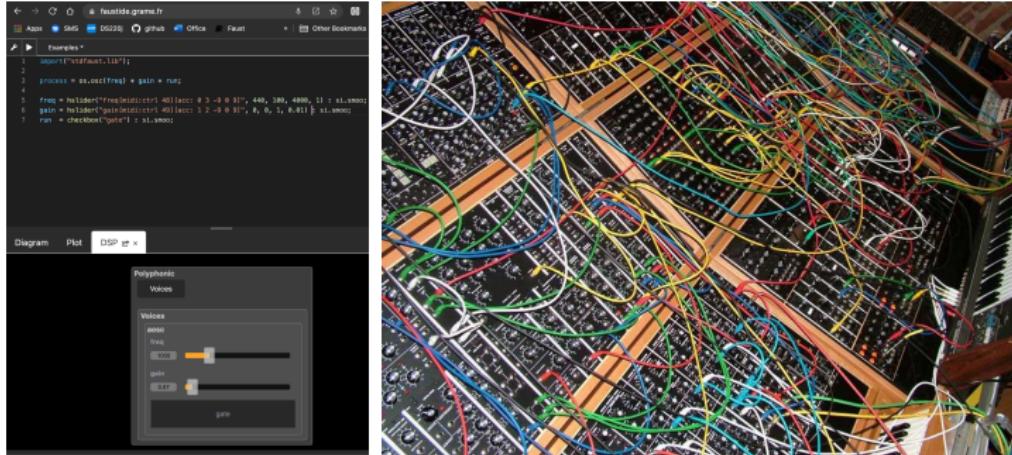




Functional
Audio
Stream

The Faust Programming Language

What is Faust (<https://faust.grame.fr>) ?



Faust is a programming language for signal processing, sound synthesis, electronic music instruments, etc.

Making Realtime Audio Programming Accessible

- *"Faust is amazing! Without Faust, I could never have started making plugins. Community is fantastic!"*
- *"Faust is a really efficient and versatile language, with lots of tools and supported targets. The syntax makes the use of the language easier, also for people with no strong background in programming."*

The screenshot shows a news article from the French government's website. The URL in the address bar is <http://www.education.gouv.fr/pid/1502/2022>. The page title is "Remise des prix science ouverte du logiciel libre de la recherche". The text on the page discusses the awarding of the prize to various open-source software projects for their contributions to scientific research. The sidebar on the left includes links for "Sommaire", "The Coq proof assistant", "Faust", "Gammapy", and "Jury".

Faust awarded with the 2022
Open Source Software for Open Science Research Prize

Faust is Fully Compiled

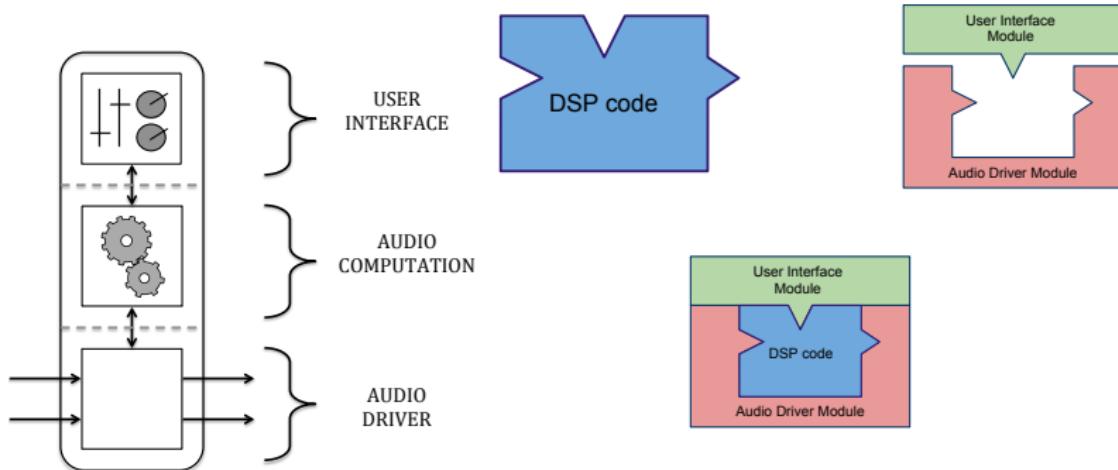
- Fully compiled to native code
- Sample level semantics
- Multiple backends: C++, WebAssembly, Rust, LLVM, etc.
- Code runs on most platforms: embedded systems, web pages, mobile devices, plug-ins, standalone applications, FPGAs, etc.



Architectures and Deployment

Separation of concern

The *architecture file* describes how to connect the audio computation to the external world.

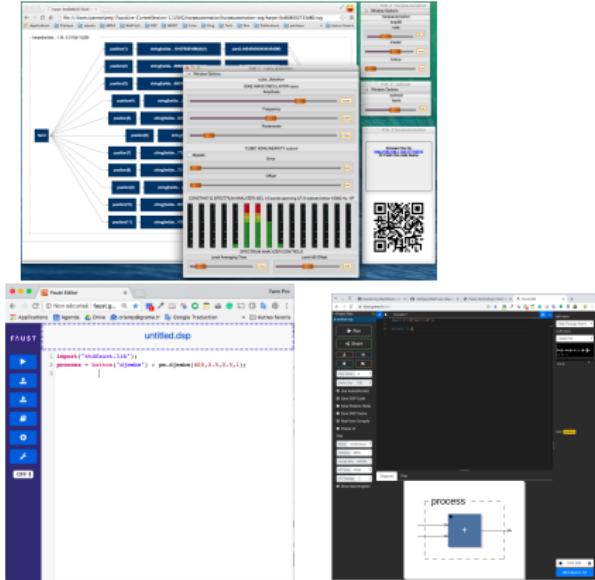
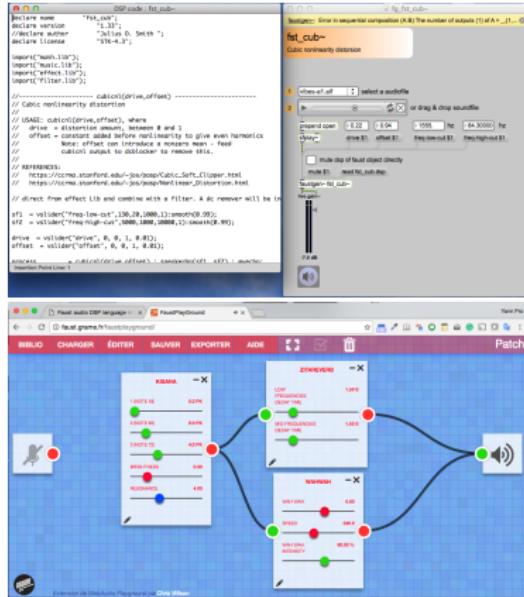


The Faust Ecosystem

Compilers

- Command Line Compilers
 - ▶ `faust` command line
 - ▶ `faust2xxx` command line
 - ▶ FaustWorks (IDE)
- Embedded Compilers (libfaust)
 - ▶ FaustLive (self contained)
 - ▶ Faustgen for Max/MSP
 - ▶ Faustcompile, etc. for Csound (V. Lazzarini)
 - ▶ Faust4processing
 - ▶ Antescofo (IRCAM's score follower)
- Web Based Compilers
 - ▶ Online documentation (<https://faustdoc.grame.fr>)
 - ▶ Faustplayground (<https://faustplayground.grame.fr>)
 - ▶ Online IDE (<https://faustide.grame.fr>)

The Faust Ecosystem



Quick Demo

Scan the QR code with your smartphone



- <https://tinyurl.com/45sxjt5m>
- <https://faustide.grame.fr/?autorun=1&code=https://raw.githubusercontent.com/orlarey/wahoo/master/examples/wahoo.dsp>

Documentation, Examples, etc.

<https://faust.grame.fr>



```
FAUST Home Documentation Downloads Tools Community Projects About Q Search
1 mesh.square[1] = 202 zita
2   sl.bus(4) <- par(1,4,*(-1)) <- sl.bus(4)) :> sl.bus(4); 203 {(
3 // dequantizer with square wave
4   204 with
5 mesh.square[0] = sl.bus(4**N); 205
6   206 || 207
7   ->fsmc, fsmcheck(N/2)); 208
8 }
```

What is Faust?

Faust (Functional Audio Script) is a functional programming language for sound synthesis and audio processing with a strong focus on the design of signal processing components, audio effects, etc. created at the [Institute for New Media & Department](#). Faust targets high-performance signal processing applications and audio plug-ins for a variety of platforms and standards.

The core component of Faust is its compiler. It allows to "translate" any Faust digital signal processing (DSP) specification to a wide range of non-domain specific languages such as C++, C, LLVM IR code, WebAssembly, JavaScript, etc. In this regard, Faust can be seen as an alternative to C++ but to much simpler and intuitive to learn.

Thanks to a wrapping system called "architectures," codes generated by Faust can be easily compiled into a wide variety of objects ranging from audio plug-ins to standalone applications or smartphone and web apps, etc.



Powered By Faust

This page lists the projects using Faust in different ways: musical pieces or artistic projects, plugins, standalone applications, integration in audio programming environments, development tools, research projects (possibly non-musical), embedded devices, Web applications, etc.

201 Musical Synthesizer



We're Citizen & Dulari and we're happy to announce our newest synthesizer: the 201! If you're familiar with our other modular instruments such as the Podust Para, Dipsolar, Bokta Bass, or Kafelabido, we hope you'll see that the 201 fits right in with them: the 201 is fun, portable, and packed with a medley of musical magic!

Inside, the 201 uses a combination of Pure Data and Faust musical programming environments. Users are invited to modify or create new sound engines!

OneTrick SIMIAN



Learn Faust

International:

- Stanford U./CCRMA
- Maynooth U.
- Louisiana State U.
- Aalborg U.

France:

- Jean Monnet U.
- IRCAM, ATIAM
- PARIS 8 U.

The screenshot shows a web browser displaying a course page on Kadenze. The title of the course is "Real-Time Audio Signal Processing in Faust". On the right side, there is a sidebar titled "WOULD YOU LIKE TO ENROLL?" with a large "ENROLL" button. The sidebar includes fields for "Length" (5 Sessions), "Price" (Audit (Free) Certificate (incl. w/ Premium)), "Institution" (Stanford University), "Subject" (Creative Computing), "Skill Level" (Expert), and "Topics" (Synthesis, Computer Programming, Digital Signal Processing (DSP), Field Effects). Below the sidebar, there are four small circular profile pictures of people.

<https://www.kadenze.com/courses/real-time-audio-signal-processing-in-faust/info>

Purely Functional Approach

- Signals are functions: $\mathbb{S} = \text{time} \rightarrow \text{sample}$,
- Faust primitives are signal processors: $\mathbb{P} = \mathbb{S}^m \rightarrow \mathbb{S}^n$,
- Faust composition operations (`<:` `:` `:` `,` `~`) are binary functions on signal processors: $\mathbb{A} = \mathbb{P} \times \mathbb{P} \rightarrow \mathbb{P}$,
- User defined functions are higher order functions on signal processors: $\mathbb{U} = \mathbb{P}^n \rightarrow \mathbb{P}$,
- A Faust program denotes a signal processor.

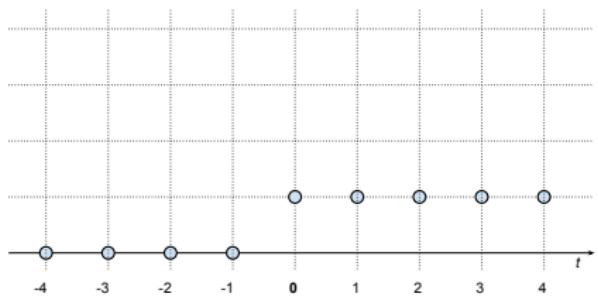
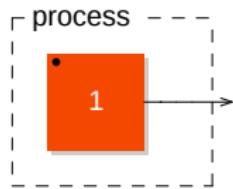
What is Faust used for?

- Faust is used on stage for concerts and artistic productions, for education and research, for open sources projects and commercial applications :
- Faust offers end-users a high-level alternative to C to develop audio applications for a large variety of platforms.
- The role of the Faust compiler is to synthesize the most efficient implementations for the target language (C, C++, LLVM, Javascript, etc.).

Signal generators

Numbers

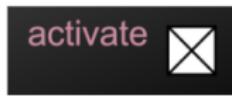
```
process = 1;
```



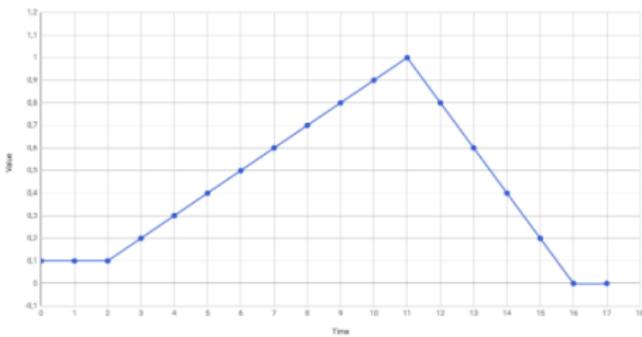
$$y(t) = \begin{cases} 1 & t \geq 0 \\ 0 & t < 0 \end{cases}$$

Signal generators

UI widgets



```
process = vslider("level", 0.1, 0, 1, 0.01);
```



Faust Primitives

Wire and Cut

| Syntax | Type | Description |
|--------|---|--|
| - | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | wire: $y(t) = x(t)$ |
| ! | $\mathbb{S}^1 \rightarrow \mathbb{S}^0$ | cut: $\langle \rangle$, $x(t)$ is ignored |

Faust Primitives

Arithmetic operations

| Syntax | Type | Description |
|----------|---|--|
| + | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | addition: $y(t) = x_1(t) + x_2(t)$ |
| - | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | subtraction: $y(t) = x_1(t) - x_2(t)$ |
| * | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | multiplication: $y(t) = x_1(t) * x_2(t)$ |
| \wedge | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | power: $y(t) = x_1(t)^{x_2(t)}$ |
| / | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | division: $y(t) = x_1(t)/x_2(t)$ |
| % | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | modulo: $y(t) = x_1(t)\%x_2(t)$ |
| int | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | cast into an int signal: $y(t) = (\text{int})x(t)$ |
| float | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | cast into an float signal: $y(t) = (\text{float})x(t)$ |

Faust Primitives

Bitwise operations

| Syntax | Type | Description |
|--------|---|---|
| & | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | logical AND: $y(t) = x_1(t) \& x_2(t)$ |
| | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | logical OR: $y(t) = x_1(t) x_2(t)$ |
| xor | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | 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: $y(t) = x_1(t) >> x_2(t)$ |

Faust Primitives

Comparison operations

| Syntax | Type | Description |
|----------|---|---|
| < | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | less than: $y(t) = x_1(t) < x_2(t)$ |
| \leq | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | less or equal: $y(t) = x_1(t) \leq x_2(t)$ |
| > | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | greater than: $y(t) = x_1(t) > x_2(t)$ |
| \geq | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | greater or equal: $y(t) = x_1(t) \geq x_2(t)$ |
| \equiv | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | equal: $y(t) = x_1(t) \equiv x_2(t)$ |
| \neq | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | different: $y(t) = x_1(t) \neq x_2(t)$ |

Faust Primitives

Trigonometric functions

| Syntax | Type | Description |
|--------|---|--|
| acos | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | arc cosine: $y(t) = \text{acosf}(x(t))$ |
| asin | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | arc sine: $y(t) = \text{asinf}(x(t))$ |
| atan | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | arc tangent: $y(t) = \text{atanf}(x(t))$ |
| atan2 | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | arc tangent of 2 signals: $y(t) = \text{atan2f}(x_1(t), x_2(t))$ |
| cos | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | cosine: $y(t) = \text{cosf}(x(t))$ |
| sin | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | sine: $y(t) = \text{sinf}(x(t))$ |
| tan | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | tangent: $y(t) = \text{tanf}(x(t))$ |

Faust Primitives

Other Math operations

| Syntax | Type | Description |
|-----------|---|--|
| exp | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | base-e exponential: $y(t) = \text{expf}(x(t))$ |
| log | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | base-e logarithm: $y(t) = \text{logf}(x(t))$ |
| log10 | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | base-10 logarithm: $y(t) = \text{log10f}(x(t))$ |
| pow | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | power: $y(t) = \text{powf}(x_1(t), x_2(t))$ |
| sqrt | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | square root: $y(t) = \text{sqrtf}(x(t))$ |
| abs | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | absolute value (int): $y(t) = \text{abs}(x(t))$ absolute value (float): $y(t) = \text{fabsf}(x(t))$ |
| min | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | minimum: $y(t) = \text{min}(x_1(t), x_2(t))$ |
| max | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | maximum: $y(t) = \text{max}(x_1(t), x_2(t))$ |
| fmod | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | float modulo: $y(t) = \text{fmodf}(x_1(t), x_2(t))$ |
| remainder | $\mathbb{S}^2 \rightarrow \mathbb{S}^1$ | float remainder: $y(t) = \text{remainderf}(x_1(t), x_2(t))$ |
| floor | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | largest int \leq : $y(t) = \text{floorf}(x(t))$ |
| ceil | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | smallest int \geq : $y(t) = \text{ceilf}(x(t))$ |
| rint | $\mathbb{S}^1 \rightarrow \mathbb{S}^1$ | closest int: $y(t) = \text{rintf}(x(t))$ |

Faust Primitives

Delays and Tables

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

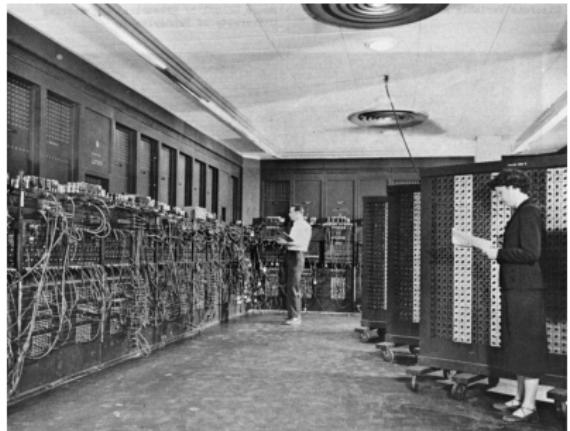
Faust Primitives

Other User Interface Primitives

| Syntax | Example |
|---|--|
| <code>vgroup(str, block-diagram)</code> | <code>vgroup("reverb", ...)</code> |
| <code>hgroup(str, block-diagram)</code> | <code>hgroup("mixer", ...)</code> |
| <code>tgroup(str, block-diagram)</code> | <code>vgroup("parametric", ...)</code> |
| <code>vbargraph(str, min, max)</code> | <code>vbargraph("input", 0, 100)</code> |
| <code>hbargraph(str, min, max)</code> | <code>hbargraph("signal", 0, 1.0)</code> |

Block-Diagram Algebra

Programming by patching is familiar to musicians :



Block-Diagram Algebra

Today programming by patching is widely used in Visual Programming Languages like Max/MSP:

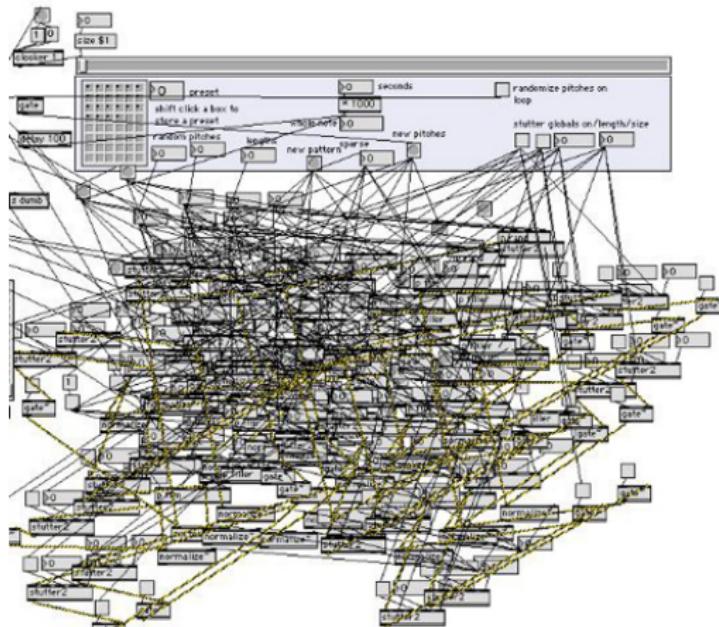


Figure: Block-diagrams can be a mess

Block-Diagram Algebra

Faust allows structured block-diagrams

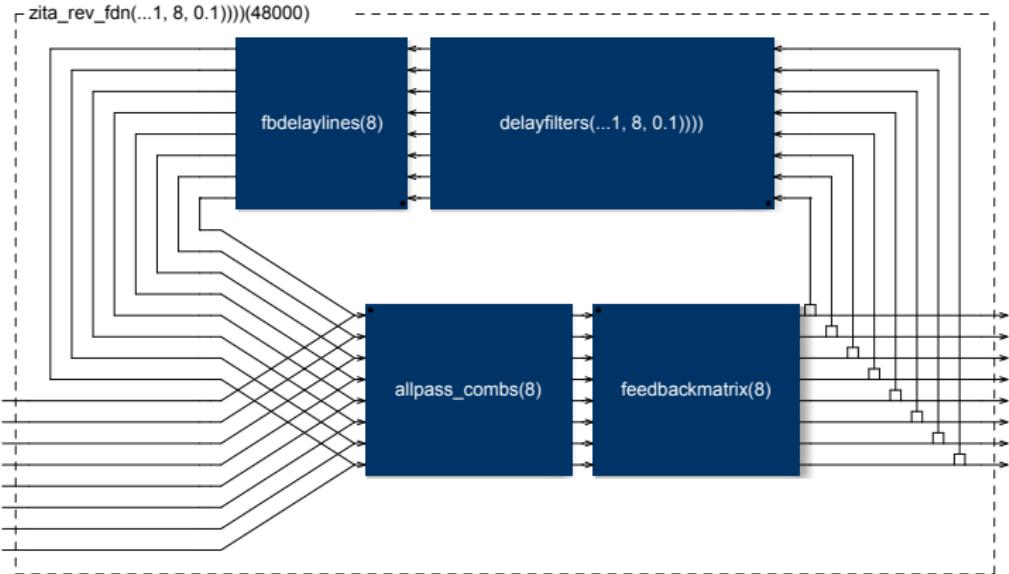


Figure: A complex but structured block-diagram

Block-Diagram Algebra

Faust syntax is based on a *block diagram algebra*

5 Composition Operators

- $(A \sim B)$ recursive composition (priority 4)
- (A, B) parallel composition (priority 3)
- $(A : B)$ sequential composition (priority 2)
- $(A <: B)$ split composition (priority 1)
- $(A :> B)$ merge composition (priority 1)

2 Constants

- $!$ cut
- $_$ wire

Block-Diagram Algebra

Parallel Composition

The *parallel composition* (A, B) is probably the simplest one. It places the two block-diagrams one on top of the other, without connections.

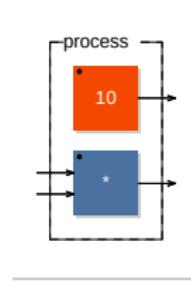


Figure: Example of parallel composition $(10, *)$

Block-Diagram Algebra

Sequential Composition

The *sequential composition* ($A : B$) connects the outputs of A to the inputs of B . $A[0]$ is connected to $[0]B$, $A[1]$ is connected to $[1]B$, and so on.

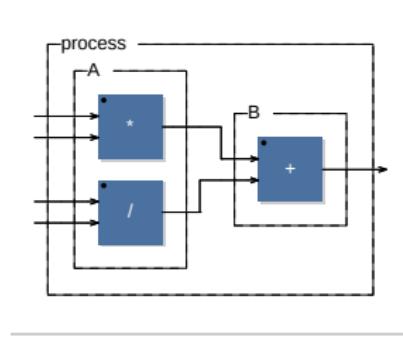


Figure: Example of sequential composition $((*,/):+)$

Note that the number of outputs of A must be equal to the number of inputs of B .

Block-Diagram Algebra

Split Composition

The *split composition* ($A <: B$) operator is used to distribute A outputs to B inputs.

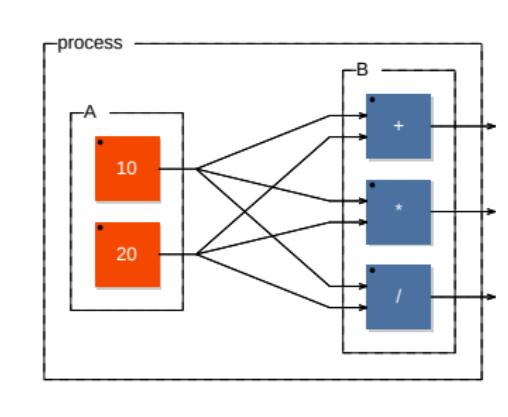


Figure: example of split composition $((10,20) <: (+,*,/))$

Block-Diagram Algebra

Merge Composition

The *merge composition* ($A :> B$) is used to connect several outputs of A to the same inputs of B .

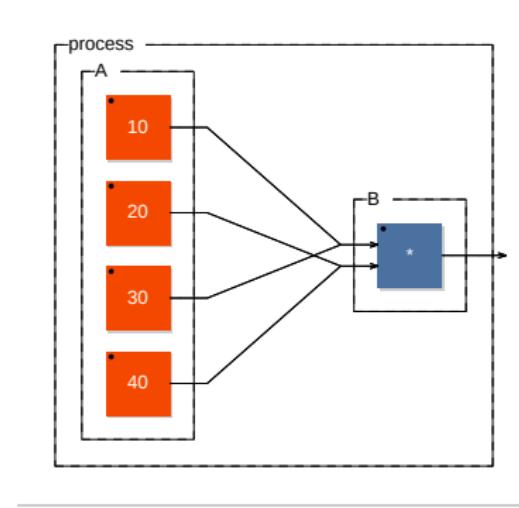


Figure: example of merge composition $((10, 20, 30, 40) :> *)$

Block-Diagram Algebra

Recursive Composition

The *recursive composition* ($A^\sim B$) is used to create cycles in the block-diagram in order to express recursive computations.

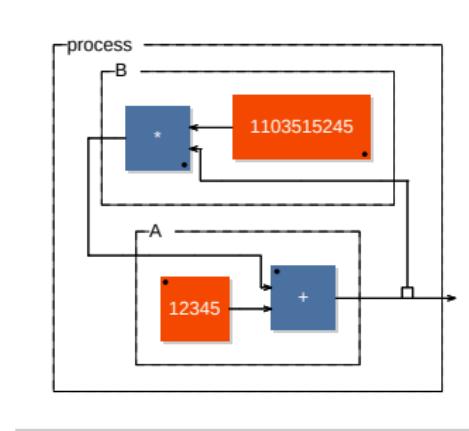


Figure: example of recursive composition $+(12345) \sim *(1103515245)$