Channel mapping for Studio 114

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author	Henrik Frisk
basics.lib/name	Faust Basic Element Library
basics.lib/version	0.0
copyright	(c) dinergy 2018
filename	KMH114_channel_map_C
license	BSD
maths.lib/author	GRAME
maths.lib/copyright	GRAME
maths.lib/license	LGPL with exception
maths.lib/name	Faust Math Library
maths.lib/version	2.1
name	Channel mapping for Studio 114
version	0.1

This document provides a mathematical description of the Faust program text stored in the `src/KMH114_channel_map_C.dsp` file. See the notice in Section 3 (page 3) for details.

1 Mathematical definition of `process`

The *KMH114_channel_map_C* program evaluates the signal transformer denoted by `process`, which is mathematically defined as follows:

1. Output signals y_i for $i \in [1, 15]$ such that

$$y_1(t) = x_1(t)$$
$$y_2(t) = x_3(t)$$
$$y_3(t) = x_2(t)$$
$$y_4(t) = x_{15}(t)$$
$$y_5(t) = x_8(t)$$
$$y_6(t) = x_5(t)$$
$$y_7(t) = x_9(t)$$

$$y_8(t) = x_4(t)$$
$$y_9(t) = x_7(t)$$
$$y_{10}(t) = x_6(t)$$
$$y_{11}(t) = x_{10}(t)$$
$$y_{12}(t) = x_{11}(t)$$
$$y_{13}(t) = x_{13}(t)$$
$$y_{14}(t) = x_{12}(t)$$
$$y_{15}(t) = x_{14}(t)$$

2. Input signals x_i for $i \in [1, 15]$
3. Intermediate signals r_i for $i \in [1, 15]$ such that

$$r_1(t) = \max\left(r_1(t-1) - k_1, |x_1(t)|\right)$$
$$r_2(t) = \max\left(r_2(t-1) - k_1, |x_3(t)|\right)$$
$$r_3(t) = \max\left(r_3(t-1) - k_1, |x_2(t)|\right)$$
$$r_4(t) = \max\left(r_4(t-1) - k_1, |x_{15}(t)|\right)$$
$$r_5(t) = \max\left(r_5(t-1) - k_1, |x_8(t)|\right)$$
$$r_6(t) = \max\left(r_6(t-1) - k_1, |x_5(t)|\right)$$
$$r_7(t) = \max\left(r_7(t-1) - k_1, |x_9(t)|\right)$$
$$r_8(t) = \max\left(r_8(t-1) - k_1, |x_4(t)|\right)$$
$$r_9(t) = \max\left(r_9(t-1) - k_1, |x_7(t)|\right)$$
$$r_{10}(t) = \max\left(r_{10}(t-1) - k_1, |x_6(t)|\right)$$
$$r_{11}(t) = \max\left(r_{11}(t-1) - k_1, |x_{10}(t)|\right)$$
$$r_{12}(t) = \max\left(r_{12}(t-1) - k_1, |x_{11}(t)|\right)$$
$$r_{13}(t) = \max\left(r_{13}(t-1) - k_1, |x_{13}(t)|\right)$$
$$r_{14}(t) = \max\left(r_{14}(t-1) - k_1, |x_{12}(t)|\right)$$
$$r_{15}(t) = \max\left(r_{15}(t-1) - k_1, |x_{14}(t)|\right)$$

4. Constant k_1 such that

$$k_1 = \frac{1}{\min\left(192000, \max\left(1, f_S\right)\right)}$$

2 Block diagram of `process`

The block diagram of `process` is shown on Figure 1 (page 35).

3 Notice

- This document was generated using Faust version 2.6.3 on September 28, 2018.
- The value of a Faust program is the result of applying the signal transformer denoted by the expression to which the `process` identifier is bound to input signals, running at the f_S sampling frequency.
- Faust (*Functional Audio Stream*) is a functional programming language designed for synchronous real-time signal processing and synthesis applications. A Faust program is a set of bindings of identifiers to expressions that denote signal transformers. A signal s in S is a function mapping[1] times $t \in \mathbb{Z}$ to values $s(t) \in \mathbb{R}$, while a signal transformer is a function from S^n to S^m, where $n, m \in \mathbb{N}$. See the Faust manual for additional information (http://faust.grame.fr).
- Every mathematical formula derived from a Faust expression is assumed, in this document, to having been normalized (in an implementation-dependent manner) by the Faust compiler.
- A block diagram is a graphical representation of the Faust binding of an identifier I to an expression E; each graph is put in a box labeled by I. Subexpressions of E are recursively displayed as long as the whole picture fits in one page.
- The `KMH114_channel_map_C-mdoc/` directory may also include the following subdirectories:
  - `cpp/` for Faust compiled code;
  - `pdf/` which contains this document;
  - `src/` for all Faust sources used (even libraries);
  - `svg/` for block diagrams, encoded using the Scalable Vector Graphics format (http://www.w3.org/Graphics/SVG/);
  - `tex/` for the LaTeX source of this document.

4 Faust code listings

This section provides the listings of the Faust code used to generate this document, including dependencies.

[1] Faust assumes that $\forall\, s \in S, \forall\, t \in \mathbb{Z}, s(t) = 0$ when $t < 0$.

Listing 1: `KMH114_channel_map_C.dsp`

```
declare name   "Channel mapping for Studio 114";
declare version " 0.1 ";
declare author " Henrik Frisk " ;
declare license " BSD ";
declare copyright "(c) dinergy 2018 ";

//---------------‘Channel mapping plugin‘ --------------------------
//
// Channel mapping plugin that takes 15 channels of input (center speaker included)
// and maps it to the channel/speaker configuration of the studio 114 according to:
//
// * 1 -> 1 (L)
// * 2 -> 2 (R)
// * 3 -> 3 (C)
// * 4 -> 5 (LSR)
// * 5 -> 6 (RSR)
// * 6 -> 7 (LSF)
// * 7 -> 8 (RSF)
// * 8 -> 9 (RL)
// * 9 -> 10 (RR)
// * 10 -> 11 (ULF)
// * 11 -> 12 (URF)
// * 12 -> 13 (URL)
// * 13 -> 14 (URR)
// * 14 -> 15 (VOG)
//
//---------------------------------------------------

import("stdfaust.lib");

vmeter(x)  = attach(x, envelop(x) : vbargraph("[unit:dB]", -70, +5));
hmeter(x)  = attach(x, envelop(x) : hbargraph("[2][unit:dB]", -70, +5));
envelop       = abs : max ~ -(1.0/ma.SR) : max(ba.db2linear(-70)) : ba.linear2db;

process(L, C, R, RSF, RSR, RR, RL, LSR, LSF, ULF, URF, URL, URR, VOG, x) =
  vgroup("", (L, R, C, x, LSR, RSR, LSF, RSF, RL, RR) : hgroup("lower ring", par(i, 10,
      vgroup("%i", vmeter)))),
  vgroup("", (ULF, URF, URR, URL) : hgroup("upper ring", par(i, 4, vgroup("%i", vmeter)))),
  vgroup("", (VOG) : hgroup("vog", par(i, 1, vgroup("%i", vmeter))));
```

Listing 2: `stdfaust.lib`

```
//################################# stdfaust.lib ##########################################
// The purpose of this library is to give access to all the Faust standard libraries
// through a series of environment.
//##########################################################################################

an = library("analyzers.lib");
ba = library("basics.lib");
co = library("compressors.lib");
de = library("delays.lib");
dm = library("demos.lib");
dx = library("dx7.lib");
en = library("envelopes.lib");
fi = library("filters.lib");
ho = library("hoa.lib");
ma = library("maths.lib");
ef = library("misceffects.lib");
os = library("oscillators.lib");
no = library("noises.lib");
pf = library("phaflangers.lib");
pm = library("physmodels.lib");
```

```
re = library("reverbs.lib");
ro = library("routes.lib");
sp = library("spats.lib");
si = library("signals.lib");
so = library("soundfiles.lib");
sy = library("synths.lib");
ve = library("vaeffects.lib");
sf = library("all.lib");
```

Listing 3: maths.lib

```
//################################### maths.lib ##########################################
//  Mathematic library for Faust. Its official prefix is `ma`.
//########################################################################################
// Some functions are implemented as Faust foreign functions of `math.h` functions
// that are not part of Faust's primitives. Defines also various constants and several
// utilities.
//########################################################################################

// ## History
// * 06/13/2016 [RM]  normalizing and integrating to new libraries
// * 07/08/2015 [YO]  documentation comments
// * 20/06/2014 [SL]  added FTZ function
// * 20/06/2014 [SL]  added FTZ function
// * 22/06/2013 [YO]  added float|double|quad variants of some foreign functions
// * 28/06/2005 [YO]  postfixed functions with 'f' to force float version instead of double
// * 28/06/2005 [YO]  removed 'modf' because it requires a pointer as argument

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************************************************************************
FAUST library file
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************************************************************************
************************************************************************/

declare name "Faust Math Library";
declare version "2.1";
declare author "GRAME";
declare copyright "GRAME";
```

```
declare license "LGPL with exception";

//=============================Functions Reference========================================
//========================================================================================


//---------------------------------`(ma.)SR`--------------------------------------
// Current sampling rate (between 1000Hz and 192000Hz). Constant during
// program execution.
//
// #### Usage
//
// ```
// SR : _
// ```
//----------------------------------------------------------------------------
SR         = min(192000.0, max(1.0, fconstant(int fSamplingFreq, <math.h>)));


//---------------------------------`(ma.)BS`--------------------------------------
// Current block-size. Can change during the execution.
//
// #### Usage
//
// ```
// BS : _
// ```
//----------------------------------------------------------------------------
BS         = fvariable(int count, <math.h>);


//---------------------------------`(ma.)PI`--------------------------------------
// Constant PI in double precision.
//
// #### Usage
//
// ```
// PI : _
// ```
//----------------------------------------------------------------------------
PI         = 3.1415926535897932385;

//---------------------------------`(ma.)INFINITY`-----------------------------
// Constant INFINITY inherited from `math.h`.
//
// #### Usage
//
// ```
// INFINITY : _
// ```
//----------------------------------------------------------------------------
INFINITY = fconstant(float INFINITY, <math.h>);

//---------------------------------`(ma.)FTZ`--------------------------------------
// Flush to zero: force samples under the "maximum subnormal number"
// to be zero. Usually not needed in C++ because the architecture
// file take care of this, but can be useful in javascript for instance.
//
// #### Usage
//
// ```
// _ : ftz : _
// ```
//
// See : <http://docs.oracle.com/cd/E19957-01/806-3568/ncg_math.html>
//----------------------------------------------------------------------------
FTZ(x)     = x * (abs(x) > 1.17549435e-38);

```

```

//---------------------------------`(ma.)neg`---------------------------------------
// Invert the sign (-x) of a signal.
//
// #### Usage
//
// ```
// _ : neg : _
// ```
//-----------------------------------------------------------------------------
neg(x)     = -x;


//-------`(ma.)sub(x,y)`------------------
// Subtract `x` and `y`.
//------------------------------
sub(x,y) = y-x;


//---------------------------------`(ma.)inv`---------------------------------------
// Compute the inverse (1/x) of the input signal.
//
// #### Usage
//
// ```
// _ : inv : _
// ```
//-----------------------------------------------------------------------------
inv(x)     = 1/x;


//---------------------------------`(ma.)cbrt`--------------------------------------
// Computes the cube root of of the input signal.
//
// #### Usage
//
// ```
// _ : cbrt : _
// ```
//-----------------------------------------------------------------------------
cbrt       = ffunction(float cbrtf|cbrt|cbrtl (float), <math.h>,"");


//---------------------------------`(ma.)hypot`-------------------------------------
// Computes the euclidian distance of the two input signals
// sqrt(x*x+y*y) without undue overflow or underflow.
//
// #### Usage
//
// ```
// _,_ : hypot : _
// ```
//-----------------------------------------------------------------------------
hypot      = ffunction(float hypotf|hypot|hypotl (float, float), <math.h>,"");


//---------------------------------`(ma.)ldexp`-------------------------------------
// Takes two input signals: x and n, and multiplies x by 2 to the power n.
//
// #### Usage
//
// ```
// _,_ : ldexp : _
// ```
//-----------------------------------------------------------------------------
ldexp      = ffunction(float ldexpf|ldexp|ldexpl (float, int), <math.h>,"");

```

```
//---------------------------------`(ma.)scalb`-----------------------------------
// Takes two input signals: x and n, and multiplies x by 2 to the power n.
//
// #### Usage
//
// ```
// _,_ : scalb : _
// ```
//-----------------------------------------------------------------------------
scalb      = ffunction(float scalbnf|scalbn|scalbnl (float, int), <math.h>,"");


//---------------------------------`(ma.)log1p`---------------------------------
// Computes log(1 + x) without undue loss of accuracy when x is nearly zero.
//
// #### Usage
//
// ```
// _ : log1p : _
// ```
//-----------------------------------------------------------------------------
log1p      = ffunction(float log1pf|log1p|log1pl (float), <math.h>,"");


//---------------------------------`(ma.)logb`-------------------------------------
// Return exponent of the input signal as a floating-point number.
//
// #### Usage
//
// ```
// _ : logb : _
// ```
//-----------------------------------------------------------------------------
logb       = ffunction(float logbf|logb|logbl (float), <math.h>,"");


//---------------------------------`(ma.)ilogb`-----------------------------------
// Return exponent of the input signal as an integer number.
//
// #### Usage
//
// ```
// _ : ilogb : _
// ```
//-----------------------------------------------------------------------------
ilogb      = ffunction(int ilogbf|ilogb|ilogbl (float), <math.h>,"");


//---------------------------------`(ma.)log2`------------------------------------
// Returns the base 2 logarithm of x.
//
// #### Usage
//
// ```
// _ : log2 : _
// ```
//-----------------------------------------------------------------------------
log2(x) = log(x)/log(2.0);


//---------------------------------`(ma.)expm1`-----------------------------------
// Return exponent of the input signal minus 1 with better precision.
//
// #### Usage
//
// ```
// _ : expm1 : _
// ```
```

````
//-----------------------------------------------------------------------------
expm1      = ffunction(float expm1f|expm1|expm1l (float), <math.h>,"");


//---------------------------------`(ma.)acosh`-------------------------------------
// Computes the principle value of the inverse hyperbolic cosine
// of the input signal.
//
// #### Usage
//
// ```
// _ : acosh : _
// ```
//-----------------------------------------------------------------------------
acosh      = ffunction(float acoshf|acosh|acoshl (float), <math.h>, "");


//--------------------------------`(ma.)asinh`-----------------------------------
// Computes the inverse hyperbolic sine of the input signal.
//
// #### Usage
//
// ```
// _ : asinh : _
// ```
//-----------------------------------------------------------------------------
asinh      = ffunction(float asinhf|asinh|asinhl (float), <math.h>, "");


//--------------------------------`(ma.)atanh`-----------------------------------
// Computes the inverse hyperbolic tangent of the input signal.
//
// #### Usage
//
// ```
// _ : atanh : _
// ```
//-----------------------------------------------------------------------------
atanh      = ffunction(float atanhf|atanh|atanhl (float), <math.h>, "");


//---------------------------------`(ma.)sinh`----------------------------------------
// Computes the hyperbolic sine of the input signal.
//
// #### Usage
//
// ```
// _ : sinh : _
// ```
//-----------------------------------------------------------------------------
sinh       = ffunction(float sinhf|sinh|sinhl (float), <math.h>, "");


//---------------------------------`(ma.)cosh`--------------------------------------
// Computes the hyperbolic cosine of the input signal.
//
// #### Usage
//
// ```
// _ : cosh : _
// ```
//-----------------------------------------------------------------------------
cosh       = ffunction(float coshf|cosh|coshl (float), <math.h>, "");


//---------------------------------`(ma.)tanh`--------------------------------------
// Computes the hyperbolic tangent of the input signal.
//
````

```
// #### Usage
//
// ‘‘‘
// _ : tanh : _
// ‘‘‘
//-----------------------------------------------------------------------------
tanh       = ffunction(float tanhf|tanh|tanhl (float), <math.h>,"");


//--------------------------------‘(ma.)erf‘-------------------------------------
// Computes the error function of the input signal.
//
// #### Usage
//
// ‘‘‘
// _ : erf : _
// ‘‘‘
//-----------------------------------------------------------------------------
erf        = ffunction(float erff|erf|erfl(float), <math.h>,"");


//--------------------------------‘(ma.)erfc‘-------------------------------------
// Computes the complementary error function of the input signal.
//
// #### Usage
//
// ‘‘‘
// _ : erfc : _
// ‘‘‘
//-----------------------------------------------------------------------------
erfc       = ffunction(float erfcf|erfc|erfcl(float), <math.h>,"");


//--------------------------------‘(ma.)gamma‘-----------------------------------
// Computes the gamma function of the input signal.
//
// #### Usage
//
// ‘‘‘
// _ : gamma : _
// ‘‘‘
//-----------------------------------------------------------------------------
gamma      = ffunction(float tgammaf|tgamma|tgammal(float), <math.h>,"");


//--------------------------------‘(ma.)lgamma‘----------------------------------
// Calculates the natural logorithm of the absolute value of
// the gamma function of the input signal.
//
// #### Usage
//
// ‘‘‘
// _ : lgamma : _
// ‘‘‘
//-----------------------------------------------------------------------------
lgamma     = ffunction(float lgammaf|lgamma|lgammal(float), <math.h>,"");


//--------------------------------‘(ma.)J0‘--------------------------------------
// Computes the Bessel function of the first kind of order 0
// of the input signal.
//
// #### Usage
//
// ‘‘‘
// _ : J0 : _
// ‘‘‘
//-----------------------------------------------------------------------------
```

```
J0         = ffunction(float j0(float), <math.h>,"");


//---------------------------------‘(ma.)J1‘--------------------------------------
// Computes the Bessel function of the first kind of order 1
// of the input signal.
//
// #### Usage
//
// ```
// _ : J1 : _
// ```
//-----------------------------------------------------------------------------
J1         = ffunction(float j1(float), <math.h>,"");


//---------------------------------‘(ma.)Jn‘--------------------------------------
// Computes the Bessel function of the first kind of order n
// (first input signal) of the second input signal.
//
// #### Usage
//
// ```
// _,_ : Jn : _
// ```
//-----------------------------------------------------------------------------
Jn         = ffunction(float jn(int, float), <math.h>,"");


//---------------------------------‘(ma.)Y0‘--------------------------------------
// Computes the linearly independent Bessel function of the second kind
// of order 0 of the input signal.
//
// #### Usage
//
// ```
// _ : Y0 : _
// ```
//-----------------------------------------------------------------------------
Y0         = ffunction(float y0(float), <math.h>,"");


//---------------------------------‘(ma.)Y1‘--------------------------------------
// Computes the linearly independent Bessel function of the second kind
// of order 1 of the input signal.
//
// #### Usage
//
// ```
// _ : Y0 : _
// ```
//-----------------------------------------------------------------------------
Y1         = ffunction(float y1(float), <math.h>,"");


//---------------------------------‘(ma.)Yn‘--------------------------------------
// Computes the linearly independent Bessel function of the second kind
// of order n (first input signal) of the second input signal.
//
// #### Usage
//
// ```
// _,_ : Yn : _
// ```
//-----------------------------------------------------------------------------
Yn         = ffunction(float yn(int, float), <math.h>,"");
```

```
//----------------------------‘(ma.)fabs‘, ‘(ma.)fmax‘, ‘(ma.)fmin‘---------------------------
// Just for compatibility...
//
// ‘‘‘
// fabs = abs
// fmax = max
// fmin = min
// ‘‘‘
//-----------------------------------------------------------------------------
fabs = abs;
fmax = max;
fmin = min;

//------------------------------‘(ma.)np2‘-------------------------------------
// Gives the next power of 2 of x.
//
// #### Usage
//
// ‘‘‘
// np2(n) : _
// ‘‘‘
//
// Where:
//
// * ‘n‘: an integer
//-----------------------------------------------------------------------------
np2 = -(1) <: >>(1)|_ <: >>(2)|_ <: >>(4)|_ <: >>(8)|_ <: >>(16)|_ : +(1);


//----------------------------‘(ma.)frac‘--------------------------------------
// Gives the fractional part of n.
//
// #### Usage
//
// ‘‘‘
// frac(n) : _
// ‘‘‘
//
// Where:
//
// * ‘n‘: a decimal number
//------------------------------------------------------------------------------
frac(n) = n - floor(n);
decimal = frac;
// NOTE: decimal does the same thing as frac but using floor instead. JOS uses frac a lot
// in filters.lib so we decided to keep that one... decimal is declared though for
// backward compatibility.
// decimal(n)  = n - floor(n);

//------------------------------‘(ma.)modulo‘---------------------------------------
// Modulus operation.
//
// #### Usage
//
// ‘‘‘
// modulo(x,N) : _
// ‘‘‘
//
// Where:
//
// * ‘x‘: the numerator
// * ‘N‘: the denominator
//------------------------------------------------------------------------------
modulo(x,N) = (x % N + N) % N;


//---------------‘(ma.)isnan‘----------------
```

```
// Return non-zero if and only if x is a NaN.
//
// #### Usage
//
// ```
// isnan(x)
// _ : isnan : _
// ```
//
// Where:
//
// * `x`: signal to analyse
//------------------------------------------
isnan      = ffunction(int isnan (float),<math.h>,"");
nextafter  = ffunction(float nextafter(float, float),<math.h>,"");


//---------------------------`(ma.)chebychev`-------------------------------
// Chebychev transformation of order n.
//
// #### Usage
//
// ```
// _ : chebychev(n) : _
// ```
//
// Where:
//
// * `n`: the order of the polynomial
//
// #### Semantics
//
// ```
// T[0](x) = 1,
// T[1](x) = x,
// T[n](x) = 2x*T[n-1](x) - T[n-2](x)
// ```
//
// #### Reference
//
// <http://en.wikipedia.org/wiki/Chebyshev_polynomial>
//-------------------------------------------------------------------------
chebychev(0) = !:1;
chebychev(1) = _;
chebychev(n) = _ <: *(2)*chebychev(n-1)-chebychev(n-2);


//-----------------------`(ma.)chebychevpoly`-------------------------------
// Linear combination of the first Chebyshev polynomials.
//
// #### Usage
//
// ```
// _ : chebychevpoly((c0,c1,...,cn)) : _
// ```
//
// Where:
//
// * `cn`: the different Chebychevs polynomials such that:
//  chebychevpoly((c0,c1,...,cn)) = Sum of chebychev(i)*ci
//
// #### Reference
//
// <http://www.csounds.com/manual/html/chebyshevpoly.html>
//-------------------------------------------------------------------------
chebychevpoly(lcoef) = _ <: L(0,lcoef) :> _
    with {
        L(n,(c,cs)) = chebychev(n)*c, L(n+1,cs);
```

```
        L(n,c)     = chebychev(n)*c;
    };


//-----------------`(ma.)diffn`---------------------------
// Negated first-order difference.
//
// #### Usage
//
// ```
// _ : diffn : _
// ```
//-----------------------------------------------------
diffn(x) = x' - x; // negated first-order difference

//-----------------`(ma.)signum`---------------------------
// The signum function signum(x) is defined as
// -1 for x<0, 0 for x==0, and 1 for x>0;
//
// #### Usage
//
// ```
// _ : signum : _
// ```
//-----------------------------------------------------
signum(x) = (x>0)-(x<0);
```

Listing 4: `basics.lib`

```
//#################################### basics.lib ########################################
// A library of basic elements. Its official prefix is `ba`.
//########################################################################################
// A library of basic elements for Faust organized in 5 sections:
//
// * Conversion Tools
// * Counters and Time/Tempo Tools
// * Array Processing/Pattern Matching
// * Selectors (Conditions)
// * Other Tools (Misc)

//########################################################################################

/************************************************************************
************************************************************************
FAUST library file, GRAME section

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************************************************************************
************************************************************************/

ma = library("maths.lib");
ro = library("routes.lib");
ba = library("basics.lib"); // so functions here can be copy/pasted out

declare name "Faust Basic Element Library";
declare version "0.0";

//=============================Conversion Tools==========================================
//========================================================================================


//-------`(ba.)samp2sec`----------
// Converts a number of samples to a duration in seconds.
// `samp2sec` is a standard Faust function.
//
// #### Usage
//
// ```
// samp2sec(n) : _
// ```
//
// Where:
//
// * `n`: number of samples
//----------------------------
samp2sec = /(ma.SR);


//-------`(ba.)sec2samp`----------
// Converts a duration in seconds to a number of samples.
// `samp2sec` is a standard Faust function.
//
// #### Usage
//
// ```
// sec2samp(d) : _
// ```
//
// Where:
//
// * `d`: duration in seconds
//----------------------------
sec2samp = *(ma.SR);


//-------`(ba.)db2linear`----------
// Converts a loudness in dB to a linear gain (0-1).
// `db2linear` is a standard Faust function.
//
// #### Usage
//
// ```
// db2linear(l) : _
// ```
```

```
//
// Where:
//
// * `l`: loudness in dB
//-----------------------------
db2linear(n) = pow(10, n/20.0);


//-------`(ba.)linear2db`----------
// Converts a linear gain (0-1) to a loudness in dB.
// `linear2db` is a standard Faust function.
//
// #### Usage
//
// ```
// linear2db(g) : _
// ```
//
// Where:
//
// * `g`: a linear gain
//-----------------------------
linear2db(n) = 20*log10(n);


//----------`(ba.)lin2LogGain`------------------
// Converts a linear gain (0-1) to a log gain (0-1).
//
// #### Usage
//
// ```
// _ : lin2LogGain : _
// ```
//---------------------------------------------
lin2LogGain = _ <: _*_;


//----------`(ba.)log2LinGain`------------------
// Converts a log gain (0-1) to a linear gain (0-1).
//
// #### Usage
//
// ```
// _ : log2LinGain : _
// ```
//---------------------------------------------
log2LinGain = sqrt;

// end GRAME section
//###########################################################################################
/************************************************************************
FAUST library file, jos section

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************************************************************************/

//-------`(ba.)tau2pole`----------
// Returns a real pole giving exponential decay.
// Note that t60 (time to decay 60 dB) is ~6.91 time constants.
// `tau2pole` is a standard Faust function.
```

```
//
// #### Usage
//
// ```
// _ : smooth(tau2pole(tau)) : _
// ```
//
// Where:
//
// * `tau`: time-constant in seconds
//-----------------------------
  tau2pole(tau) = exp(-1.0/(tau*ma.SR));


//-------`(ba.)pole2tau`----------
// Returns the time-constant, in seconds, corresponding to the given real,
// positive pole in (0,1).
// `pole2tau` is a standard Faust function.
//
// #### Usage
//
// ```
// pole2tau(pole) : _
// ```
//
// Where:
//
// * `pole`: the pole
//-----------------------------
  pole2tau(pole) = -1.0/(log(pole)*ma.SR);


//-------`(ba.)midikey2hz`----------
// Converts a MIDI key number to a frequency in Hz (MIDI key 69 = A440).
// `midikey2hz` is a standard Faust function.
//
// #### Usage
//
// ```
// midikey2hz(mk) : _
// ```
//
// Where:
//
// * `mk`: the MIDI key number
//-----------------------------
  midikey2hz(mk) = 440.0*pow(2.0, (mk-69.0)/12);


//-------`(ba.)hz2midikey`----------
// Converts a frequency in Hz to a MIDI key number (MIDI key 69 = A440).
// `hz2midikey` is a standard Faust function.
//
// #### Usage
//
// ```
// hz2midikey(f) : _
// ```
//
// Where:
//
// * `f`: frequency in Hz
//-----------------------------
  hz2midikey(f) = 12*ma.log2(f/440.0) + 69.0;


//-------`(ba.)pianokey2hz`----------
// Converts a piano key number to a frequency in Hz (piano key 49 = A440).
```

```
//
// #### Usage
//
// ```
// pianokey2hz(pk) : _
// ```
//
// Where:
//
// * `pk`: the piano key number
//----------------------------
  pianokey2hz(pk) = 440.0*pow(2.0, (pk-49.0)/12);


//-------`(ba.)hz2pianokey`----------
// Converts a frequency in Hz to a piano key number (piano key 49 = A440).
//
// #### Usage
//
// ```
// hz2pianokey(f) : _
// ```
//
// Where:
//
// * `f`: frequency in Hz
//----------------------------
  hz2pianokey(f) = 12*ma.log2(f/440.0) + 49.0;

// end jos section
//##########################################################################################
/*************************************************************************
FAUST library file, GRAME section 2
*************************************************************************/

//=============================Counters and Time/Tempo Tools=============================
//=======================================================================================

//----------------------------`(ba.)countdown`------------------------------
// Starts counting down from n included to 0. While trig is 1 the output is n.
// The countdown starts with the transition of trig from 1 to 0. At the end
// of the countdown the output value will remain at 0 until the next trig.
// `countdown` is a standard Faust function.
//
// #### Usage
//
// ```
// countdown(n,trig) : _
// ```
//
// Where:
//
// * `count`: the starting point of the countdown
// * `trig`: the trigger signal (1: start at `n`; 0: decrease until 0)
//-----------------------------------------------------------------------------
countdown(count, trig) = \(c).(if(trig>0, count, max(0, c-1))) ~_;


//---------------------------`(ba.)countup`-------------------------------
// Starts counting up from 0 to n included. While trig is 1 the output is 0.
// The countup starts with the transition of trig from 1 to 0. At the end
// of the countup the output value will remain at n until the next trig.
// `countup` is a standard Faust function.
//
// #### Usage
//
// ```
// countup(n,trig) : _
```

```
// ```
//
// Where:
//
// * `count`: the maximum count value
// * `trig`: the trigger signal (1: start at 0; 0: increase until `n`)
//-----------------------------------------------------------------------------
countup(count, trig)  = \(c).(if(trig>0, 0, min(count, c+1))) ~_;


//--------------------`(ba.)sweep`--------------------------
// Counts from 0 to `period` samples repeatedly, while `run` is 1.
// Outsputs zero while `run` is 0.
//
// #### Usage
//
// ```
// sweep(period,run) : _
// ```
//----------------------------------------------------------------
// Author: Jonatan Liljedahl, markdown by RM
sweep = %(int(*:max(1)))~+(1);


//-------`(ba.)time`----------
// A simple timer that counts every samples from the beginning of the process.
// `time` is a standard Faust function.
//
// #### Usage
//
// ```
// time : _
// ```
//------------------------
time = (+(1)~_ ) - 1;


//-------`(ba.)tempo`----------
// Converts a tempo in BPM into a number of samples.
//
// #### Usage
//
// ```
// tempo(t) : _
// ```
//
// Where:
//
// * `t`: tempo in BPM
//------------------------
tempo(t) = (60*ma.SR)/t;


//-------`(ba.)period`----------
// Basic sawtooth wave of period `p`.
//
// #### Usage
//
// ```
// period(p) : _
// ```
//
// Where:
//
// * `p`: period as a number of samples
//------------------------
// NOTE: may be this should go in oscillators.lib
period(p) = %(int(p))~+(1');
```

```
//-------‘(ba.)pulse‘----------
// Pulses (10000) generated at period ‘p‘.
//
// #### Usage
//
// ‘‘‘
// pulse(p) : _
// ‘‘‘
//
// Where:
//
// * ‘p‘: period as a number of samples
//-----------------------
// NOTE: may be this should go in oscillators.lib
pulse(p) = period(p)==0;


//-------‘(ba.)pulsen‘----------
// Pulses (11110000) of length ‘n‘ generated at period ‘p‘.
//
// #### Usage
//
// ‘‘‘
// pulsen(n,p) : _
// ‘‘‘
//
// Where:
//
// * ‘n‘: the length of the pulse as a number of samples
// * ‘p‘: period as a number of samples
//-----------------------
// NOTE: may be this should go in oscillators.lib
pulsen(n,p) = period(p)<n;


//----------------------‘(ba.)cycle‘--------------------------
// Split nonzero input values into ‘n‘ cycles.
//
// #### Usage
//
// ‘‘‘
// _ : cycle(n) <:
// ‘‘‘
//
// Where:
//
// * ‘n‘: the number of cycles/output signals
//--------------------------------------------------------
// Author: Mike Olsen
cycle(n) = _ <: par(i,n,resetCtr(n,(i+1)));


//-------‘(ba.)beat‘----------
// Pulses at tempo ‘t‘.
// ‘beat‘ is a standard Faust function.
//
// #### Usage
//
// ‘‘‘
// beat(t) : _
// ‘‘‘
//
// Where:
//
// * ‘t‘: tempo in BPM
//-----------------------
```

````
beat(t) = pulse(tempo(t));


//---------------------------`(ba.)pulse_countup`-----------------------------------
// Starts counting up pulses. While trig is 1 the output is
// counting up, while trig is 0 the counter is reset to 0.
//
// #### Usage
//
// ```
// _ : pulse_countup(trig) : _
// ```
//
// Where:
//
// * `trig`: the trigger signal (1: start at next pulse; 0: reset to 0)
//-----------------------------------------------------------------------------
//TODO: author "Vince"
pulse_countup(t) = + ~ _ * t ;


//---------------------------`(ba.)pulse_countdown`---------------------------------
// Starts counting down pulses. While trig is 1 the output is
// counting down, while trig is 0 the counter is reset to 0.
//
// #### Usage
//
// ```
// _ : pulse_countdown(trig) : _
// ```
//
// Where:
//
// * `trig`: the trigger signal (1: start at next pulse; 0: reset to 0)
//-----------------------------------------------------------------------------
//TODO: author "Vince"
pulse_countdown(t) = - ~ _ * t ;


//---------------------------`(ba.)pulse_countup_loop`------------------------------
// Starts counting up pulses from 0 to n included. While trig is 1 the output is
// counting up, while trig is 0 the counter is reset to 0. At the end
// of the countup (n) the output value will be reset to 0.
//
// #### Usage
//
// ```
// _ : pulse_countup_loop(n,trig) : _
// ```
//
// Where:
//
// * `n`: the highest number of the countup (included) before reset to 0.
// * `trig`: the trigger signal (1: start at next pulse; 0: reset to 0)
//-----------------------------------------------------------------------------
//TODO: author "Vince"
pulse_countup_loop(n, t) = + ~ cond(n)*t
with {
  cond(n) = _ <: _ * (_ <= n) ;
};


//----------------------`(ba.)resetCtr`------------------------
// Function that lets through the mth impulse out of
// each consecutive group of `n` impulses.
//
// #### Usage
//
````

```
// ```
// _ : resetCtr(n,m) : _
// ```
//
// Where:
//
// * `n`: the total number of impulses being split
// * `m`: index of impulse to allow to be output
//-----------------------------------------------------------
// Author: Mike Olsen
resetCtr(n,m) = _ <: (_,pulse_countup_loop(n-1,1)) : (_,(_==m)) : *;


//----------------------------`(ba.)pulse_countdown_loop`----------------------------
// Starts counting down pulses from 0 to n included. While trig is 1 the output
// is counting down, while trig is 0 the counter is reset to 0. At the end
// of the countdown (n) the output value will be reset to 0.
//
// #### Usage
//
// ```
// _ : pulse_coundown_loop(n,trig) : _
// ```
//
// Where:
//
// * `n`: the highest number of the countup (included) before reset to 0.
// * `trig`: the trigger signal (1: start at next pulse; 0: reset to 0)
//-------------------------------------------------------------------------------
//TODO: author "Vince:
pulse_countdown_loop(n, t) = - ~ cond(n)*t
with {
  cond(n) = _ <: _ * (_ >= n) ;
};


//==============================Array Processing/Pattern Matching=======================
//=====================================================================================

//--------------------------------`(ba.)count`---------------------------------
// Count the number of elements of list l.
// `count` is a standard Faust function.
//
// #### Usage
//
// ```
// count(l)
// count ((10,20,30,40)) -> 4
// ```
//
// Where:
//
// * `l`: list of elements
//------------------------------------------------------------------------------
count ((xs, xxs)) = 1 + count(xxs);
count (xx) = 1;


//-----------------------------`(ba.)take`----------------------------------
// Take an element from a list.
// `take` is a standard Faust function.
//
// #### Usage
//
// ```
// take(e,l)
// take(3,(10,20,30,40)) -> 30
// ```
```

```
//
// Where:
//
// * `p`: position (starting at 1)
// * `l`: list of elements
//-----------------------------------------------------------------------------
take (1, (xs, xxs))   = xs;
take (1, xs)          = xs;
take (nn, (xs, xxs))  = take (nn-1, xxs);


//---------------------------`(ba.)subseq`--------------------------------
// Extract a part of a list.
//
// #### Usage
//
// ```
// subseq(l, p, n)
// subseq((10,20,30,40,50,60), 1, 3) -> (20,30,40)
// subseq((10,20,30,40,50,60), 4, 1) -> 50
// ```
//
// Where:
//
// * `l`: list
// * `p`: start point (0: begin of list)
// * `n`: number of elements
//
// #### Note:
//
// Faust doesn't have proper lists. Lists are simulated with parallel
// compositions and there is no empty list
//-----------------------------------------------------------------------------
subseq((head, tail), 0, 1)   = head;
subseq((head, tail), 0, n)   = head, subseq(tail, 0, n-1);
subseq((head, tail), p, n)   = subseq(tail, p-1, n);
subseq(head, 0, n)           = head;


//===========================Selectors (Conditions)====================================
//====================================================================================

//----------------------------`(ba.)if`----------------------------------
// if-then-else implemented with a select2.
//
// #### Usage
//
// *  `if(c, t, e) : _`
//
// Where:
//
// * `c`: condition
// * `t`: signal selected while c is true
// * `e`: signal selected while c is false
//-----------------------------------------------------------------------------
if(cond,thn,els) = select2(cond,els,thn);
// TODO: perhaps it would make more sense to have an if(a,b) and an ifelse(a,b,c)?

//----------------------------`(ba.)selector`---------------------------------
// Selects the ith input among n at compile time.
//
// #### Usage
//
// ```
// selector(i,n)
// _,_,_,_ : selector(2,4) : _ // selects the 3rd input among 4
// ```
//
```

````
// Where:
//
// * `i`: input to select (`int`, numbered from 0, known at compile time)
// * `n`: number of inputs (`int`, known at compile time, `n > i`)
//
// There is also cselector for selecting among complex input signals of the form (real,imag).
//
//-----------------------------------------------------------------------------
selector(i,n) = par(j, n, S(i, j)) with { S(i,i) = _; S(i,j) = !; };
cselector(i,n) = par(j, n, S(i, j)) with { S(i,i) = (_,_); S(i,j) = (!,!); }; // for complex numbers


//-----------------------------`(ba.)selectn`---------------------------------
// Selects the ith input among N at run time.
//
// #### Usage
//
// ```
// selectn(N,i)
// _,_,_,_ : selectn(4,2) : _ // selects the 3rd input among 4
// ```
//
// Where:
//
// * `N`: number of inputs (int, known at compile time, N > 0)
// * `i`: input to select (int, numbered from 0)
//
// #### Example test program
//
// ```
// N=64;
// process = par(n,N, (par(i,N,i) : selectn(N,n)));
// ```
//-----------------------------------------------------------------------------
selectn(N,i) = S(N,0)
    with {
       S(1,offset) = _;
       S(n,offset) = S(left, offset), S(right, offset+left) : select2(i >= offset+left)
            with {
                right = int(n/2);
                left  = n-right;
            };
    };


//--------------------`(ba.)select2stereo`--------------------
// Select between 2 stereo signals.
//
// #### Usage
//
// ```
// _,_,_,_ : select2stereo(bpc) : _,_,_,_
// ```
//
// Where:
//
// * `bpc`: the selector switch (0/1)
//------------------------------------------------------------
  select2stereo(bpc) = ro.cross2 : select2(bpc), select2(bpc) : _,_;
//====================================Other=============================================
//======================================================================================

//---------------------------`(ba.)latch`--------------------------------
// Latch input on positive-going transition of "clock" ("sample-and-hold").
//
// #### Usage
//
````

```
// ```
// _ : latch(clocksig) : _
// ```
//
// Where:
//
// * `clocksig`: hold trigger (0 for hold, 1 for bypass)
//------------------------------------------------------------
  latch(c,x) = x * s : + ~ *(1-s) with { s = ((c'<=0)&(c>0)); };


//-------------------------`(ba.)sAndH`------------------------------
// Sample And Hold.
// `sAndH` is a standard Faust function.
//
// #### Usage
//
// ```
// _ : sAndH(t) : _
// ```
//
// Where:
//
// * `t`: hold trigger (0 for hold, 1 for bypass)
//----------------------------------------------------------------
// Author: RM
sAndH(t) = select2(t,_,_)~_;


//-------------------------`(ba.)downSample`-------------------------------
// Down sample a signal. WARNING: this function doesn't change the
// rate of a signal, it just holds samples...
// `downSample` is a standard Faust function.
//
// #### Usage
//
// ```
// _ : downSample(freq) : _
// ```
//
// Where:
//
// * `freq`: new rate in Hz
//----------------------------------------------------------------
// Author: RM
downSample(freq) = sAndH(hold)
with{
  hold = time%int(ma.SR/freq) == 0;
};


//-----------------`(ba.)peakhold`--------------------------
// Outputs current max value above zero.
//
// #### Usage
//
// ```
// _ : peakhold(mode) : _;
// ```
//
// Where:
//
// `mode` means: 0 - Pass through. A single sample 0 trigger will work as a reset.
//    1 - Track and hold max value.
//----------------------------------------------------------------
// TODO: author Jonatan Liljedahl, revised by RM
peakhold = (*,_:max) ~ _;
```

```
//-----------------`(ba.)peakholder`--------------------------
// Tracks abs peak and holds peak for 'holdtime' samples.
//
// #### Usage
//
// ```
// _ : peakholder(holdtime) : _;
// ```
//------------------------------------------------------------
// TODO: author Jonatan Liljedahl
peakholder(holdtime) = peakhold2 ~ reset : (!,_) with {
    reset = ba.sweep(holdtime) > 0;
    // first out is gate that is 1 while holding last peak
    peakhold2 = _,abs <: peakhold,!,_ <: >=,_,!;
};


//------------------------`(ba.)impulsify`--------------------------
// Turns the signal from a button into an impulse (1,0,0,... when
// button turns on).
// `impulsify` is a standard Faust function.
//
// #### Usage
//
// ```
// button("gate") : impulsify ;
// ```
//------------------------------------------------------------
impulsify = _ <: _,mem : - : >(0);


//----------------------`(ba.)automat`----------------------------
// Record and replay to the values the input signal in a loop.
//
// #### Usage
//
// ```
// hslider(...) : automat(bps, size, init) : _
// ```
//-------------------------------------------------------------------
automat(bps, size, init, input) = rwtable(size+1, init, windex, input, rindex)
with {
    clock  = beat(bps);
    rindex  = int(clock) : (+ : %(size)) ~ _;  // each clock read the next entry of the table
    windex  = if (timeToRenew, rindex, size);  // we ignore input unless it is time to renew
    timeToRenew   = int(clock) & (inputHasMoved | (input <= init));
    inputHasMoved  = abs(input-input') : countfrom(int(clock)') : >(0);
    countfrom(reset) = (+ : if(reset, 0, _)) ~ _;
};


//----------------`(ba.)bpf`------------------
// bpf is an environment (a group of related definitions) that can be used to
// create break-point functions. It contains three functions :
//
// * `start(x,y)` to start a break-point function
// * `end(x,y)` to end a break-point function
// * `point(x,y)` to add intermediate points to a break-point function
//
// A minimal break-point function must contain at least a start and an end point :
//
// ```
// f = bpf.start(x0,y0) : bpf.end(x1,y1);
// ```
//
// A more involved break-point function can contains any number of intermediate
// points:
```

```
//
// ```
// f = bpf.start(x0,y0) : bpf.point(x1,y1) : bpf.point(x2,y2) : bpf.end(x3,y3);
// ```
//
// In any case the `x_{i}` must be in increasing order (for all `i`, `x_{i} < x_{i+1}`).
// For example the following definition :
//
// ```
// f = bpf.start(x0,y0) : ... : bpf.point(xi,yi) : ... : bpf.end(xn,yn);
// ```
//
// implements a break-point function f such that :
//
// * `f(x) = y_{0}` when `x < x_{0}`
// * `f(x) = y_{n}` when `x > x_{n}`
// * `f(x) = y_{i} + (y_{i+1}-y_{i})*(x-x_{i})/(x_{i+1}-x_{i})` when `x_{i} <= x`
// and `x < x_{i+1}`
//
// `bpf` is a standard Faust function.
//--------------------------------------------------------
bpf = environment
{
  // Start a break-point function
  start(x0,y0) = \(x).(x0,y0,x,y0);
  // Add a break-point
  point(x1,y1) = \(x0,y0,x,y).(x1, y1, x , if (x < x0, y, if (x < x1, y0 + (x-x0)*(y1-y0)/(
        x1-x0), y1)));
  // End a break-point function
  end  (x1,y1) = \(x0,y0,x,y).(if (x < x0, y, if (x < x1, y0 + (x-x0)*(y1-y0)/(x1-x0), y1)));
};


//-------------------`(ba.)listInterp`-------------------------
// Linearly interpolates between the elements of a list.
//
// #### Usage
//
// ```
// foo = listInterp((800,400,350,450,325),index);
// i = 1.69; // range is 0-4
// process = foo(i);
// ```
//
// Where:
//
// * `index`: the index (float) to interpolate between the different values.
// The range of `index` depends on the size of the list.
//------------------------------------------------------------
// Author: RM
listInterp(v) =
  bpf.start(0,take(1,v)) :
  seq(i,count(v)-2,bpf.point(i+1,take(i+2,v))) :
  bpf.end(count(v)-1,take(count(v),v));


//-------------------`(ba.)bypass1`-------------------------
// Takes a mono input signal, route it to `e` and bypass it if `bpc = 1`.
// `bypass1` is a standard Faust function.
//
// #### Usage
//
// ```
// _ : bypass1(bpc,e) : _
// ```
//
// Where:
//
```

```
// * `bpc`: bypass switch (0/1)
// * `e`: a mono effect
//------------------------------------------------------------
// Author: JOS
// License: STK-4.3
bypass1(bpc,e) = _ <: select2(bpc,(inswitch:e),_)
  with {
    inswitch = select2(bpc,_,0);
  };

//-------------------`(ba.)bypass2`-------------------------
// Takes a stereo input signal, route it to `e` and bypass it if `bpc = 1`.
// `bypass2` is a standard Faust function.
//
// #### Usage
//
// ```
// _,_ : bypass2(bpc,e) : _,_
// ```
//
// Where:
//
// * `bpc`: bypass switch (0/1)
// * `e`: a stereo effect
//------------------------------------------------------------
// Author: JOS
// License: STK-4.3
bypass2(bpc,e) = _,_ <: ((inswitch:e),_,_) : select2stereo(bpc)
  with {
    inswitch = _,_ : (select2(bpc,_,0), select2(bpc,_,0)) : _,_;
  };

//-------------------`(ba.)bypass1to2`-------------------------
// Bypass switch for effect `e` having mono input signal and stereo output.
// Effect `e` is bypassed if `bpc = 1`.
// `bypass1to2` is a standard Faust function.
//
// #### Usage
//
// ```
// _ : bypass1(bpc,e) : _,_
// ```
//
// Where:
//
// * `bpc`: bypass switch (0/1)
// * `e`: a mono-to-stereo effect
//------------------------------------------------------------
// Author: JOS
// License: STK-4.3
bypass1to2(bpc,e) = _ <: ((inswitch:e),_,_) : ba.select2stereo(bpc)
  with {
    inswitch = select2(bpc,_,0);
  };

//---------------------------`(ba.)toggle`------------------------------------------
// Triggered by the change of 0 to 1, it toggles the output value
// between 0 and 1.
//
// #### Usage
//
// ```
// _ : toggle : _
// ```
// #### Examples
//
// ```
// button("toggle") : toggle : vbargraph("output", 0, 1)
```

```
// (an.amp_follower(0.1) > 0.01) : toggle : vbargraph("output", 0, 1) // takes audio input
// ```
//
//-----------------------------------------------------------------------------
// TODO: author "Vince"
toggle = trig : loop
  with {
    trig(x) = (x-x') == 1;
    loop = (_ != _) ~ _ ;
  };


//---------------------------`(ba.)on_and_off`-----------------------------------------
// The first channel set the output to 1, the second channel to 0.
//
// #### Usage
//
// ```
// _ , _ : on_and_off : _
// ```
//
// #### Example
//
// ```
// button("on"), button("off") : on_and_off : vbargraph("output", 0, 1)
// ```
//
//-----------------------------------------------------------------------------
// TODO: author "Vince"
on_and_off(a, b) = (a : trig) : loop(b)
with {
  trig(x) = (x-x') == 1;
  loop(b) = + ~ (_ >= 1) * ((b : trig) == 0) ;
};


//----------------------------`(ba.)selectoutn`---------------------------------
// Route input to the output among N at run time.
//
// #### Usage
//
// ```
// _ : selectoutn(n, s) : _,_,...n
// ```
//
// Where:
//
// * `n`: number of outputs (int, known at compile time, N > 0)
// * `s`: output number to route to (int, numbered from 0) (i.e. slider)
//
// #### Example
//
// ```
// process = 1 : selectoutn(3, sel) : par(i,3,bar) ;
// sel = hslider("volume",0,0,2,1) : int;
// bar = vbargraph("v.bargraph", 0, 1);
// ```
//------------------------------------------------------------------------
// TODO: author "Vince"
selectoutn(n, s) = _ <: par(i,n, _* (s==i) ) ;

//================================Sliding Reduce========================================
// Provides various operations on the last N samples using a high order
// `slidingReduce(op,N,maxN,disabledVal,x)`` fold-like function :
//
// * `slidingSumN(n,maxn)`: the sliding sum of the last n input samples
// * `slidingMaxN(n,maxn)`: the sliding max of the last n input samples
// * `slidingMinN(n,maxn)`: the sliding min of the last n input samples
```

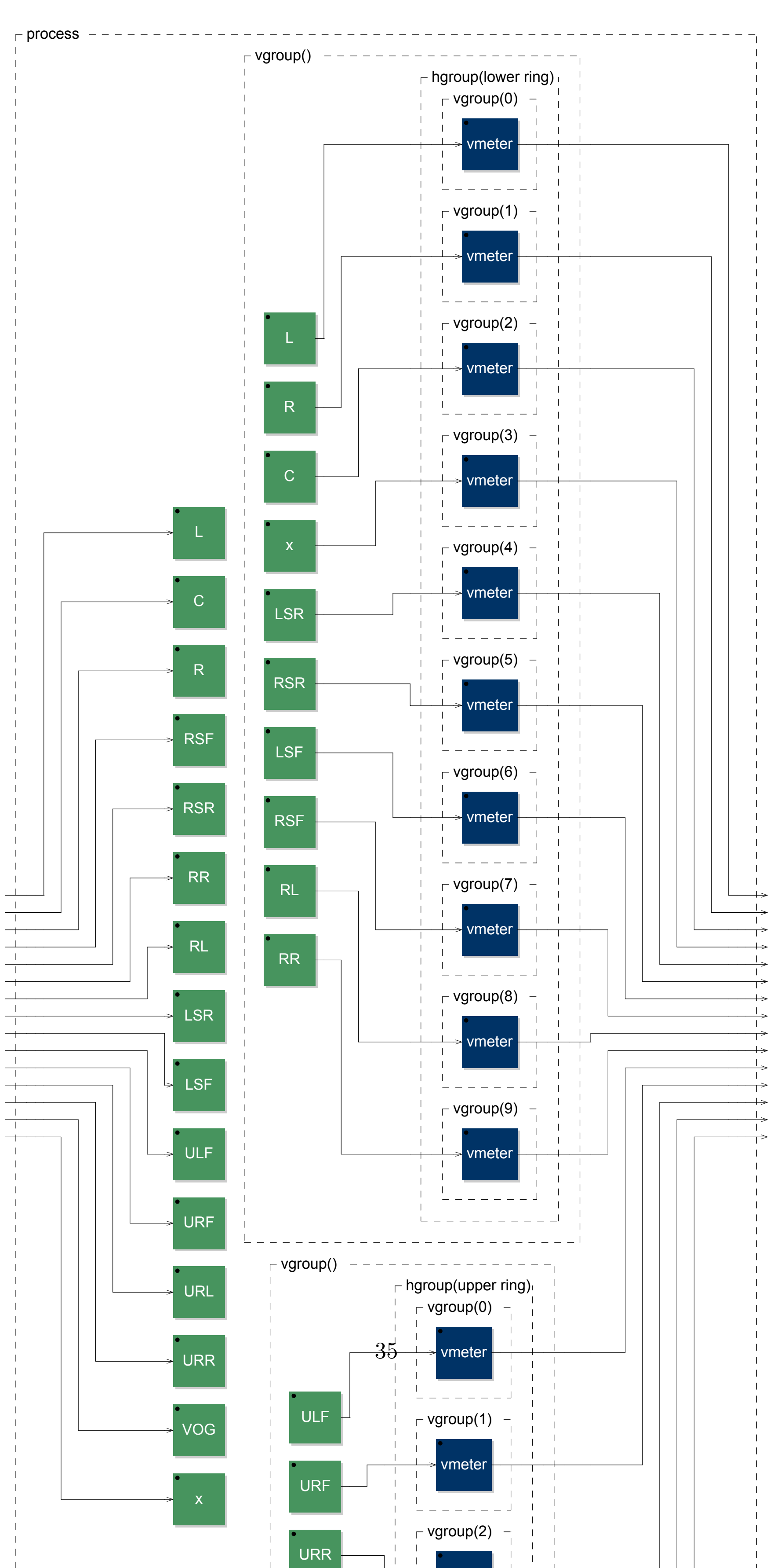
```
// * `slidingMeanN(n,maxn)`: the sliding mean of the last n input samples
// * `slidingRMSn(n,maxn)`: the sliding RMS of the last n input samples
//
// #### Working Principle
//
// If we want the maximum of the last 8 values, we can do that as:
//
// ```
// simpleMax(x) =
//  (
//    (
//      max(x@0,x@1),
//      max(x@2,x@3)
//    ) :max
//  ),
//  (
//    (
//      max(x@4,x@5),
//      max(x@6,x@7)
//    ) :max
//  )
//  :max;
// ```
//
// `max(x@2,x@3)` is the same as `max(x@0,x@1)@2` but the latter re-uses a
// value we already computed,so is more efficient. Using the same trick for
// values 4 trough 7, we can write:
//
// ```
// efficientMax(x)=
//  (
//    (
//      max(x@0,x@1),
//      max(x@0,x@1)@2
//    ) :max
//  ),
//  (
//    (
//      max(x@0,x@1),
//      max(x@0,x@1)@2
//    ) :max@4
//  )
//  :max;
// ```
//
// We can rewrite it recursively, so it becomes possible to get the maximum at
// have any number of values, as long as it's a power of 2.
//
// ```
// recursiveMax =
//  case {
//    (1,x) => x;
//    (N,x) => max(recursiveMax(N/2,x) , recursiveMax(N/2,x)@(N/2));
//  };
// ```
//
// What if we want to look at a number of values that's not a power of 2?
// For each value, we will have to decide whether to use it or not.
// If N is bigger than the index of the value, we use it, otherwise we replace
// it with (`0-(ma.INFINITY)`):
//
// ```
// variableMax(N,x) =
//  max(
//    max(
//      (
//        (x@0 : useVal(0)),
//        (x@1 : useVal(1))
```

```
//      ):max,
//      (
//        (x@2 : useVal(2)),
//        (x@3 : useVal(3))
//      ):max
//    ),
//    max(
//      (
//        (x@4 : useVal(4)),
//        (x@5 : useVal(5))
//      ):max,
//      (
//        (x@6 : useVal(6)),
//        (x@7 : useVal(7))
//      ):max
//    )
//  )
//  with{
//  useVal(i) = select2( (N>=i) , (0-(ma.INFINITY)),_);
// };
// ```
//
// Now it becomes impossible to re-use any values. To fix that let's first look
// at how we'd implement it using recursiveMax, but with a fixed N that is not
// a power of 2. For example, this is how you'd do it with `N=3`:
//
// ```
// binaryMaxThree(x) =
//  (
//    recursiveMax(1,x)@0, // the first x
//    recursiveMax(2,x)@1 // the second and third x
//  ):max;
// ```
//
// `N=6`
//
// ```
// binaryMaxSix(x) =
//  (
//    recursiveMax(2,x)@0, // first two
//    recursiveMax(4,x)@2 // third trough sixt
//  ):max;
// ```
//
// Note that `recursiveMax(2,x)` is used at a different delay then in
// `binaryMaxThree`, since it represents 1 and 2, not 2 and 3. Each block is
// delayed the combined size of the previous blocks.
//
// `N=7`
//
// ```
// binaryMaxSeven(x) =
//  (
//    (
//      recursiveMax(1,x)@0, // first x
//      recursiveMax(2,x)@1 // second and third
//    ):max,
//    (
//      recursiveMax(4,x)@3 // fourth trough seventh
//    )
//  ):max;
// ```
//
// To make a variable version, we need to know which powers of two are used,
// and at which delay time.
//
// Then it becomes a matter of:
//
```

````
// * lining up all the different block sizes in parallel: the first `par()`
//  statement
// * delaying each the appropriate amount: `sumOfPrevBlockSizes()`
// * turning it on or off: `useVal()`
// * getting the maximum of all of them: `combine()`
//
// In faust, we can only do that for a fixed maximum number of values: `maxN`
//
// ```
// variableBinaryMaxN(N,maxN,x) =
//  par(i,maxNrBits,recursiveMax(pow2(i),x)@sumOfPrevBlockSizes(N,maxN,i) : useVal(i)) : combine(maxNrBits) with {
//    // The sum of all the sizes of the previous blocks
//    sumOfPrevBlockSizes(N,maxN,0) = 0;
//    sumOfPrevBlockSizes(N,maxN,i) = (ba.subseq((allBlockSizes(N,maxN)),0,i):>_);
//    allBlockSizes(N,maxN) = par(i, maxNrBits, pow2(i) * isUsed(i) );
//    maxNrBits = int2nrOfBits(maxN);
//    // get the maximum of all blocks
//    combine(2) = max;
//    combine(N) = max(combine(N-1),_);
//    // Decide wether or not to use a certain value, based on N
//    useVal(i) = select2( isUsed(i), (0-(ma.INFINITY)),_);
//    isUsed(i) = ba.take(i+1,(int2bin(N,maxN)));
//  };
// ```
//========================================================================================
// Section contributed by Bart Brouns (bart@magnetophon.nl).
// SPDX-License-Identifier: GPL-3.0
// Copyright (C) 2018 Bart Brouns

//-----------------------------`(ba.)slidingReduce`-----------------------------
// Fold-like high order function. Apply a commutative binary operation `<op>` to
// the last `<n>` consecutive samples of a signal `<x>`. For example :
// `slidingReduce(max,128,128,-(ma.INFINITY))` will compute the maximum of the last
// 128 samples. The output is updated each sample, unlike reduce, where the
// output is constant for the duration of a block
//
// #### Usage
//
// ```
// _ : slidingReduce(op,N,maxN,disabledVal) : _
// ```
//
// Where:
//
// * `N`: the number of values to process
// * `maxN`: the maximum number of values to process, needs to be a power of 2
// * `op`: the operator. Needs to be a commutative one.
// * `disabledVal`: the value to use when we want to ignore a value.
//
// In other words, `op(x,disabledVal)` should equal to `x`. For example,
// `+(x,0)` equals `x` and `min(x,ma.INFINITY)` equals `x`. So if we want to
// calculate the sum, we need to give 0 as `disabledVal`, and if we want the
// minimum, we need to give `ma.INFINITY` as `disabledVal`.
//------------------------------------------------------------------------------
slidingReduce(op,N,maxN,disabledVal,x) =
  par(i,maxNrBits,fixedDelayOp(pow2(i),x)@sumOfPrevBlockSizes(N,maxN,i)
    : useVal(i)) : combine(maxNrBits)
  with {
    // apply <op> to the last <N> values of <x>, where <N> is fixed
    fixedDelayOp = case {
      (1,x) => x;
      (N,x) => op(fixedDelayOp(N/2,x) , fixedDelayOp(N/2,x)@(N/2));
    };
    // The sum of all the sizes of the previous blocks
    sumOfPrevBlockSizes(N,maxN,0) = 0;
    sumOfPrevBlockSizes(N,maxN,i) = (subseq((allBlockSizes(N,maxN)),0,i):>_);
    allBlockSizes(N,maxN) = par(i, maxNrBits, (pow2(i)) * isUsed(i) );
````

```
    maxNrBits = int2nrOfBits(maxN);
    // Apply <op> to <N> parallel inputsignals
    combine(2) = op;
    combine(N) = op(combine(N-1),_);
    // Decide wether or not to use a certain value, based on N
    // Basically only the second <select2> is needed,
    // but this version also works for N == 0
    // 'works' in this case means 'does the same as reduce
    useVal(i) =
      _ <: select2(
        (i==0) & (N==0) ,
        select2( isUsed(i) , disabledVal,_),
        _
      );
    // useVal(i) =
    //    select2( isUsed(i) , disabledVal,_);
    isUsed(i) = take(i+1,(int2bin(N,maxN)));
    pow2(i) = 1<<i;
    // same as:
    // pow2(i) = int(pow(2,i));
    // but in the block diagram, it will be displayed as a number, instead of a formula

    // convert N into a list of ones and zeros
    int2bin(N,maxN) = par(j,int2nrOfBits(maxN),int(floor(N/(pow2(j))))%2);
    // calculate how many ones and zeros are needed to represent maxN
    int2nrOfBits(0) = 0;
    int2nrOfBits(maxN) = int(floor(log(maxN)/log(2))+1);
  };


//-----------------------------`(ba.)slidingSumN`-----------------------------
// The sliding sum of the last n input samples.
//
// #### Usage
//
// ```
// _ : slidingSumN(N,maxN) : _
// ```
//
// Where:
//
// * `N`: the number of values to process
// * `maxN`: the maximum number of values to process, needs to be a power of 2
//----------------------------------------------------------------------------
slidingSumN(n,maxn) = slidingReduce(+,n,maxn,0);


//---------------------------`(ba.)slidingMaxN`-------------------------------
// The sliding maximum of the last n input samples.
//
// #### Usage
//
// ```
// _ : slidingMaxN(N,maxN) : _
// ```
//
// Where:
//
// * `N`: the number of values to process
// * `maxN`: the maximum number of values to process, needs to be a power of 2
//----------------------------------------------------------------------------
slidingMaxN(n,maxn) = slidingReduce(max,n,maxn,-(ma.INFINITY));


//--------------------------`(ba.)slidingSumN`--------------------------------
// The sliding minimum of the last n input samples.
//
// #### Usage
```

```
//
// ```
// _ : slidingMinN(N,maxN) : _
// ```
//
// Where:
//
// * `N`: the number of values to process
// * `maxN`: the maximum number of values to process, needs to be a power of 2
//----------------------------------------------------------------------------
slidingMinN(n,maxn) = slidingReduce(min,n,maxn,ma.INFINITY);


//---------------------------`(ba.)slidingMeanN`------------------------------
// The sliding mean of the last n input samples.
//
// #### Usage
//
// ```
// _ : slidingMeanN(N,maxN) : _
// ```
//
// Where:
//
// * `N`: the number of values to process
// * `maxN`: the maximum number of values to process, needs to be a power of 2
//----------------------------------------------------------------------------
slidingMeanN(n,maxn) = slidingSumN(n,maxn)/n;


//-------------------------`(ba.)slidingRMSn`---------------------------------
// The root mean square of the last n input samples.
//
// #### Usage
//
// ```
// _ : slidingRMSn(N,maxN) : _
// ```
//
// Where:
//
// * `N`: the number of values to process
// * `maxN`: the maximum number of values to process, needs to be a power of 2
//----------------------------------------------------------------------------
slidingRMSn(n,maxn) = pow(2):slidingMeanN(n,maxn) : sqrt;


////////////////////////////////Deprecated Functions//////////////////////////////////
// This section implements functions that used to be in music.lib but that are now
// considered as "deprecated".
//////////////////////////////////////////////////////////////////////////////////////

millisec   = ma.SR/1000.0;

time1s  = hslider("time", 0, 0, 1000, 0.1)*millisec;
time2s  = hslider("time", 0, 0, 2000, 0.1)*millisec;
time5s  = hslider("time", 0, 0, 5000, 0.1)*millisec;
time10s = hslider("time", 0, 0, 10000, 0.1)*millisec;
time21s = hslider("time", 0, 0, 21000, 0.1)*millisec;
time43s = hslider("time", 0, 0, 43000, 0.1)*millisec;
```



process
vgroup()
hgroup(lower ring)
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hgroup(upper ring)
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vgroup(1)
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ULF
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