EARLY DRAFT

Graph-Interpreter
a scheduler of DSP/ML nanoApps

Contents

Use-cases

Graph-Interpreter is a scheduler of **DSP/ML nanoApps** designed with three objectives:

1. **Accelerate time to market**

Graph-Interpreter helps system integrators and OEM who develop complex DSP/ML stream processing. It allows going fast from prototypes validated on a computer to the final tuning steps on production boards, by updating a graph of computing nodes and their coefficients without device recompilation.

2. **NanoApps repositories**

It provides an opaque interface of the platform memory hierarchy to the computing nodes. It arranges the data flow is translated to the desired formats of each node. It prepares the conditions where nodes will be delivered from a Store.

3. **Portability, scalability**

Use the same stream-based processing methodology from devices using 1 Kbytes of internal RAM to multiprocessor heterogeneous architectures. Nodes can be produced in any programming languages. The Graph are portable when interpreted on another platform.

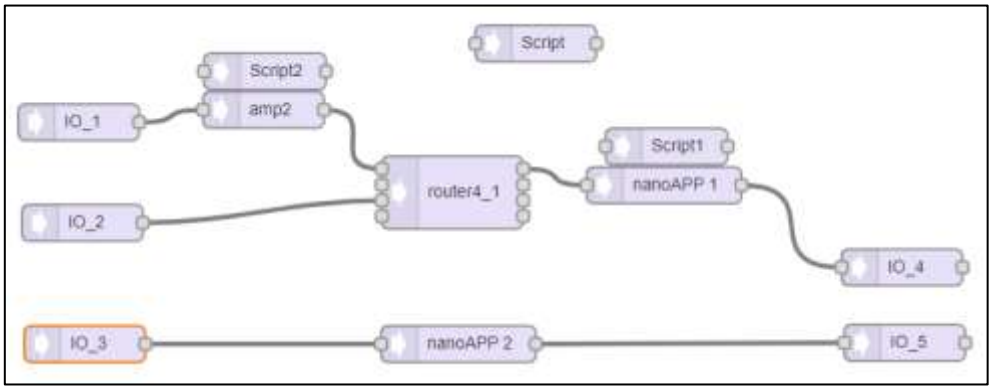
Use-case example :

Tuning interfaces for AI preprocessing

Example of a graph implementing a cascade of DSP/ML algorithms and signal feature extraction before using a classifier (NPU). The system integration task consists in tuning the signal levels and the coefficients of several filters. The system integrator tunes the nodes in charge of rescaling and triggers a GPIO based on level detection. The system integrator updates the parameters of the nodes without recompilation. The memory mapping of the node is tuned on target without recompilation. The task dispatching between processors is tuned for performance optimization, without code recompilation.

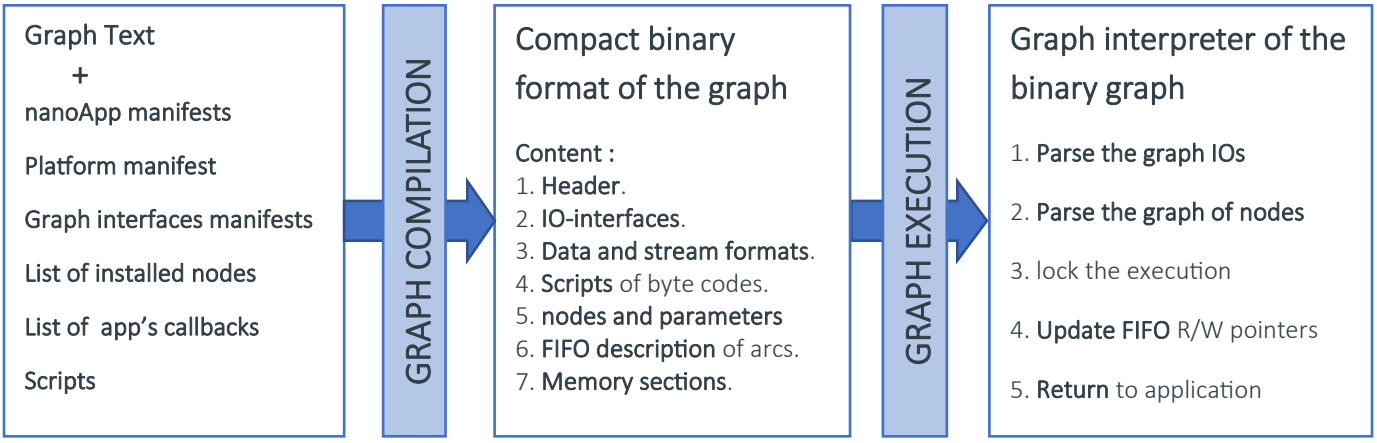
Overview

An example of computing graph is given in the picture below. The "**nodes**" are processing data provided through "**arcs**". Each arc's stream is characterized by its **data format** (raw format, number of channels, interleaving options, time-stamps, sampling-rate, frame size).



Graph of nodes for stream-based computing

The graph to be **interpreted** is coded in a **binary graph** resulting from the **compilation** of the original graph in human-made text format. The graph compiler is a tool executed offline receives the graph and several files called **manifests** giving the characteristics of the platform, of the nodes and graph interfaces ("**IOs**"). The node designers deliver their code with a **node manifest**. The system integrator provides a **platform manifest,** and **IO manifests** of the possible stream connexions.



Processing flow for the binary graph generation

The binary graph is a list of data structures describing : the nodes, the list of arcs (**FIFO descriptors** of the buffers used by the arcs) and their connexions between nodes.

The graph scheduler starts parsing the arcs at the boundary of the graph to fill new data or push new data out. Then it parses the list of arcs searching for the ones holding enough data to trigger the execution of a consumer node, and checking this node has enough free space in its output arc buffer. The parsing activity is configured to stop after a node execution or when no more data is available.

The graph scheduler is written in C90 and delivered with a small set of nodes implementing basic operators like : filters, mixer, router, detector, compressor, rate and data format converters.

Implementation

Introduction

In short, a graph is made of arcs and nodes. The arcs are implemented as circular buffers. The nodes are single-entry-point subroutines with four parameters: a **command**, a pointer to the node **instance**, a pointer to the list of input/output buffers, and a returned status.
The commands are “reset”, “set” and “read parameters”, “run” and “stop”. A minimal wrapper will make legacy codes compatible with this interface.

A node is delivered with a Manifest giving : the name, the author and the parameters (the number of arcs it is connected to, how memory is allocated, etc ..). The manifest is minimal in the following situation :

- The node has one input arc and one output arc, the processing can be managed using any frame length, there is one channel per frame, the raw data format is made of fixed-point integers in Q15 format, there is no time-stamps on frames, the processing is independent of the data rate, the amount of data consumed and produced is identical, the average data rate is identical on the two arcs.
- The node manages its memory allocation by calling the C standard library or by static allocation of its objects.

In all other situations the “node manifest” syntax helps tuning those parameters.
The graph Interpreter manages combination of situations and stream domains (image streams, audio, drifting stream, nodes assigned to a specific processor, three levels of priorities assigned to nodes, embedded scripts of byte-codes for debug and control ..).

Manifests, introduction

The Graph Interpreter is managing the same ways a wide variety of situations. The manifest files are used define the specific situations and options on each parameters. The **parameters options** have the following syntax : a name and options within brackets.

Name_of_the_parameter_with_options *{* index values_or_ranges *}*

If “index” is null it means "any value is possible", the list can be empty. When “index” is a positive integer the following data (in floating-point format) are a list of allowed values the scheduler can select. The Index tells the default value to take at reset time (starting from 1).
When “index” is a negative integer it is followed by three values to describe a range: the first possible value, the increment step and the last possible value. The absolute value of the index selects the value in this range (starting from 1).

Example, a graph interface can have a sampling rate within a predefined list of values, and the 3rd one if the default selected at reset (44.1kHz).

```
io_sampling_rate  { 3 16000 32000 44100 48000 }
```

Example, a graph interface allows to control the gain within a range going from -12dB to +12dB by steps of 0.5dB, and the default gain value is the 25th in this range (corresponding to 0dB).

```
io_digital_gain  { -25 -12 0.5 12 }
```

Graph Text, introduction

The graph gives the list of stream formats, the graph boundaries and the parameter to set during the initialization of the nodes. In the example below a stream of data from an IO named “ADC” (in pratice it may be a data stream from the calling application) is filtered through a 4th order bandpass filter, the result is used for a signal detector which triggers a GPIO.

Here below the graph syntax for declaring the detector node is “ node arm_stream_detector 0 ”, where the second field is the name of the node declared in the platform manifest (see below) and “0” is the instance index of the node in case several detectors are used in the application.

Graph text, minimal example

```
;-------------------------------------------------------------------
;   Stream-based processing using a graph interpreter :
;
;       - The ADC detection is used to toggle a GPIO
;
;   +----------+     +--------+      +--------+     +--------+
;   | ADC      +-----> filter1+------>detect  +-----> GPIO   |
;   +----------+     +--------+      +--------+     +--------+
;
;-------------------------------------------------------------------
format                  0
format_frame_length     8
;-------------------------------------------------------------------
stream_io               0
stream_io_hwid          2       ; io_platform_analog_sensor_0.txt
stream_io               1
stream_io_hwid          7       ; io_platform_gpio_out_0.txt
;-------------------------------------------------------------------
node arm_stream_filter  0
    node_preset         1                   Q15 filter
    node_map_hwblock    1  5                TCM = VID5
    node_parameters     0                   TAG = "all parameters"
        1  u8;  2                           Two biquads
        1  u8;  0                           postShift
        5 s16; 9315 14928  9315 0 -0
        5 s16; 9315  5736  9315  0 -0
    _end_
;-------------------------------------------------------------------
node arm_stream_detector 0
    node_preset         3                   detector setting
;-------------------------------------------------------------------
arc_input   0 arm_stream_filter     0 0 0
arc_output  1 arm_stream_detector   0 1 0
arc arm_stream_filter 0 1 0 arm_stream_detector 0 0 0
```

Binary graph, compilation result

```
//---------------------------------------
//  DATE Mon Jun 24 14:42:00 2024
//  AUTOMATICALLY GENERATED CODES
//  DO NOT MODIFY !
//---------------------------------------
0x00000030, // ------- words in the graph
0x00000000, // 000 000 [0] Destination in RAM 0, and RAM split 0
0x00000041, // 004 001 [1] Number of IOs 2, Formats 1, Scripts 0
0x00000015, // 008 002 [2] LinkedList size 21, Collision table 0, Arc debug 0
0x00000003, // 00C 003 [3] Nb arcs 3  SchedCtrl 0 ScriptCtrl 0
0x00000001, // 010 004 [4] Processors allowed
0x00000000, // 014 005 [5] memory consumed 0,1,2,3
0x00000000, // 018 006 [6] memory consumed 4,5,6,7
0x00000000, // 01C 007 settings of io(graph 0) 2 arc 0 set0_copy1=0 rx0tx1=0
0x00000000, // 020 008 settings of io(graph 1) 7 arc 1 set0_copy1=0 rx0tx1=1
0x00C04807, // 024 009 -----  arm_stream_filter(0) idx:7 Nrx 1 Ntx 1 ArcFmt 1 lockArc 1
0x08020000, // 028 00A ARC 0 Rx0Tx1 0 dbgpage0 -- ARC 2 Rx0Tx1 1 dbgpage0
0x100000D8, // 02C 00B Reserved static memory bank(0) = bank 0 stat0work1ret2 = 0
0x0000004C, // 030 00C           size 76
0x12000000, // 034 00D Scratch memory bank(1) = bank 2 stat0work1ret2 = 1
0x00000008, // 038 00E           size 8
0x01000007, // 03C 00F ParamLen 6+1 Preset 1 Tag0ALL 0
0x24630002, // 040 010 (0)
0x24633A50, // 044 011 (1)
0x00000000, // 048 012 (2)
0x16682463, // 04C 013 (3)
0x00002463, // 050 014 (4)
0x00000000, // 054 015 (5)
0x00404808, // 058 016 -----  arm_stream_detector(0) idx:8 Nrx 1 Ntx 1 ArcFmt 0 lockArc 1
0x08010002, // 05C 017 ARC 2 Rx0Tx1 0 dbgpage0 -- ARC 1 Rx0Tx1 1 dbgpage0
0x10000118, // 060 018 Reserved static memory bank(0) = bank 0 stat0work1ret2 = 0
0x00000034, // 064 019           size 52
0x10000148, // 068 01A Reserved static memory bank(1) = bank 0 stat0work1ret2 = 2
0x00000020, // 06C 01B           size 32
0x03000001, // 070 01C ParamLen 0+1 Preset 3 Tag0ALL 0
0x000003FF, // 074 01D --------------------  vvvvvvvvv RAM vvvvvvvvv
0x00201000, // 078 01E IO(graph0) 2 arc 0 set0_copy1=0 rx0tx1=0 servant1 1 shared 0 domain 0
0x00701801, // 07C 01F IO(graph1) 7 arc 1 set0_copy1=0 rx0tx1=1 servant1 1 shared 0 domain 0
0x00000008, // 080 020 Format  0 frameSize 8
0x00004400, // 084 021           nchan 1 raw 17
0x00000000, // 088 022           domain-dependent
0x00000000, // 08C 023           domain-dependent
0x000000C0, // 090 024 ARC descriptor(0) Base C0h (30h words) fmtProd 0
0x00000008, // 094 025     Size 8h fmtCons 0
0x00C00000, // 098 026
0x00400000, // 09C 027
0x000000C8, // 0A0 028 ARC descriptor(1) Base C8h (32h words) fmtProd 0
0x00000008, // 0A4 029     Size 8h fmtCons 0
0x00C00000, // 0A8 02A
0x00400000, // 0AC 02B
0x000000D0, // 0B0 02C ARC descriptor(2) Base D0h (34h words) fmtProd 0
0x00000008, // 0B4 02D     Size 8h fmtCons 0
0x00C00000, // 0B8 02E
0x00400000, // 0BC 02F
```

A graph description includes the **presets** (preconfigured set of parameters the developer incorporates in the node) and **parameters** of the nodes to use at graph reset time. When the parameters and states need to be exchanged dynamically during the graph execution a **script** can be coupled before/after the execution of each node.

The scripts consist in a **byte-code** language (TBD). A global **script** can be used for the interactions with the application, for example to change parameters during use-case transitions and avoid creating a dependency between the application and the way the graph is designed. A graph can be reused as a **sub-graph** of a more complex graph.

The Graph scheduler / interpreter is using two subroutine interfaces : one used by the application and one to receive notifications at the end of data moves on graph boundaries.

The first interface is :

```
arm_graph_interpreter (uint32_t command,  arm_stream_instance_t *instance, uint8_t *data, uint32_t size)
```

Where “**command**” tells either to reset the graph, execute it, check boundary IOs filling state to move data in/out, set parameters. **Instance** is the memory allocated for the execution of the graph : a structure of pointers to the binary graph, to the installed nodes, to the AL stream interfaces functions (indexed with IO_AL_idx), some debug control fields.

The second interface is the call-back used to notify the end data moves with IOs :

```
arm_graph_interpreter_io_ack (uint8_t IO_AL_idx, uint8_t *data,  uint32_t data_size)
```

The parameters of this function tell the “data” pointer with an amount of “size” bytes have been exchanged on the graph boundary with the interface indexed by IO_AL_idx.

This subroutine can be called under interrupts. It reads the binary graph information to update the **arc circular buffer descriptor** after this data move.

Platform Manifests

A **platform** is characterized by the list of interfaces, the list of processors and their **memory banks** pre-reserved for the execution of the graph (this is for embedded devices, when using Linux the memory allocation is dynamic).

The platform is characterized by the list of the **nodes pre-installed** before graph execution. The platform description is made of two files : a “top level description” with the list of possible interfaces of the graph and the list of nodes. And a “digital description” giving the memory mapping and characteristics of the processors.

Platform manifest

Indexes of the file paths to read the manifest files.

List of possible interfaces to use at the boundary of the graph.

List of pre-installed nodes and their manifests.

```
; ------------------------------------------------------------------------------------------------------------
; TOP MANIFEST :
;   paths to the files
;   processors manifests (memory and architecture)
;   IO manifests to use for stream processing
;   list of the nodes installed in the platform and their affinities with processors
; ------------------------------------------------------------------------------------------------------------
; list of paths for the included files

    3                                       three file paths
    ../../stream_platform/                   "" path index 0 is local
    ../../stream_platform/windows/manifest/  "" path index 1
    ../../stream_nodes/                      "" path index 2

; ------------------------------------------------------------------------------------------------------------
; PLATFORM DIGITAL, MIXED-SIGNAL AND IO MANIFESTS - max 32 IOs => iomask

    1   procmap_manifest_computer.txt       path index + file name

;   path:       path ID
;   Manifest    manifests file
;   FW IO IDX   index used in the graph
;   ProcCtrl    processor affinity bit-field
;   ClockDomain provision for ASRC (clock-domain)
;       some IO can be alternatively clocked from the system clock (0) or other ones. The system integrator decides
;       with this field to manage the flow errors with buffer interpolation (0) or ASRC (other clock domain index)
;       The clock domain index is just helping to group and synchronize the data flow per domain.

    10  number of IO streams available      aligned with struct platform_io_control platform_io[] and platform_computer.h

    ;Path      Manifest         IO_AL_idx ProcCtrl clock-domain     Comments           codes from platform_computer.h
    1   io_platform_data_in_0.txt       0     1        0            application processor  IO_PLATFORM_DATA_IN_0
    1   io_platform_data_in_1.txt       1     1        0            application processor  IO_PLATFORM_DATA_IN_1
    1   io_platform_analog_sensor_0.txt 2     1        0            ADC                    IO_PLATFORM_ANALOG_SENSOR_0
    1   io_platform_motion_in_0.txt     3     1        0            accelero=gyro          IO_PLATFORM_MOTION_IN_0
    1   io_platform_audio_in_0.txt      4     1        0            microphone             IO_PLATFORM_AUDIO_IN_0
    1   io_platform_2d_in_0.txt         5     1        0            camera                 IO_PLATFORM_2D_IN_0
    1   io_platform_line_out_0.txt      6     1        0            audio out stereo       IO_PLATFORM_LINE_OUT_0
    1   io_platform_gpio_out_0.txt      7     1        0            GPIO/LED               IO_PLATFORM_GPIO_OUT_0
    1   io_platform_gpio_out_1.txt      8     1        0            GPIO/PWM               IO_PLATFORM_GPIO_OUT_1
    1   io_platform_data_out_0.txt      9     1        0            application processor  IO_PLATFORM_DATA_OUT_0


; ------------------------------------------------------------------------------------------------------------
; SOFTWARE COMPONENTS MANIFESTS

    20  nodes     path index + file name, in the same order of p_stream_node node_entry_point_table[NB_NODE_ENTRY_POINTS]

    ;  p_stream_node node_entry_point_table[NB_NODE_ENTRY_POINTS] =
    2                       swc_manifest_none.txt           /*  0 ID0 is reserved for by-passes             */
    2         Basic/arm/script/swc_manifest_script.txt      /*  1 arm_stream_script          byte-code interpreter (arm_stream_script_index = 1)*/
    2         Basic/arm/script/swc_manifest_graph_control.txt /*  2 arm_stream_graph_control    scheduler control : lock, bypass, loop, if-then */
    2         Basic/arm/router/swc_manifest_router.txt      /*  3 arm_stream_router          copy input arcs and subchannel and output arcs and subchannels   */
    2      Basic/arm/converter/swc_manifest_converter.txt   /*  4 arm_stream_converter       raw data format converter */
    2      Basic/arm/amplifier/swc_manifest_amplifier.txt   /*  5 arm_stream_amplifier       amplifier mute and un-mute with ramp and delay control */
    2          Basic/arm/mixer/swc_manifest_mixer.txt       /*  6 arm_stream_mixer           multichannel mixer with mute/unmute and ramp control */
. . .
    2        AI/arm/detector2D/swc_manifest_detector2D.txt  /* 17 arm_stream_detector2D      image activity detection */
    2       image/arm/filter2D/swc_manifest_filter2D.txt    /* 18 arm_stream_filter2D       convolution filter of the image */
    2       Basic/arm/analysis/swc_manifest_analysis.txt    /* 19 arm_stream_analysis       energy, spectrum analysis  */

; ------------------------------------------------------------------------------------------------------------
```

Digital manifest

System memory map with shareable, private, speed information.

List of processors and their pre-installed list of compute services.

```
; ------------------------------------------------------------------------------------------------------------
; Processor and memory configuration + default memory mapping
; ------------------------------------------------------------------------------------------------------------
;

    1 1 9       number of architectures, number of processors, number of memory banks
```

```
;   memory banks:
;   - ID        base offset ID reference above
;   - VID       virtual ID used in the graph for manual mapping, must stay below 99 for swap controls (see NodeTemplate.txt)
;   - S         0=any/1=normal/2=fast/3=critical-Fast,
;   - W         static0/working1/retention2,
;   - P         shared0/private1,
;   - H         DMAmemHW1
;   - D         Data0/Prog1/Both2
;   - Size      minimum sizes guaranteed per VID starting from @[ID]+offset below
;   - Offset    maximum offset from the base offset ID, (continuous banks means = previous size + previous offset)

;   the memory is further split in the graph "top_memory_mapping" to ease mapping and overlays

;   ID VID  S W P H D     Size offset from offsetID
    0   0   1 0 0 0 0    95526 10       VID0=DEFAULT flat memory bank, can overlap with the others
    0   1   0 0 0 0 0    65526 10       SRAM0 static, hand tuned memory banks
    0   2   0 0 0 0 0    30000 65536    SRAM1 static
    0   3   0 1 0 0 0    15000 95536    SRAM1 working at application level
    0   4   0 1 0 0 0   256000 262144   DDR working at application level
    2   5   3 1 1 0 0     1024 262144   DTCM Private memory of processor 1
    1  10   0 2 0 0 0     1024 524288   Retention memory
    3  20   0 0 0 0 0   200000 10       Data in Flash
    2   8   3 1 1 0 1    16384 0        ITCM Private memory of processor 1


;   memory offsets ID used by all processors and physical address seen from the main processor
;   0       h20000000   image of "platform_specific_long_offset(intPtr_t long_offset[])"
;   1       h28000000       in stream_al/platform_XXXXX.c
;   2       h2C000000   TCM Private memory of processor 1
;   3       h08000000   Internal Flash

;-------------------------------------------------------------------------------------
; all architectures
    ;   all processors (processor IDs >0)
        ;-----------------------------------------------------------
        1 1 15      processor ID, boolean "I am the main processor" allowed to boot the graphs
        ;           Bit-field computation firmware extensions, on top of the basic one, embedded in Stream services
        ;                 EXT_SERVICE_MATH 1, EXT_SERVICE_DSPML 2, EXT_SERVICE_AUDIO 3, EXT_SERVICE_IMAGE 4
```

The “**ID**” and “**VID**” (memory plane Identifier) index is used to index the graph memory map addresses to physical addresses. This is a memory plane used to have compact representation of physical addresses and to help multiprocessors pointing to the same physical addresses even if they have address translators.

The platform **digital manifest** gives the base address and sizes of the memory planes addressed with up to **8 IDs**, each memory plane has multiple VID corresponding to physical memory sub-blocks. By convention the ID and VID index 0 are used for the shared RAM holding the graph’s arc FIFO descriptors (read and write index indexes to buffers).

A system integrator can avoid specifying the VID memory mapping and let the graph compiler manage using ID/VID=0. Tuning the performance means taking care of overlays, or arranging processors don’t have simultaneous access to the same physical memory sub-blocks, and this is where VID indexes are used.

IO Manifests

The arcs at the boundary of the graph are called “**IOs**” (as Input / Output ports mapped to a software or hardware interface). The IOs are characterized by the physical **domain** of operation (for example a connexion with the application, an image or audio stream, a motion sensor, a GPIO).

The IO is described by the commander / servant protocol to use, the data stream format, and a function implementing the data move, initialization, settings, and stop. Those functions are located in the scheduler’s platform **AL** (platform Abstraction Layer. Each IOs function has an index named **IO_AL_idx**.

Example of IO manifest.

```
; ---------------------------------------------------------------------------------------------------------------
; Manifest of interface abstraction to ADC converter and analog sensor
; ---------------------------------------------------------------------------------------------------------------

io_platform_sensor_in_0                    ; name for the tools
analog_in                                  ; domain name,   unit: dB, Vrms, mV/Gauss, dps, kWh, ...

io_commander0_servant1 1                   ; commander=0 servant=1 (default is servant)
io_direction_rx0tx1    1                   ; direction of the stream  0:input 1:output from graph point of view
io_subtype_units       104                 ; depending on the domain. Here Units_Vrms of the "general" domain (0 = any or underfined)
io_analogscale         0.55                ; 0.55V is corresponding to full-scale (0x7FFF or 1.0f) with the default setting
io_sampling_rate      {1 16000 44100 48000} ; sampling rate options (enumeration in Hz)
io_rescale_factor      12.24  -44.3        ; [1/a off] analog_input = invinterpa x ((samples/Full_Scale_Digital) - interpoff)
_end_
```

IO manifest Header, the domains

```
io_platform_sensor_in_0     ; IO name for the tools
analog_in                   ; domain name, among the list below :

domain name               description and examples
-----------               ------------------------
general                   (a)synchronous sensor , electrical, chemical, color, .. remote data
audio_in                  microphone, line-in, I2S, PDM RX
audio_out                 line-out, earphone / speaker, PDM TX, I2S,
gpio_in                   generic digital IO , control of relay,
gpio_out                  generic digital IO , control of relay,
motion                    accelerometer, combined or not with pressure and gyroscope
2d_in                     camera sensor
2d_out                    display, led matrix,
analog_in                 with aging control
analog_out                D/A, position piezzo, PWM converter
rtc                       ticks sent from a programmable timer
user_interface_in         button, slider, rotary button
user_interface_out        LED, digits, display,
```

IO configuration

Tags	Parameter	Comments
io_commander0_servant1	1	commander=0 servant=1 (default is servant) IO streams are managed from the graph scheduler with the help of one subroutine per IO using the template : typedef void (*p_io_function_ctrl) (uint32_t command, uint8_t *data, uint32_t length); The "command" parameter can be : STREAM_SET_PARAMETER, STREAM_DATA_START, STREAM_STOP, STREAM_SET_BUFFER. When the IO is "Commander" it calls arm_graph_interpreter_io_ack() when data move is finished When the IO is "Servant" the scheduler calls p_io_function_ctrl(STREAM_RUN, ..) to ask for data move. Once the move is done the IO driver calls arm_graph_interpreter_io_ack()
io_buffer_allocation	2.1	default is 0, which means the buffer is declared outside of the graph The floating-point number is a multiplication factor of the frame size (here 2.1 frames), the buffer byte size is computed with rounding (n = floor(X+0.5)) When more than one byte are exchanged, the IO driver needs a temporary buffer. This buffer can be allocated "outside(0)" by the IO driver, or ">1" during the graph memory mapping preparation The memory mapping of this allocation is decided in the graph and can be in general-purpose or any RAM "0" or specific memory bank for speed reason or reserved for DMA processing, etc ..
io_direction_rx0tx1	1	direction of the stream 0:input 1:output from graph point of view
io_raw_format	S16	options for the raw arithmetics computation format here STREAM_S16
io_interleaving	1	multichannel interleaved (0), deinterleaved by frame-size (1)
io_nb_channels	1	options for the number of channels
io_frame_length	{1 1 2 16 }	options of possible frame_size in number of sample (can mono or multi-channel).
io_frame_duration	{1 10 22.5}	options of possible frame_size in [milliseconds]. The default frame length is 1 sample
io_subtype_units	VRMS	depending on the domain. Here Units_Vrms of the "general" domain (0 = any or underfined)
io_subtype_multiple	{DPS GAUSS}	example for multi domain sensor : motion can have up to 4 data units for accelerometer, gyroscope, magnetometer, temperature
io_power_mode	0	to set the device at boot time in stop / off (0) running mode(1) : digital conversion (BIAS always powered for analog peripherals) running mode(2) : digital conversion BIAS shut-down between conversions Sleep (3) Bias still powered but not digital conversions
io_position meter	1.1 -2.2 0.01	unit and relative XYZ position with the platform reference point
io_euler_angles	10 20 90	Euler angles with respect to the platform reference orientation, in degrees
io_sampling_rate	{1 16000 44100 48000}	sampling rate options (enumeration in Hz)
io_sampling_period_s	{1 1 60 }	sampling period options (enumeration in [second])
io_sampling_period_day	{1 0.25 1 7}	sampling period options (enumeration in [day])
io_sampling_rate_accuracy	0.1	in percentage
io_time_stamp_format	{1 1}	0 no time-stamp, 1 absolute time, 2 relative time from last frame, 3 frame counter
io_time_stamp_length	{1 1}	0/1/2/3 corresponding to 16/32/64/64 bits time formats (default : STREAM_TIME32)

Graph description

A graph text several sections :

- Control of the scheduler : debug option, location of the graph in memory
- File path : to easily incorporate sections of data “included” with files
- Formats : most of the arcs are using the same frame length and sampling rate, to avoid repeating the same information the formats are grouped in a table and referenced by indexes
- The boundary of the graph: the IOs are a kind of node with on arc producing or consuming a stream of data
- The scripts, are a byte-code interpreted language used for simple operations like setting parameters, sharing debug information, calling “callbacks” predefined in the application.
- The list of nodes, without their connexions with other nodes. This section defines the boot parameters, the memory mapping hand optimized.
- The list of arcs, their relations with two nodes and the minimal type of debug activity on each transaction

Control of the scheduler

Tags	Parameters	Comments
set_file_path	Int String	A graph can “include” data from other file, this command creates an index to use instead of a computer file patch s Index and its file path, used for sub graphs and scripts
graph_location	1	0: destination of the binary graph is in RAM (default) 1: keep the graph in Flash and copy in RAM the portion starting from PIO (the end of node linked-list) 2: the graph is already in RAM provided by the application
debug_script_fields	24	LSB set means "call the debug script before each node is called" bit 1 (2) set means "call the debug script after each node is called" bit 2 (4) set means "call the debug script at the end of the loop" bit 3 (8) set means "call the debug script is called when starting the graph scheduling" bit 4 (16) set means "call the debug script is called when returning of the graph scheduling" no bit is set (default) the debug script is not called (default 0)
scheduler_return	3	1: return to caller after each node calls 2: return to caller once all nodes are parsed 3: return to caller when all nodes are starving (default 3)
allowed_processors	255	bit-field of the processors allowed to execute this graph, (default = 1 main processor)
graph_map_hwblock	0	index of the memory block indexes where to map the graph. Default VID's is 0 internal RAM

Tags	Parameters	Comments
format	2	index used to start the declaration of a new format
format_raw_data	17	raw data of this format (17 : S16 is the default)
format_frame_length	160	frame length in number of bytes (default :1)
format_interleaving	0	0 means interleaved data, 1 means deinterleaved data by packets of "frame size"
format_nbchan	1	number of channels in the stream (default 1)
format_time_stamp	0	time-stamp format 0:none, 1:absolute time-stamp, 2:relative time, 3:simple counter
format_time_stamp_size	0	0:16bits 1:32bits 2:64bits (see "STREAM_TIME16D" for example)
format_domain	2	domain type (0 means "any") general (a)synchronous sensor + rescaling, .. remote data, compress audio_in microphone, line-in, I2S, PDM RX audio_out line-out, earphone / speaker, PDM TX, I2S, gpio_in generic digital IO , control of relay, gpio_out generic digital IO , control of relay, motion accelerometer, combined or not with pressure and gyroscope 2d_in camera sensor 2d_out display, led matrix, analog_in with aging control analog_out D/A, position piezzo, PWM converter rtc ticks sent from a programmable timer user_interface_in button, slider, rotary button user_interface_out LED, digits, display, platform_3 platform_2 platform-specific #2, decoded with callbacks platform_1 platform-specific #1, decoded with callbacks
format_sdomain		subdomain
format_sampling_rate		tbd
format_audio_mapping		tbd
format_motion_mapping		tbd
format_2d_height		tbd
format_2d_width	int	tbd
format_2d_border	int	tbd

Tags	Parameters	Comments
stream_io	int	index used to start the declaration of a new IO
stream_io_format	int	index to the stream format (Index of the above table) (default #0)
stream_io_hwid	int	ID of the interface given in "files_manifests_computer" (default #0)
stream_io_setting1	int	setting word32 (SETTINGS_IOFMT2), the format depends on the IO domain (default #0)
stream_io	int	index used to start the declaration of a new IO

Tags	Parameters	Comments
node_parameters	0	Start of a parameter section ending with "_end_", the parameter is the "TAG" telling the index of specific parameters to update, or "0" meaning "all the parameters are reloaded with the following data". The format of the following parameters is : number of fields, data type (u8/s8/h8, u16/s16/h16, u32/s32/h32, f32, f64), ";", the data, and optional comments. For example : 1 u8; 2 Two biquads 5 f32; 0.284277f 0.455582f 0.284277f 0.780535f -0.340176f ellip(4, 1, 40, 3600/8000, 'low')
node_preset	1	parameter preset used at boot time, default = #0
node_malloc_E	12	"E" parameter used in "Memory Size Bytes", default = #0
node_map_hwblock	2 3	index of the memory block "node_mem" and the VID indexes from "procmap_manifest_xxxx.txt" where to map it. Default VID's is 0.
node_map_copy	2 3	copy the indexed "node_mem" to VID 3 (faster memory) before run
node_map_swap	2 3	swap the indexed "node_mem" to VID 3 (faster memory) before run, and restored after
node_trace_id	0	IO port used to send the trace
node_map_proc	0	execute this node on this processor (0: any possible, default)
node_map_arch	0	execute this node on this architecture (0: any possible, default)
node_map_rtos	0	execute this node on this thread index (0: any possible, default)
node_map_verbose	0	level of debug trace, default = #0
node_script	<0..127>	index of the script to call before and after execution of this node

Tags	Parameters	Comments
script_registers	2	number of registers used in this script , default 2
script_pointers	2	number of pointers used in this script , default 2
script_stack	12	size of the stack in word64 (default = 0)
script_mem_shared	1	Is it a private RAM(0) or can it be shared with other scripts(1)
script_mem_map	0	Memory mapping to VID #0 (default) this declaration creates the transmit arc of the script-node pointing to the stack/buffer area

Tags	Parameters	Comments
arc_input	1 node_name 2 0 0	Arc connected to the graph interface in a subgraph the IDX interfaces are sequential 1,2,3.. and documented like function parameters, in the main graph the "top_graph_interface" have the indexes input arc index #1 connected to "node_name" instance #2 and its arc index #0, Format #0
arc_output	2 node_name 3 1 0	output arc index #2 connected to "node_name" instance #3 and its arc index #1, Format #0
arc	node1 1 2 0 node2 3 4 1	Arc connected between two node arc between node1 instance #1 arc index #2, producer format #0 to node2 instance #3 and its arc index #4, consumer format #1
arc_flow_error	1	#1 do something depending on domain when a flow error occurs, default #0 (no interpolation)
arc_debug_cmd	1	debug action "ARC_INCREMENT_REG", default = #0 (no debug)
arc_debug_reg	3	index of the 64bits result, default = #0
arc_debug_page	0	debug registers base address + 64bits x 16 registers = 32 word32 / page, default = #0
arc_flush	0	control of register "MPFLUSH_ARCW1" : forced flush of data in MProcessing and shared tasks
arc_extend_addr	1	address range extension-mode of the arc descriptor "EXTEND_ARCW2" for large NN models, default = #0 (no extension)
arc_map_hwblock	0	mapping VID index from "procmap_manifest.txt" to map the buffer, default = #0 (VID0)
arc_jitter_ctrl	1.5	factor to apply to the minimum size between the producer and the consumer, default = 1.0 (no jitter)

Node Manifests

The interpretation process is helped by the compilation of manifests data. A node's manifest is giving the amount of memory blocks to allocate, and their characteristics (static memory blocks, scratch, retention memory, critical fast or "best effort speed", alignment). The node's manifest gives the stream format used on each input/output arc connected to the node. A node can be connected up to 8 arcs, each having different stream format (raw data, frame size, sampling-rate, interleaving, time-stamp format). Those details are packed in the node binary structure interpreted by the scheduler.

Identification

Parameters (example)	Comments
ARM	developer name
arm_stream_detector	node name

Graph parameters

Tags	Parameter	Comments
node_nb_arcs	1 1	nb arc input, output, default values "1 1"
node_arc_parameter	0	node with extra-large amount of parameters (NN models) will declare it with extra arcs
node_steady_stream	1	(0) the data flow is variable (or constant, default value :1) on all input and output arcs
node_same_data_rate	1	(0) the arcs have different data rates, (1) all arcs have the same data rate
node_use_dtcm	1	default 0 (no MP DTCM_LW2), 1: fast memory pointer placed after the arc format
node_use_arc_format	0	default 1 : the scheduler must push each arc format (LOADFMT_LW0_LSB)
node_mask_library	15	default 0 bit-field of dependencies to computing libraries
node_subtype_units	VRMS	triggers the need for rescaling and data conversion
node_architecture	0	arch compatible with (default: 0 = source code) to merge and sort for ARCHID_LW0
node_fpu_used	0	FPU option used (default 0: none, no FPU assembly or intrinsic)
node_use_unlock_key	1	a key-exchange protocol is initiated at reset time
node_node_version	101	version of the computing node
node_stream_version	1	version of the stream scheduler it is compatible with

Node memory allocation

memory allocation size in bytes =

```
A                              : memory allocation in Bytes (default 0)
+ B x nb_channels of arc(i)    : addition memory as a number of channels in arc index i (default 0)
+ C x sampling_rate of arc(j)  ; .. as proportional to the sampling rate of arc index j (default 0)
+ D x frame_size of arc(k)     ; .. as proportional to the frame size used for the arc index k (default 0)
+ E x parameter from the graph ; optional field " node_malloc_E " during the node declaration in the graph, for
                               ;   example the number of pixels in raw for a scratch area (default 0)
```

Tags	Parameter	Comments
node_mem	2	start the declaration of a new memory block with index 2
node_mem_alloc	32	"A" size = 32Bytes data memory, Static, Fast memory block
node_mem_nbchan	4 0	"B" add in Bytes : 4 x nb of channels of arc 0
node_mem_sampling_rate	0.1 1	"C" add in Bytes : 0.1 x sampling rate of arc 1
node_mem_frame_size	1 0	"D" add in Bytes : 1 x frame size of arc 0
node_mem_alignement	4	4 bytes (default)
node_mem_retention	1	0 for a Static memory allocation, preserved along the execution (default) 1 for Working (or Scratch) area which can be reused and overlaid by other nodes 2 for memory to be preserved (Retention) after a platform reboot
node_mem_speed	2	0 for 'best effort' or 'no constraint' on speed access 1 for 'fast' memory selection when possible 2 for 'critical fast' section, to be in I/DTCM when available
node_mem_relocatable	1	Default 0 : not relocatable, 1: a command 'STREAM_UPDATE_RELOCATABLE' is sent to the node to update the pointer to this memory allocation
node_mem_data0prog1	0	selection data / program

Tags	Parameters options examples	Comments
node_arc	2	start the declaration of a new arc with index 2
node_arc_rx0tx1	0	followed by 0:input 1:output, default = 0 0 and 1 1
node_arc_sampling_rate	{1 16000 44100}	sampling rate options (enumeration in Hz), default "any"
node_arc_interleaving	0	multichannel interleaved (0, default), deinterleaved by frame-size (1)
node_arc_nb_channels	{1 1 2}	options for the number of channels (default 1)
node_arc_raw_format	{1 17}	options for the raw arithmetics computation format here STREAM_S16, , default values "1 S16"
node_arc_frame_length	{1 1 2 16}	options of possible frame_size in number of sample (can mono or multi-channel)
node_arc_frame_duration	{1 10 22.5}	options of possible frame_size in [milliseconds]

		(one sample can mono or multi-channel), default is "any length"
node_arc_sampling_period_s	{1 0.1 0.2 0.4}	sampling period options (enumeration in [second])
node_arc_sampling_period_day	{1 0.25 1 7}	sampling period options (enumeration in [day])
node_arc_sampling_accuracy	0.8	sampling rate accuracy in percent
node_arc_inPlaceProcessing	1 0	index of the output arc sharing the same interface buffer as one
node_arc		input arc buffer (default: all output buffers are separated from the input buffers)
		start the declaration of a new arc with index 2

Node design

The nodes have a single entry point with the format “func (int, *,*,*)”. The first parameter is the command, a 32bits bit-field (the command to execute, the “PRESET” defined in the graph, the parameter “TAG” used during SET PARAMETER.

Command RESET

The second parameter points to the list of memory banks (field “node_mem” in the manifest), starting with the node instance. The list continues with the format of the input and output arcs (field “node_use_arc_format” in the manifest). The format structure gives the frame size, number of channels, interleaving and time-stamp scheme, raw data type, and domain-dependent details (image format, audio mapping, etc..).

The second parameter is the address the function used for services (DSP / ML / math computing libraries, time library, multimedia library, interface to the standard library for nodes delivered in binary format).

Command SET PARAMETER

The second parameter is the node instance.
The third parameter is the address of parameters to load. When the TAG is null all the parameters are updated, otherwise only the ones selected by TAG are updated after using the ones of the PRESET.

Command RUN

The second parameter is the node instance.
The third parameter points to a list of buffers : [{data pointer size1}{data pointer size2}..]. For input streams the “size” if the amount of data in the buffer, for output streams the “size” is the free area available in the buffer.

When the manifest tells “node_steady_stream 0” the buffers have variable consumption and production size, the node updates the “size” field with the meaning “amount of input data consumed” for input streams, and “amount of data produced” on the output arcs.

When a stream data format is “deinterleaved” (for example Left and Right audio samples are in this order : LLLL..LLLLRRRR...RRRR) the size of the first buffer (the "frame") the pointer to the following channels is computed by incrementing the base pointer address with the size of the frame.

Annexe

Domain-specific IO configuration (TBD)

Domain “general”

Tags	Parameter	Comments
io_commander0_servant1	1	commander=0 servant=1 (default is servant) IO stream are managed from the graph scheduler with the help of one subroutine per IO using the template : typedef void (*p_io_function_ctrl) (uint32_t command, uint8_t *data, uint32_t length); The "command" parameter can be : STREAM_SET_PARAMETER, STREAM_DATA_START, STREAM_STOP, STREAM_SET_BUFFER. And one subroutine for all IOs in charge of acknowledge the end of the data move, to update the circular buffer, manage overflows. This subroutine can be called from ISR void arm_graph_interpreter_io_ack (uint8_t fw_io_idx, uint8_t *data, uint32_t data_size); Where fw_io_idx is the index given in "top_manifest_xxxx.txt" When the IO is "Commander" it calls arm_graph_interpreter_io_ack() when data is read When the IO is "Servant" the scheduler call p_io_function_ctrl(STREAM_DATA_START, ..) to ask for data move. Once the move is done the IO driver calls arm_graph_interpreter_io_ack()
io_buffer_allocation	2.1	default is 0, which means the buffer is declared outside of the graph The floating-point number is a multiplication factor of the frame size (here 2 frames), the buffer size is computed with rounding (n = floor(X+0.5)) When more than one byte are exchanged, the IO driver needs a temporary buffer. This buffer can be allocated "outside(0)" by the IO driver, or ">1" during the graph memory mapping preparation The memora mapping of this allocation is decided in the graph and can be in general-purpose or any RAM "0" or specific memory bank for speed reason or reserved for DMA processing, etc ..
io_direction_rx0tx1	1	direction of the stream 0:input 1:output from graph point of view
io_raw_format	S16	options for the raw arithmetics computation format here STREAM_S16
io_interleaving	1	multichannel interleaved (0), deinterleaved by frame-size (1)
io_nb_channels	1	options for the number of channels

audio_in

Tags	Parameter	Comments
io_nb_channels	{1 1 2}	options for the number of channels
io_channel_mapping	1	mono (Front Left), 18 channels can be controlled : Front Left FL bit0 Front Right FR 1 Front Center FC 2 Low Frequency LFE 3 Back Left BL 4 Back Right BR 5 Front Left of Center FLC 6 Front Right of Center FRC 7 Back Center BC 8 Side Left SL 9 Side Right SR 10 Top Center TC 11 Front Left Height TFL 12 Front Center Height TFC 13 Front Right Height TFR 14 Rear Left Height TBL 15 Rear Center Height TBC 16 Rear Right Height TBR 17
io_analog_gain	{1 0 12 24 }	analog gain (PGA)
io_digital_gain	{-1 -12 1 12 }	digital gain range
io_hp_filter	{1 1 20 50 300 }	high-pass filter (DC blocker) ON(1)/OFF(0) followed by cut-off frequency options

audio_out

Tags	Parameter	Comments
io_subtype_units	87	Units is [mV]
io_analog_scale	1400	1400nV is corresponding to full-scale with the default setting
io_sampling_rate	{1 16000 44100 48000}	sampling rate options (enumeration in Hz)
io_nb_channels	{1 1 1 2 }	multichannel interleaved (0), deinterleaved by frame-size (1) + options for the number of channels
io_channel_mapping	1	mono (Front Left), 18 channels can be controlled :

Data types

```
Raw data types
STREAM_DATA_ARRAY 0  see stream_array: [0NNNTT00] 0, type, nb
STREAM_S1         1  S, one signed bit, "0" = +1                              one bit per data
STREAM_U1         2  one bit unsigned, boolean
STREAM_S2         3  SX                                                      two bits per data
STREAM_U2         4  XX
STREAM_Q1         5  Sx ~stream_s2 with saturation management
STREAM_S4         6  Sxxx                                                    four bits per data
STREAM_U4         7  xxxx
STREAM_Q3         8  Sxxx
STREAM_FP4_E2M1   9  Seem  micro-float [8 .. 64]
STREAM_FP4_E3M0  10  Seee  [8 .. 512]
STREAM_S8        11  Sxxxxxxx                                                 eight bits per data
STREAM_U8        12  xxxxxxxx  ASCII char, numbers..
STREAM_Q7        13  Sxxxxxxx  arithmetic saturation
STREAM_CHAR      14  xxxxxxxx
STREAM_FP8_E4M3  15  Seeeemmm  NV tiny-float [0.02 .. 448]
STREAM_FP8_E5M2  16  Seeeeemm  IEEE-754 [0.0001 .. 57344]
STREAM_S16       17  Sxxxxxxx.xxxxxxxx                                        2 bytes per data
STREAM_U16       18  xxxxxxxx.xxxxxxxx  Numbers, UTF-16 characters
STREAM_Q15       19  Sxxxxxxx.xxxxxxxx  arithmetic saturation
STREAM_FP16      20  Seeeeemm.mmmmmmmm  half-precision float
STREAM_BF16      21  Seeeeeee.mmmmmmmm  bfloat
STREAM_Q23       22  Sxxxxxxx.xxxxxxxx.xxxxxxxx  24bits                      3 bytes per data
STREAM_Q23_32    23  SSSSSSSS.Sxxxxxxx.xxxxxxxx.xxxxxxxx                      4 bytes per data
STREAM_S32       24  one long word
STREAM_U32       25  xxxxxxxx.xxxxxxxx.xxxxxxxx.xxxxxxxx UTF-32, ..
STREAM_Q31       26  Sxxxxxxx.xxxxxxxx.xxxxxxxx.xxxxxxxx
STREAM_FP32      27  Seeeeeee.mmmmmmmm.mmmmmmmm.mmmmmmmm  FP32
STREAM_CQ15      28  Sxxxxxxx.xxxxxxxx Sxxxxxxx.xxxxxxxx (I Q)
STREAM_CFP16     29  Seeeeemm.mmmmmmmm Seeeeemm.mmmmmmmm (I Q)
STREAM_S64       30  long long                                               8 bytes per data
STREAM_U64       31  unsigned  64 bits
STREAM_Q63       32  Sxxxxxxx.xxxxxx ....... xxxxx.xxxxxxxx
STREAM_CQ31      33  Sxxxxxxx.xxxxxxxx.xxxxxxxx.xxxxxxxx Sxxxx..
STREAM_FP64      34  Seeeeeee.eeemmmmm.mmmmmmm ... double
STREAM_CFP32     35  Seeeeeee.mmmmmmmm.mmmmmmmm.mmmmmmmm Seee.. (I Q)
STREAM_FP128     36  Seeeeeee.eeeeeeee.mmmmmmm ... quadruple precision       16 bytes per data
STREAM_CFP64     37  fp64 fp64 (I Q)
STREAM_FP256     38  Seeeeeee.eeeeeeee.eeeeemm ... octuple precision         32 bytes per data
STREAM_TIME16    39  sssssssssssqqqq q14.2   1 hour + 8mn +/- 0.0625
STREAM_TIME16D   40  qqqqqqqqqqqqqqqq q15 [s] time difference +/- 15us
STREAM_TIME32    41  sssssssssssssssssssssssssqqqq q28.4  [s] (8.5 years +/- 0.0625s)
STREAM_TIME32D   42  sssssssssssssssqqqqqqqqqqqqqqq q17.15 [s] (36h, +/- 30us) time difference
STREAM_TIMESTMP  43  sssssssssssssssssssqqqqqqqqqqqq q20.12 [s] (12 days, +/- 0.25ms)
STREAM_TIME64    44  ____sssssssssssssssssssssssssssssssqqqqqqqqqqqqqqqqqqqqqqqqqqqqqq q32.28 [s] 140 Y +Q28 [s]
STREAM_TIME64MS  45  _____________________mmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmm ms
STREAM_TIME64ISO 46  ___..YY..YY..YY..YY..MM..MM..DD..DD..SS..SS.....offs..MM..MM..MM ISO8601 signed offset 2024-05-04T21:12:02+07:00
STREAM_WGS84     47  <--LATITUDE 32B--><--LONGITUDE 32B-->  lat="52.518611" 0x4252130f   lon="13.376111" 0x4156048d - dual IEEE754
STREAM_HEXBINARY 48  UTF-8 lower case hexadecimal byte stream
STREAM_BASE64    49  RFC-2045 base64 for xsd:base64Binary XML data
STREAM_STRING8   50  UTF-8 string of char terminated by 0
STREAM_STRING16  51  UTF-16 string of char terminated by 0

Physical units (RFC8428 RFC8798)
STREAM_SUBT_ANA_ANY             0         any
STREAM_SUBT_ANA_METER           1  m         meter
STREAM_SUBT_ANA_KGRAM           2  kg        kilogram
STREAM_SUBT_ANA_GRAM            3  g         gram*
STREAM_SUBT_ANA_SECOND          4  s         second
STREAM_SUBT_ANA_AMPERE          5  A         ampere
STREAM_SUBT_ANA_KELVIB          6  K         kelvin
STREAM_SUBT_ANA_CANDELA         7  cd        candela
STREAM_SUBT_ANA_MOLE            8  mol       mole
STREAM_SUBT_ANA_HERTZ           9  Hz        hertz
STREAM_SUBT_ANA_RADIAN         10  rad       radian
STREAM_SUBT_ANA_STERADIAN      11  sr        steradian
STREAM_SUBT_ANA_NEWTON         12  N         newton
STREAM_SUBT_ANA_PASCAL         13  Pa        pascal
STREAM_SUBT_ANA_JOULE          14  J         joule
STREAM_SUBT_ANA_WATT           15  W         watt
STREAM_SUBT_ANA_COULOMB        16  C         coulomb
STREAM_SUBT_ANA_VOLT           17  V         volt
STREAM_SUBT_ANA_FARAD          18  F         farad
STREAM_SUBT_ANA_OHM            19  Ohm       ohm
STREAM_SUBT_ANA_SIEMENS        20  S         siemens
STREAM_SUBT_ANA_WEBER          21  Wb        weber
STREAM_SUBT_ANA_TESLA          22  T         tesla
STREAM_SUBT_ANA_HENRY          23  H         henry
STREAM_SUBT_ANA_CELSIUSDEG     24  Cel       degrees Celsius
STREAM_SUBT_ANA_LUMEN          25  lm        lumen
STREAM_SUBT_ANA_LUX            26  lx        lux
STREAM_SUBT_ANA_BQ             27  Bq        becquerel
STREAM_SUBT_ANA_GRAY           28  Gy        gray
STREAM_SUBT_ANA_SIVERT         29  Sv        sievert
STREAM_SUBT_ANA_KATAL          30  kat       katal
STREAM_SUBT_ANA_METERSQUARE    31  m2        square meter (area)
STREAM_SUBT_ANA_CUBICMETER     32  m3        cubic meter (volume)
STREAM_SUBT_ANA_LITER          33  l         liter (volume)
STREAM_SUBT_ANA_M_PER_S        34  m/s       meter per second (velocity)
STREAM_SUBT_ANA_M_PER_S2       35  m/s2      meter per square second (acceleration)
STREAM_SUBT_ANA_M3_PER_S       36  m3/s      cubic meter per second (flow rate)
STREAM_SUBT_ANA_L_PER_S        37  l/s       liter per second (flow rate)*
STREAM_SUBT_ANA_W_PER_M2       38  W/m2      watt per square meter (irradiance)
STREAM_SUBT_ANA_CD_PER_M2      39  cd/m2     candela per square meter (luminance)
STREAM_SUBT_ANA_BIT            40  bit       bit (information content)
STREAM_SUBT_ANA_BIT_PER_S      41  bit/s     bit per second (data rate)
STREAM_SUBT_ANA_LATITUDE       42  lat       degrees latitude[1]
STREAM_SUBT_ANA_LONGITUDE      43  lon       degrees longitude[1]
STREAM_SUBT_ANA_PH             44  pH        pH value (acidity; logarithmic quantity)
STREAM_SUBT_ANA_DB             45  dB        decibel (logarithmic quantity)
STREAM_SUBT_ANA_DBW            46  dBW       decibel relative to 1 W (power level)
STREAM_SUBT_ANA_BSPL           47  Bspl      bel (sound pressure level; log quantity)
STREAM_SUBT_ANA_COUNT          48  count     1 (counter value)
STREAM_SUBT_ANA_PER            49  /         1 (ratio e.g., value of a switch; [2])
STREAM_SUBT_ANA_PERCENT        50  %         1 (ratio e.g., value of a switch; [2])*
STREAM_SUBT_ANA_PERCENTRH      51  %RH       Percentage (Relative Humidity)
STREAM_SUBT_ANA_PERCENTEL      52  %EL       Percentage (remaining battery energy level)
STREAM_SUBT_ANA_ENERGYLEVEL    53  EL        seconds (remaining battery energy level)
```

```
STREAM_SUBT_ANA_1_PER_S        54  1/s       1 per second (event rate)
STREAM_SUBT_ANA_1_PER_MIN      55  1/min     1 per minute (event rate, "rpm")*
STREAM_SUBT_ANA_BEAT_PER_MIN   56  beat/min  1 per minute (heart rate in beats per minute)
STREAM_SUBT_ANA_BEATS          57  beats     1 (Cumulative number of heart beats)*
STREAM_SUBT_ANA_SIEMPERMETER   58  S/m       Siemens per meter (conductivity)
STREAM_SUBT_ANA_BYTE           59  B         Byte (information content)
STREAM_SUBT_ANA_VOLTAMPERE     60  VA        volt-ampere (Apparent Power)
STREAM_SUBT_ANA_VOLTAMPERESEC  61  VAs       volt-ampere second (Apparent Energy)
STREAM_SUBT_ANA_VAREACTIVE     62  var       volt-ampere reactive (Reactive Power)
STREAM_SUBT_ANA_VAREACTIVESEC  63  vars      volt-ampere-reactive second (Reactive Energy)
STREAM_SUBT_ANA_JOULE_PER_M    64  J/m       joule per meter (Energy per distance)
STREAM_SUBT_ANA_KG_PER_M3      65  kg/m3     kg/m3 (mass density, mass concentration)
STREAM_SUBT_ANA_DEGREE         66  deg       degree (angle)*
STREAM_SUBT_ANA_NTU            67  NTU       Nephelometric Turbidity Unit

Secondary Unit (rfc8798)           Description          SenML Unit     Scale     Offset
STREAM_SUBT_ANA_MS             68  millisecond                 s      1/1000    0       1ms = 1s x [1/1000]
STREAM_SUBT_ANA_MIN            69  minute                      s      60        0
STREAM_SUBT_ANA_H              70  hour                        s      3600      0
STREAM_SUBT_ANA_MHZ            71  megahertz                   Hz     1000000   0
STREAM_SUBT_ANA_KW             72  kilowatt                    W      1000      0
STREAM_SUBT_ANA_KVA            73  kilovolt-ampere             VA     1000      0
STREAM_SUBT_ANA_KVAR           74  kilovar                     var    1000      0
STREAM_SUBT_ANA_AH             75  ampere-hour                 C      3600      0
STREAM_SUBT_ANA_WH             76  watt-hour                   J      3600      0
STREAM_SUBT_ANA_KWH            77  kilowatt-hour               J      3600000   0
STREAM_SUBT_ANA_VARH           78  var-hour                    vars   3600      0
STREAM_SUBT_ANA_KVARH          79  kilovar-hour                vars   3600000   0
STREAM_SUBT_ANA_KVAH           80  kilovolt-ampere-hour        VAs    3600000   0
STREAM_SUBT_ANA_WH_PER_KM      81  watt-hour per kilometer     J/m    3.6       0
STREAM_SUBT_ANA_KIB            82  kibibyte                    B      1024      0
STREAM_SUBT_ANA_GB             83  gigabyte                    B      1e9       0
STREAM_SUBT_ANA_MBIT_PER_S     84  megabit per second          bit/s  1000000   0
STREAM_SUBT_ANA_B_PER_S        85  byteper second              bit/s  8         0
STREAM_SUBT_ANA_MB_PER_S       86  megabyte per second         bit/s  8000000   0
STREAM_SUBT_ANA_MV             87  millivolt                   V      1/1000    0
STREAM_SUBT_ANA_MA             88  milliampere                 A      1/1000    0
STREAM_SUBT_ANA_DBM            89  decibel rel. to 1 milliwatt dBW    1       -30     0 dBm = -30 dBW
STREAM_SUBT_ANA_UG_PER_M3      90  microgram per cubic meter   kg/m3  1e-9      0
STREAM_SUBT_ANA_MM_PER_H       91  millimeter per hour         m/s    1/3600000 0
STREAM_SUBT_ANA_M_PER_H        92  meterper hour               m/s    1/3600    0
STREAM_SUBT_ANA_PPM            93  partsper million            /      1e-6      0
STREAM_SUBT_ANA_PER_100        94  percent                     /      1/100     0
STREAM_SUBT_ANA_PER_1000       95  permille                    /      1/1000    0
STREAM_SUBT_ANA_HPA            96  hectopascal                 Pa     100       0
STREAM_SUBT_ANA_MM             97  millimeter                  m      1/1000    0
STREAM_SUBT_ANA_CM             98  centimeter                  m      1/100     0
STREAM_SUBT_ANA_KM             99  kilometer                   m      1000      0
STREAM_SUBT_ANA_KM_PER_H      100  kilometer per hour          m/s    1/3.6     0
STREAM_SUBT_ANA_GRAVITY       101  earth gravity               m/s2   9.81      0       1g = m/s2 x 9.81
STREAM_SUBT_ANA_DPS           102  degrees per second          1/s    360       0     1dps = 1/s x 1/360
STREAM_SUBT_ANA_GAUSS         103  Gauss                       Tesla  10-4      0       1G = Tesla x 1/10000
STREAM_SUBT_ANA_VRMS          104  Volt rms                    Volt   0.707     0    1Vrms = 1Volt (peak) x 0.707
STREAM_SUBT_ANA_MVPGAUSS      105  Hall effect, mV/Gauss       millivolt 1       0    1mV/Gauss
```

Filter and Detector used in the examples

```
;-------------------------------------------------------------------------------------
;   7     arm_stream_filter
;-------------------------------------------------------------------------------------
;   Operation : receives one multichannel stream and produces one filtered multichannel stream.
;   Parameters : biquad filters coefficients used in cascade. Implementation is 2 Biquads max.
;   (see www.w3.org/TR/audio-eq-cookbook)
;   Option : either the same coefficients for all channels or list of coefficients for each channel
;
;   presets:
;   #1 : bypass
;   #2 : LPF fc=fs/4
;   #3 : DC-filter (use-case: audio, XYZ gravity compensation/estimation)
;
;   parameter of filter :
;   - number of biquads in cascade (1 or 2)
;   - coefficients in FP32
;
node
    arm_stream_filter 0                 node subroutine name + instance ID

    node_preset         1               ; parameter preset used at boot time, default = #0
    node_map_hwblock    0  0            ; list of "nb_mem_block" VID indexes of "procmap_manifest.txt" where to map the allocated memory

    parameters     0                    ; TAG   "load all parameters"
        1  u8;  2       Two biquads
        1  i8;  0       postShift
        5 f32; 0.284277f 0.455582f 0.284277f 0.780535f -0.340176f  b0/b1/b2/-a1/-a2  ellip(4, 1, 40, 3600/8000, 'low')
        5 f32; 0.284277f 0.175059f 0.284277f 0.284669f -0.811514f
        ; or  _include    1   arm_stream_filter_parameters_x.txt      (path + file-name)
    _end_
_end_



;-------------------------------------------------------------------------------------
;   8     arm_stream_detector
;-------------------------------------------------------------------------------------
;   Operation : provides a boolean output stream from the detection of a rising
;   edge above a tunable signal to noise ratio.
;   A tunable delay allows to maintain the boolean value for a minimum amount of time
;   Use-case example 1: debouncing analog input and LED / user-interface.
;   Use-case example 2: IMU and voice activity detection (VAD)
;   Parameters : time-constant to gate the output, sensitivity of the use-case
;
;   presets control
;   #1 : no HPF pre-filtering, fast and high sensitivity detection (button debouncing)
```

```
;   #2 : VAD with HPF pre-filtering, time constants tuned for ~10kHz
;   #3 : VAD with HPF pre-filtering, time constants tuned for ~44.1kHz
;   #4 : IMU detector : HPF, slow reaction time constants
;   #5 : IMU detector : HPF, fast reaction time constants
;
;   Metadata information can be extracted with the command "TAG_CMD" from parameter-read:
;   0 read the floor noise level
;   1 read the current signal peak
;   2 read the signal to noise ratio
;
node
    arm_stream_detector 0       node name  + instance ID

    preset              1               ; parameter preset used at boot time, default = #0

    parameters 0                        ; TAG   "load all parameters"
        8; i8; 1 2 3 4 5 6 7 8  the 8 bytes of "struct detector_parameters"
    _end_
_end_
;
```