)
          DATA F /2H99,4H CON/
C         obligatory :
          DATA J/0,0,
C         connections = function 4 followed by data words:
          9         4,7119,7220,7321,7422,7519,7620,7721,7822,
          9         7977,8077,8178,8278,8378,7201,7402,7613,7814,
C         intensities  = function 3 followed by data words:
          9         3,19400,20400,21400,22400/
C         obligatory :
          DATA K/0,0,
C         reverberation time = function 6 followed by data words :
          9         6,112,208/
          CALL ENTER(2,F)
          WRITE(2)J
          WRITE(2)K
          CALL CLOSE(2)
          END
```

6.4 IMP files consist of one logical binary record containing 10,224 data words; they are written and read with FORTRAN unformatted I/O statements.

```
          INTEGER PARSTO,ADSTO,JOYSTO
          COMMON PARSTO(288),ADSTO(720),JOYSTO(9216), KEYSTO(567)
          ....
    C     PT - CREATE IMP FILE
    C
          WRITE(12)PARSTO,ADSTO,JOYSTO, KEYSTO
          ....
    C     GT - READ IN IMP FILE
    C
          READ(12)PARSTO,ADSTO,JOYSTO , KEYSTO
          ....
```

PARSTO has nine banks of thirty-two words each for storing the PAR table.

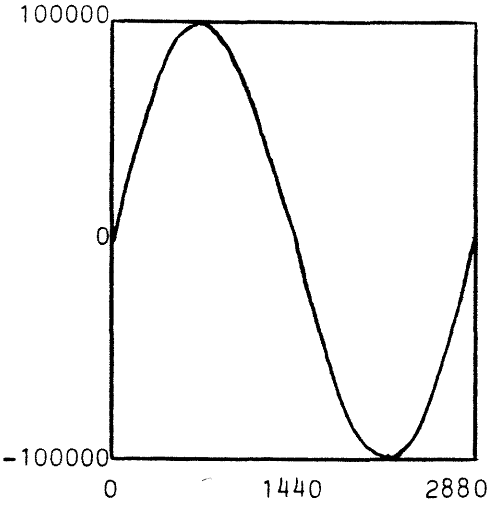
ADSTO has nine banks of eighty words each for storing the AD table.

JOYSTO has nine banks of 1024 words each for storing Joystick movements; the first word in each bank contains the number of coordinate pairs which have been recorded into the bank, minus 1023.

KEYSTO has nine banks of 63 words each containing even the time (i.e. the number of studio samples) between each pressing. The time between successive pressings should not exceed 1023 samples.

6.5 The sine-wave table

The real-time program`s sine-wave generator and the vibrato function on frequency generators are calculated by looking up values in the sine-wave table. This consists of 2880 integers, between -100000 and 100000, which describe one period of a sinus oscillation.



The sine-wave generator is merely a pointer moving through this table, its speed governed by the parameter SI; the higher the value for SI, the faster the pointer moves.

For calculation of vibrato, there is one pointer for each of the frequency generators; these pointers move independently of one another, their speed governed by VS.

N.B.
1) If a pointer moves with a speed of zero or 2880 it remains, in effect, still - the oscillation comes to a halt.
2) Values between 1440 and 2880 are mirror images of those between zero and 1440; so a speed of 2879 is the same as a speed of 1.

6.6 Special uses of the studio registers

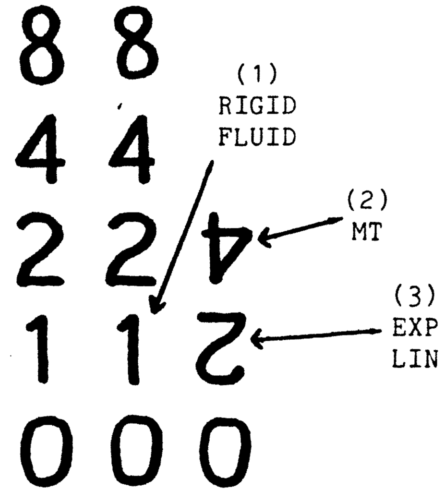
The studio registers for the noise generator and amplitude modulators are used for special purposes.

The noise-generator register shows the number of the most recently created BLOCK-file.

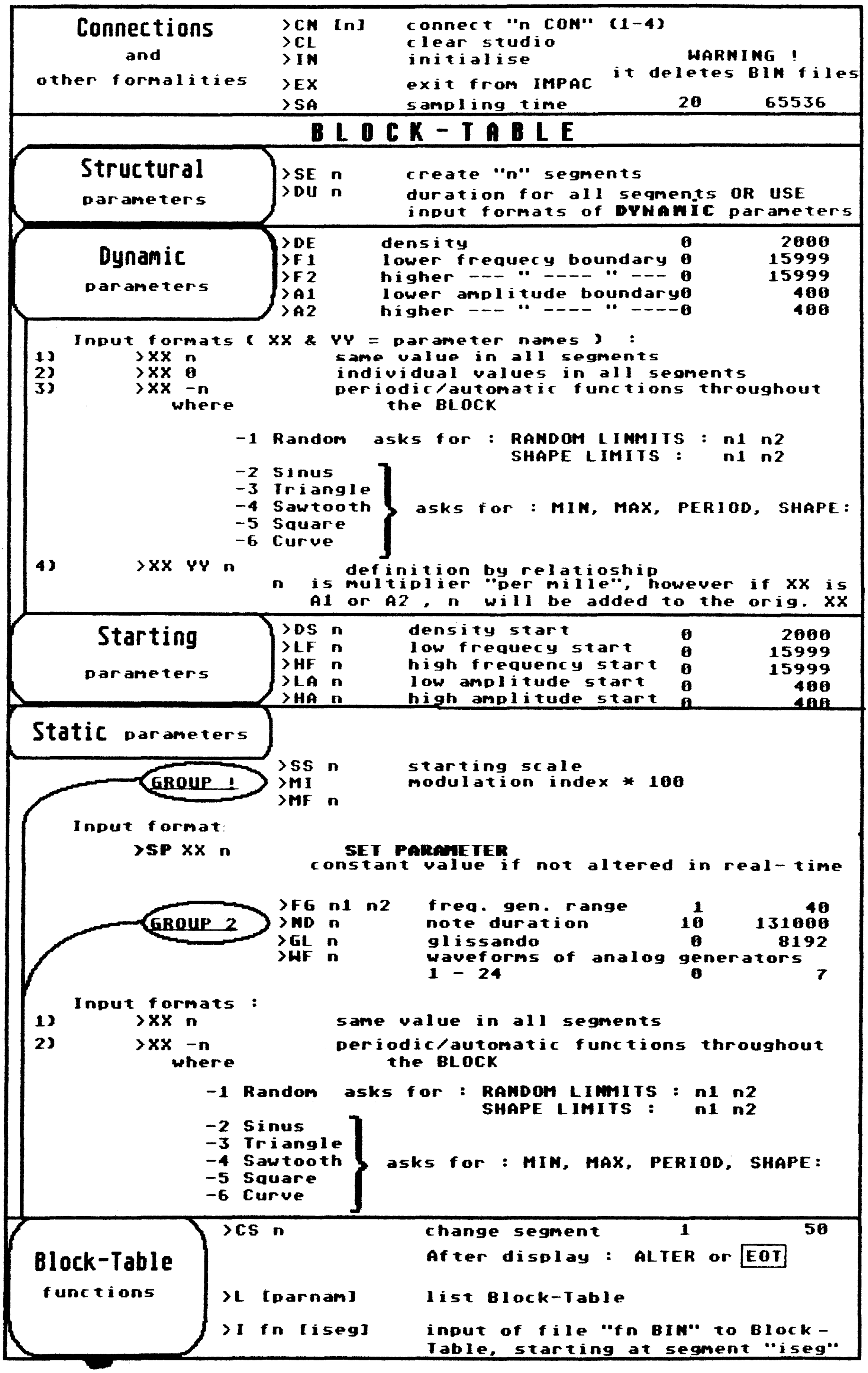
Amplitude-modulator 1 displays the sampling time in milliseconds. This is not the time defined by the user with "SA", but the actual time taken for calculations. See also §3.4.2.

Amplitude-modulator 2 displays the status of three switches:

1) on = RIGID
   off = FLUID
2) on = MT-switch on
   off = MT-switch off
3) on = exponential frequency distribution
   off = linear distribution



7 Summary



```
Connections          >CN [n]   connect "n CON" (1-4)
    and              >CL       clear studio
                     >IN       initialise                WARNING !
other formalities                                it deletes BIN files
                     >EX       exit from IMPAC
                     >SA       sampling time           20      65536
```

B L O C K - T A B L E

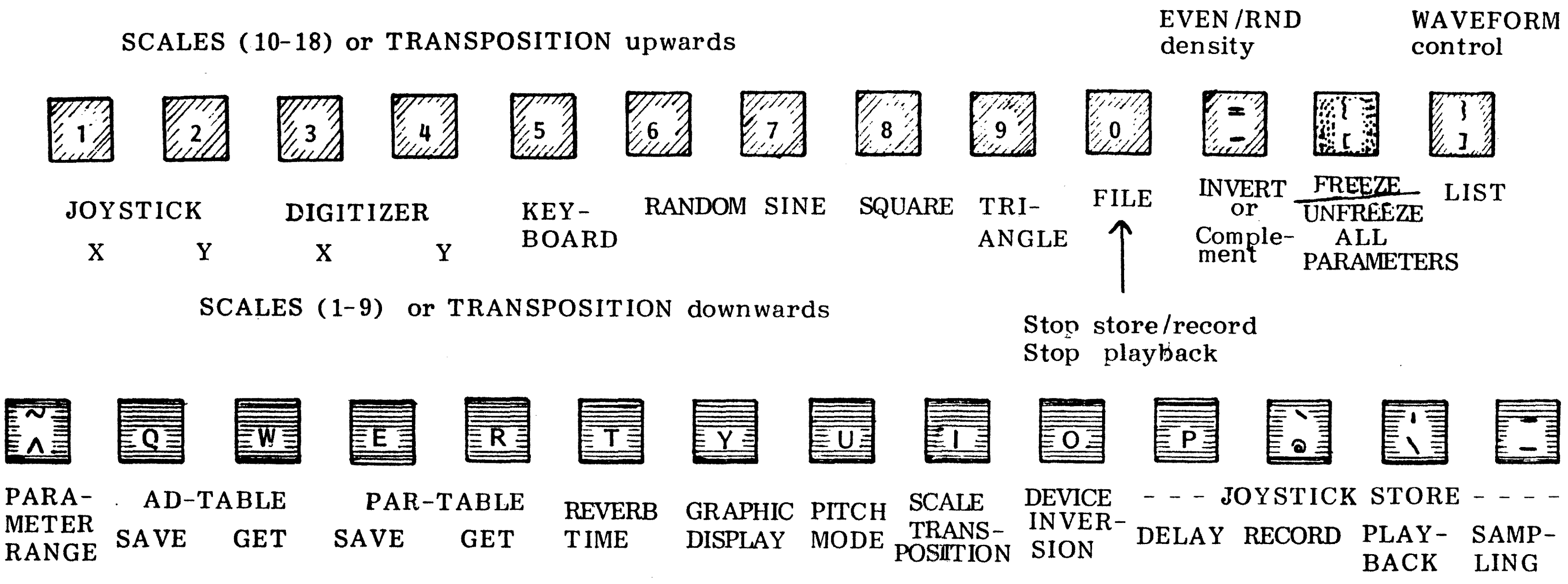
```
Structural           >SE n     create "n" segments
parameters           >DU n     duration for all seqments OR USE
                               input formats of DYNAMIC parameters

Dynamic              >DE       density                   0       2000
parameters           >F1       lower frequecy boundary   0      15999
                     >F2       higher --- " ---- " ---   0      15999
                     >A1       lower amplitude boundary0          400
                     >A2       higher --- " ---- " ----0          400

    Input formats ( XX & YY = parameter names )  :
1)       >XX n            same value in all segments
2)       >XX 0            individual values in all segments
3)       >XX -n           periodic/automatic functions throughout
            where                the BLOCK

                  -1 Random   asks for : RANDOM LINMITS : n1 n2
                                         SHAPE LIMITS :   n1 n2
                  -2 Sinus
                  -3 Triangle
                  -4 Sawtooth  } asks for : MIN, MAX, PERIOD, SHAPE:
                  -5 Square
                  -6 Curve
4)       >XX YY n           definition by relatioship
                      n  is multiplier "per mille", however if XX is
                         A1 or A2 , n  will be added to the orig. XX

Starting             >DS n     density start             0       2000
parameters           >LF n     low frequecy start        0      15999
                     >HF n     high frequency start      0      15999
                     >LA n     low amplitude start       0        400
                     >HA n     high amplitude start      0        400

Static parameters

                     >SS n     starting scale
      GROUP !        >MI       modulation index * 100
                     >MF n
    Input format:
          >SP XX n         SET PARAMETER
                         constant value if not altered in real-time

                     >FG n1 n2   freq. gen. range        1         40
      GROUP 2        >ND n       note duration          10     131000
                     >GL n       glissando               0       8192
                     >WF n       waveforms of analog generators
                                 1 - 24                  0          7
    Input formats :
1)       >XX n            same value in all segments
2)       >XX -n           periodic/automatic functions throughout
            where                the BLOCK

               -1 Random   asks for : RANDOM LINMITS : n1 n2
                                      SHAPE LIMITS :   n1 n2
               -2 Sinus
               -3 Triangle
               -4 Sawtooth  } asks for : MIN, MAX, PERIOD, SHAPE:
               -5 Square
               -6 Curve

Block-Table       >CS n            change segment         1          50
functions                          After display :  ALTER or [EOT]

                  >L [parnam]      list Block-Table

                  >I fn [iseg]     input of file "fn BIN" to Block-
                                   Table, starting at segment "iseg"
```

NOTE !! "fn" can be both numeric and non-numeric file name.

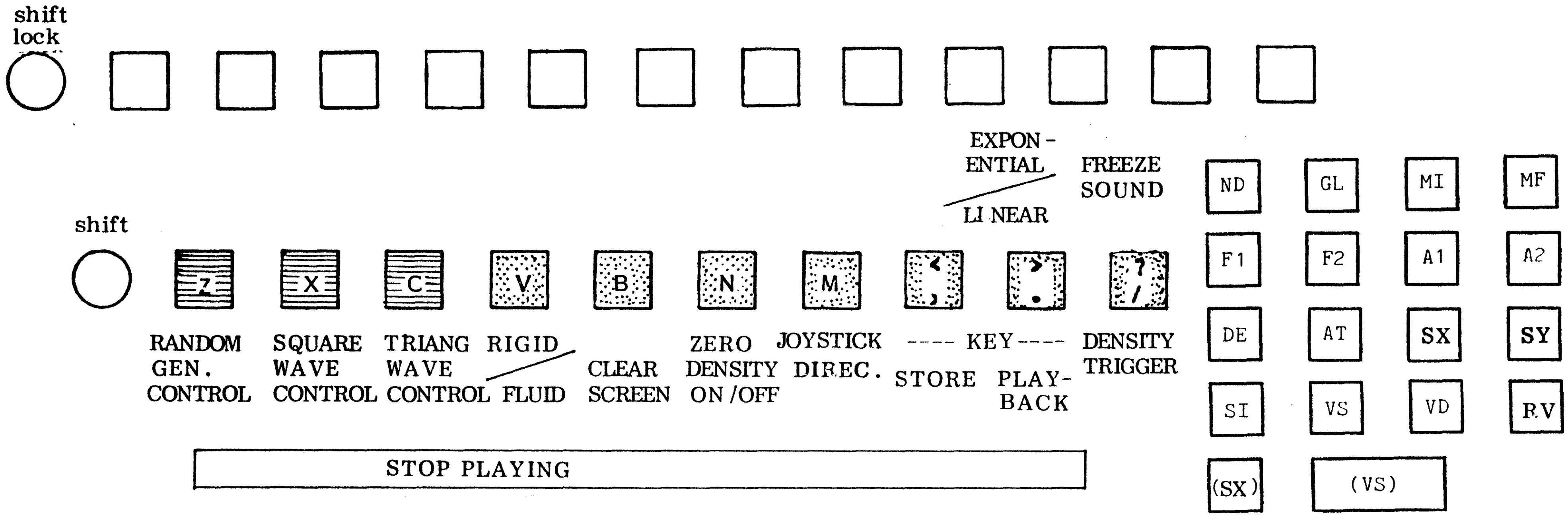
See ↓	BLOCK-file manipulations	
4.4	Playing and creating BLOCK-filen	>PL [fn] PLAY "fn BIN" >PP [fn] PLAY PART of "fn BIN" SEGMENTS:n1 n2 >PF [fn] PART FILE : create new file from SEGMENTS:n1 n2 part of existing one >RN fn1 fn2 RENAME : fn1=old name,fn2=new name >WR [fn] WRITE "fn BIN" >TM [fn] TIME: write duration of "fn BIN" - - - - - - - - - - - - - - - - >F↵ FILE : create new file named according to the current file pointer (see >FP)
4.4.6 4.6.2 5.9.2	Numbering of files	>FP n1 n2 FILE POINTER default n1 = 0 BLOCK files 1 BIN = 1 KEEP files 1000 BIN = 4 REAL-TIME STORE files 1 IMP n2 is number of next file to be created.
4.5	Internal FILE EDITOR Submonitor - Parameter commands - Other operations	>ED [fn] EDIT BLOCK-file "fn BIN" :DU n } multiplication factor (1059= 1.059) 0 131071 :DE n 0 131071 :F1 n 0 8192 :F2 n 0 8192 :A1 n } addition factor -400 400 :A2 n -400 400 :FG n1 n2 } new value 1 40 :WF n 0 7 :GL n 0 8192 :ND n 10 131000 : empty line= perform editing :SE n SEGMENT :D DELETE one segment :G fn n2 GET file "fn BIN" it appends "fn BIN" to current file n2= 0 : smooth transition n2= 1 no transition :AB ABORT - ORIGINAL FILE KEPT : EOT ABORT
4.6	Horizontal mixing	>KP fn n2 KEEP "fn BIN" n2= 0 : smooth transition

Monitor commands affecting real-time control

See ↓					
	AD-table submonitor	>AD n	ANALOGUE DEVICE connect to device n		
5.3	- Parameter ranges	:ND n1 n2		10	131000
		:GL n1 n2		0	8192
		:MI n1 n2		0	4095
		:MF n1 n2		0	2000
		:F1 n1 n2		0	15999
		:F2 n1 n2		0	15999
		:A1 n1 n2		0	400
		:A2 n1 n2		0	400
		:DE n1 n2		0	2000
		:AT n1 n2		0	131000
		:RV n1 n2		0	400
		:SI n1 n2		0	2880
		:VS n1 n2		0	2880
		:VD n1 n2		0	1000
	- Other operations	:L	LIST AD-table		
		:S n	SAVE table to AD-store	1	9
		:G n	GET table from AD-store	1	9
5.3.2		:AD n	ANALOGUE DEVICE 1-9: connect to device and define range 0: connect to BLOCK-file (no range definition) -1: put all parameter/device connections to zero 10: alter ranges only (no connections)		
		:↲	empty line returns to program monitor.		
4.1.4	Fixed values on real-time parameters (no file output by setting this parameters)	>SP pn [n]	SET PARAMETERS "pn" with value "n" pn→ ND GL MI MF F1 F2 A1 A2 DE AT SX SY SI VS VD RV "n" must be legal value as in AD above If "n" is undefined, negative or zero, current value printed - define new value or EOT to keep old one		
5.9	Real-time store save and get	>PT [fn]	PUT current AD-store, PAR-store, joystick - and Key-store on to a file named by the current file pointer or "fn IMP"		
	IMP	>GT n or >GT fn	GET file "n IMP" or "fn IMP" created with PT into real-time stores		
	SCA	>PT fn 1	PUT current SCALE-table on to file "fn SCA"		
		>GT fn 1	GET file "fn SCA" in to SCALE TABLE		
6.5	Memory inspect and modify	>RM n	READ MEMORY - 32 words, starting at octal address "n", are printed : carriage return= continue : EOT = return to program monitor		
		>WM n1 n2	WRITE MEMORY - octal value n2 is put into word at octal address n1.		



MANUAL 3: KEYBOARD (DEVICE 5)


shift lock
EXPONENTIAL
LINEAR
FREEZE SOUND
ND
GL
MI
MF
F1
F2
A1
A2
DE
AT
SX
SY
SI
VS
VD
RV
(SX)
(VS)
shift
Z
X
C
V
B
N
M
<
,
>
.
?
/
RANDOM GEN. CONTROL
SQUARE WAVE CONTROL
TRIANG WAVE CONTROL
RIGID
FLUID
CLEAR SCREEN
ZERO DENSITY ON/OFF
JOYSTICK DIREC.
---- KEY ----
STORE
PLAY-BACK
DENSITY TRIGGER
STOP PLAYING