Faust Quick Reference

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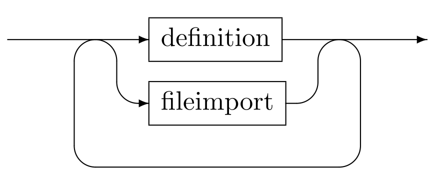
1 Introduction

This document is a quick-reference to the Faust language (version 0.9.4), a programming language for real-time signal processing and synthesis that targets high-performance signal processing applications and audio plugins.

2 Faust program

A Faust program describes a *signal processor* that transforms input signals into output signals. A Faust program is made of one or more source files. A source file is essentially a list of *definitions* with the possibility to recursively import definitions from other source files. Each definition associates an identifier (with an optional list of parameters) with a *block-diagram* that it represents.

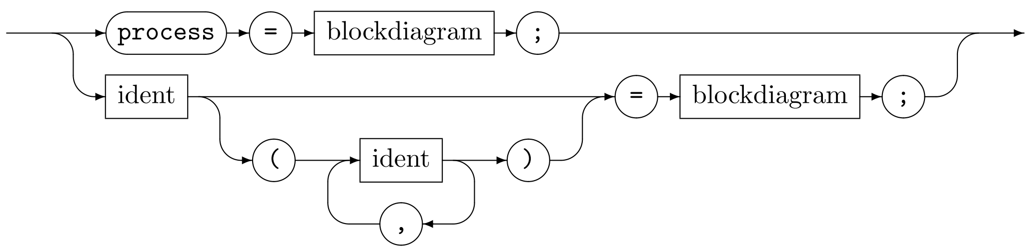
program



2.1 Definitions

A valid Faust program must contain at least one definition for the keyword *process* (the equivalent of *main* in C) . Definitions can appear in any order. In particular an identifier can be used before being defined. But recursive definitions are not allowed and generate error messages. Multiple definitions of the same identifier generate warning messages.

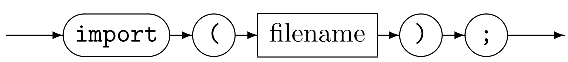
definition



2.2 File Imports

File imports allow to add the definitions of another source file to the definitions of the current file. File imports can appear every where in a source file and in any order. Mutual recursive imports are allowed and handled correctly.

fileimport



It is common for a Faust program to import the definitions of math.lib and music.lib files by including the lines : `import`(”`math.lib`”); and `import`(”`music.lib`”);.

3 Block-Diagrams

Faust is a *block-diagram* language. Specific *composition operations* are used to ”connect” two block-diagrams together in order to form a new one. For example the sequential composition operation (’:’) connect the outputs of the first block-diagram to the corresponding inputs of the second block-diagram. Five high-level composition operations are provided : *recursive composition*, *parallel composition*, *sequential composition*, *split composition* and *merge composition*. Moreover a block-diagram can have an associated set of local definitions.

Syntax	**Pri.**	**Description**
blockdiagram $\sim$ *blockdiagram*	4	recursive composition
blockdiagram `,` *blockdiagram*	3	parallel composition
blockdiagram `:` *blockdiagram*	2	sequential composition
blockdiagram `<:` *blockdiagram*	1	split composition
blockdiagram `:>` *blockdiagram*	1	merge composition
blockdiagram `with` { *definition* ...}	0	local definitions
expression		block-diagrams are made of expressions

All these composition operations are left associative. Based on these associativity and priority rules the block-diagram : $\texttt{A} : \texttt{B}, \texttt{C} \sim \texttt{D}, \texttt{E} :> \texttt{F}$ should be interpreted as: $(\texttt{A} : ((\texttt{B}, (\texttt{C} \sim \texttt{D})), \texttt{E})) :> \texttt{F}$.

4 Expressions

Faust *Expressions* provide *syntactic sugar* allowing traditional infix notation and function calls. For example instead of : $2, \texttt{A} : *, \texttt{B} : +$ one can write the infix expression : $2 * \texttt{A} + \texttt{B}$. Or instead of : $\texttt{A}$: sin one can use the function call notation : sin($\texttt{A}$).

Syntax	**Pri.**	**Description**
expression`(`*arg*`,...)`	10	function call
expression`.`*ident*	10	access to lexical environment
expression`'`	9	one sample delay
expression `@` *expression*	8	fixed delay
expression `*` *expression*	7	multiplication
expression `/` *expression*	7	division
expression `%` *expression*	7	modulo
expression `&` *expression*	7	logical and
expression $\wedge$ *expression*	7	logical xor
expression `<<` *expression*	7	arithmetic left shift
expression `>>` *expression*	7	arithmetic right shift
expression `+` *expression*	6	addition
expression `-` *expression*	6	substraction
expression `|` *expression*	6	logical or
expression `<` *expression*	5	less than
expression `<=` *expression*	5	less or equal
expression `>` *expression*	5	greater than
expression `>=` *expression*	5	greater or equal
expression `==` *expression*	5	equal
expression `!=` *expression*	5	not equal
primitive		expressions are made of primitives

Binary operators can also be used in function call notation. For example $+(2, \texttt{A})$ is equivalent to $2 + \texttt{A}$. Moreover partial applications are allowed like in $*(3)$.

5 Primitive Signal Processing Operations

The primitive signal processing operations represent the built-in functionalities of Faust, that is the atomic operations provided by the language. All these primitives (and the block-diagrams build on top of them) denote *signal processors*, functions transforming *input signals* into *output signals*. Let's define more precisely what a *signal processor* is.

A *signal* s is a discrete function of time $s : \mathbb{N} \rightarrow \mathbb{R}$. The value of signal s at time t is written $s(t)$. We denote by $\mathbb{S}$ the set of all possible signals : $\mathbb{S} = \mathbb{N} \rightarrow \mathbb{R}$. A n-tuple of signals is written $(s_1, \ldots, s_n) \in \mathbb{S}^n$. The *empty tuple*, single element of $\mathbb{S}^0$ is notated $()$. A *signal processors* p is a function from n-tuples of signals to m-tuples of signals $p : \mathbb{S}^n \rightarrow \mathbb{S}^m$. We notate $\mathbb{P}$ the set of all signal processors : $\mathbb{P} = \bigcup_{n,m} \mathbb{S}^n \rightarrow \mathbb{S}^m$.

All primitives and block-diagram expressed in Faust are members of $\mathbb{P}$ (i.e. signal processors) including numbers. For example number 3.14 doesn't represent neither a sample, nor a signal, but a *signal processor* : $\mathbb{S}^0 \rightarrow \mathbb{S}^1$ that transforms the empty tuple () into a 1-tuple of signals (s) such that $\forall t \in \mathbb{N}, s(t) = 3.14$.

5.1 C-equivalent primitives

Most Faust primitives are analogue to their C counterpart but lifted to signal processing. For example $+$ is a function of type $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ that transforms a pair of signals (x_1, x_2) into a 1-tuple of signals (y) such that $\forall t \in \mathbb{N}, y(t) = x_1(t) + x_2(t)$.

Syntax	**Type**	**Description**
n	$\mathbb{S}^0 \rightarrow \mathbb{S}^1$	integer number: $y(t) = n$
$n.m$	$\mathbb{S}^0 \rightarrow \mathbb{S}^1$	floating point number: $y(t) = n.m$
`_`	$\mathbb{S}^1 \rightarrow \mathbb{S}^1$	identity function: $y(t) = x(t)$
`!`	$\mathbb{S}^1 \rightarrow \mathbb{S}^0$	cut function: $\forall x \in \mathbb{S}, (x) \rightarrow ()$
`int`	$\mathbb{S}^1 \rightarrow \mathbb{S}^1$	cast into an int signal: $y(t) = (int)x(t)$
`float`	$\mathbb{S}^1 \rightarrow \mathbb{S}^1$	cast into an float signal: $y(t) = (float)x(t)$
`+`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	addition: $y(t) = x_1(t) + x_2(t)$
`-`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	substraction: $y(t) = x_1(t) - x_2(t)$
`*`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	multiplication: $y(t) = x_1(t) * x_2(t)$
`/`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	division: $y(t) = x_1(t)/x_2(t)$
`%`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	modulo: $y(t) = x_1(t)\%x_2(t)$
`&`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	logical AND: $y(t) = x_1(t)\&x_2(t)$
`|`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	logical OR: $y(t) = x_1(t) \vert x_2(t)$
$\wedge$	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	logical XOR: $y(t) = x_1(t) \wedge x_2(t)$
`<<`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	arith. shift left: $y(t) = x_1(t) << x_2(t)$
`>>`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	arith. shift right: $y(t) = x_1(t) >> x_2(t)$
`<`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	less than: $y(t) = x_1(t) < x_2(t)$
`<=`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	less or equal: $y(t) = x_1(t) <= x_2(t)$
`>`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	greater than: $y(t) = x_1(t) > x_2(t)$
`>=`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	greater or equal: $y(t) = x_1(t) >= x_2(t)$
`==`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	equal: $y(t) = x_1(t) == x_2(t)$
`!=`	$\mathbb{S}^2 \rightarrow \mathbb{S}^1$	different: $y(t) = x_1(t)! = x_2(t)$

5.2 `math.h`-equivalent primitives

Most of the C `math.h` functions are also built-in as primitives (the others are defined as external functions in file `math.lib`).

Syntax	**Type**	**Description**
`acos`	$\mathbb{S}^1 \to \mathbb{S}^1$	arc cosine: $y(t) = \mathrm{acosf}(x(t))$
`asin`	$\mathbb{S}^1 \to \mathbb{S}^1$	arc sine: $y(t) = \mathrm{asinf}(x(t))$
`atan`	$\mathbb{S}^1 \to \mathbb{S}^1$	arc tangent: $y(t) = \mathrm{atanf}(x(t))$
`atan2`	$\mathbb{S}^2 \to \mathbb{S}^1$	arc tangent of 2 signals: $y(t) = \mathrm{atan2f}(x_1(t), x_2(t))$
`cos`	$\mathbb{S}^1 \to \mathbb{S}^1$	cosine: $y(t) = \mathrm{cosf}(x(t))$
`sin`	$\mathbb{S}^1 \to \mathbb{S}^1$	sine: $y(t) = \mathrm{sinf}(x(t))$
`tan`	$\mathbb{S}^1 \to \mathbb{S}^1$	tangent: $y(t) = \mathrm{tanf}(x(t))$
`exp`	$\mathbb{S}^1 \to \mathbb{S}^1$	base-e exponential: $y(t) = \mathrm{expf}(x(t))$
`log`	$\mathbb{S}^1 \to \mathbb{S}^1$	base-e logarithm: $y(t) = \mathrm{logf}(x(t))$
`log10`	$\mathbb{S}^1 \to \mathbb{S}^1$	base-10 logarithm: $y(t) = \mathrm{log10f}(x(t))$
`pow`	$\mathbb{S}^2 \to \mathbb{S}^1$	power: $y(t) = \mathrm{powf}(x_1(t), x_2(t))$
`sqrt`	$\mathbb{S}^1 \to \mathbb{S}^1$	square root: $y(t) = \mathrm{sqrtf}(x(t))$
`abs`	$\mathbb{S}^1 \to \mathbb{S}^1$	absolute value (int): $y(t) = \mathrm{abs}(x(t))$
		absolute value (float): $y(t) = \mathrm{fabsf}(x(t))$
`min`	$\mathbb{S}^2 \to \mathbb{S}^1$	minimum: $y(t) = \min(x_1(t), x_2(t))$
`max`	$\mathbb{S}^2 \to \mathbb{S}^1$	maximum: $y(t) = \max(x_1(t), x_2(t))$
`fmod`	$\mathbb{S}^2 \to \mathbb{S}^1$	float modulo: $y(t) = \mathrm{fmodf}(x_1(t), x_2(t))$
`remainder`	$\mathbb{S}^2 \to \mathbb{S}^1$	float remainder: $y(t) = \mathrm{remainderf}(x_1(t), x_2(t))$
`floor`	$\mathbb{S}^1 \to \mathbb{S}^1$	largest int $\leq$: $y(t) = \mathrm{floorf}(x(t))$
`ceil`	$\mathbb{S}^1 \to \mathbb{S}^1$	smallest int $\geq$: $y(t) = \mathrm{ceilf}(x(t))$
`rint`	$\mathbb{S}^1 \to \mathbb{S}^1$	closest int: $y(t) = \mathrm{rintf}(x(t))$

5.3 Delay, Table, Selector primitives

The following primitives allow to define fixed delays, read-only and read-write tables and 2 or 3-ways selectors (see figure 1).

Syntax	**Type**	**Description**
`mem`	$\mathbb{S}^1 \to \mathbb{S}^1$	1-sample delay: $y(t+1) = x(t), y(0) = 0$
`prefix`	$\mathbb{S}^2 \to \mathbb{S}^1$	1-sample delay: $y(t+1) = x_2(t), y(0) = x_1(0)$
`@`	$\mathbb{S}^2 \to \mathbb{S}^1$	fixed delay: $y(t + x_2(t)) = x_1(t), y(t < x_2(t)) = 0$
`rdtable`	$\mathbb{S}^3 \to \mathbb{S}^1$	read-only table: $y(t) = T[r(t)]$
`rwtable`	$\mathbb{S}^5 \to \mathbb{S}^1$	read-write table: $T[w(t)] = c(t); y(t) = T[r(t)]$
`select2`	$\mathbb{S}^3 \to \mathbb{S}^1$	select between 2 signals: $T[] = \{x_0(t), x_1(t)\}; y(t) = T[s(t)]$
`select3`	$\mathbb{S}^4 \to \mathbb{S}^1$	select between 3 signals: $T[] = \{x_0(t), x_1(t), x_2(t)\}; y(t) = T[s(t)]$

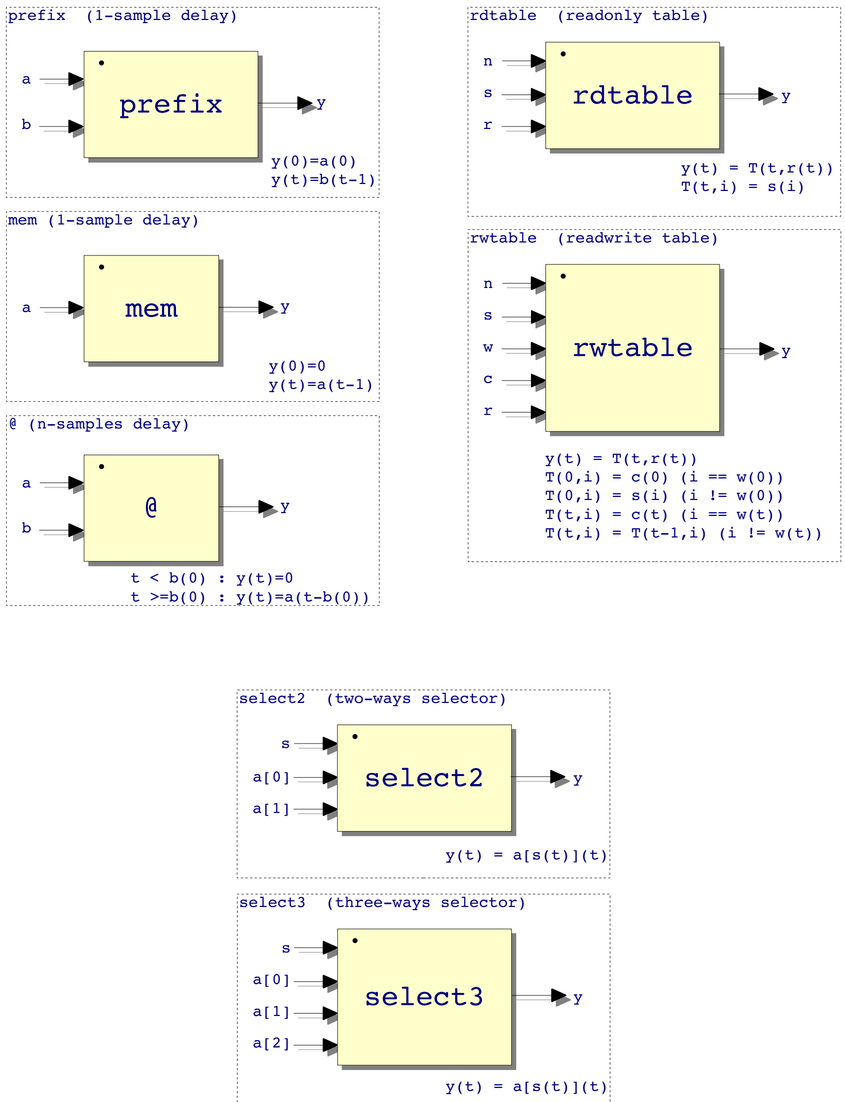


Figure 1: Delays, tables and selectors primitives

5.4 User Interface Elements

Faust user interface widgets allow an abstract description of the user interface from within the Faust code. This description is independent of any GUI toolkits. It is based on *buttons*, *checkboxes*, *sliders*, etc. that are grouped together vertically and horizontally using appropriate grouping schemes.

All these GUI elements produce signals. A button for example (see figure 2) produces a signal which is 1 when the button is pressed and 0 otherwise. These signals can be freely combined with other audio signals.

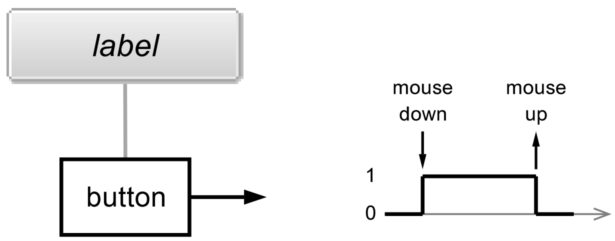


Figure 2: User Interface Button

Syntax	**Example**
`button(`*str*`)`	`button("play")`
`checkbox(`*str*`)`	`checkbox("mute")`
`vslider(`*str*`,`*cur*`,`*min*`,`*max*`,`*step*`)`	`vslider("vol",50,0,100,1)`
`hslider(`*str*`,`*cur*`,`*min*`,`*max*`,`*step*`)`	`hslider("vol",0.5,0,1,0.01)`
`nentry(`*str*`,`*cur*`,`*min*`,`*max*`,`*step*`)`	`nentry("freq",440,0,8000,1)`
`vgroup(`*str*`,`*block-diagram*`)`	`vgroup("reverb", ...)`
`hgroup(`*str*`,`*block-diagram*`)`	`hgroup("mixer", ...)`
`tgroup(`*str*`,`*block-diagram*`)`	`vgroup("parametric", ...)`
`vbargraph(`*str*`,`*min*`,`*max*`)`	`vbargraph("input",0,100)`
`hbargraph(`*str*`,`*min*`,`*max*`)`	`hbargraph("signal",0,1.0)`

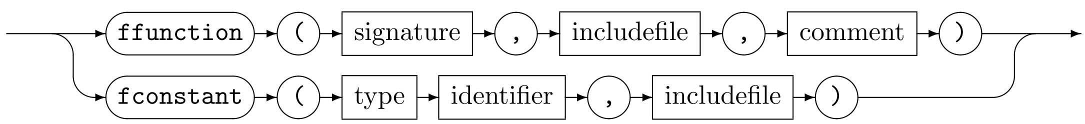
note : The *str* string used in widgets can contain variable parts. These variable parts are indicated by the sign '%' followed by the name of a variable. For example `par(i,8,hslider("Voice %i", 0.9, 0, 1, 0.01))` creates 8 different sliders in parallel : `hslider("Voice 0", 0.9, 0, 1, 0.01)`, `hslider("Voice 1", 0.9, 0, 1, 0.01)`,...,`hslider("Voice 7", 0.9, 0, 1, 0.01)`.

An escape mechanism is provided. If the sign '%' is followed by itself, it will be included in the resulting string. For example `"feedback (%%)"` will result in `"feedback (%)"`.

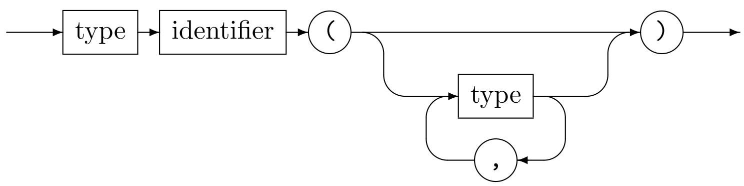
5.5 Foreign Functions and Constants

Any C function or constant can be introduced using the foreign function mechanism. It allows to declare an external C function by indicating its name and signature as well as the required include file. The syntax of foreign function and foreign constant declarations is the following :

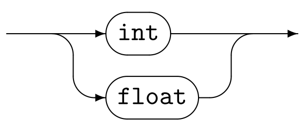
foreign



signature



type



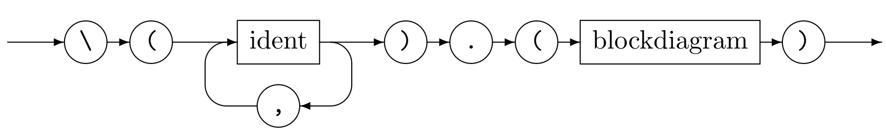
The file math.lib included in the Faust package defines most of the standard mathematical function of <math.h> (that are not already builtins) using the foreign function mechanism. Here is the list of these functions :

Name	Definition
SR	fconstant(int fSamplingFreq, <math.h>)
PI	3.1415926535897932385
cbrt	ffunction(float cbrt (float), <math.h>,"")
hypot	ffunction(float hypot (float, float), <math.h>,"")
ldexp	ffunction(float ldexp (float, int), <math.h>,"")
scalb	ffunction(float scalb (float, float), <math.h>,"")
log1p	ffunction(float log1p (float), <math.h>,"")
logb	ffunction(float logb (float), <math.h>,"")
ilogb	ffunction(int ilogb (float), <math.h>,"")
expm1	ffunction(float expm1 (float), <math.h>,"")
acosh	ffunction(float acosh (float), <math.h>, "")
asinh	ffunction(float asinh (float), <math.h>, "")
atanh	ffunction(float atanh (float), <math.h>, "")
sinh	ffunction(float sinh (float), <math.h>, "")
cosh	ffunction(float cosh (float), <math.h>, "")
tanh	ffunction(float tanh (float), <math.h>,"")
erf	ffunction(float erf(float), <math.h>,"")
erfc	ffunction(float erfc(float), <math.h>,"")
gamma	ffunction(float gamma(float), <math.h>,"")
J0	ffunction(float j0(float), <math.h>,"")
J1	ffunction(float j1(float), <math.h>,"")
Jn	ffunction(float jn(int, float), <math.h>,"")
lgamma	ffunction(float lgamma(float), <math.h>,"")
Y0	ffunction(float y0(float), <math.h>,"")
Y1	ffunction(float y1(float), <math.h>,"")
Yn	ffunction(float yn(int, float), <math.h>,"")
isnan	ffunction(int isnan (float),<math.h>,"")
nextafter	ffunction(float nextafter(float, float),<math.h>,"")

5.6 Special constructions

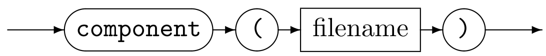
Additionally several "special" constructions are provides.

Abstraction



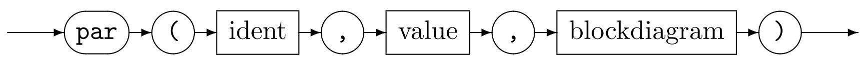
Abstractions allow to define anonymous functions like for example a square function : $\backslash(x).(x * x)$.

Component

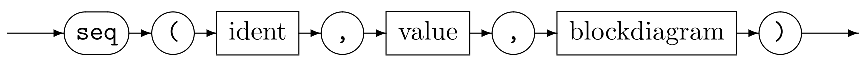


The *component* construction allows to include a whole Faust program as a single expression in another program.

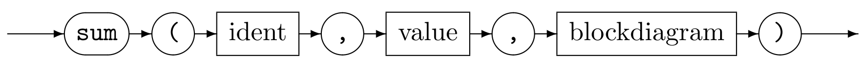
par



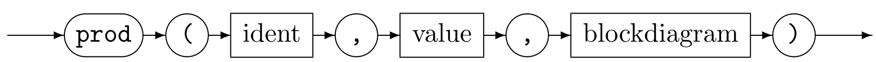
seq



sum



prod



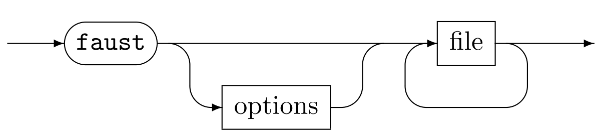
The `par`, `seq`, `sum` and `prod` constructions allow algorithmic descriptions of block-diagrams. For example :

`par(i,8,E(i))`	is equivalent to	`E(0),E(1),...,E(7)`
`seq(i,8,E(i))`	is equivalent to	`E(0):E(1):...:E(7)`
`sum(i,8,E(i))`	is equivalent to	`E(0)+E(1)+...+E(7)`
`prod(i,8,E(i))`	is equivalent to	`E(0)*E(1)*...*E(7)`

6 Invoking the Faust compiler

The Faust compiler is invoked using the `faust` command. It translate Faust programs into C++ code. The generated code can be wrapped into an optional *architecture file* allowing to directly produce a fully operational program.

compiler



Compilation options are listed in the following table :

Short	**long**	**Description**
`-h`	`--help`	print the help message
`-v`	`--version`	print version information
`-d`	`--details`	print compilation details
`-ps`	`--postscript`	generate block-diagram postscript file
`-svg`	`--svg`	generate block-diagram svg file
`-lb`	`--left-balanced`	generate left-balanced expressions
`-mb`	`--mid-balanced`	generate mid-balanced expressions (default)
`-rb`	`--right-balanced`	generate right-balanced expressions
`-a` *file*		C++ wrapper file
`-o` *file*		C++ output file

The main available architecture files are :

File name	**Description**
`max-msp.cpp`	Max/MSP plugin
`vst.cpp`	VST plugin
`jack-gtk.cpp`	Jack GTK full application
`alsa-gtk.cpp`	Alsa GTK full application
`ladspa.cpp`	LADSPA plugin
`q.cpp`	Q language plugin
`sndfile.cpp`	soundfile transformation command
`bench.cpp`	speed benchmark

Here is an example of compilation command that generates the C++ source code of a Jack application using the GTK graphic toolkit:

`faust -a jack-gtk.cpp -o freeverb.cpp freeverb.dsp`.