

## Contents

Stream-based processing with a graph interpreter.....	6
What.....	6
Why .....	6
How .....	7
How (detailed).....	8
Graph Interpreter instance.....	9
Top Manifest.....	10
Processor Manifest .....	11
IO Manifest.....	12
IO manifest header .....	12
IO Domains .....	13
Declaration of “options” .....	13
Default values of an IO manifest .....	13
Common information of all digital stream.....	14
io_commander0_servant1 “0/1” .....	14
io_buffer_allocation “x” .....	14
io_set0copy1 “0/1” .....	14
io_direction_rx0tx1 “0/1” .....	14
io_raw_format “n” .....	14
io_interleaving “0/1” .....	15
io_nb_channels “n” .....	15
io_frame_length “o” .....	15
io_frame_duration “o” .....	15
io_setup_time.....	15
io_units_rescale “u a b max” .....	15
io_subtype_multiple “x” .....	15
io_position “x” .....	15
io_euler_angles “x” .....	15
io_sampling_rate “x” .....	15
io_sampling_period_s “s” .....	15
io_sampling_period_day “d” .....	16
io_sampling_rate_accuracy “p” .....	16
io_time_stamp_format “n” .....	16
IO Controls Bit-fields per domain .....	16
Domain “general” .....	16
Domain audio_in.....	16

Domain audio_out.....	17
Domain gpio_in .....	18
Domain gpio_out .....	18
Domain motion .....	18
Domain 2d_in.....	18
Domain 2d_out.....	19
Domain analog_in .....	19
Domain analog_out.....	19
Domain RTC .....	19
Domain user_interface_in .....	19
Domain user_interface_out .....	19
Comments section for IOs .....	19
Node manifest.....	19
Declaration of “options” .....	20
Example of node manifest.....	20
Manifest header.....	20
node_developer_name “name” .....	20
node_name “name” .....	21
node_logo “file name” .....	21
node_nb_arcs “in out” .....	21
node_arc_parameter “n” .....	21
node_variable_rxtx_data_rate “0/1” .....	21
node_using_arc_format “0/1” .....	21
node_mask_library “n” .....	21
node_architecture “name” .....	22
node_fpu_used “option” (TBD) .....	22
node_key “x” .....	22
node_version “n” .....	22
node_complexity_index “n” .....	22
node_not_reentrant “n” .....	22
node_stream_version “n” .....	22
node_logo “file name” .....	22
Node memory allocation.....	22
node_mem “index” .....	23
node_mem_alloc “A” .....	23
node_mem_nbchan “B” “i” .....	23
node_mem_sampling_rate “C” “j” .....	23
node_mem_frame_size “D” “k” .....	23

node_mem_alignment “n” .....	23
node_mem_type “n” .....	23
node_mem_speed “n” .....	24
node_mem_relocatable “0/1” .....	24
node_mem_data0prog1 “0/1” .....	24
Configuration of the arcs attached to the node .....	24
node_arc “n” .....	24
node_arc_rx0tx1 “0/1” .....	24
node_arc_interleaving “0/1” .....	25
node_arc_nb_channels “n” .....	25
node_arc_units_scale “unit” “scale” .....	25
node_arc_units_scale_multiple “unit” “scale” .....	25
node_arc_raw_format “f” .....	25
node_arc_frame_length “n” .....	25
node_arc_frame_duration “t” .....	25
node_arc_sampling_rate “fs” .....	25
node_arc_sampling_period_s “T” .....	25
node_arc_sampling_period_day “D” .....	25
node_arc_sampling_accuracy “p” .....	26
node_arc_inPlaceProcessing “in out” .....	26
Node design .....	26
General recommendations .....	26
Node parameters .....	26
Command parameter .....	27
Instance .....	27
Data .....	27
Status .....	27
Node calling sequence .....	27
Reset command .....	27
Set Parameter command .....	28
Run command .....	28
Test-bench and non-regression test-patterns .....	28
Node example .....	28
Conformance checks .....	30
Services provided to the nodes .....	30
Graph design .....	31
Binary format of the graph .....	31
Example of graph .....	32

Graph: control of the scheduler .....	33
graph_location "x" .....	33
graph_location_offset "x" .....	34
debug_script_fields "x" .....	34
scheduler_return "x" .....	34
allowed_processors "x" .....	34
set_file_path "index" "path" .....	34
graph_memory_bank "x" .....	34
Graph: IO control and stream data formats .....	35
format "n" .....	35
format_raw_data "n" .....	35
format_frame_length "n" .....	35
format_nbchan "n" .....	35
format_interleaving "n" .....	35
format_time_stamp "n" .....	35
format_domain "n" .....	36
Information specific of domains .....	36
Graph: interfaces of the graph.....	37
stream_io "n" .....	37
stream_io_hwid "ID" .....	37
stream_io_format "n" .....	37
stream_io_setting "W32 W32 W32" .....	37
stream_io_setting_callback "cb" "X" .....	37
Graph: memory mapping.....	37
Memory fill .....	37
Graph: subgraphs .....	38
Graph: nodes declarations .....	38
node_preset "n" .....	38
node_malloc_add "n" "i" .....	38
node_map_hwblock "m" "o" .....	38
node_map_copy / node_map_swap "m" "o" .....	39
node_trace_id "io" .....	39
node_map_proc, node_map_arch, node_map_rtos .....	39
node_map_verbose "level" .....	39
node_memory_isolation "0/1" .....	39
node_memory_clear "m" .....	39
node_script "index" .....	39
node_user_key "key" .....	39

node_parameters “tag” .....	40
Graph Scripts byte codes .....	40
Test instructions .....	40
Arithmetic operations .....	40
Graph syntax .....	41
System calls .....	42
Arcs of the graph .....	42
arc flow control .....	43
arc debug .....	43
arc_flush .....	43
arc_map_hwblock .....	43
arc_jitter_ctrl .....	43
arc_parameters .....	43
Common tables .....	44
Stream format Words 0,1,2 .....	44
Stream format Word 3 .....	44
Audio stream format .....	44
Motion .....	45
2D .....	45
Data Types .....	45
Units .....	46
Stream format “domains” .....	49
Architectures codes of platform manifest .....	49
List of pre-installed nodes (development) .....	49
arm_stream_script .....	50
arm_stream_format_converter (TBD) .....	51
arm_stream_router (TBD) .....	51
sigp_stream_converter (TBD) .....	51
arm_stream_amplifier (TBD) .....	52
arm_stream_mixer (TBD) .....	52
arm_stream_filter .....	53
sigp_stream_detector .....	53
arm_stream_rescaler (TBD) .....	54
sigp_stream_compressor (TBD) .....	54
sigp_stream_decompressor (TBD) .....	54
arm_stream_modulator (TBD) .....	55
arm_stream_demodulator (TBD) .....	56
sigp_stream_resampler (TBD) .....	56

arm_stream_qos (TBD).....	56
arm_stream_split (TBD).....	57
arm_stream_analysis (TBD) .....	57
sigp_stream_detector2D (TBD).....	57
arm_stream_filter2D (TBD) .....	57
JPG encoder.....	58
JPG decoder.....	58

## Stream-based processing with a graph interpreter

### What

**Graph-Interpreter** is a scheduler of **DSP/ML Nodes** 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.

### Why

The complexity of IoT systems using signal processing and machine-learning is continuously rising. In four years (picture below) we have seen the average time-to-market going from months to years. We must ease the tasks of the integrators by **splitting the problems in small pieces**, which translates in the definition of standard interfaces between those pieces.

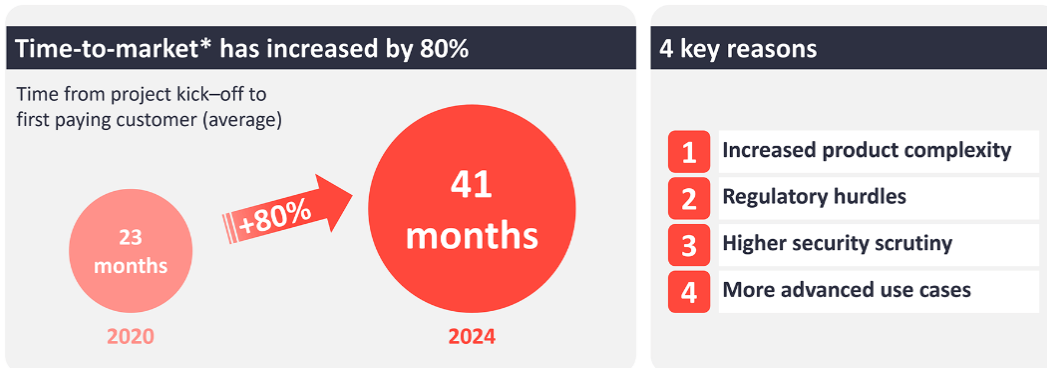
Here are some examples of signal processing “pieces” and software portability issues :

- an algorithm is extracting metadata from a pressure sensor, the samples of which are a stream of floating-point data at 10Hz sampling rate. Can the algorithm be ported as-is to a platform using a pressure sensor using 16bits integers at 25Hz sampling rate ?
- a pattern recognition algorithm is using images of format 300x300 pixels RGB888. What happens when the platform is using a sensor with VGA image format ?
- an industrial proximity detector is using a 25kHz wave generator and an ultrasound echo detector using a stream of Q15 samples at 96kHz normalized at 120dBSPL full-scale. Can we manage the same behavior and performance with a 88.1kHz sampling-rate ?
- an audio algorithm using 50kB of RAM from which 4kB are critical on speed access and 25kB have no speed constraint. What happens when several algorithms want to use the fast tightly-coupled memory bank (TCM), how do we manage data swapping before/after calling the algorithms ?

- a motion sensor subsystem is designed to integrate components from different silicon vendors. How do we manage automatically the scaling factors associated with the sensors, to have the same dynamic range and sampling-rates in the data stream ?
- a microprocessor has a dot-product and FFT accelerator. Can we offer an abstraction layer to the algorithm designers for such coprocessors : the developer will have one software release and a software implementation of the FFT will be used instead when there is no coprocessor.

Creating standard interfaces allows software component developers to deliver their IP without having to care about the capabilities of the platform used during system integration.

## Time to market for IoT-connected products



Note: \*Time to market = time needed (in months) to get from project kick-off to first paying customer.  
Source: IoT Analytics Research 2024 – IoT Commercialization & Business Model Adoption Report 2024. We welcome republishing of images but ask for source citation with a link to the original post and company website.

We want the algorithms developer to focus on their domain of expertise without creating a dependency with the protocols used in the graph or the data formats used by the preceding and following nodes of the graph.

The data format translators (provided with the graph scheduler) consists in changing :

- the data frame length and the interleaving scheme (block or sample-based)
- the raw sample data format (pixel format, integer / floating point samples)
- the sampling-rate and the management of time-stamps
- the scaling of the data with respect to standard physical units ([see, RFC8428](#) and [RFC8798](#))

Computing nodes and platforms have to explain in “[Manifests](#)” their interfaces in a formal way.

We want to anticipate the creation of Stores of computing nodes, signed to a specific platform, delivered in a binary format.

We want to let the graph to be modified without needing to recompile and re-flash the entire application. The graph will incorporate sections of interpreted code to manage state-machines, scripting, parameters updates and to interface with the application.

---

### How

Graph Interpreter is a scheduler and interpreter of a binary representation of a [graph](#). For portability reason the Graph Interpreter uses a minimal platform abstraction layer (AL) to the memory and to the input/output stream interfaces. Graph Interpreter manages the data flow of “arcs” between “nodes”.

This binary graph description is a compact data structure using indexes to the physical addresses of the nodes and memory instances. This graph description is generated in three steps:

1. [platform manifest](#) and [IO manifest](#) are prepared ahead of the graph design and describe the hardware. The manifests are giving the processing capabilities (processor architecture, minimum guaranteed amount of memory per RAM blocks and their speed, TCM sizes). The platform manifest gives references to [node manifests](#) for each of the installed

processing Nodes : developer identification, input/output data formats, memory consumption, documentation of the parameters and a list of “presets”, test-patterns and expected results (see also [node design](#)).

2. The graph is described in a readable text format (example [here](#)) and can be manually modified.
3. **the binary file to be used on the target is generated / compiled.** The file format is either a C source file, or a binary table to load in a specific flash memory block, to allow quick tuning cycles without full recompilation.

**The platform provides an abstraction layer (AL) with the following services:**

1. **Share the physical memory map base addresses.** The graph is using indexes to the base addresses of 63 different *memory banks*: shared external memory, fast shared internal, fast private per processor (TCM), and indexed the same way for multiprocessing without MMU. The AL has access to the entry points of the nodes installed in the device.
2. **Interface with the graph boundary generating/consuming data streams,** declared in the platform manifest and addressed as indexes from the scheduler when the FIFOs at the boundary of the graph are full or empty.
3. **Share time and low-level information for scripts.** The graph embeds byte-codes of “Scripts” used to implement state-machines, to change nodes parameters, to check the arcs data content, trigger GPIO connected to the graph, generated strings of characters to the application, etc. The [Scripts](#) provide a simple interface to the application without code recompilation.

Graph-Interpreter is delivered with a generic implementation of the above services, with device drivers emulated with precomputed data, time information emulated with counters.

---

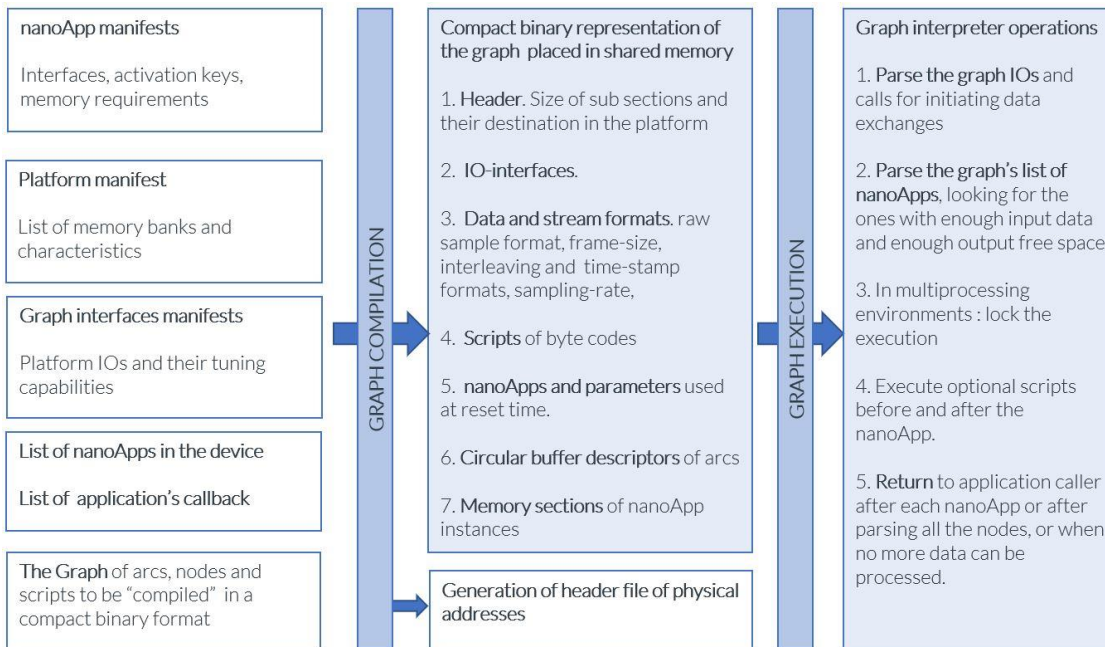
## How (detailed)

Stream-based processing is facilitated using Graph-Interpreter:

1. The Graph Interpreter has only two functions. One entry point for the application `void arm_graph_interpreter()`, and one entry point for the data moves: a function used to tell the data moves with the outside of the graph are done `void arm_graph_interpreter_io_ack()`.
2. Nodes can be written in **any computer languages**. The scheduler is addressing the nodes from a **single entry point** using a 4-parameters [API](#) format. There is no restriction in having the nodes delivered in binary format, compiled with “**position independent execution**” option. There is no dynamic linking issue: the nodes delivered in binary can still have access to a subset of the C standard libraries through a Graph-Interpreter service. The nodes are offered the access to DSP/ML CMSIS kernels (compiled without the position-independent option) or executed with platform-specific accelerators: the execution speed will scale with the targeted processor capabilities without recompilation.
3. **Drift management.** The streams don’t need to be perfectly isochronous (peripherals using different hardware clock trees). Rate conversion service is provided by nodes delivered with the interpreter when the sampling conversion can be expressed with a ratio of integers. The scheduler defines different quality of services (QoS) when a main stream is processed with drifting secondary streams. The time-base is adjusted to the highest-QoS streams (minimum latency and distortion), leaving the secondary streams managed with interpolators in case of flow issues.
4. Graph-Interpreter manages **TCM access**. When a Node declares, in its manifest, the need for a “critical speed memory bank” of small size (ideally less than 16kBytes), the graph compilation step will allocate it to TCM area, and can arrange data swapping if several nodes have the same need.
5. **Backup/Retention RAM.** Some applications are requiring a fast recovery in case of failures (“warm boot”) or when the system restores itself after deep-sleep periods. One of the memory banks allows developers to save the state of algorithms for fast return to normal operations. The node retention memory should be limited to tens of bytes.
6. Graph allows memory size optimization with overlays of different nodes’ working/scratch memory banks.
7. **Multiprocessing** SMP and AMP with 32+64bits processor architectures. The graph description is placed in a shared memory, and any processor having access to this shared memory can contribute to the processing. The node reservation protocol is lock-free. The nodes are described with bit-fields to map execution on a specific processor and architecture. The buffers associated to arcs can be allocated to a processor’s private memory-banks.
8. **Scripting** are designed to avoid going back and forth with the application interfaces for simple decisions, without the need to recompile the application (Low-code/No-code strategy, for example toggling a GPIO, changing node parameter, building a JSON string...) the graph scheduler interprets a compact byte-stream of codes to execute simple scripts.
9. **Process isolation.** The nodes never read the graph description data, the arc descriptors and the memory mapping is designed for the use of hardware memory protection.



10. **Format conversions.** The developer declares, in the manifests, the input/output data formats of the node. The Graph Interpreter implements the format translation between nodes: sampling-rates conversions, changes of raw data, removal of time-stamps, channels de-interleaving. Specific conversion nodes are inserted in the graph during its binary file translation.
11. Graph-Interpreter manages the various **methods of controlling I/O** with one function per IO: parameters setting and buffer allocation, data move, stop, mixed-signal components settings.
12. Graph-Interpreter is **open-source**, and portable to Cortex-M, Cortex-R, Cortex-A and computers.
13. Example of Nodes: image and voice codec, data conditioning, motion classifiers, data mixers. Graph-Interpreter comes with short list of components doing data routing, mixing, conversion and detection.
14. **From the developer point of view**, it creates opaque memory interfaces to the input/output streams of a graph, and arranges data are exchanged in the desired formats of each Node. Graph-Interpreter manages the memory mapping with speed constraints, provided by the developer, at instance creation. This lets software run with maximum performance in rising situations of memory bounded problems.
15. **From the system integrator view**, it eases the tuning and the replacement of one Node by another one and is made to ease processing split with multiprocessors. The stream is described with a graph (a text file) designed with a graphical tool. The development of DSP/ML processing will be possible without need to write code and allow graph changes and tuning without recompilation.
16. **Graph-Interpreter design objectives:** Low RAM footprint. Graph descriptor can be placed in Flash with a small portion in RAM. Use-cases go from small Cortex-M0 with 1kBytes RAM to SMP/AMP/coprocessor and mix of 32/64bits thanks to the concept of shared RAM and indexes to memory banks provided by the local processor abstraction layer. Each arc descriptors can address buffer sizes of up to 64GBytes.
17. **Computing libraries** are provided under compilation options, to avoid replicating CMSIS-DSP in nodes with binary code deliveries, and to allow arm-v7M codes able to benefit from arm-v8.1M vector processing extensions without the need for code recompilation.



## Graph Interpreter instance

The Graph Interpreter has two functions. One entry point `void arm_graph_interpreter()`, and a function used to tell the data moves with the outside of the graph are confirmed `void arm_graph_interpreter_io_ack()`. The two functions can be called once the instance is created by the platform AL (`void platform_init_stream_instance(arm_stream_instance_t *S)`).

Interpreter instance structure:

name of the field	comments
long_offset	Table of pointer to memory banks (up to 63 indexes). The graph is not using physical memory but

name of the field	comments
	offsets to one of those 63 memory banks, defined in the “platform manifest”.
graph	The pointer to the compiled binary version of the graph remapped in RAM. The original binary graph is usually in a flash memory area. The AL function (platform_init_stream_instance()) moves it in RAM starting from the first byte of the above “long_offset” index 0. When the device has a small internal RAM the graph is split with a portion staying in Flash (this graph pointer is pointing to) and a portion RAM placed at long_offset[0] address.
linked_list	pointer to the linked-list of nodes of the graph
platform_io	table of functions (IO_AL_idx) associated to each IO stream of the platform
node_entry_points	table of entry points to each node (see “TOP” manifest)
application_callbacks	the application can propose a list of functions to be called from scripts.
al_services	pointer to the function proposing services (time, script, stdlib, compute)
iomask	bit-field of the allowed IOs this interpreter instance can use
scheduler_control	execution options of the scheduler (return to the application after each node execution, after a full graph parsing, when there is no data to process)
script_offsets	pointer to scripts used as subroutines for the other scripts placed in the node “arm_stream_script” parameter section.
all_arcs	pointer to the list of arc descriptors (structures giving the base address, size of the associated circular buffer, read, write index, data format of the arc consumer/producer, and debug/trace information).
all_formats	pointer to the section of the graph describing the stream formats. This section is in RAM.
ongoing	pointer to a table of bytes associated to each IO ports of the graph. Each byte tells if a transfer is on-going.

## Top Manifest

The “Top” platform manifest has four sections :

- the list of file paths to ease readability
- the manifest file describing the processing architecture (see next paragraph)
- the list of available data stream ready to be connected to the graph : this list corresponds to manifest files of the data format options, and gives an index (IO\_AL\_idx) to the function to call to read/write data and update the stream configuration (when this is possible).
- the list of the nodes already installed in the device. This is also a list of manifest files giving a formal way to describe how to connect the nodes each others

```

; -----
; 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
; -----
; list of paths for the included files
2
../../stream_platform/computer/manifest/      ; path 1
../../stream_nodes/                          ; path 2
; -----
; PLATFORM DIGITAL, MIXED-SIGNAL AND IO MANIFESTS

1   procmap_manifest_computer.txt             path index + file name

; path:           path ID
; Manifest        manifests file
; IO IDX          index of the IO used in the graph
; ProcCtrl        processor affinity bit-field
; ClockDomain     provision for insertion of ASRC

10 : number of IO streams available

```

```

;Path      Manifest      IO_AL_idx ProcCtrl clock-domain
1 io_platform_data_in_0.txt      0      1      0
1 io_platform_data_in_1.txt      1      1      0
1 io_platform_analog_sensor_0.txt 2      1      0
1 io_platform_motion_in_0.txt    3      1      0
1 io_platform_audio_in_0.txt     4      1      0
1 io_platform_2d_in_0.txt        5      1      0
1 io_platform_line_out_0.txt     6      1      0
1 io_platform_gpio_out_0.txt     7      1      0
1 io_platform_gpio_out_1.txt     8      1      0
1 io_platform_data_out_0.txt     9      1      0

; -----
; PATH + SOFTWARE COMPONENTS MANIFESTS
2      node_manifest_none.txt
2      arm/script/node_manifest_script.txt
2      arm/script/node_manifest_graph_control.txt
2      arm/router/node_manifest_router.txt
2 signal-processingFR/converter/node_manifest_converter.txt
2      arm/amplifier/node_manifest_amplifier.txt
2      arm/mixer/node_manifest_mixer.txt
2      arm/filter/node_manifest_filter.txt
2 signal-processingFR/detector/node_manifest_detector.txt
2      arm/rescaler/node_manifest_rescaler.txt
2 signal-processingFR/compressor/node_manifest_compressor.txt
2 signal-processingFR/decompressor/node_manifest_decompressor.txt
2      arm/modulator/node_manifest_modulator.txt
2      arm/demodulator/node_manifest_demodulator.txt
2 signal-processingFR/resampler/node_manifest_resampler.txt
2      arm/qos/node_manifest_qos.txt
2      arm/split/node_manifest_split.txt
2 signal-processingFR/detector2D/node_manifest_detector2D.txt
2      arm/filter2D/node_manifest_filter2D.txt
2      arm/analysis/node_manifest_analysis.txt
2      bitbank/JPEGENC/node_manifest_bitbank_JPEGENC.txt
2      elm-lang/TjpgDec/node_manifest_TjpgDec.txt
2      arm/format_converter/node_manifest_format_converter.txt
; -----

```

## Processor Manifest

The processor manifest gives the minimum guaranteed amount of memory per memory bank to help the graph compilation process to map the working/static memory requirements of each node.

```

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

1 1 9 4 number of architectures, processors, memory banks, offsets

;memory banks:
;- ID      base offset ID reference above
;- VID     virtual ID used in the graph for manual mapping,
;- 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 bank starting from @[ID]+offset
;- Offset  maximum offset from the base offset ID,
;
; the graph uses the "node_map_hwbblock" command for manual memory mapping

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,
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 proc 1 (>0)
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 proc 1

; offsets used by all processors and addresses seen from the main processor
0 h20000000 image of platform_specific_long_offset
1 h28000000 in stream_al/platform_XXXXX.c
2 h2C000000 TCM Private memory of processor 1
3 h08000000 Internal Flash

;-----
; loop on all architectures
4 1 architecture code (4=armv8), 1 processor
; all processors for this architecture (processor IDs >0)
;-----
1 1 15 processor ID,
; boolean "main processor" allowed to boot the graphs
; Bit-field computation firmware extensions,

```

When memory and speed optimization is not necessary, the system integrator can declare a simplified single continuous block of memory with average speed performance, for example :

```

; -----
; Simplified memory plan
; -----
1 1 1 1 number of architectures, processors, memory banks, offsets

;ID VID S W P H D Size offset
0 0 1 0 0 0 0 95526 10
0 h20000000 image of platform_specific_long_offset
;-----
; loop on all architectures
4 1 architecture code (4=armv8), 1 processor
; all processors for this architecture (processor IDs >0)
;-----
1 1 15 processor ID,
; boolean "main processor" allowed to boot the graphs
; Bit-field computation firmware extensions,

```

## IO Manifest

The graph interface manifests ("IO manifests") is a text file of commands used by the graph compiler to understand the type of data flowing through the IOs of the graph. A manifest gives a precise list of information about the data format (frame length, data type, sampling rate, ...). This paragraph gives the syntax used in an IO manifest.

An IO manifest starts with a *Header* of general information, followed by the list of command used for the description of the stream. The IO manifest reader is assuming default values and associated command are useless and inserted by the programmer for information and readability.

Because of the variety of stream data types and setting options, the graph interpreter introduces the concept of physical "*domains*" (audio, motion, 2D, ...). The document gives starts with the list of general information for the stream digital format, followed by the specification of domain-related information.

### IO manifest header

The "IO manifest" starts with the name which will be used in a design tool, followed by the "domain" (list below).

Example of a simple IO manifest :

```
io_name io_platform_sensor_in_0      ; the IO name
io_domain  analog_in                 ; the domain of operation
```

### IO Domains

Domain name	Code	Comments
GENERAL	0	Any stream, for example (a)synchronous sensor data + electrical, chemical, pixels, .. data from/to the other applications of the processors, compressed streams, JSON, etc ..
AUDIO_IN	1	audio files from the application, A/D data from a microphone, line-in, serial audio stream (I2S, PDM RX)
AUDIO_OUT	2	line-out, earphone / speaker, PDM TX, I2S
GPIO_IN	3	generic digital IO
GPIO_OUT	4	generic digital IO , control of relay,
MOTION	5	accelerometer, combined or not with magnetometer and gyroscope
2D_IN	6	camera sensor
2D_OUT	7	display, led matrix
ANALOG_IN	8	analog sensor with aging/sensitivity/THR control, example : light, pressure, proximity, humidity, color, voltage
ANALOG_OUT	9	D/A interface, position piezo , PWM converter
RTC	10	ticks sent from a programmable timer
USER_INTERFACE_IN	11	button, slider, rotary button
USER_INTERFACE_OUT	12	LED, digits, display,
PLATFORM_3	13	platform-specific #3
PLATFORM_2	14	platform-specific #2
PLATFORM_1	15	platform-specific #1

### Declaration of “options”

The manifest gives the list of **options** possible described as a **list**, or as a **range** of values. The syntax is : an index and the list of numbers within brackets “{” and “}”. The index gives the default value to consider in the list. Index “1” corresponds to the first element of the list. Index value “0” means “any value”. The list can be empty in that case.

Example of a list of options between five values, the index is 2 meaning the default value is the second in the list (value = 6).

```
{ 2   5 6 7 8 9 }
```

When the index is negative the list is decoded as a “range”. A Range is a set of three fields :

- the first option
- the step to the next possible option
- the last (included) option

The absolute index value selects the default value in this range.

Example of is an option list of values (1, 1.2, 1.4, 1.6, 1.8, .. , 4.2), the index is -3 meaning the default value is the third in the list (value = 1.4).

```
{ -3   1 0.2 4.2 }
```

### Default values of an IO manifest

When not mentioned in the manifest the following assumptions are :

- the interface is servant (data move is triggered with a call to the IO\_AL\_idx function)
- the interface does not need memory to be reserved from the graph interpreter
- the data can be processed in-place (no need to copy it in another buffer)
- the raw data format is int16\_t, single channel, one sample per frame

- the IO is “RX” : the graph is receiving the data stream

## Common information of all digital stream

IO manifests describe the stream data format and how to copy/use the data. This is common to the digital streams of any IO. The next section (“IO Controls Bit-fields per domain”) is specific to each domain of operation.

### io\_commander0\_servant1 “0/1”

The IO is “commander” when it initiates the data exchanges with the graph without the control from the scheduler (for example an audio Codec). It is “servant” when the scheduler needs to pull or push the by calling the IO functions (for example an interface to the main application). IO stream are managed from the graph scheduler with the help of one subroutine per IO (IO\_AL\_idx function) using the template :

```
typedef void (*p_io_function_ctrl) (uint32_t command, void *data, uint32_t length);
```

The “command” parameter can be : STREAM\_SET\_PARAMETER (set the domain-specific IO parameters), STREAM\_DATA\_START (initiate a data exchange), STREAM\_STOP, STREAM\_SET\_BUFFER (tell the IO interface the location of the next address for the data move).

Once the move is done the external IO driver calls arm\_graph\_interpreter\_io\_ack() to tell the scheduler to update the corresponding arc.

Example :

```
io_commander0_servant1 1 ; default is servant (1)
```

## Graph interpreter implementation details

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.

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\_RUN, ..) to ask for data move. Once the move is done the IO driver calls arm\_graph\_interpreter\_io\_ack()

### io\_buffer\_allocation “x”

When data are exchanged there is a need for a temporary exchange buffer. This buffer can be allocated outside by the IO driver, or during the graph memory mapping preparation. The memory mapping of this allocation is decided in the graph and can be in general-purpose RAM or specific memory bank for speed reason or reserved for DMA processing, etc ..

```
io_buffer_allocation 2.0 0
```

This command tells to reserve memory for the data exchanges with the IO function. The parameter value “0” means the buffer is declared outside of the graph. The second parameter is the VID memory bank index, or 0 to tell “any”.

The parameter is a floating-point number used has a multiplication factor of the frame size (here 2 frames), the allocated buffer size is computed with rounding ( $n = \text{floor}(X+0.5)$ ).

### io\_set0copy1 “0/1”

Declares if the IO stream is used with **setting** a pointer to the data (value 0, default) or with a memory **copy** (value 1).

```
io_set0_copy1 1
```

### io\_direction\_rx0tx1 “0/1”

Declaration of the direction of the stream from the graph scheduler point of view.

```
io_direction_rx0tx1 1 ; direction of the stream 0:input 1:output
```

### io\_raw\_format “n”

Declaration of the size and type of the raw data.

io\_raw\_format S16 ; options for the raw arithmetic's computation format here STREAM\_S16

#### io\_interleaving "0/1"

io\_interleaving 1 ; multichannel interleaved (0), deinterleaved by frame-size (1)

#### io\_nb\_channels "n"

io\_nb\_channels 1 ; options for the number of channels

#### io\_frame\_length "o"

io\_frame\_length {1 1 2 16} ; options of possible frame\_size in number of sample (can mono or multi-channel).

#### io\_frame\_duration "o"

io\_frame\_duration {1 10 22.5} ; options of possible frame\_size in [milliseconds]. The default frame length is 1 sample

#### io\_setup\_time

Information of the time it takes before valid / calibrated samples are ready for processing after reset. This is "for information" and given for documentation purpose.

io\_setup\_time 12.5 ; wait 12.5ms before receiving valid data

#### io\_units\_rescale "u a b max"

Syntax : "physical unit name" "coefficient a" "coefficient b" "maximum value". Rescaling information between normalized (1.0 or 0x7FFF) digital ("D") and physical ("P") units with the formulae  $P = a \times (D - b)$ .

See file "Table.md" for the list of available Units from RFC8798 and RFC8428.

io\_units\_rescale VRMS 0.0135 -10.1 0.15

;  $V_{\text{physical}} = a \times (X_{\text{sample}} - b)$  with the default hardware settings  
;  $V [\text{VRMS}] \Leftrightarrow 0.0135 \times (X + 10.1)$ , max 0.15 Vrms  
;  $0.15 \text{ VRMS} \Leftrightarrow 0.0135 \times (1.0 - (-10.1))$

#### io\_subtype\_multiple "x"

Multiple units interleaved streams with rescaling factors of above "io\_units\_rescale". Used for example with motion sensors delivering acceleration, speed, magnetic field, temperature, etc ..

io\_subtype\_multiple DPS a b max GAUSS a b max

#### io\_position "x"

Relative position of the IO in the platform reference space.

io\_position meter 1.1 -2.2 0.01 ; unit and relative XYZ position with the platform reference point

#### io\_euler\_angles "x"

Relative angles of the IO in the platform reference space.

io\_euler\_angles 10 20 90 ; Euler angles with respect to the platform reference orientation, in degrees

#### io\_sampling\_rate "x"

IO stream sampling rate in Hertz.

io\_sampling\_rate {1 16000 44100 48000} ; sampling rate options (enumeration in Hz)

#### io\_sampling\_period\_s "s"

Sampling rate in time unit.

io\_sampling\_period\_s {1 1 60 120} ; sampling period options (enumeration in [second])



io\_sampling\_period\_day “d”

Sampling rate in time unit for long periods in days.

io\_sampling\_period\_day {1 0.25 1 7 } ; sampling period options (enumeration in [day])

io\_sampling\_rate\_accuracy “p”

Percentage of accuracy (or inaccuracy) of the given sampling rate.

io\_sampling\_rate\_accuracy 0.1 ; in percentage

io\_time\_stamp\_format “n”

See file “Table.md” for the definition of time-stamp format :

- 0: no time stamp
- 1: simple counter
- 39: STREAM\_TIME16 format q14.2 in seconds, maximum range 1 hour + 8mn +/- 0.0625
- 40: STREAM\_TIME16D format q15 seconds, for time differences +/- 15us
- 41: STREAM\_TIME32 format q28.4 seconds, maximum 8.5 years +/- 0.0625s
- 42: STREAM\_TIME32D format q17.15 seconds, maximum 36hours +/- 30us for time differences
- 43: STREAM\_TIME64 format q32.28 seconds, maximum 140 years +/- 4ns
- 44: STREAM\_TIME64MS format u42 in milliseconds, amximum 140 years
- 45: STREAM\_TIME64ISO ISO8601 with signed offset, example 2024-05-04T21:12:02+07:00

io\_time\_stamp\_format {1 39 41 } ; time-stamp format options

---

IO Controls Bit-fields per domain

Three 32bits words are allocated to each IO stream for time specific items of their domains.

Domain “general”

N/A

---

Domain audio\_in

Channel mapping with a bit-field (20 channels description see [audio channels](#)) :

io\_channel\_mapping 0x0B ; Front Left + Right + LFE

Name		bit position
Front Left	FL	0
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

#### Control of the gains and filters

```

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)
io_agc            0                ; agc automatic gain control, ON(1)/OFF(0)
io_router         {1 0 1 2 3      } ; router from AMIC0 DMIC1 HS2 LINE3 BT/FM4
io_gbass_filter    {1 1 1 0 -3 3 6} ; ON(1)/OFF(0) options for gains in dB
io_fbass_filter    {1 20 100 200   } ; options for frequencies
io_gmid_filter     {1 1 1 0 -3 3 6} ; ON(1)/OFF(0) options for gains in dB
io_fmids_filter    {1 500 1000     } ; options for frequencies
io_ghigh_filter    {1 1 0 -3 3 6   } ; ON(1)/OFF(0) options for gains in dB
io_fhigh_filter    {1 4000 8000    } ; options for frequencies

```

---

### Domain audio\_out

Channel mapping with a bit-field (18 channels description, identical to audio\_in domain) :

```
io_channel_mapping 0x0B ; Front Left + Right + LFE
```

Name		bit position
Front Left	FL	0
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

#### Control of the gains and filters

```

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)
io_agc            0                ; agc automatic gain control, ON(1)/OFF(0)
io_router         {1 0 1 2 3      } ; router from AMIC0 DMIC1 HS2 LINE3 BT/FM4
io_gbass_filter    {1 1 1 0 -3 3 6} ; ON(1)/OFF(0) options for gains in dB
io_fbass_filter    {1 20 100 200   } ; options for frequencies
io_gmid_filter     {1 1 1 0 -3 3 6} ; ON(1)/OFF(0) options for gains in dB
io_fmids_filter    {1 500 1000     } ; options for frequencies
io_ghigh_filter    {1 1 0 -3 3 6   } ; ON(1)/OFF(0) options for gains in dB
io_fhigh_filter    {1 4000 8000    } ; options for frequencies

```

---

## Domain gpio\_in

To be completed

State : High-Z, low, high  
type : PWM, motor control, GPIO  
PWM duty, duration, frequency (buzzer)  
Servo motor control -120 .. +120 deg  
keep the servo position

---

## Domain gpio\_out

To be completed

---

## Domain motion

Selection of the multichannel interleaving :

aXg0m0 1 only accelerometer  
a0gXm0 2 only gyroscope  
a0g0mX 3 only magnetometer  
aXgXm0 4 A + G  
aXg0mX 5 A + M  
a0gXmX 6 G + M  
aXgXmX 7 A + G + M

---

## Domain 2d\_in

To be completed

Feature name	Description
io_raw_format_2d	(U16 + RGB16) (U8 + Grey) (U8 + YUV422)
io_trigger flash	activate the flash when polling a new image
io_synchronize_IR	sync with IR transmitter
io_frame rate per second	
io_exposure time	The amount of time the photosensor is capturing light, in seconds.
io_image size	
io_modes	portrait, landscape, barcode, night modes
io_Gain	Amplification factor applied to the captured light. >1.0 is brighter <1.0 is darker.
io_WhiteBalanceColorTemp	Temperature parameter when using the regular HDRP color balancing.
io_MosaicPattern	Color Filter Array pattern for the colors
io_WhiteBalanceRGBCoefficients	RGB scaling values for white balance, used only if EnableWhiteBalanceRGBCoefficients is selected.
io_EnableWhiteBalanceRGBCoefficients	Enable using custom RGB scaling values for white balance instead of temperature and tint.
io_Auto White Balance	Assumes the camera is looking at a white reference, and calibrates the WhiteBalanceRGBCoefficients
io_wdr	wide dynamic range
io_watermark	watermark insertion
io_flip	image format
io_night_mode	
motion detection	sensitivity (low, medium, high)

Feature name	Description
io_detection_zones	+ {center pixel (in %) radius}, {}, {}
io_focus_area	
io_auto exposure	on focus area
io_focus_distance	forced focus to infinity or xxx meter
io_jpeg_quality	

---

#### Domain 2d\_out

8b backlight brightness control

---

#### Domain analog\_in

```
/* IO_DOMAIN_ANALOG_IN */
```

```
    detection threshold
    detection attack time
    detection release time
    aging control
```

#### Domain analog\_out

aging option (usage counter, time)

```
unit_linear,      PCM and default format PCM and default format
unit_decibel,    Q11.4 :  1dB <> 0x0010 Q19.12 :  1dB <> 0x0000 1000
unit_percentage  Q11.4 :  1 % <> 0x0010 Q19.12 :  1 % <> 0x0000 1000
unit_meter,      Q11.4 :  10 m <> 0x00A0 Q19.12 :  10 m <> 0x0000 A000
unit_g = 20,     Q11.4 :  1g <> 0x0010 Q19.12 :  1g <> 0x0000 1000
```

#### Domain RTC

#### Domain user\_interface\_in

#### Domain user\_interface\_out

0 ; time-stamp (none)

### Comments section for IOs

Information examples :

- jumpers to set on the board
  - manufacturer references for components and internet URLs
  - any other system integration warning and recommendations
- 

## Node manifest

A node manifest file gives the name of the software component, the author, the targeted architecture, the description of input and output streams connected to it.

The graph interpreter allocates a predefined amount of memory and this file explains the way to compute the memory allocation. When the first non-blank character is a semi-colon “;” the entire line is skipped as a comment

## Declaration of “options”

The manifest give the list of compatible options possible. Some options are described as a **list**, or as a **range** of values. The syntax is : an index and the list of numbers within brackets “{” and “}”. The index gives the default value to consider in the list. Index “1” corresponds to the first element of the list. Index value “0” means “any value”. The list can be empty in that case.

Example of an option list between five values, the index is 2 meaning the default value is the second in the list (value = 6).

```
{ 2    5 6 7 8 9 }
```

When the index is negative the list is decoded as a “range”. A Range is a set of three numbers :

- the first option
- the step to the next possible option
- the last (included) option

The absolute index value selects the default value in this range.

Example of is an option list of values (1, 1.2, 1.4, 1.6, 1.8, .. , 4.2), the index is -3 meaning the default value is the third in the list (value = 1.4).

```
{ -3    1    0.2    4.2 }
```

## Example of node manifest

```
; -----
; SOFTWARE COMPONENT MANIFEST - "arm_stream_filter"
; -----
;
node_developer_name    ARM                ; developer name
node_name              arm_stream_filter  ; node name

node_using_arc_format  1                  ; to let filter manage q15 and fp32
node_mask_library      64                 ; dependency with DSP services

; -----
;   MEMORY ALLOCATIONS

node_mem               0                  ; first memory bank (node instance)
node_mem_alloc         76                 ; amount of bytes

node_mem               1                  ; second memory bank (node fast working area)
node_mem_alloc         52                 ;
node_mem_type           1                  ; working memory
node_mem_speed          2                  ; critical fast
; -----
;   ARCS CONFIGURATION
node_arc               0
node_arc_nb_channels    {1 1 2}           ; arc intleaved, options for the number of channels
node_arc_raw_format     {1 17 27}         ; options for the raw arithmetics STREAM_S16, STREAM_FP32

node_arc               1
node_arc_nb_channels    {1 1 2}           ; options for the number of channels
node_arc_raw_format     {1 17 27}         ; options for the raw arithmetics STREAM_S16, STREAM_FP32

end
```

## Manifest header

The manifest starts with the identification of the node.

### node\_developer\_name “name”

Name of the developer/company having the legal owner of this node. Example:

```
node_developer_name CompanyA & Sons Ltd
```

### node\_name "name"

Name of the node when using a graphical design environment. Example:

```
node_name arm_stream_filter
```

### node\_logo "file name"

Name of the graphical logo file (file path of the manifest) of the node when using a graphical design environment. Example:

```
node_logo arm_stream_filter.gif
```

### node\_nb\_arcs "in out"

Number of input and output arcs of the node used for data streaming. Example

```
node_nb_arcs 1 1 ; nb arc input, output, default values "1 1"
```

### node\_arc\_parameter "n"

When the amount of parameters exceeds 256kB (deep-learning models, video file, etc..) the parameters must be read from extra arcs. Example

```
node_arc_parameter 2 ; 2 additional arcs for large parameters
```

### node\_variable\_rxtx\_data\_rate "0/1"

The nodes are called with a data structure for each arc giving :

- a pointers on input and out arcs
- the amount of data (input arcs) and free space (output arcs)

The nodes returns after updating the data structures, but to lower the computation overhead in the node it can tell here if the data flow can vary between input and output arcs. If the data rate do not change it tells here the scheduler to update the data structure automatically.

Examples of variable data rate (node\_variable\_rxtx\_data\_rate 1): MP3 encoder with variable rate encoding option, audio rate converter at using 160/147 ratio. Examples of identical data rate (node\_variable\_rxtx\_data\_rate 0) : an audio filter, an amplifier receiving and delivering the same data formats and frame sizes.

Parameter value "1" tells the data flow is variable, the scheduler proposes input buffers as large as possible and output buffers with as much free space as possible. It is the responsibility of the node to read and write to good amount of data to avoid underflow on input and overflow on output arcs.

**The default is "0"** : ALL input and output arcs have the same raw data rate (same number of bytes consumed and produced per call), the scheduler arranges to find the minimum common denominator between all arcs. The nodes do not have to update buffer consumption and production which known before the call. Example :

```
node_variable_rxtx_data_rate 1 ; variable stream rates
```

### node\_using\_arc\_format "0/1"

During the RESET phase of the node, the scheduler will push (with "1" or not with "0") the arc data formats of all the arcs. The arc format is described in the chapter "IO control and stream data formats" of the file "Graph Template". Example

```
node_using_arc_format 1 the node is using arc stream format
```

### node\_mask\_library "n"

The graph interpreter offers a short list of optimized DSP/ML and Math functions optimized for the platform using dedicated vector instructions and coprocessors. Some platform may not incorporate all the libraries, the "node\_mask\_library" is a bit-field associate to one of the library service. This list of service is specially useful when the node is delivered in binary format.

bit 4 for the STDLIB library (string.h, malloc) bit 5 for MATH (trigonometry, random generator, time processing) bit 6 for DSP\_ML (filtering, FFT, 2D convolution-8bits) bit 7 for audio codecs bit 8 for image and video codec

Example :

`node_mask_library 64 ; the node has a dependency to DSP/ML computing services`

### **node\_architecture “name”**

Create a dependency of the execution of the node to a specific processor architecture. For example when the code is incorporating in-line assembly of a specific architecture.

Example:

```
node_architecture    armv6m ; a node made for Cortex-M0
```

### **node\_fpu\_used “option” (TBD)**

The command creates a dependency on the FPU capabilities Example :

```
node_fpu_used    0 ; fpu option used (default 0: none, no FPU assembly or intrinsic)
```

### **node\_key “x”**

The key is sent to the node during the reset sequence, is placed after the memory allocation pointers.

The node receives this “node\_key”, the “user\_key” placed in the graph, and the “platform key” from the scheduler to decide the features to activate. Example :

```
node_key    0x83560234 ; node key to check against the platform's one
```

### **node\_version “n”**

For information, the version of the node Example :

```
node_version    101 ; version of the computing node
```

### **node\_complexity\_index “n”**

For information and debug to set a watchdog timer: the parameters give the maximum amount of cycles for the initialization of the node and the processing of a frame. Example :

```
node_complexity_index 1e5 1e6 ; maximum number of cycles at initialization time and execution of a frame
```

`node_not_reentrant`

### **node\_not\_reentrant “n”**

Information of reentrancy : the function cannot be called again before it completes its previous execution. Default is “0”, nodes are reentrant. Example :

```
node_not_reentrant 1 ; one single instance of the node can be scheduled in the graph
```

### **node\_stream\_version “n”**

Version of the stream scheduler it is compatible with. Example :

```
node_stream_version    101
```

### **node\_logo “file name”**

File name of the node logo picture (JPG/GIF format) to use in the GUI.

---

## **Node memory allocation**

A node can ask for **up to 6 memory banks** with tunable fields :

- type (static, working/scratch, static with periodic backup)
- speed (normal, fast, critical fast)
- relocatable (the location can change after the node was notified)

- program / data
- size in bytes

The size can be a simple number of bytes or a computed number coupled to a function of stream format parameters (number of channels, sampling rate, frame size) and a flexible parameter defined in the graph, here. The total memory allocation size in bytes =

A	fixed memory allocation in Bytes (default 0)
+ B x nb_channels of arc(i)	number of channels in arc index i (default 0)
+ C x sampling_rate of arc(j)	sampling rate of arc index j (default 0)
+ D x frame_size of arc(k)	frame size used for the arc index k (default 0)
+ parameter from the graph	optional field "node_malloc_add"

**The first memory block is the node instance**, followed by other blocks. This block has the index #0.

#### node\_mem "index"

The command is used to start a memory block declaration with the index in the parameter. Example :

```
` node_mem 0 ; starts the declaration section of memory block #0 `
```

#### node\_mem\_alloc "A"

The parameter gives the "A" value of fixed memory allocation in Bytes. Example :

```
node_mem_alloc 32 ; size = 32Bytes data memory, default Static, default Fast memory block
```

#### node\_mem\_nbchan "B" "i"

Declaration of extra memory in proportion to the number of channel of a specified arc index. Example :

```
node_mem_nbchan 44 3 ; add this amount of bytes : 44 x nb of channels of arc 3
```

#### node\_mem\_sampling\_rate "C" "j"

Declaration of extra memory in proportion with the sampling rate of a given arc index. Example :

```
node_mem_sampling_rate 44.0 3 ; add this amount of bytes : 44.0 x sampling_rate in Hertz of arc 3
```

#### node\_mem\_frame\_size "D" "k"

Declaration of extra memory in proportion with the frame size of the stream flowing through a specified arc index. Example :

```
node_mem_frame_size 44 3 ; add this amount of bytes : 44 x frame size of arc 3
```

#### node\_mem\_alignment "n"

Declaration of the memory Byte alignment Example :

```
node_mem_aligment 4 ; 4 bytes to (default) `
```

#### node\_mem\_type "n"

Definition of the dynamic characteristics of the memory block :

0 STATIC : memory content is preserved (default )

1 WORKING : scratch memory content is not preserved between two calls

2 PERIODIC\_BACKUP static parameters to reload during a warm reboot

3 PSEUDO\_WORKING static only during the uncompleted execution state of the NODE

Example :

```
node_mem_type 3 ; memory block put in a backup memory area when possible
```

### node\_mem\_speed "n"

Declaration of the memory desired for the memory block.

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

Example :

```
node_mem_speed 0 ; relax speed constraint for this block
```

### node\_mem\_relocatable "0/1"

Declares if the pointer to this memory block is relocatable (parameter '1'), or assigned a fixed address at reset (default, parameter '0'). When the memory block is relocatable a command 'STREAM\_UPDATE\_RELOCATABLE' is sent to the node with address changes. Example :

```
node_mem_relocatable 1 ; the address of the block can change
```

### node\_mem\_data0prog1 "0/1"

This command tells if the memory will be used for data or program accesses. Default is '0' for data access. Example :

```
node_mem_data0prog1 1 ; program memory block
```

---

## Configuration of the arcs attached to the node

The arc configuration gives the list of compatible options possible for the node processing. Some options are described as a list, or as a range of values. The syntax is : an index and the list of numbers within brackets "{" and "}". The index gives the default value to consider in the list. Index "1" corresponds to the first element of the list. Index value "0" means "any value". The list can be empty in that case.

Example of an option list between five values, the index is 2 meaning the default value is the second in the list (value = 6). { 2 5 6 7 8 9 } When the index is negative the list is decoded as a "range". A Range is a set of three numbers :

- the first option
- the step to the next possible option
- the last (included) option

The absolute index value selects the default value in this range.

Example of is an option list of values (1, 1.2, 1.4, 1.6, 1.8, .. , 4.2), the index is -3 meaning the default value is the third in the list (value = 1.4).

```
{ -3 1 0.2 4.2 }
```

### node\_arc "n"

The command starts the declaration of a new arc, followed by its index used when connecting two nodes. Example :

```
node_arc 2 ; start the declaration of a new arc with index 2
```

Implementation comment : all the nodes have at least one arc on the transmit side used to manage the node's locking field.

### node\_arc\_rx0tx1 "0/1"

Declares the direction of the arc from the node point of view : "0" means a stream is received through this arc, "1" means the arc is used to push a stream of processed data.

```
node_arc_rx0tx1 0 ; followed by 0:input 1:output, default = 0 and 1
```



### node\_arc\_interleaving "0/1"

Arc data stream interleaving scheme: "0" for no interleaving (independent data frames per channel), "1" for data interleaving at raw-samples levels. Example :

```
node_arc_interleaving 0      data is deinterleaved on this arc
```

### node\_arc\_nb\_channels "n"

Number of the channels possible for this arc (default is 1). Example :

```
node_arc_nb_channels {1 1 2} ; options for the number of channels is mono or stereo
```

### node\_arc\_units\_scale "unit" "scale"

Command used when the node needs the streams to be rescaled to absolute scaled units (See paragraph "Units" of [Tables.md](#)).

```
node_arc_units_scale VRMS 0.15 ; full-scale is equivalent to 0.15 VRMS
```

### node\_arc\_units\_scale\_multiple "unit" "scale"

Command used when the node needs the streams to be rescaled to absolute scaled units and there are multiple units in sequence (See paragraph "Units" of [Tables.md](#)).

```
node_arc_units_scale_multiple DPS 360 GAUSS 0.002  
; interleaved format with maximum 360 dps and 0.002 Gauss
```

### node\_arc\_raw\_format "f"

Raw samples data format for read/write and arithmetic's operations. The stream in the "2D domain" are defining other sub-format Example :

```
node_arc_raw_format {1 17 27} raw format options: STREAM_S16, STREAM_FP32, default values S16
```

### node\_arc\_frame\_length "n"

Frame size options in Bytes. node\_arc\_frame\_length {1 1 2 16} ; options of possible frame\_size in number of sample (can mono or multi-channel) Example :

```
node_arc_frame_length 2      ; start the declaration of a new arc with index 2
```

### node\_arc\_frame\_duration "t"

Duration of the frame in milliseconds. The translation to frame length in Bytes is made during the compilation of the graph from the sampling-rate and the number of channels. A value "0" means "any duration" which is the default. Example :

```
node_arc_frame_duration {1 10 22.5} frame of 10ms (default) or 22.5ms
```

### node\_arc\_sampling\_rate "fs"

Declaration of the allowed options for the node\_arc\_sampling\_rate in Hertz. Example :

```
node_arc_sampling_rate {1 16000 44100} ; sampling rate options, 16kHz is the default value if not specified
```

### node\_arc\_sampling\_period\_s "T"

Duration of the frame in seconds. The translation to frame length in Bytes is made during the compilation of the graph from the sampling-rate and the number of channels. A value "0" means "any duration" which is the default. Example :

```
node_arc_sampling_period_s {-2 0.1 0.1 1} frame sampling going from 100ms to 1000ms, with default 200ms
```

### node\_arc\_sampling\_period\_day "D"

Duration of the frame in days. The translation to frame length in Bytes is made during the compilation of the graph from the sampling-rate and the number of channels. A value "0" means "any duration" which is the default. Example :

```
node_arc_sampling_period_day {-2 1 1 30} frame sampling going from 1 day to 1 month with steps of 1 day.
```

### node\_arc\_sampling\_accuracy “p”

When a node does not need the input data to be rate-accurate, this command allows some rate flexibility without the need for the insertion of a synchronous rate converter. The command parameter is in percent. Example :

```
node_arc_sampling_accuracy 0.1 ; sampling rate accuracy is 0.1%
```

### node\_arc\_inPlaceProcessing “in out”

Memory optimization with arc buffer overlay. This command tells the “in” arc index is overlaid with the “out” arc index. The default configuration is to allocate different memory for input and output arcs. The arc descriptors are different but the base address of the buffers are identical. Example :

```
node_arc_inPlaceProcessing 1 2 ; in-place processing can be made between arc 1 and 2
```

---

## Node design

All the programs can be used with the Graph-scheduler (also called computing “nodes”) as soon as a minimal amount of description is given in a “manifest” and the program can be used through a single entry point with a wrapper using the prototype :

```
void (node) (uint32_t command, stream_handle_t instance, stream_xdmbuffer_t *data, uint32_t *state);
```

Where “command” tells to reset, run, set parameters, .. “instance” is an opaque access to the static area of the node, “data” is a table of pointers+size pairs of all the arcs used by the node, and “state” returns information of computing completion of the subroutine for the data being shared through the arcs.

During “reset” sequence of the graph the node are initialized. Nothing prevents a node to call the standard library for memory allocations or math computing. But the context of the graph interpreter is Embedded IoT, with extreme optimization for costs and power consumption.

---

## General recommendations

General programming guidelines of Node :

- Nodes must be C callable, or respecting the EABI.
- Nodes are reentrant, or this must be mentioned in the manifest.
- Data are treated as little endian by default.
- Data references are relocatable, there is no “hard-coded” data memory locations.
- All Node code must be fully relocatable: there cannot be hard coded program memory locations.
- Nodes are independent of any particular I/O peripheral, there is no hard coded address.
- Nodes are characterized by their memory, and MIPS requirements when possible (with respect to buffer length to process).
- Nodes must characterize their ROM-ability; i.e., state whether or not they are ROM-able (no self-modifying code unless documented so).
- Run-time object creation should be avoid : memory reservation should be done once during the initialization step.
- Nodes are managing buffers with pointer using physical addresses and shared in the parameters.
- Processors have no MMU : there is no mean of mapping physically non-contiguous segments into a contiguous block.
- Cache coherency is managed in Graph-Interpreter at transitions from one node to the next one.
- Nodes should not use stack allocated buffers as the source or destination of any graph services for memory transfer.
- Static/persistent data, retention data used for warm-boot, scratch data, stack and heap usage will be documented.
- Manifest is detailing the memory allocation section with respect to latency/speed requirements.

## Node parameters

A node is using the following prototype

```
void (node) (uint32_t command, void *instance, void *data, uint32_t *state);
```

With following parameters:

Parameter name	Details	Types
command	input parameter	uint32_t
instance	instance	void * casted to the node type
data	input data	casted pointer to struct stream_xdmbuffer { int address; int size; }
state	returned state	uint32_t *

### Command parameter

Command bit-fields :

Bit-fields	Name	Details
31-24	reserved	
16-23	node tag	different roles depending on the command. With “set parameter” it gives the index of the parameter to update from the data* address (if 0 then all the parameters are prepared in data*)
15-12	preset	the node can define 16 “presets”, preconfigured sets of parameters
11-5	reserved	
4	extended	set to 1 for a reset command with warm boot : static areas need to be initialized except the memory segments assigned to a retention memory in the manifest. When the processor has no retention memory those static areas are cleared by the scheduler.
3-0 (LSB)	command	1: reset 2: set parameter 3: read parameter 4: run 5: stop 6: update a relocatable memory segment

### Instance

Instance is an opaque memory pointer (void \*) to the main static area of the node. The memory alignment requirement is specified in the node manifest.

### Data

The multichannel data field is a pointer of arcs’ data. This is pointer to list of structures of two “INTPTR\_T” (32bits or 64bits wide depending on the processor architecture). The first INTPTR\_T is a pointer to the data, the second tells the number of bytes to process (for an input arc) or the number of bytes available in the buffer (for output arcs).

In the default situations all the “size” fields are identical : the number of bytes to process is equal to the amount of memory free to take the computation result. But the node manifest can specify `node_variable_rxtx_data_rate=1` and the scheduler may call the node with different “size” fields.

A node can have **4 arcs**. Each of them can have individual format (number of channels, frame length, interleaving scheme, raw sample type, sampling rate, time-stamps).

### Status

Nodes return state is “0” unless the data processing is not finished, then the returned status of “1”.

### Node calling sequence

The nodes are first called with the command *reset* followed by *set parameters*, several *run* commands and finally *stop* to release memory. This paragraph details the content of the parameters of the node during “reset”, “set parameter” and “run” :

```
void (node) (uint32_t command, void *instance, void *data, uint32_t *state);
```

### Reset command

Each Node is define by an index on 10 bits and a “synchronization Byte” with 3-bits defining the architecture it made for (from 1 to 7, “0” means any architecture), 3-Bits defining the processor index within this architecture (from 1 to 7, “0” means any processor), and 2-bits for thread instance (“0” means any thread, “1, 2, 3” respectively for low-latency, normal latency, and

background tasks. At reset time processor 1, of architecture 1 is allowed to copy the graph from Flash to RAM and unlock the others.

Then each processor parses the graph looking nodes associated to him, resets it and updates the parameters from graph data. When all the nodes have been set the application is notified and the graph switches to “run” mode. Each graph scheduler instance takes care input and output streams are not blocked : each IOs is associated to a processor. Most of the time a single processor is in charge of all.

The multiprocessor synchronization mechanisms are abstracted outside of the graph interpreter (in the platform abstraction layer), a software-based lock is proposed by default.

**The second parameter “instance”** is a pointer to the list of memory banks reserved by the scheduler for the node, in the same sequence order of the declarations made in the node manifest. The first element of the list is the instance of the node, followed by the pointers to the data (or program) memory reservations.

After this list addresses the scheduler will push (when the manifest command *node\_using\_arc\_format* = 1) the arc data formats of all the arcs. The arc format is described in the chapter “IO control and stream data formats” of the file “Graph design”.

**The third parameter “data”** is used to share the address of function providing computing services.

#### Set Parameter command

The bit-field “Node Tag” tells which (or all) parameter will be updated.

**The third parameter “data”** is a pointer to the new parameters.

#### Run command

The bit-field “Node Tag” tells which (or all) parameter will be updated.

**The third parameter “data”** is a pointer to the list buffer (“struct stream\_xdmbuffer { int address; int size; }”) associated to each arc connected to the node.

### Test-bench and non-regression test-patterns

Nodes are delivered with a test-bench (code and non-regression database).

#### Node example

```
typedef struct
{
    q15_t coefs[MAX_NB_BIQUAD_Q15*6];
    q15_t state[MAX_NB_BIQUAD_Q15*4];
} arm_filter_memory;

typedef struct
{
    arm_filter_memory *TCM;
} arm_filter_instance;

void arm_stream_filter (int32_t command, void *instance, void *data, uint32_t *status)
{
    *status = NODE_TASKS_COMPLETED;    /* default return status, unless processing is not finished */

    switch (RD(command,COMMAND_CMD))
    {
        /* func(command = (STREAM_RESET, COLD, PRESET, TRACEID tag, NB ARCS IN/OUT)
           instance = memory_results and all memory banks following
           data = address of Stream function

           memresults are followed by 4 words of STREAM_FORMAT_SIZE_W32 of all the arcs
           memory pointers are in the same order as described in the NODE manifest

           memresult[0] : instance of the component
           memresult[1] : pointer to the allocated memory (biquad states and coefs)

           memresult[2] : input arc Word 0 SIZSFTRAW_FMT0 (frame size..)
           memresult[ ] : input arc Word 1 SAMPINGNCHANM1_FMT1
```

```

..
memresult[ ] : output arc Word 0 SIZSFTRAW_FMT0
memresult[ ] : output arc Word 1 SAMPINGNCHANM1_FMT1

preset (8bits) : number of biquads in cascade, max = 4, from NODE manifest
tag (8bits) : unused
*/
case STREAM_RESET:
{
    uint8_t *pt8b, i, n;
    intPtr_t *memreq;
    arm_filter_instance *pinstance;
    uint8_t preset = RD(command, PRESET_CMD);
    uint16_t *pt16dst;

    /* read memory banks */
    memreq = (intPtr_t *)instance;
    pinstance = (arm_filter_instance *) (*memreq++);          /* main instance */
    pinstance->TCM = (arm_filter_memory *) (*memreq);          /* second bank = fast memory */

    /* here reset */
    pt8b = (uint8_t *) (pinstance->TCM->state);
    n = sizeof(pinstance->TCM->state);
    for (i = 0; i < n; i++) { pt8b[i] = 0; }

    /* load presets */
    pt16dst = (uint16_t *)(&(pinstance->TCM->coefs[0]));
    switch (preset)
    {
        default:
            case 0:      /* by-pass*/
                pt16dst[0] = 0x7FFF;
                break;
    }
    break;
}

/* func(command = bitfield (STREAM_SET_PARAMETER, PRESET, TAG, NB ARCS IN/OUT)
   TAG of a parameter to set, NODE_ALL_PARAM means "set all the parameters" in a raw
   *instance,
   data = (one or all)
*/
case STREAM_SET_PARAMETER:
{
    uint8_t *pt8bsrc, i, numStages;
    uint16_t *pt16src, *pt16dst;
    int8_t postShift;
    arm_filter_instance *pinstance = (arm_filter_instance *) instance;

    pt8bsrc = (uint8_t *) data;
    numStages = (*pt8bsrc++);
    postShift = (*pt8bsrc++);

    pt16src = (uint16_t *)pt8bsrc;
    pt16dst = (uint16_t *)(&(pinstance->TCM->coefs[0]));
    for (i = 0; i < numStages; i++)
    {
        /* format: {b10, 0, b11, b12, a11, a12, b20, 0, b21, b22, a21, a22, ...} */
        *pt16dst++ = *pt16src++;    /* b10
        *pt16dst++ = 0;              /* 0
        *pt16dst++ = *pt16src++;    /* b11
        *pt16dst++ = *pt16src++;    /* b12
        *pt16dst++ = *pt16src++;    /* a11
        *pt16dst++ = *pt16src++;    /* a12
    }

    stream_filter_arm_biquad_cascade_df1_init_q15(
        &(pinstance->TCM->biquad_casd_df1_inst_q15),
        numStages,
        (const q15_t *)&(pinstance->TCM->coefs[0]),

```

```

        (q15_t *)&(pinstance->TCM->state),
        postShift);
    break;
}

/* func(command = STREAM_RUN, PRESET, TAG, NB ARCS IN/OUT)
   instance,
   data = array of [{*input size} {*output size}]

   data format is given in the node's manifest used during the YML->graph translation
   this format can be FMT_INTERLEAVED or FMT_DEINTERLEAVED_1PTR
*/
case STREAM_RUN:
{
    arm_filter_instance *pinstance = (arm_filter_instance *) instance;
    intPtr_t nb_data, stream_xdmbuffer_size;
    stream_xdmbuffer_t *pt_pt;
    int16_t *inBuf, *outBuf;

    /* the node is declared with node_variable_rxtx_data_rate=0, there is no need to update
    stream_xdmbuffer_t after processing */
    pt_pt = data;    inBuf = (int16_t *)pt_pt->address;
                    stream_xdmbuffer_size = pt_pt->size; /* data amount in the input buffer */
    pt_pt++;         outBuf = (int16_t *) (pt_pt->address);
    nb_data = stream_xdmbuffer_size / sizeof(int16_t);

    /* .. */
    break;
}

case STREAM_STOP:
case STREAM_READ_PARAMETER:
case STREAM_UPDATE_RELOCATABLE:
default : break;
}

```

## Conformance checks

Purpose: create an automatic process to incorporate new NODE in a large repository and have a scalable mean to check conformance:

- verification of the conformance to the APIs
- injection of typical and non-typical data aligned with NODE description
- check of outbound parameter behavior
- check of stack consumption and memory leakage.

## Services provided to the nodes

The “service” function has the following prototype

```
typedef void    (services) (uint32_t service_command, uint8_t *ptr1, uint8_t *ptr2, uint8_t *ptr3, uint32_t n);
```

Service command bit-fields :

Bit-fields	Name	Details
31-28	control	set/init/run w/wo wait completion, in case of coprocessor usag
27-24	options	compute accuracy, in-place processing, frame size
23-4	function	Operation/function within the Group
3-0	Group	index to the groups of services : SERV_INTERNAL 1 SERV_SCRIPT 2 SERV_CONVERSION 3 : raw data

Bit-fields	Name	Details
(LSB)		format conversion (fp32 to int16, etc..)SERV_STDLIB 4 : extract of string and stdlib.h (atof, memset, strstr, malloc..)SERV_MATH 5 : extract of math.h (srand, sin, tan, sqrt, log..)SERV_DSP_ML 6 : filtering, spectrum fixed point and integerSERV_DEEPL 7 : fully-connected and convolutional network SERV_MM_AUDIO 8 : audio codecs (TBD)SERV_MM_IMAGE 9 : image processing (TBD)

TODO : application\_callbacks (or scripts)

## Graph design

The Graph-Interpreter is scheduling a linked-list of computing nodes interconnected with arcs. Nodes descriptors tell which processor can execute the code, which arc it is connected to. The arcs descriptors tell the base address of the buffers, read/write indexes, debug/trace information to log and a flag to tell the consumer node to wrap data to the base addresses. The buffers base address are portable using 6-bits “offset” and 22-bits “index”. The offset is translated by each graph interpreter instance of each processor in a physical address given in the Platform-Manifest.

The graph is placed in a shared memory for all processors, there is no message passing scheme, the Graph-Interpreter scheduler’s instances and doing the same estimations in parallel, deciding which node needs to be executed in priority.

A graph text has several sections :

- **Control of the scheduler** : debug option, location of the graph in memory
- **File paths** : 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 IOs or boundaries of the graph** : the IOs are a kind of arcs producing or consuming a stream of data
- **The scripts** are byte-code interpreted programs used for simple operations like setting parameters, sharing debug information, calling “callbacks” predefined in the application.
- The list of **nodes** (“linked-list” of nodes), without their connexions with other nodes. This section defines also the boot parameters, the memory mapping
- The list of **arcs**, their relations with two nodes and the minimal type of debug activity on data moves

## Binary format of the graph

Graph section name	Description
—— next sections can either be in RAM or Flash	
Header (7 words)	The header tells where the graph will be in RAM the size of the following sections, the processors allowed to use it, the percentage of memory consumed in the memory banks
IO description and links to the device-driver abstraction (4 words/IO)	Each IO descriptor tell if data will be copied in the arc buffers or if the arc descriptor will be set to point directly to the data.
Scripts byte code and parameters	Scripts are made to update parameters, interface with the application’s callbacks, implement simple state-machines, interface with the IOs of the graph
List of Nodes instance and their parameters to use at reset time	This section is the translation of the node manifests with additional information from the graph : memory mapping of the node data banks and parameters (preset and specific paremeters)
—— graph sections in RAM area starts here	
List of flags telling if data requests are on-going on the IOs (1 byte/IO)	The flags “on-going” are set by the scheduler and reset upon data transfer completion
List of debug/trace registers used by arcs (2 words/debug register)	Basic programmable data stream analysis (time of last access, average values, estimated data rate)
List of Formats, max 256, 4 words/format	Frame length, number of channels, interleaving scheme, specific data of the domain
List of arc descriptors (5	Base address in the portable format (6bits offset 22bits index in words), read/write

Graph section name	Description
words/arc)	indexes with Byte accuracy. The descriptor has an "extension" factor to scale all parameter up to 64GB addressing space.

## Example of graph

The graph in text format :

```

;-----
;   Stream-based processing using a graph interpreter :
;
;   - The ADC detection is used to toggle a GPIO
;
;   +-----+   +-----+   +-----+   +-----+
;   | ADC      +-----> filter +-----> detect +-----> GPIO   |
;   +-----+   +-----+   +-----+   +-----+
;
;-----
format_index      0
format_frame_length 8
format_index      1
format_frame_length 16
;-----
stream_io          0           ; IO0
stream_io_hwid     1           ; io_platform_data_in_1.txt
stream_io          1           ; IO1
stream_io_hwid     9           ; io_platform_data_out_0.txt
;-----
node arm_stream_filter 0           ; first node
    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; 1                 ; postShift
        5 s16; 681 422 681 23853 -15161 ; band-pass 1450..1900/16kHz
        5 s16; 681 -1342 681 26261 -15331 ;
    end
;-----
node sigp_stream_detector 0           ; second node
    node_preset      3           ; detector preset
;-----
;   arc connexions between IOs and node and between nodes

arc_input  0 1 0 arm_stream_filter 0 0 0
arc_output 1 1 1 sigp_stream_detector 0 1 1

; arc going from the filter to the detector
arc arm_stream_filter 0 1 0 sigp_stream_detector 0 0 1
arc_jitter_ctrl 1.5 ; increase the buffer size

end

```

The compiled result which will be the input file of the interpreter:

```

//-----
//   DATE Thu Sep 19 19:49:37 2024
//   AUTOMATICALLY GENERATED CODES
//   DO NOT MODIFY !
//-----
0x0000003C, // ----- Graph size = Flash=36[W]+RAM24[W] +Buffers=48[B] 12[W]
0x00000000, // 000 000 [0] Destination in RAM 0, and RAM split 0
0x00000042, // 004 001 [1] Number of IOs 2, Formats 2, Scripts 0
0x00000015, // 008 002 LinkedList size = 21, ongoing IO bytes, Arc debug table size 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 ...

```



```

0x00083000, // 01C 007 IO(graph0) 1 arc 0 set0copy1=1 rx0tx1=0 servant1 1 shared 0 domain 0
0x00000000, // 020 008 IO(settings 0, fmtProd 0 (L=8) fmtCons 0 (L=8)
0x00000000, // 024 009
0x00000000, // 028 00A
0x00483801, // 02C 00B IO(graph1) 9 arc 1 set0copy1=1 rx0tx1=1 servant1 1 shared 0 domain 0
0x00000000, // 030 00C IO(settings 0, fmtProd 1 (L=16) fmtCons 1 (L=16)
0x00000000, // 034 00D
0x00000000, // 038 00E
0x00C04807, // 03C 00F ----- arm_stream_filter(0) idx:7 Nrx 1 Ntx 1 ArcFmt 1 lockArc 1
0x08020000, // 040 010 ARC 0 Rx0Tx1 0 L=8 dbgpage0 -- ARC 2 Rx0Tx1 1 L=16 dbgpage0
0x30000048, // 044 011 Nb Memreq-1 1 XDM11_same_rate 1
0x0000004C, // 048 012 Reserved static memory bank(0) = bank 0 stat0work1ret2 = 0 size 76
0x30800000, // 04C 013
0x00000034, // 050 014 Scratch memory bank(1) = bank 2 stat0work1ret2 = 1 size 52
0x01000007, // 054 015 ParamLen 6+1 Preset 1 Tag0ALL 0
0x02A90102, // 058 016 (0)
0x02A901A6, // 05C 017 (1)
0xC4C75D2D, // 060 018 (2)
0xFAC202A9, // 064 019 (3)
0x669502A9, // 068 01A (4)
0x0000C41D, // 06C 01B (5)
0x00C04808, // 070 01C ----- sigp_stream_detector(0) idx:8 Nrx 1 Ntx 1 ArcFmt 1 lockArc 1
0x08010002, // 074 01D ARC 2 Rx0Tx1 0 L=8 dbgpage0 -- ARC 1 Rx0Tx1 1 L=16 dbgpage0
0x30000058, // 078 01E Nb Memreq-1 1 XDM11_same_rate 1
0x00000034, // 07C 01F Reserved static memory bank(0) = bank 0 stat0work1ret2 = 0 size 52
0x30000064, // 080 020
0x00000020, // 084 021 Reserved static memory bank(1) = bank 0 stat0work1ret2 = 2 size 32
0x03000001, // 088 022 ParamLen 0+1 Preset 3 Tag0ALL 0
0x000003FF, // 08C 023 ^^^^^^^^^ LINKED-LIST END ^^^^^^^^^ vvvvvvvvvvv RAM vvvvvvvvvvv
0xFFFF7F7F, // 090 024 LinkedList size = 21, ongoing IO bytes, Arc debug table size 0
0x00000008, // 094 025 Format 0 frameSize 8
0x00004400, // 098 026 nchan 1 raw 17
0x00000000, // 09C 027 domain-dependent
0x00000000, // 0A0 028 domain-dependent
0x00000010, // 0A4 029 Format 1 frameSize 16
0x00004400, // 0A8 02A nchan 1 raw 17
0x00000000, // 0AC 02B domain-dependent
0x00000000, // 0B0 02C domain-dependent
0x0000003C, // 0B4 02D IO-ARC descriptor(0) Base 3Ch (Fh words) fmtProd_0 frameL 8.0
0x00000008, // 0B8 02E Size 8h[B] fmtCons_0 FrameL 8.0 jitterScaling 1.0
0x00000000, // 0BC 02F
0x00000000, // 0C0 030
0x00000000, // 0C4 031 fmtCons 0 fmtProd 0 dbgreg 0 dbgcmd 0
0x0000003E, // 0C8 032 IO-ARC descriptor(1) Base 3Eh (Fh words) fmtProd_1 frameL 16.0
0x00000010, // 0CC 033 Size 10h[B] fmtCons_1 FrameL 16.0 jitterScaling 1.0
0x00000000, // 0D0 034
0x00000000, // 0D4 035
0x00000101, // 0D8 036 fmtCons 1 fmtProd 1 dbgreg 0 dbgcmd 0
0x00000042, // 0DC 037 ARC descriptor(2) Base 42h (10h words) fmtProd_0 frameL 8.0
0x00000018, // 0E0 038 Size 18h[B] fmtCons_1 FrameL 16.0 jitterScaling 1.5
0x00000000, // 0E4 039
0x00000000, // 0E8 03A
0x00000100, // 0EC 03B fmtCons 1 fmtProd 0 dbgreg 0 dbgcmd 0

```

## Graph: control of the scheduler

The first words of the binary graph give the portion of the graph to move to RAM. To have addresses portability of addresses between processors, the graph interpreter is managing a list of “memory-offsets”. Every physical address is computed from a 28 bit-field structure made of: 6 bits used to select maximum 64 memory-offsets (or memory bank). And a 22bits field used as an index in this memory bank. The function “platform\_init\_stream\_instance()” initializes the interpreter memory-offset table.

### graph\_location “x”

Parameter x :

- 0: (default) the destination of the binary graph is fully in RAM address corresponding to the first memory-offset
- 1: the graph stays in Flash and the static portion is copied in RAM is starting from the end of nodes linked-list

- 2: the graph is provided by the application, already in RAM, there is nothing to do

Example :

```
graph_location 2 ; copy the compiled graph in RAM
```

#### **graph\_location\_offset “x”**

The parameter (default 0) gives the binary graph destination offset from the memory-offset #0

Example :

```
graph_location_offset 1024 ; copy the graph at (long_offset[0] + 1024)
```

#### **debug\_script\_fields “x”**

The parameter is a bit-field of flags controlling the scheduler loop :

- bit 0 (lsb 1) set means “call the debug/trace 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 when starting the graph scheduling”
- bit 4 (16) set means “call the debug script when returning from the graph scheduling”
- no bit is set (default) the debug script is not called

Example :

```
debug_script_fields 0 ; no debug script activated
```

#### **scheduler\_return “x”**

- 1: return to application caller subroutines after each node execution calls
- 2: return to caller once all node of the graph are parsed
- 3: return to caller when all nodes are starving (default 3)

Example :

```
debug_script_fields 0 ; no debug script activated
```

#### **allowed\_processors “x”**

bit-field of the processors allowed to execute this graph, (default = 1 main processor)

Example :

```
allowed_processors 0x81 ; (10000001) processor ID 1 and 8 can read the graph
```

#### **set\_file\_path “index” “path”**

Index and its file path, used when including files (sub graphs, parameter files and scripts).

Example :

```
set_file_path 2 ../nodes/ ; file path index 2 to the folder ../nodes
```

#### **graph\_memory\_bank “x”**

Command used in the context of memory mapping tuning. “x” : index of the memory bank indexes where to map the graph (default 0).

Example :

```
graph_memory_bank 1 ; select of memory bank 1 of the Platform manifest
```

---

## Graph: IO control and stream data formats

There are three data declared in the graph scheduler instance (*arm\_stream\_instance\_t*): A - a pointer to a RAM area giving

- on-going transfer flag

B - a pointer to the list of IOs bit-fields controlling the setting of the IO, the content of which depends on the *Domain*:

- the index of the arc creating the interface between the IO and a node of the graph ("arcID")
- the Rx/Tx direction of the stream, from the point of view of the graph
- the dynamic behavior : data polling initiated by the scheduler or transfer initiated outside of the graph
- flag telling if the data are copied in the arc's buffer or if the arc's descriptor is modified to point directly to the data
- flag telling if the buffer used by the IO interface must be reserved by the graph compiler
- physical Domain of the data (see command "format\_domain")
- index to the Abstraction Layer in charge of operating the transfers
- for audio (mixed-signal setting, gains, sampling-rate, ..)

C - a pointer to the "Formats" which are structures of four words giving :

- word 0 : frame size 4MB (Byte accurate)
- word 1 : number of channels (1..32), interleaving scheme, time-stamp, raw format, domain, sub-type, frame size extension (up to 64GB +/-16kB)
- word 2 : sampling rate in [Hz], truncated IEEE FP32 on 24bits : S\_E8\_M15
- word 3 : specific to each domain (audio and motion channel mapping, image format and border)

### format "n"

This command starts the declaration of a new format. example `format_raw_data 2 ;` all further details are for format index 2 index used to start the declaration of a new format

### format\_raw\_data "n"

The parameter is the raw data code of the table below. Example `format_raw_data 17 ;` raw data is "signed integers of 16bits" The default index is 17 : `STREAM_16` (see Annexe "Data Types").

### format\_frame\_length "n"

Frame length in number of bytes of the current format declaration (default :1) Example `format_frame_length 160`

### format\_nbchan "n"

Number of channels in the stream (default 1) Example `format_nbchan 2 ;` stereo format

### format\_interleaving "n"

Example `format_interleaving 0 0` means interleaved raw data, 1 means deinterleaved data by packets of "frame size"

### format\_time\_stamp "n"

Example `format_time_stamp 40 ;` time-stamp format `TIME16D` time-stamp format :

- 0: no time stamp
- 1: simple counter
- 39: `STREAM_TIME16` format q14.2 in seconds, maximum range 1 hour + 8mn +/- 0.0625
- 40: `STREAM_TIME16D` format q15 seconds, for time differences +/- 15us
- 41: `STREAM_TIME32` format q28.4 seconds, maximum 8.5 years +/- 0.0625s
- 42: `STREAM_TIME32D` format q17.15 seconds, maximum 36hours +/- 30us for time differences
- 43: `STREAM_TIME64` format q32.28 seconds, maximum 140 years +/- 4ns
- 44: `STREAM_TIME64MS` format u42 in milliseconds, amximum 140 years
- 45: `STREAM_TIME64ISO` ISO8601 with signed offset, example 2024-05-04T21:12:02+07:00

## format\_domain “n”

Usage context of this command is for the section “B” of above chapter “IO control and stream data formats”. Example `format_domain 2` ; this format uses specific details of audio out domain

DOMAIN	CODE	COMMENTS
GENERAL	0	(a)synchronous sensor, electrical, chemical, color, remote data, compressed streams, JSON, SensorThings, application processor
AUDIO_IN	1	microphone, line-in, I2S, PDM RX
AUDIO_OUT	2	line-out, earphone / speaker, PDM TX, I2S,
MOTION	5	accelerometer, combined or not with pressure and gyroscope audio_in microphone, line-in, I2S, PDM RX
2D_IN	6	camera sensor audio_out line-out, earphone / speaker, PDM TX, I2S,
2D_OUT	7	display, led matrix, gpio_in generic digital IO

## Information specific of domains

Word 3 of “Formats” holds specific information of each domain.

### Audio

Audio channel mapping is encoded on 20 bits. For example a stereo channel holding “Back Left” and “Back Right” will be encoded as 0x0030.

Channel name	Name	Bit
Front Left	FL	0
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
Channel 19	C19	18
Channel 20	C20	19

### Motion

Motion sensor channel mapping (w/wo the temperature)

Motion sensor data	Code
only accelerometer	1
only gyroscope	2

Motion sensor data	Code
only magnetometer	3
A + G	4
A + M	5
G + M	6
A + G + M	7

## 2D

Format of the images in pixels: height, width, border.

---

## Graph: interfaces of the graph

### stream\_io “n”

This command starts a section for the declaration of IO “n”. The parameter is the interface index used in the graph. This declaration starts the definition of a new IO Example

```
stream_io 2
```

### stream\_io\_hwid “ID”

The stream\_io is using the ID of the physical interface given in platform manifests (default #0) Example

```
stream_io_hwid 2
```

### stream\_io\_format “n”

Parameter: index to the table of formats (default #0) Example

```
stream_io_format 0
```

### stream\_io\_setting “W32 W32 W32”

“IO settings” is a specific bit-field structure, specific to the IO domain, placed at the beginning of the binary graph, and used during the initialization sequence of the graph. Up to three control words in hexadecimal can be used. Example

```
stream_io_setting 7812440
```

### stream\_io\_setting\_callback “cb” “X”

The function “platform\_init\_stream\_instance()” initializes the interpreter pointers to the callbacks proposed by the platform. Example

```
stream_io_setting_callback 6 7812440 ; Use callback 6 for the setting of the
; current stream_io using parameter 7812440
```

---

## Graph: memory mapping

Split the memory mapping to ease memory overlays between nodes and arcs by defining new memory-offset index (“ID”). Format : ID, new ID to use in the node/arc declarations, byte offset within the original ID, length of the new memory offset.

```
;          original_id  new_id    start    length
; memory_mapping      2      100     1024     32700
```

### Memory fill

Filling pattern placed after the arc descriptors

```
mem_fill_pattern 5 3355AAFF    memory fill 5 word32 value 0x3355AAFF (total 20 Bytes)
```

---

## Graph: subgraphs

(To be defined)

A subgraph is equivalent to program subroutines for graphs. A subgraph can be reused in several places in the graph or in other subgraph. The graph compiler creates references by name mangling from the call hierarchy. A subgraph receives indexes of IO streams and memory bank indexes for tuning the memory map. The caller gives its indexes of the arcs to use in the subgraph, and the memory mapping offset indexes. Example :

```
subgraph
  sub1                ; subgraph name, used for name mangling
  3 sub_graph_0.txt    ; path and file name
  5 i16: 0 1 2 3 4     ; 5 streaming interfaces data_in_0, data_out_0 ..
  3 i16: 0 0 0         ; 3 partitions for fast/slow/working (identical here)
```

---

## Graph: nodes declarations

Nodes are declared with their name and respective instance index in the graph (or subgraph). The system integrator can set a “preset” (pre-tuned list of parameters described on node’s documentation) and node-specific parameters to load at boot-time. The address offset of the nodes is provided as a result of the graph compilation step. Declaration syntax example :

```
node arm_stream_filter 0 ; first instance of the nore "arm_stream_filter"
```

### node\_preset “n”

The system integrator can select 16 “presets” when using a node, each corresponding to a configuration of the node (see its documentation). The Preset value is with RESET and SET\_PARAMETER commands, the default value is 0. Example :

```
node_preset          1      ; parameter preset used at boot time
```

### node\_malloc\_add “n” “i”

A node memory allocation is described in its manifest. A node can ask for up to 6 memory banks with tunable fields :

- type (static, working, static with periodic backup)
- speed (normal, fast, critical fast)
- relocatable (the location can change after the node was notified)
- program / data
- size in bytes

The size can be a simple number of bytes or a computed number coupled to a function of stream format parameters (number of channels, sampling rate, frame size) and a flexible parameter defined in the graph, here. The total memory allocation size in bytes =

A	fixed memory allocation in Bytes (default 0)
+ B x nb_channels of arc(i)	number of channels in arc index i (default 0)
+ C x sampling_rate of arc(j)	sampling rate of arc index j (default 0)
+ D x frame_size of arc(k)	frame size used for the arc index k (default 0)
+ parameter from the graph	optional field "node_malloc_add"

For example an extra scratch area allocation can added as a function of the number of pixels in the images to process (default 0). Example :

```
node_malloc_add 12 0 ; add 12 bytes to segment 0
```

### node\_map\_hwbblock “m” “o”

This command is used to tune the memory mapping and bypass the speed requirement of the node manifest. It tells to force the memory segment index given in the first parameter to be mapped to the memory offset index of the second parameter. Example :

```
node_map_hwblock 0 2 ; memory segment 0 is mapped to bank offset 2
```

### **node\_map\_copy / node\_map\_swap “m” “o”**

This command is used to optimize the memory mapping of small and fast memory segment by copying, or swapping, a memory segment content from and other memory offset (usually a slower one). Usage :

```
node_map_copy 1 0; forced copy of the indexed node memory segment 1 to hardware memory offset 0
node_map_swap 1 0; forced swap of the indexed node memory segment 1 to hardware memory offset 0
```

In the above both cases the memory segment 1 is copied from offset memory segment 1 (a dummy arc descriptor is created to access this temporary area). In the second swap case the scheduler reads node memory segment and updates the slow memory.

### **node\_trace\_id “io”**

Selection of the graph IO interface used for sending the debug and trace informations. Example :

```
node_trace_id 0 ; IO port 0 is used to send the trace
```

### **node\_map\_proc, node\_map\_arch, node\_map\_rtos**

The graph can be executed in a multiprocessor and multi tasks platform. Those commands allow the graph interpreter scheduler to skip the nodes not associated to the current processor / architecture and task. The platform can define 7 architectures and 7 processors. When the parameter is not defined (or with value 0) the scheduler interprets it as “any processor” or “any architecture” can execute this node. Several OS threads can interpret the graph at the same time. A parameter “0” means any thread can execute this node, and the value “1” is associated to low-latency tasks, “3” to background tasks. Examples :

```
node_map_proc 2 ; run this node on processor 2 defined in the architecture manifest
node_map_arch 1 ; run this node on architecture 1 defined in the architecture manifest
node_map_rtos 1 ; run this node on thread index 1 (low-latency)
```

### **node\_map\_verbose “level”**

The default verbose level on the debug trace of this node is level “0”, meaning “quiet”. Other values from 1 to 3 tell to trace more information. Example:

```
node_map_verbose 3 ; highest level of verbose debug trace
```

### **node\_memory\_isolation “0/1”**

Activate (parameter “1”) the processor memory protection unit (on code, private memory allocated segments, and stack) during the execution of this node. Example :

```
node_memory_isolation 1 ; activation of the memory protection unit (MPU), default 0
```

### **node\_memory\_clear “m”**

Debug and security feature: Clear the memory bank “m” before and after the execution of the node. Example :

```
node_memory_clear 2 ; clear the memory bank 2 as seen in the manifest before and after execution
```

### **node\_script “index”**

The indexed script is executed before and after the node execution. The conditional is set on the first call and cleared on the second call. Example :

```
node_script 12 ; call script #12 associated to this node
```

### **node\_user\_key “key”**

The key is sent to the node during the reset sequence, It is placed after the memory allocation pointers.

The node receives the “node\_key” from the node manifest file, this “user\_key”, and the “platform key” from the scheduler to decide the features to activate. Example :

node\_user\_key 0x2334809458

### node\_parameters "tag"

This command declares the parameters to share with the node during the RESET sequence. If the "tag" parameter is null it tells the following parameters is a full set. Otherwise it is an index of a subset defined in the node documentation. The following declaration is a list of data terminated with the "end". Example of a packed structure of 22 bytes of parameters:

```
node_parameters      0          TAG = "all parameters"
  1 u8;  2          Two biquads
  1 u8;  1          postShift
  5 s16; 681  422  681 23853 -15161 elliptic band-pass 1450..1900/16kHz
  5 s16; 681 -1342  681 26261 -15331
end
```

---

## Graph Scripts byte codes

Scripts are interpreted byte-codes designed for control and calls to the graph scheduler for node control and parameter settings. Scripts are declared as standard nodes with extra parameters to declare memory size and allowing it to be reused for several scripts. The script-nodes have the transmit arc used to hold the instance memory (registers, stack and heap memory).

The virtual engine has 20 instructions and up to 12 registers.

There are two formats of instructions:

- test and load : [test field] [register to test or to load] [ALU operation] [ALU operands]
- jump and special operations : calls, scatter/gather load, bit-field operations

### Test instructions

The result of the test is evaluated by adding a conditional field to any instruction :

List of test instructions :

test_equ	test if equal
test_leq	test if less or equal
test_lt	test if lower
test_neq	test if non equal
test_geq	test if great or equal
test_gt	test if greater

test the result :

```
if_yes ...
if_no ...
```

### Arithmetic operations

add	addition of two operands
sub	substraction
mul	multiplication
div	division
or	logical OR, FP32 operands are pre-converted to "int"
nor	logical NOR
and	logical AND
xor	logical XOR
shr	shift right, sign extension applied on "signed" registers
shl	shift left
set	set a bit
clr	clear a bit
max	compute the maximum of two operands
min	minimum
amax	maximum of absolute values
amin	minmum of absolute values
norm	normalize to MSB and return the amount of shifts



addmod	addition with modulo defined by "base" and "size"
submod	subtraction with modulo

The 12 registers of the virtual machine are "r0" .. "r11". Using "sp0" (or simply "sp") means an access to the data located at the stack pointer position, "sp1" tells to increment the stack pointer **SP** after a write to the stack and to decrement it after a read. In case several stack accesses are made in the same instruction the update of the stack pointer are made when reading the instructions from right to left.

For example : `sp1 = add sp1 #float 3.14` : the literal constant "3.14" is added to the data on top of the stack and SP is post-decremented after the read ("pop" operation), the result of the addition is saved on the stack ("push") with SP post-incremented. `sp1 = add sp0` `sp1` pops the stack adds the next stack value (without SP decrement) and the result is pushed.

<code>r6 = 3</code>	<code>r6 = 3</code> (the default literals type is int32)
<code>r11 = sp</code>	read data from the top of the stack
<code>r6 = add r5 3</code>	<code>r6 = ( r5 + 3 )</code>
<code>sp1 = r6</code>	push the result on stack (SP incremented)
<code>test_eq r6 = sub r5 r4</code>	test if <code>r6 == ( r5 - r4 )</code>
<code>if_yes r6 = add r5 3</code>	conditional addition of r5 with 3 saved in r6

Literal constants are signed integers by default, if other data types are needed the constant is preceded by "#float" or "uint8", for example :

<code>r3 = #float 3.14159</code>	load PI in r3
<code>r4 = mul r3 12</code>	floating-point multiplication saved in r4

Other instructions examples :

<code>swap r2 sp1</code>	swap r2 with the top of the stack, pop it
<code>label L1</code>	label declaration
<code>if_not call L1</code>	conditional call
<code>banz L1 r2</code>	decrement r2 and branch if not zero
<code>jump L1 r1</code>	jump to label and push up to 2 registers
<code>call L1 r2 r3</code>	call a subroutine and save 2 registers
<code>set r4 #uint32</code>	cast r4 to an unsigned integer
<code>set r4 #heap L2</code>	load r4 with an address in the heap RAM
<code>set r4 base L2</code>	set the base address of a circular buffer
<code>set r0 graph node_name_2</code>	set r0 with the graph's node instance #2
<code>save r4 r5 r0 r2 r11</code>	push 5 registers on the stack
<code>restore r4 r5</code>	pop 2 registers from the stack
<code>delete 4</code>	remove the last 4 registers from the stack
<code>[ r4 12 ]+ = r5</code>	scatter load with pre-increment
<code>r3 = [ r4 ] r0</code>	gather load
<code>r3   8 15   = r2</code>	bit-field load of r2 to the 2nd byte of r3
<code>r3 = r2   0 7  </code>	bit-field extract the LSB of r2 to r3
<code>return</code>	return from subroutine or script
<code>callsys 1 r1 r4 r5</code>	to address nodes and arcs

## Graph syntax

<code>script 1</code>	<code>; script (instance) index</code>
<code>script_stack 12</code>	<code>; size of the stack in word64</code>
<code>script_registers 4</code>	<code>; only r0..r3 will be used to save memory</code>
<code>script_mem_shared 1</code>	<code>; default is private memory (0) or shared (1)</code>

`script_code`

```
...
return ; return to the graph scheduler
script_parameters 0 ;
  1 u8 ; 34 ; data section following the code
  label BBB ; label to the the second byte
  2 u32; 0x33333333 0x44444444 ;
  label CCC
  1 u8 ; 0x55 ; second label address
  1 u32; 0x66666666 ;
```

<code>script_heap</code>	<code>; heap RAM section (arc buffer)</code>
<code>1 u8 ; 0</code>	<code>; RAM</code>
<code>label DDD</code>	

```

4 u32; 0 0 0 0 ; label DDD points to a byte address
label EEE
1 u8 ; 0 ; heap is initialized at node reset
end

```

## System calls

The "callsys" instruction gives access to nodes (set/read parameters) and arc (read/write data). It allows the access to other system information:

- FIFO content (read/write), filling status and access to the arc debug information (last time-stamp access, average of samples, etc ..)
- Node parameters read and update, with / without a reset of the node
- Basic compute and data move functions
- The call-backs provided by the application (use-case, change the graph IO parameters, debug and trace)

### Callsys syntax

Callsys 1st index	register parameters
1 (access to nodes)	1: address of the node2: command (tag, reset id, cmd) set/read parameter=2/33: address of data4: number of bytes
2 (access to arcs)	1: arc's ID2: command set/read data=8/93: address of data4: number of bytes
3 (callbacks of the application)	1: application_callback's ID2: parameter1 (depends on CB)3: parameter2 (depends on CB)4: parameter3 (depends on CB)
4 (IO settings)	1: IO's graph index2: command set/read parameter=2/33: address of data4: number of bytes
5 (debug and trace)	TBD
6 (computation)	TBD
7 (timers and idle controls)	TBD, read time, delta-time, in the three formats (16, 32, 64 bits). Compute difference of time. Share to the application the recommended Idle strategy to apply (small or deep-sleep). Read Node descriptor from the graph, check the script is executed from a specific processor.
8 (low-level functions)	TBD, peek/poke directly to memory, direct access to IOs (I2C driver, GPIO setting, interrupts generation and settings)

## Arcs of the graph

The syntax is different for arcs connected to the boundary of the graph, and arcs placed between two nodes. Depending on real-time behaviors (CPU load and jitter, task priorities, speed of data streams) the data can be processed in-place (large input images for examples) or it can be mandatory to copy the data in temporary FIFO before being processed in the graph. The parameter "set0copy1" is set to 0 (default value) for a processing made "in-place": the base address the arc FIFO descriptor is modified during the transfer acknowledgment subroutine `arm_graph_interpreter_io_ack()` to point directly to the IO data (no data move). When the parameter is 1 the data is copied in the arc FIFO. The graph compiler will allocate an amount of memory corresponding to a frame length.

Example :

```

; Syntax :
; arc_input  { io / set0copy1 / fmtProd } + { node / inst / arc / fmtCons }
; arc_output { io / set0copy1 / fmtCons } + { node / inst / arc / fmtProd }
; arc { node1 / inst / arc / fmtProd } + { node2 / inst / arc / fmtCons }

arc_input 4 1 0    xxfilter 6 0 8    ; IO-4 sends data to the node xxfilter

; output arc from node xxdetector instance 5 output #1 using format #2
;          to graph IO 7 using set0copy1=0 and format #9
arc_output 5 1 2    xxdetector 5 1 2

arc between nodeAAA instance 1 output #2 using format #0
      and nodeBBB instance 3 output #4 using format #1
arc nodeAAA 1 2 0    nodeBBB 3 4 1

```

## arc flow control

### Example

```
arc_flow_error 1 ; #1 do something depending on the IO domain when a flow error occurs, default #0 (no extra processing, just skip data)
```

## arc debug

Each arc descriptor can be configured to have an operation (in a list of 32) implemented with result returned in a dedicated memory section of the graph.

CODE	DEBUG OPERATION
0	no operation
1	increment DEBUG_REG_ARCW1 with the number of RAW samples
2	set a 0 in to *DEBUG_REG_ARCW1, 5 MSB gives the bit to clear
3	set a 1 in to *DEBUG_REG_ARCW1, 5 MSB gives the bit to set
4	increment *DEBUG_REG_ARCW1
5	
6	call-back in the application side, data rate estimate in DEBUG_REG_ARCW1
7	second call-back : wake-up processor from DEBUG_REG_ARCW1=[ProcID, command]
8	
9	time_stamp_last_access
10	peak with forgetting factor 1/256 in DEBUG_REG_ARCW1
11	mean with forgetting factor 1/256 in DEBUG_REG_ARCW1
12	min with forgetting factor 1/256 in DEBUG_REG_ARCW1
13	absmin with forgetting factor 1/256 in DEBUG_REG_ARCW1
14	when data is changing the new data is push to another arc DEBUG_REG_ARCW1=[ArcID]
15	automatic rewind read/write

### Example :

```
arc_debug_cmd 1 debug action "ARC_INCREMENT_REG"
arc_debug_reg 3 index of the 64bits result, default = #0
arc_debug_page 0 page of 32 words / page, default = #0
```

## arc\_flush

```
arc_flush 0 ; forced flush of data in MProcessing and shared tasks
```

## arc\_map\_hwblock

```
arc_map_hwblock 0 map the buffer to a memory offset, default = #0 (VID0)
```

## arc\_jitter\_ctrl

Command used during the compilation step for the FIFO buffer memory allocation with some margin.

```
arc_jitter_ctrl 1.5 ; factor to apply to the minimum size between the producer and the consumer,
default = 1.0 (no jitter)
```

## arc\_parameters

Arcs are used to node parameters when the inlined way (with the node declaration) is limited to 256kBytes. The node manifest declares the number of arcs used for large amount of parameters (NN model, video file, etc ..).

```
arc_parameters 0 ; (parameter arcs) buffer preloading, or arc descriptor set with script
7 i8; 2 3 4 5 6 7 8 ; parameters
include 1 filter_parameters.txt ; path + text file-name using parameter syntax
end
```

---

## Common tables

### Stream format Words 0,1,2

Words 0, 1 and 2 are common to all domains :

Word	Bits	Comments
0	0..21	frame size in Bytes (including the time-stamp field)
0	22..31	reserved
1	0..4	nb channels-1 [1..32 channels]
1	5	0 for raw data interleaving (for example L/R audio or IMU stream), 1 for a pointer to the first channel, next channel address is computed by adding the frame size divided by the number of channels
1	6..7	time-stamp format of the stream applied to each frame :0: no time-stamp 1: absolute time reference 2: relative time from previous frame 3: simple counter
1	8..9	time-stamp size on 16bits 32/64/64-ISO format
1	10..15	raw data format
1	16..19	domain of operations (see list below)
1	20..21	extension of the size and arc descriptor indexes by a factor 1/64/1024/16k
1	22..26	sub-type (see below) for pixel type and analog formats
2	0..7	reserved
2	8..31	IEEE-754 FP32 truncated to 24bits (S-E8-M15), 0 means “asynchronous”

### Stream format Word 3

Word 3 of “Formats” holds specific information of each domain.

#### Audio stream format

Audio channel mapping is encoded on 20 bits. For example a stereo channel holding “Back Left” and “Back Right” will be encoded as 0x0030.

Channel name	Name	Bit
Front Left	FL	0
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
Channel 19	C19	18

Channel name	Name	Bit
Channel 20	C20	19

## Motion

Motion sensor channel mapping (w/wo the temperature)

Motion sensor data	Code
only accelerometer	1
only gyroscope	2
only magnetometer	3
A + G	4
A + M	5
G + M	6
A + G + M	7

## 2D

Format of the images in pixels: height, width, border. The “extension” bit-field of the word -1 allow managing larger images.

2D data	bits range	comments
smallest dimension	0 - 11	the largest dimension is computed with (frame_size - time_stamp_size)/smallest_dimension
image ratio	12 - 14	TBD =0, 1/1 =1, 4/3 =2, 16/9 =3, 3/2=4
image format	15	0 for horizontal, 1 for vertical
image sensor border	17 - 18	0 .. 3 pixels border

## Data Types

Raw data types

TYPE	CODE	COMMENTS
STREAM_DATA_ARRAY	0	stream_array : [0NNNTT00] number, type
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	uu
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	See [8 .. 512]
STREAM_S8	11	Sxxxxxxx eight bits per data
STREAM_U8	12	xxxxxxx ASCII char, numbers..
STREAM_Q7	13	Sxxxxxxx arithmetic saturation
STREAM_CHAR	14	xxxxxxx
STREAM_FP8_E4M3	15	Seeemmm NV tiny-float [0.02 .. 448]
STREAM_FP8_E5M2	16	Seeemm IEEE-754 [0.0001 .. 57344]
STREAM_S16	17	Sxxxxxxx.xxxxxxxx 2 bytes per data

TYPE	CODE	COMMENTS
STREAM_U16	18	xxxxxxxx.xxxxxxxxx Numbers, UTF-16 characters
STREAM_Q15	19	Sxxxxxxxx.xxxxxxxxx arithmetic saturation
STREAM_FP16	20	Seeeeemm.mmmmmmm half-precision float
STREAM_BF16	21	Seeeeeee.mmmmmmm bfloat
STREAM_Q23	22	Sxxxxxxxx.xxxxxxxxx.xxxxxxxxx 24bits 3 bytes per data
STREAM_Q23_	32	SSSSSSSS.Sxxxxxxxx.xxxxxxxxx.xxxxxx 4 bytes per data
STREAM_S32	24	one long word
STREAM_U32	25	xxxxxxxx.xxxxxxxxx.xxxxxxxxx.xxxxxxxxx UTF-32, ..
STREAM_Q31	26	Sxxxxxxxx.xxxxxxxxx.xxxxxxxxx.xxxxxxxxx
STREAM_FP32	27	Seeeeeee.mmmmmmm.mmmmmmm. . FP32
STREAM_CQ15	28	Sxxxxxxxx.xxxxxxxxx+Sxxxxxxxx.xxxxxxxxx (I Q)
STREAM_CFP16	29	Seeeeemm.mmmmmmm+Seeeeemm. . (I Q)
STREAM_S64	30	long long 8 bytes per data
STREAM_U64	31	unsigned 64 bits
STREAM_Q63	32	Sxxxxxxxx.xxxxxx ..... xxxxx.xxxxxxxxx
STREAM_CQ31	33	Sxxxxxxxx.xxxxxxxxx.xxxxxxxxx.xxxxxxxxx Sxxxx. .
STREAM_FP64	34	Seeeeeee.eeemmmm.mmmmmmm ... double
STREAM_CFP32	35	Seeeeeee.mmmmmmm.mmmmmmm.m..+Seee.. (I Q)
STREAM_FP128	36	Seeeeeee.eeeeeeee.mmmmmmm ... quadruple precision
STREAM_CFP64	37	fp64 + fp64 (I Q)
STREAM_FP256	38	Seeeeeee.eeeeeeee.eeeeeemm ... octuple precision
STREAM_TIME16	39	ssssssssssqqqq q14.2 1 hour + 8mn +/- 0.0625s
STREAM_TIME16D	40	qqqqqqqqqqqqqqqq q15 [s] time difference +/- 15us
STREAM_TIME32	41	ssssss .. sssssssssssqqqq q28.4 [s] 8.5 years +/- 0.0625s
STREAM_TIME32D	42	ssssss..sssqqqq.. q17.15 [s] 36h +/- 30us time difference
STREAM_TIME64	43	____ssssssssssssss..qqqqqqqqq q32.28 [s] 140 Y +Q28 [s]
STREAM_TIME64MS	44	_____mmmmmmmmmmmmmmmmmm u42 [ms], 140Y
STREAM_TIME64ISO	45	ISO8601__..YY .. MM..MM..DD..DD..SS..SS.....offs..MM ..
STREAM_WGS84	46	<-LAT 32B-><-LONG 32B->
STREAM_HEXBINARY	47	UTF-8 lower case hexadecimal byte stream
STREAM_BASE64	48	RFC-2045 base64 for xsd:base64Binary XML data
STREAM_STRING8	49	UTF-8 string of char terminated by 0
STREAM_STRING16	50	UTF-16 string of char terminated by 0

## Units

NAME	CODE	UNIT	COMMENT
_ANY	0		any
_METER	1	m	meter
_KGRAM	2	kg	kilogram
_GRAM	3	g	gram
_SECOND	4	s	second
_AMPERE	5	A	ampere
_KELVIB	6	K	kelvin
_CANDELA	7	cd	candela
_MOLE	8	mol	mole

NAME	CODE	UNIT	COMMENT
_HERTZ	9	Hz	hertz
_RADIAN	10	rad	radian
_STERADIAN	11	sr	steradian
_NEWTON	12	N	newton
_PASCAL	13	Pa	pascal
_JOULE	14	J	joule
_WATT	15	W	watt
_COULOMB	16	C	coulomb
_VOLT	17	V	volt
_FARAD	18	F	farad
_OHM	19	Ohm	ohm
_SIEMENS	20	S	siemens
_WEBER	21	Wb	weber
_TESLA	22	T	tesla
_HENRY	23	H	henry
_CELSIUSDEG	24	Cel	degrees Celsius
_LUMEN	25	lm	lumen
_LUX	26	lx	lux
_BQ	27	Bq	becquerel
_GRAY	28	Gy	gray
_SIVERT	29	Sv	sievert
_KATAL	30	kat	katal
_SQUAREMETER	31	m2	square meter (area)
_CUBICMETER	32	m3	cubic meter (volume)
_LITER	33	l	liter (volume)
_M_PER_S	34	m/s	meter per second (velocity)
_M_PER_S2	35	m/s2	meter per square second (acceleration)
_M3_PER_S	36	m3/s	cubic meter per second (flow rate)
_L_PER_S	37	l/s	liter per second (flow rate)
_W_PER_M2	38	W/m2	watt per square meter (irradiance)
_CD_PER_M2	39	cd/m2	candela per square meter (luminance)
_BIT	40	bit	bit (information content)
_BIT_PER_S	41	bit/s	bit per second (data rate)
_LATITUDE	42	lat	degrees latitude[1]
_LONGITUDE	43	lon	degrees longitude[1]
_PH	44	pH	pH value (acidity; logarithmic quantity)
_DB	45	dB	decibel (logarithmic quantity)
_DBW	46	dBW	decibel relative to 1 W (power level)
_BSPL	47	Bspl	bel (sound pressure level; log quantity)
_COUNT	48	count	1 (counter value)
_PER	49	/	1 (ratio e.g., value of a switch; )
_PERCENT	50	%	1 (ratio e.g., value of a switch; )
_PERCENTRH	51	%RH	Percentage (Relative Humidity)
_PERCENTEL	52	%EL	Percentage (remaining battery energy level)
_ENERGYLEVEL	53	EL	seconds (remaining battery energy level)

NAME	CODE	UNIT	COMMENT
_1_PER_S	54	1/s	1 per second (event rate)
_1_PER_MIN	55	1/min	1 per minute (event rate, "rpm")
_BEAT_PER_MIN	56	beat/min	1 per minute (heart rate in beats per minute)
_BEATS	57	beats	1 (Cumulative number of heart beats)
_SIEMPERMETER	58	S/m	Siemens per meter (conductivity)
_BYTE	59	B	Byte (information content)
_VOLTAMPERE	60	VA	volt-ampere (Apparent Power)
_VOLTAMPERESEC	61	VAs	volt-ampere second (Apparent Energy)
_VAREACTIVE	62	var	volt-ampere reactive (Reactive Power)
_VAREACTIVESEC	63	vars	volt-ampere-reactive second (Reactive Energy)
_JOULE_PER_M	64	J/m	joule per meter (Energy per distance)
_KG_PER_M3	65	kg/m3	kg/m3 (mass density, mass concentration)
_DEGREE	66	deg	degree (angle)
_NTU	67	NTU	Nephelometric Turbidity Unit
--- rfc8798 ---		Secondary Unit (SenML Unit)	Scale and Offset
_MS	68	s millisecond	scale = 1/1000 1ms = 1s x [1/1000]
_MIN	69	s minute	scale = 60
_H	70	s hour	scale = 3600
_MHZ	71	Hz megahertz	scale = 1000000
_KW	72	W kilowatt	scale = 1000
_KVA	73	VA kilovolt-ampere	scale = 1000
_KVAR	74	var kilovar	scale = 1000
_AH	75	C ampere-hour	scale = 3600
_WH	76	J watt-hour	scale = 3600
_KWH	77	J kilowatt-hour	scale = 3600000
_VARH	78	vars var-hour	scale = 3600
_KVARH	79	vars kilovar-hour	scale = 3600000
_KVAH	80	VAs kilovolt-ampere-hour	scale = 3600000
_WH_PER_KM	81	J/m watt-hour per kilometer	scale = 3.6
_KIB	82	B kibibyte	scale = 1024
_GB	83	B gigabyte	scale = 1e9
_MBIT_PER_S	84	bit/s megabit per second	scale = 1000000
_B_PER_S	85	bit/s byteper second	scale = 8
_MB_PER_S	86	bit/s megabyte per second	scale = 8000000
_MV	87	V millivolt	scale = 1/1000
_MA	88	A milliampere	scale = 1/1000
_DBM	89	dBW decibel rel. to 1 milliwatt	scale = 1 Offset = -30 0 dBm = -30 dBW
_UG_PER_M3	90	kg/m3 microgram per cubic meter	scale = 1e-9
_MM_PER_H	91	m/s millimeter per hour	scale = 1/3600000
_M_PER_H	92	m/s meterper hour	scale = 1/3600
_PPM	93	/ partsper million	scale = 1e-6
_PER_100	94	/ percent	scale = 1/100
_PER_1000	95	/ permille	scale = 1/1000
_HPA	96	Pa hectopascal	scale = 100
_MM	97	m millimeter	scale = 1/1000



NAME	CODE	UNIT	COMMENT
_CM	98	m centimeter	scale = 1/100
_KM	99	m kilometer	scale = 1000
_KM_PER_H	100	m/s kilometer per hour	scale = 1/3.6
_GRAVITY	101	m/s2 earth gravity	scale = 9.81 1g = m/s2 x 9.81
_DPS	102	1/s degrees per second	scale = 360 1dps = 1/s x 1/360
_GAUSS	103	Tesla Gauss	scale = 10-4 1G = Tesla x 1/10000
_VRMS	104	Volt Volt rms	scale = 0.707 1Vrms = 1Volt (peak) x 0.707
_MVPGAUSS	105	millivolt Hall effect, mV/Gauss	scale = 1 1mV/Gauss
_DBSPL	106	Bspl versus dB SPL(A)	scale = 1/10

### Stream format “domains”

Domain name	Code	Comments
GENERAL	0	(a)synchronous sensor + rescaling, electrical, chemical, color, .. remote data, compressed streams, JSON, SensorThings
AUDIO_IN	1	microphone, line-in, I2S, PDM RX
AUDIO_OUT	2	line-out, earphone / speaker, PDM TX, I2S,
GPIO_IN	3	generic digital IO
GPIO_OUT	4	generic digital IO , control of relay,
MOTION	5	accelerometer, combined or not with pressure and gyroscope
2D_IN	6	camera sensor
2D_OUT	7	display, led matrix,
ANALOG_IN	8	analog sensor with aging/sensitivity/THR control, example : light, pressure, proximity, humidity, color, voltage
ANALOG_OUT	9	D/A, position piezzo, PWM converter
RTC	10	ticks sent from a programmable timer
USER_INTERFACE_IN	11	button, slider, rotary button
USER_INTERFACE_OUT	12	LED, digits, display,
PLATFORM_3	13	platform-specific #3
PLATFORM_2	14	platform-specific #2
PLATFORM_1	15	platform-specific #1

### Architectures codes of platform manifest

Architecture codes (<https://sourceware.org/binutils/docs/as/ARM-Options.html>) armv1, armv2, armv2a, armv2s, armv3, armv3m, armv4, armv4xm, armv4t, armv4txm, armv5, armv5t, armv5txm, armv5te, armv5texp, armv6, armv6j, armv6k, armv6z, armv6kz, armv6-m, armv6s-m, armv7, armv7-a, armv7ve, armv7-r, armv7-m, armv7e-m, armv8-a, armv8.1-a, armv8.2-a, armv8.3-a, armv8-r, armv8.4-a, armv8.5-a, armv8-m.base, armv8-m.main, armv8.1-m.main, armv8.6-a, armv8.7-a, armv8.8-a, armv8.9-a, armv9-a, armv9.1-a, armv9.2-a, armv9.3-a, armv9.4-a, armv9.5-a

### List of pre-installed nodes (development)

ID	Name	Comments
1	arm_stream_script	byte-code interpreter index “arm_stream_script_INDEX”
2	sigp_stream_resampler	high-quality sampling-rate converter
3	arm_stream_router	copy input arcs and subchannel and output arcs and subchannels
4	sigp_stream_converter	raw data interleaving simple rate converter
5	arm_stream_amplifier	amplifier mute and un-mute with ramp and delay control

ID	Name	Comments
6	arm_stream_mixer	multichannel mixer with mute/unmute and ramp control
7	arm_stream_filter	cascade of DF1 filters
8	sigp_stream_detector	estimates peaks/floor of the mono input and triggers a flag on high SNR
9	arm_stream_rescaler	raw data values remapping using "interp1"
10	sigp_stream_compressor	raw data compression with adaptive prediction
11	sigp_stream_decompressor	raw data decompression
12	arm_stream_modulator	signal generator with modulation
13	arm_stream_demodulator	signal demodulator frequency estimator
14	sigp_stream_resampler	asynchronous high-quality sample-rate converter
15	arm_stream_qos	raw data interpolator with synchronization to one HQoS stream
16	arm_stream_split	let a buffer be used by several nodes
17	sigp_stream_detector2D	activity detection pattern detection
18	arm_stream_filter2D	filter rescale/zoom/extract rotate exposure compensation
19	arm_stream_analysis	arm_stream_analysis
20	bitbank_jpg_encoder	jpeg encoder
21	elm_jpg_decoder	TjpgDec
22	arm_stream_format_converter	format converter

## arm\_stream\_script

Scripts are nodes interpreted from byte codes declared in the indexed SCRIPTS section of the graph, or inlined in the parameter section of the node "arm\_stream\_script". The first one are simple code sequences used as subroutines or called in the "node\_script"index".

The nodes can manage the data RAM location in a shared arc for all script (instance registers+stack parameters) constants are placed after the byte-codes.

The default memory configuration is "shared" meaning the buffers associated with the script are sharing the same memory buffer.

To have individual static memory associated to a script the "script\_mem\_shared" must be 0.

Special functions activated with callsys and conditional instructions: - lock : a block of nodes to a processor to have good cache performance, - if-then: a block of nodes based on script decision (FIFO content/debug registers, ..)

- loop : repeat a list of node several time for cache efficiency and small frame size
- Checks if the data it needs is available and returns to the scheduler

```

node arm_stream_script 1 ; script (instance) index
script_stack          12 ; size of the stack in word64
script_register        6 ; number of registers in word64
script_parameter      30 ; size of the parameter/heap in word32
script_mem_shared      1 ; private memory (0) or shared(1)
script_mem_map         0 ; mapping to VID #0 (default)

script_code
    r1 = add r2 3      ; r1 = add r2 3
    label AAA
        set r2 graph sigp_stream_detector_0
        r0 = 0x412      ; r0 = STREAM_SET_PARAMETER(2)
        set r3 param BBB ; set r3 param BBB
        sp0 = 1         ; push 1 Byte (threshold size in BBB)
        callsys 1 r2 r0 r3 sp0 ; callsys NODE(1) r2(cmd=set_param) r0(set) r3(data)
        return          ; return
end

script_parameters      0
    1 u8 ; 34

```

```

2 u32; 0x33333333 0x44444444
label BBB
1 u8 ; 0x55
1 u32; 0x66666666
end

```

---

### arm\_stream\_format\_converter (TBD)

node arm\_stream\_format\_converter 0

TBD

end

### arm\_stream\_router (TBD)

I/O streams have the same RAW format size, if time-stamped then only with frame size of 1 sample

table of routing : a list of 16bits words (source 8b + destination 8b) format: router arc index (3b) up to 8 arcs sub-channel index -1 (5b) up to 32 channels

example with the router\_2x2 used to merge 2 stereo input in a 4-channels output

```

node arm_stream_router 0
  parameters      0          ; TAG    "load all parameters"

  2 i8; 2 2          nb input/output arcs
  4 i16; 0 0 2 0      move arc0,chan0, to arc2,chan0
  4 i16; 0 1 2 1      move arc0,chan1, to arc2,chan1
  4 i16; 1 0 2 2      move arc1,chan0, to arc2,chan2
  4 i16; 1 1 2 3      move arc1,chan1, to arc2,chan3
end
end

```

---

### sigp\_stream\_converter (TBD)

Operation : convert input arc format to the format of the output arc. Conversion takes care of RAW data, frame size, interleaving, time-stamp format, number of channels, sampling-rate.

Operations :

- copy input data to the first internal scratch buffer with the management of the target number of channels and using deinterleave intermediate format. The start of the deinterleaved buffer is a copy of the previously processed end of buffers, for the implementation of filters using a memory.
- sampling rate converter, with a dedicated processing for the asynchronous to synchronous conversion, to second scratch buffer
- raw data conversion, interleaving conversion and copy of the result

The case of IMU format is managed like other one-dimension format.

The case of 2D format is special with operations of pixel area extraction, zoom, interpolate, rotation and pixel format conversions.

Parameters :

node arm\_stream\_converter 0

TBD

end

---

## arm\_stream\_amplifier (TBD)

Operation : control of the amplitude of the input stream with controlled time of ramp-up/ramp-down. The gain control “mute” is used to store the current gain setting, being reloaded with the command “unmute” Option : either the same gain/controls for all channels or list of parameters for each channel

Parameters : new gain/mute/unmute, ramp-up/down slope, delay before starting the slope. Use-cases : Features : adaptive gain control (compressor, expander, AGC) under a script control with energy polling Metadata features : “saturation occurred” “energy” Mixed-Signal glitches : remove the first seconds of an IR sensor until it was self-calibrated (same for audio Class-D)

parameters of amplifier (variable size): TAG\_CMD = 1, uint8\_t, 1st-order shifter slope time (as stream\_mixer, 0..75k samples) TAG\_CMD = 2, uint16\_t, desired gain FP\_8m4e, 0dB=0x0805 TAG\_CMD = 3, uint8\_t, set/reset mute state TAG\_CMD = 4, uint16\_t, delay before applying unmute, in samples TAG\_CMD = 5, uint16\_t, delay before applying mute, in samples

```
node arm_stream_amplifier 0
```

```
parameters      0          ; TAG "load all parameters"
  1 i8; 1          load only rising/falling coefficient slope
  1 h16; 805       gain -100dB .. +36dB (+/- 1%)
  1 i8; 0          muted state
  2 i16; 0 0       delay-up/down
end
end
```

---

## arm\_stream\_mixer (TBD)

Operation : receives several mono or multichannel streams and produces one output arc. Mixer manages up to 8 multichannels input arcs, the number is given at STREAM\_RESET stage.

Parameters : input arcs names, their associated gain and time-constant in [ms], name of the output arc and an extra mixing gain

- index of the HQoS input arc to use for the frame size to use, if the other arcs have flow-errors it will be managed with their respective OVERFLRD\_ARCW2 index

Synchronization operation : arranges multiple input streams are delivered at the same time. Use-case: multi-channel audio stream, each channel is processed with independent signal processing feature. The problem is to avoid (on MP devices) one channel to be delivered to the final mixer ahead and desynchronized from the others (should be OK when the arcs have the sma buffer size / framesize)

preset : #1 (default) : mixer-4 with all arcs unmuted with gain = 0dB, slopes of ~1000 samples #2 (shut-down) : mixer-4 with all arcs with gain = -96dB, slopes of ~100 samples

2 : number of input channels

parameters of mixer (variable size):

- slopes of rising and falling gains, identical to all channels slope coefficient = 0..15 (iir\_coef =  $1 - 1/2^{\text{coef}}$  = 0 .. 0.99)  
Convergence time to 90% of the target in samples: slope nb of samples to converge 0 0 1 3 2 8 3 17 4 36 5 73 6 146 7 294 8 588 9 1178 10 2357 11 4715 12 9430 13 18862 14 37724 15 75450 convergence in samples =  $\text{abs}(\text{round}(1./\text{abs}(\log_{10}(1-1./2.^{\text{coef}})))$
- output mixer gain format FP

format to be packed in 32bits words: input arc index (4b) up to 15 arcs sub-channel index -1 (5b) up to 32 channels per arc of the input arc sub-channel index -1 (5b) up to 32 channels per arc of the output arc gain (16b) format FP muted (1b) 1 = “muted”

```

node arm_stream_mixer 0

; Example: 4 input one mono, one stereo, output is stereo
parameters      0          ; TAG "load all parameters"

2 i8; 6 6          rising/falling slope on all arcs
1 h32; 807         -12dB output gain in FP_8m4e format;

4 i16; 0 0 0       arcID0 inputChan0 outputChan0
1 h32; 805         0dB gain; mono mixed on the left output

4 i16; 0 0 1       arcID0 inputChan0 outputChan1
1 h32; 805         0dB gain; mono mixed on the right output

4 i16; 1 0 0       arcID1 inputChan0 outputChan0
1 h32; 805         0dB gain; stereo input left to the left

4 i16; 1 1 1       arcID1 inputChan0 outputChan1
1 h32; 803         +12dB gain; stereo input right to the right
end
end

```

---

## 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](http://www.w3.org/TR/audio-eq-cookbook)) Presets: #0 : bypass #1 : LPF  $fc=fs/4$  #2 : HPF  $fc=fs/8$  #3 : DC-filter (use-case: audio, XYZ gravity compensation/estimation) #4 : long Median filter

parameter of filter :

- number of biquads in cascade (1 or 2)

```

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
                             ; "procmmap_manifest_xxxx.txt" where to map
                             ; the allocated memory
                             ; default = #0
node_map_verbose 1          ; level #1 of debug trace
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
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

```

---

## sigp\_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
end

```

---

### arm\_stream\_rescaler (TBD)

Operation : applies  $vq = \text{interp1}(x,v,xq)$  Following <https://fr.mathworks.com/help/matlab/ref/interp1.html> linear of polynomial interpolation (implementation) Parameters : X,V vectors, size max = 32 points

no preset ('0')

```

node arm_stream_rescaler 0

    parameters      0              ; TAG    "load all parameters"

;
    input  output
    2; f32; -1    1
    2; f32;  0    0    ; this table creates the abs(x) conversion
    2; f32;  1    1
end
end

```

---

### sigp\_stream\_compressor (TBD)

Operation : wave compression using IMADPCM(4bits/sample) Parameters : coding scheme

presets (provision codes):

- 1 : coder IMADPCM
- 2 : coder LPC
- 3 :
- 4 : coder CVSD for BT speech
- 5 : coder LC3
- 6 : coder SBC
- 7 : coder mSBC
- 7 : coder OPUS Silk
- 8 : coder MP3
- 9 : coder MPEG-4 aacPlus v2
- 10: coder OPUS CELT
- 11: coder JPEG

```

node
    arm_stream_compressor 0

    parameters      0              ; TAG    "load all parameters"
        4; i32; 0 0 0 0    provision for extra parameters in other codecs
    end
end

```

---

### sigp\_stream\_decompressor (TBD)

Operation : decompression of encoded data Parameters : coding scheme and a block of 16 parameter bytes for codecs

dynamic parameters : pause, stop, fast-forward x2 and x4.

WARNING : if the output format can change (mono/stereo, sampling-rate, ..)  
the variation is detected by the node and reported to the scheduler with  
"STREAM\_SERVICE\_INTERNAL\_FORMAT\_UPDATE", the "uint32\_t \*all\_formats" must be

mapped in a RAM for dynamic updates with "COPY\_CONF\_GRAPH0\_COPY\_ALL\_IN\_RAM"

Example of data to share with the application

```
outputFormat: AndroidOutputFormat.MPEG_4,  
audioEncoder: AndroidAudioEncoder.AAC,  
sampleRate: 44100,  
numberOfChannels: 2,  
bitRate: 128000,
```

presets provision

- 1: decoder IMADPCM
- 2: decoder LPC
- 3: MIDI player / tone sequencer
- 4: decoder CVSD for BT speech
- 5: decoder LC3
- 6: decoder SBC
- 7: decoder mSBC
- 7: decoder OPUS Silk
- 8: decoder MP3
- 9: decoder MPEG-4 aacPlus v2
- 10: decoder OPUS CELT
- 11: decoder JPEG

node arm\_stream\_decompressor 0

```
parameters      0          ; TAG   "load all parameters"  
4; i32; 0 0 0 0    provision for extra parameters in other codecs  
end  
end
```

---

## arm\_stream\_modulator (TBD)

Operation : sine, noise, square, saw tooth with amplitude or frequency modulation use-case : ring modulator, sweep generation with a cascade of a ramp generator and a frequency modulator

Parameters types and Tags: u8 #1 wave type : 1=sine 2=square 3=white noise 4=pink noise 5=sawtooth 6=triangle 7=pulse 8=prerecorded pattern playback from arc 9=sigma-delta with OSR control for audio on PWM ports and 8b DAC 10=PWM 11=ramp 12=step

parameter format for wave generation:

```
u16 #2 linear amplitude, format UQ16 0dB .. -96dB  
u16 #3 amplitude offset, format Q15 [-1 .. +1]  
f32 #4 wave frequency [Hz] [0.1uHz .. 250kHz], 0Hz translates to DC level.  
s16 #5 starting phase, format S15 [-pi .. +pi]/pi  
u8  #6 modulation type, 0:amplitude, 1:frequency (reserved 2:FSK, ..)  
u8  #7 modulation, 0:none 1=from arc bit stream, 2=from arc q15 words  
u16 #8 modulation index (a) and offset (b), in q15 as fraction of frequency or amplitude  
      modulation y=ax+b, x=input data.  
f32 #9 modulation frequency [Hz] separating two data bits/samples from the arc
```

node arm\_stream\_modulator (i)

```
parameters      0          ; TAG   "load all parameters"  
  
1  u8; 1      sinewave  
2  h16; FFFF 0 full-scale, no offset  
1  f32; 1200   1200Hz  
1  s16; 0      initial phase  
2  u8; 1 1     frequency modulation from bit-stream  
2  h16; 8000 0 full amplitude modulation with sign inversion of the bit-stream  
1  f32; 300    300Hz modulation => (900Hz .. 1500Hz modulation)
```

```
end
end
```

---

## arm\_stream\_demodulator (TBD)

Operation : decode a bit-stream from analog data. Use-case: IR decoder, CAN/UART on SPI/I2S audio. Parameters : clock and parity setting or let the algorithm discover the frame setting after some time.

[https://en.wikipedia.org/wiki/Universal\\_asynchronous\\_receiver-transmitter](https://en.wikipedia.org/wiki/Universal_asynchronous_receiver-transmitter)

presets control : #1 .. 10: provision for demodulators

Metadata information can be extracted with the command "parameter-read": TAG\_CMD = 1 read the signal amplitude  
TAG\_CMD = 2 read the signal to noise ratio

```
node
  arm_stream_demodulator (i)
    parameters      0          ; TAG    "load all parameters"

    2  i8; 2 2          nb input/output arcs
    4  i16; 0 0 2 0     move arc0,chan0, to arc2,chan0
  end
end
```

---

## sigp\_stream\_resampler (TBD)

Operation : convert multichannel input data rate to the rate of the output arcs

- synchronous rate conversion with +/- 100ppm adjustment
- conversion of time-stamp asynchronous to synchronous stream

SSRC synchronous rate converter, FS in/out are exchanged during STREAM\_RESET ASRC asynchronous rate converter using time-stamps (in) to synchronous FS (out) pre-LP-filtering tuned from Fout/Fin ratio + Lagrange polynomial interpolator

drift compensation managed with STREAM\_SET\_PARAMETER command: TAG\_CMD = 0 to stop drift compensation TAG\_CMD = 1 to continuously apply a drift compensation of +100ppm TAG\_CMD = 2 to continuously apply a drift compensation of -100ppm

The script associated to the node is used to read the in/out arcs filling state to tune the drift control

```
node arm_stream_resampler (i)

  parameters      0          ; TAG    "load all parameters"

  2  i8; 2 2          nb input/output arcs
  4  i16; 0 0 2 0     move arc0,chan0, to arc2,chan0
end
```

---

## arm\_stream\_qos (TBD)

Operation : align the content of arc buffers with respect to an high-priority one. (HQOS) Parameters : the list of arcs and the one taken as time-alignment reference

```
node arm_stream_qos (i)

  parameters      0          ; TAG    "load all parameters"
TBD
end
end
```



---

## arm\_stream\_split (TBD)

Operation : share the input arc to several output arcs, to let several nodes have access to the same buffer without data duplication. Consolidate the output read indexes before updating the input arc read index. There is no priority managed between output arcs. The base, size and write index of the output arcs are identical to the input arc

Parameters : the list of arcs , no memory for instances is needed

```
node
  arm_stream_split (i)
    parameters      0          ; TAG    "load all parameters"

    2 i8; 2 2          nb input/output arcs
    4 i16; 0 0 2 0      move arc0,chan0, to arc2,chan0
    4 i16; 0 1 2 1      move arc0,chan1, to arc2,chan1
    4 i16; 1 0 2 2      move arc1,chan0, to arc2,chan2
    4 i16; 1 1 2 3      move arc1,chan1, to arc2,chan3
  end
end
```

---

## arm\_stream\_analysis (TBD)

Operation : spectrum and energy analysis Use-case : debug with script control results are used with "read\_parameter"

presets : #1 : frequency estimator, counting the number of periods Operation : input signal frequency estimator with second-order auto-regression Use-case example: measure 50Hz from power lines on the three phases (a -1% deviation means "power-down"). Parameters : none. output data estimate sampling rate is provided at reset #2 : energy estimation and DC offset #3 : energy analysis on 3 frequency points (Goertzel) #4 : full spectrum 64 points in decibels

```
node arm_stream_analysis (i)

  parameters      0          ; TAG    "load all parameters"

  end
end
```

---

## sigp\_stream\_detector2D (TBD)

Motion and pattern detector (lines)

Operation : detection of movement(s) and computation of the movement map Parameters : sensitivity, floor-noise smoothing factors Metadata : decimated map of movement detection

```
node arm_stream_detector2D (i)

TBD

end
```

---

## arm\_stream\_filter2D (TBD)

Filter, rescale/zoom/extract, rotate, exposure compensation

Operation : 2D filters Parameters : convolutional kernels, decimation, distortion, color mapping/effect

presets: #1 : bypass

parameter of filter :

```
node arm_stream_filter2D    (i)
```

```
    TBD  
end
```

---

## JPG encoder

From “bitbank”

## JPG decoder

From “EML”