Iris

Version 1.0

User Guide

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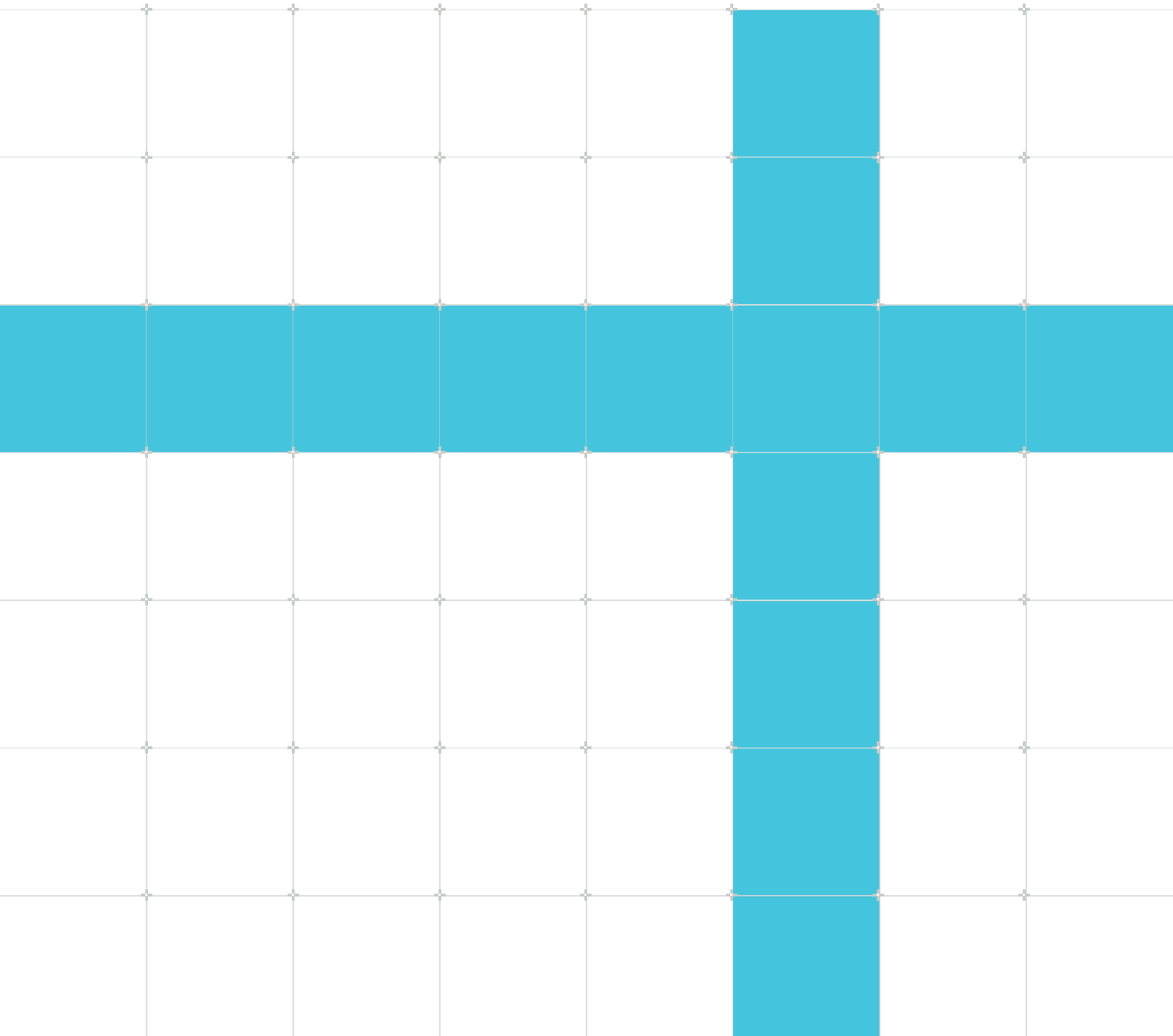

Iris
User Guide

Release Information

Document history

Issue	Date	Confidentiality	Change
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Contents

1. Introduction

This document describes the Iris interface for debug and trace on Fast Models and other targets. Iris defines a generic function call mechanism, an object model, and a set of concrete functions for debug and trace.

1.1 Conventions

The following subsections describe conventions used in Arm documents.

Glossary

The Arm® Glossary is a list of terms used in Arm documentation, together with definitions for those terms. The Arm Glossary does not contain terms that are industry standard unless the Arm meaning differs from the generally accepted meaning.

See the Arm Glossary for more information: developer.arm.com/glossary.

Convention	Use
italic	Citations.
bold	Terms in descriptive lists, where appropriate.
`monospace`	Text that you can enter at the keyboard, such as commands, file and program names, and source code.
`monospace underline`	A permitted abbreviation for a command or option. You can enter the underlined text instead of the full command or option name.
`<and>`	Encloses replaceable terms for assembler syntax where they appear in code or code fragments. For example: `MRC p15, 0, <Rd>, <CRn>, <CRm>, <Opcode_2>`
SMALL CAPITALS	Terms that have specific technical meanings as defined in the *Arm® Glossary*. For example, **IMPLEMENTATION DEFINED**, **IMPLEMENTATION SPECIFIC**, **UNKNOWN**, and **UNPREDICTABLE**.

Recommendations. Not following these recommendations might lead to system failure or damage.

Requirements for the system. Not following these requirements might result in system failure or damage.

Requirements for the system. Not following these requirements will result in system failure or damage.

An important piece of information that needs your attention.

A useful tip that might make it easier, better or faster to perform a task.

A reminder of something important that relates to the information you are reading.

1.2 Other information

See the Arm® website for other relevant information.

- Arm® Developer.
- Arm® Documentation.
- Technical Support.
- Arm® Glossary.

1.3 Useful resources

This document contains information that is specific to this product. See the following resources for other useful information.

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- Non-Confidential documents are available at developer.arm.com/documentation. Each document link in the following tables goes to the online version of the document.
- Confidential documents are available to licensees only through the product package.

Arm® product resources	Document ID	Confidentiality
Arm® Development Studio User Guide	101470	Non-Confidential
Fast Models Fixed Virtual Platforms (FVP) Reference Guide	100966	Non-Confidential
Iris Python Debug Scripting User Guide	101421	Non-Confidential
IrisSupportLib Reference Guide	101319	Non-Confidential

Arm® architecture and specifications	Document ID	Confidentiality
DWARF for the Arm® Architecture, DWARF for the Arm® 64-bit Architecture	-	Non-Confidential

Non-Arm® resources	Document ID	Organization
ELF Header specification	-	Xinuos
Introducing JSON	-	http://json.org
JSON-RPC 2.0 Specification	-	http://www.jsonrpc.org
JSON-RPC 2.0 Transport: HTTP	-	https://www.simple-is-better.org
RFC 7230: Hypertext Transfer Protocol (HTTP/1.1): Message Syntax and Routing	RFC 7230	Internet Engineering Task Force (IETF)

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2. Iris overview

This chapter describes the purpose and implementation of Iris.

Iris consists of:

- A generic function call interface that uses JSON-RPC 2.0 format and semantics.
- A simple object model in which all entities, for example components, debuggers, clients, and plug-ins are represented by instances. Instances can discover and communicate with all other instances.
- A defined set of functions for debug and trace.

It has several benefits over previous debug and trace solutions:

- Network native. Both simulation control and trace are available over the network.
- Plug-ins and trace can be loaded at any point during the simulation.
- Guaranteed synchronisation between trace and simulation control, when required.
- Improvements to debug APIs. Iris provides:
  - Asynchronous trace.
  - Address translation.
  - Table API.
- Extensibility. New functionality can be added without breaking compatibility.
- Improvements to debug functionality offered by components.

2.1 Overview

The Iris interface consists of the following:

- A generic function call interface. Functions are called by name. Arguments and return values are passed by name and by value.
- An object model. Iris systems consist of a set of *instances*. Instances are entities that can send and receive Iris function calls, for instance modeled components, hardware targets, debuggers, plug-ins, and framework components. All instances can:
  - Discover and communicate with all other instances.
  - Call functions on and receive function calls from all other instances.

  Each instance is identified by an instance id, `instId`.
- A defined set of functions that are supported by instances. Most are optional.

It has the following design principles:

- Function calls are generally split into a request and an asynchronous response.

- Function calls and responses are represented using JSON data types, for example integers, strings, arrays, objects, and booleans.
- All types of events, for instance trace, debug, and semihosting events, are exposed through the same event mechanism.
- When calling a function, the caller can generally choose between sending:
  - A request. The callee sends a response back to the caller when it has finished processing the function. This is called a *synchronous* or *blocking* function call, as the caller is blocked while waiting for the response.
  - A notification. The callee does not send a response, so the caller does not know when the callee has finished. This is called an *asynchronous* or *non-blocking* function call. It is faster than a request and is preferred.
- Instances can connect to a simulation either using *Inter-Process Communication* (IPC) or within the same process. In either case, the interface is the same.
- JSON RPC 2.0 semantics are used for all function calls, whether using IPC or in-process.
- It uses U64JSON, a proprietary binary equivalent of JSON that is based on a sequence of `uint64_t` values, in-process to remove the JSON parsing overhead.

2.2 Terms and abbreviations

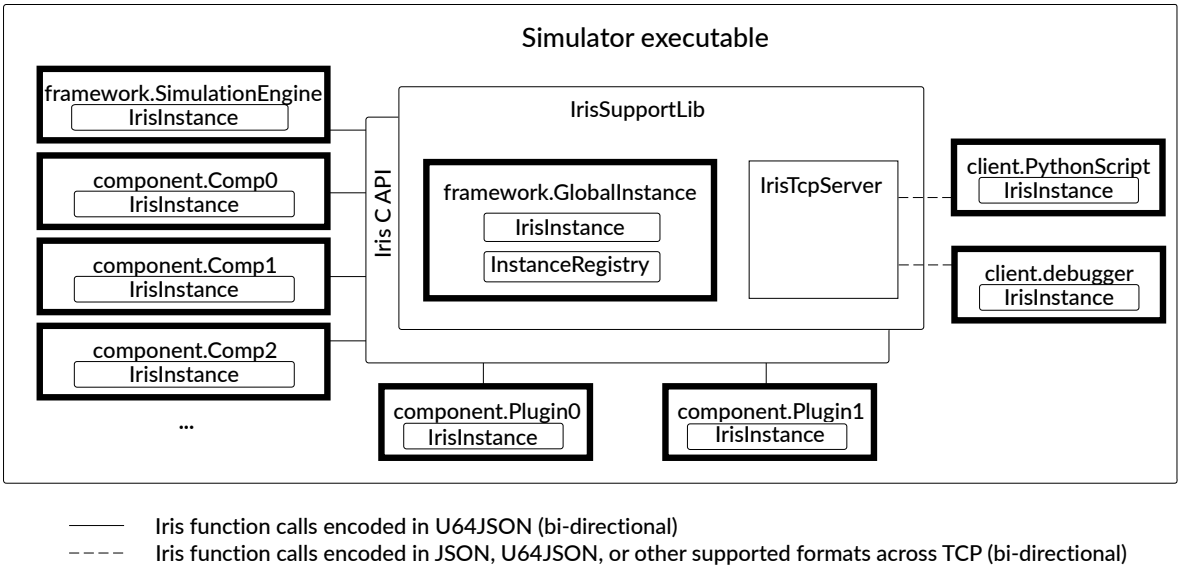
This table defines some terms and abbreviations that are commonly used in the Iris documentation, or have a meaning that is Iris-specific:

Term	Description
iff	Short for *if and only if*.
IPC	Inter-Process Communication, either on the same host, for example TCP or pipes, or on different hosts, for example TCP.
DSO	Dynamic Shared Object (`*.so`) or DLL.
JSON	JavaScript Object Notation. A compact textual representation of data.
JSON RPC	Remote Procedure Call protocol using JSON.
U64JSON	Binary JSON variant that is based on arrays of 64-bit values. It is defined in 4.5 U64JSON on page 35.
Component	A piece of software with well-defined abstract interfaces that represents a piece of hardware or other functionality.
Target	Sometimes used as a synonym for *component* or *instance* but generally avoided in this document.
Instance	An entity that provides functionality to other instances, or uses functionality that is provided by other instances, or both. For example, components, debuggers, clients, and plug-ins are all instances.
Event	Any event that is produced by an instance. This might be a trace event, for example `INST` for each executed instruction, a simulation event, for example `IRIS_BREAKPOINT_HIT`, or any other kind of event. Clients can observe events upon request.
Iris	An interface for debug and trace. Not an abbreviation or acronym.

2.3 Interfaces and communication

The following diagram provides an overview of the Iris interfaces:

Figure 2-1: Iris architecture



An Iris system consists of the following:

Simulator executable

The simulator executable can be implemented using C or C++, SystemC, Gem5, or Fast Models. It can be a standalone executable or a DSO.

Iris instances

The term *Iris instance*, or just *instance*, refers to an entity that can send and receive Iris function calls. This includes all components, plug-ins, clients, for example debuggers, and framework entities, for example the global instance. All Iris instances can send and receive Iris function calls to and from all other instances. In Figure 2-1: Iris architecture on page 19, Iris instances are shown by boxes with a bold outline.

IrisSupportLib

A static library named `IrisSupport.lib` or `libIrisSupport.a` that provides the following core Iris functionality:

- The global instance and the global instance registry.
- Routes all Iris messages.
- Plug-in loading.
- The IrisTcpServer.

It is linked and managed by the model. IrisSupportLib is documented in IrisSupportLib Reference Guide.

framework.GlobalInstance

This is the central routing instance between all Iris instances. The global instance registry records all Iris instances in the system. All Iris instances must register and unregister themselves in the instance registry, and they can use it to query a list of all other instances.

IrisTcpServer

TCP server that is provided by IrisSupportLib and runs as part of the simulator executable. It listens for connections from TCP clients, typically an `IrisTcpClient`. It transparently forwards function calls and responses. It does not explicitly support Iris functions, so extending the Iris interface, for example by adding functions or arguments, or adding new data structures, does not require any changes to the `IrisTcpServer`.

The `IrisInterface` communication trivially maps onto a TCP socket because it is inherently split between request and response, and because function calls and responses are data only. This data is transmitted almost unchanged over TCP between clients and servers.

IrisC API

A C interface that is used on DSO boundaries. It is equivalent to the C++ `IrisInterface`.

U64JSON

A proprietary binary variant of JSON, which is JSON-compatible. It is based on `uint64_t` arrays and is optimized for speed, not size. It removes the runtime overhead of JSON parsing and data conversion. It is used in-process and is one of many options for out-of-process, or IPC communication.

IrisInterface

An in-process, generic mechanism that transports Iris function calls, including callbacks and responses. In-process function calls and responses are made according to the JSON RPC 2.0 specification and are encoded in U64JSON. Instance implementations usually use a helper class, `IrisInstance`, which hides the internals of `IrisC`, `IrisInterface`, and U64JSON.

IrisInstance

Implements all necessary boilerplate code to provide debuggers and components with easy access to Iris functions. IrisSupportLib provides implementations for C++ and Python. For example, it provides:

- Encoding and decoding of function calls.
- Blocking function call semantics.
- Data in native data types for the language being used.
- Generic error messages.

IrisTcpClient

TCP client that is provided by IrisSupportLib. As with the `IrisTcpServer`, extending the Iris interface does not require any changes to the `IrisTcpClient`. Using the `IrisTcpClient` to connect to the `IrisTcpServer` is not mandatory, but is convenient. A client application, for example a debugger, typically uses an `IrisInstance` connected to an `IrisTcpClient` to connect to an Iris server running in the model process.

Iris function calls over TCP

The protocol that is used over TCP and the format and semantics of all Iris functions are defined and public. In Figure 2-1: Iris architecture on page 19, they are shown by dashed lines.

client.debugger

A C++ client application that uses IrisSupportLib, built from source. It can call Iris functions directly from C++ and can update the IrisSupportLib source at any time. An update is not mandatory after the simulator executable has updated any part of the system. Clients and simulators can update at different times. There are no shared header files, but both sides must follow the Iris specification to be compatible.

client.PythonScript

The same as `client.debugger` but written in Python.

component.Plugin0 and component.Plugin1

These plug-ins use `IrisInstance` to communicate with the rest of the system. There is no difference between a plug-in and a client that is connected using IPC in how they call and are called by Iris functions, except for the plug-in loading mechanism and speed considerations.


Note

Plug-ins can communicate with each other in the same way as with the rest of the system, including with clients connected using IPC.

component.Comp0-2

Components written in C++, LISA, or SystemC, that model hardware or perform other simulation functionality. They use `IrisInstance` to avoid being exposed to the internals of the function call mechanism, and to use infrastructure that is common to a lot of components, for example meta information for registers and memory spaces. Internally in the `IrisInstance`, they send and receive U64JSON-encoded Iris function calls through the low-level `IrisC` API. They might buffer these function calls in an event queue. Later on, and typically from another thread, they send the response back to the `IrisInterface` of the global instance.

Transports

Iris function calls are transported using the following mechanisms:

- In-process. The transport is the `IrisC` interface on DSO boundaries and the C++ `IrisInterface` inside DSOs. The Iris interface is bi-directional so it can send function calls and responses in both directions. `IrisInterface` only supports U64JSON directly, but adapters exist to enable function calls from C++ and Python directly, or to use other formats, for example JSON. The in-process mechanism is used whenever possible, typically by:
  - Plug-ins that communicate with component instances, for example to receive trace and to inspect components.
  - The global instance to communicate with component instances. For example, components register themselves with the global instance at startup.

- The `IrisTcpServer` to communicate with component instances and with the global instance.

- *Inter Process Communication* (IPC). The transport is a TCP socket. Usually the simulation contains a TCP server which listens for inbound connections. Iris calls and their responses are sent in both directions across the same TCP socket. The TCP connection is persistent.

  Various formats can be used across the TCP connection, including U64JSON and JSON. IPC is used only if necessary, typically by IPC clients, for example debuggers, shells, and IPC plug-ins, to communicate with component instances, the global instance, plug-ins, or even other clients.

Related information

IrisSupportLib Reference Guide

2.4 Iris specification changelog

Lists all relevant changes to the Iris specification, especially all changes to `Objects/*.json` and `Functions/*.json`.


Note

This topic does not list user-visible changes to IrisSupportLib. For these changes see 2.5 IrisSupportLib changelog on page 23.

Table 2-2: Iris specification changelog

Date	Description
2019-04-01	Changed the way register fields are exposed. Added `ResourceInfo.parentRscId` which if present indicates that this is a child resource. It contains the resource id of the parent resource. Both `name` and `cname` in ResourceInfo no longer contain the hierarchical name of the child register but instead just the name of the child register itself (interface change), without any parent register names prepended. A dot in the `name` or `cname` members no longer indicates a parent/child relationship. This change is not fully backwards compatible with old clients, but the consequences of breaking the interface are so minor (only affects the naming of child registers) and the old behavior was so obscure that it can be assumed that no clients relied on it anyway.
2019-04-03	Made `ResourceInfo.cname` and `ResourceGroupInfo.cname` non-optional to simplify client behavior and clarify expectations. Existing clients are unaffected. Clients can now rely on `cname` always being present.
2019-04-04	Clarified that each resource is either a register or a parameter.
2019-04-16	Added `ResourceTags.isFramePointer`.
2019-04-17	Defined ElfDwarf scheme for register. canonicalRnScheme. Defined canonical register numbers for Arm cores.
2019-04-23	Clarified that parameters are not hierarchical (there are no child parameters). Specified that all parameter resources must be in group `Parameters`.
2019-08-01	Added function `instance_getCppInterfaceIrisInstance()` to allow enhancing IrisInstances with tightly coupled plugins.
2019-08-02	Marked the following arguments as `optional` for consistency as originally intended: 'AttributeInfo.descr', all `EventCounterMode` fields, 'InstantiationError.parameterName', 'TableColumnInfo.formatLong', 'TableColumnInfo.formatShort' and 'MemoryReadResult.error'.

Date	Description
2019-08-02	Consistency fixes: Removed old leftover field 'EventSourceInfo.stop'. Fixed 'ResourceInfo.subRscId' (was erroneously called `subResId` in the specification).
2019-10-25	Consistency fix: Renamed `descr` to `description` everywhere.
2019-10-28	Removed 'IrisInterface::irisObtainInterface()' since it was not used and is superseded by Iris `getCppInterfaceXYZ()` calls.
2022-01-21	Added two functions, `event_registerProxyEventSource()` and `event_unregisterProxyEventSource()`. They provide the ability to expose an event on a proxy instance while it is implemented in the target instance.

2.5 IrisSupportLib changelog

Lists changes to the IrisSupportLib implementation (except for minor changes).

Table 2-3: IrisSupportLib changelog

Date	Description
2019-03-21	Bugfixes: Properly initialized all optional members in objects `returned` through an output reference in Iris C++ functions (for example, `ResourceReadResult.error` in `resource_read()`). Made `TableColumnInfo.rwMode` optional. Clients might now receive an empty string which means `rw` as specified. Made `TableInfo.indexFormatHint` optional. Clients might now receive an empty string which means `hex` as specified.
2019-04-05	Cleaned-up building parameter resources: Replaced `addResource().setParameterInfo()` with `addParameter()` in IrisInstanceBuilder. Same for string parameters. Removed functions `addResource()`, `addStringResource()` and `addNoValueResource()`. Each resource is either a register or a parameter and must be added using `addRegister()` or `addParameter()`, respectively.
2019-04-11	Removed defaults for register. canonicalRnScheme and memory. canonicalMsnScheme. Instance implementations now need to set these explicitly.
2019-04-15	Added support for canonical register number scheme `ElfDwarf`. In particular added 'include/iris/detail/IrisElfDwarf.h', 'include/iris/IrisElfDwarfArm.h' and 'IrisInstanceBuilder::RegisterBuilder::setCanonicalRnElfDwarf()'.
2019-04-16	Child registers no longer implicitly inherit canonicalRn and addressOffset from their parents.
2019-04-23	Added options to `iris_inspect.py`: --cpus-only, --first-only, --canonicalRn-table (generate a table of all registers that have a canonicalRn assigned), --properties, --resource-groups and -1 (single line details).
2019-04-23	Added IrisElfDwarfArm.h header which defines canonicalRns for `ARM` cores.
2019-04-23	Added 'ResourceTags.isFramePointer'.
2019-04-29	Added support for out-of-process trace clients to Examples/Plugin/SimpleTrace.
2019-06-13	Added disassembly and target property support to Python/Examples/IrisDebugger.py.
2019-06-19	Added IrisInstanceSemihosting::unblock() to allow unblocking of blocked semihosting requests.
2019-06-20	Added handle_semihosting_io() to Python iris. debug to explicitly request handling semihosting output in Python. The default is to continue to print it to the console.
2019-06-20	Removed IrisInstanceSyncLevel without replacement as it was not applicable to the sole use-case.
2019-06-24	Added sync level and partial tables support to Python/Examples/IrisDebugger.py
2019-07-02	Fixed deadlock in IrisTcpClient. java.
2019-07-05	Added plugin support to Python/Examples/IrisDebugger.py.
2019-07-16	Added semihosting input and debuggable state support to Python/Examples/IrisDebugger.py
2019-07-23	Added Python/Examples/IrisViewer.py, an experimental Iris low-level debugger.
2019-08-01	Added function `instance_getCppInterfaceIrisInstance()` to allow enhancing IrisInstances with tightly coupled plugins.

Date	Description
2019-08-02	Made `cname` fields mandatory (in `ResourceInfo` and `ResourceGroupInfo`), according to the specification.
2019-09-26	Added Examples/Plugin/EnhanceInstance which shows how to enhance a C++ IrisInstance with a tightly coupled plugin.
2021-10-09	Added blocking simulation time functions to IrisInstance to simplify clients.
2022-01-18	Added irisbench tool which can print and benchmark various aspects like single stepping, running, and trace.
2022-01-21	Added functions to get/list instances and event sources and to read/write resources to IrisInstance to simplify clients.
2022-02-10	Added convenience resource access functions to IrisInstance (`resourceRead()` and `resourceWrite()`).
2022-02-10	Replaced old Registers example with new Resource, ResourceTools, and PrintCoreRegs examples.
2022-02-11	Added `ResourceInfo.hierarchicalName/hierarchicalCName` and `calcHierarchicalNames()` to provide hierarchical names and the original `ResourceInfo` at the same time.
2022-02-11	Removed non-functional `ResourceInfo.descr` dummy member which was kept only for transitional backward compatibility.
2022-02-11	Added Examples/Client/ListInstances.

Related information

IrisSupportLib Reference Guide

3. Iris examples

This chapter describes the examples of Iris clients, plug-ins, and Python scripts. Each client and plug-in example contains source code and a makefile for GCC or project file for Microsoft Visual Studio.

3.1 C++ client examples

The following C++ client examples are located in `$IRIS_HOME/Examples/Client/`.

- When launching the model to connect the example to, use the `--iris-connect` option to start the Iris server. For more information, see FVP command-line options.
- Some of these examples require you to specify a target instance. Use the full hierarchical instance name, for example:

```
./breakpoints localhost:7100
 component.FVP_Base_Cortex_A32x1.cluster0.cpu0 --list
```

  For information about Iris instance names, see 6.19.1 Hierarchical instance names and instance classes on page 203.
- Most examples have a `--help` option to display usage information.

Table 3-1: C++ client examples

Example	Description
`Breakpoints`	• Sets or deletes code or data breakpoints. • Prints information about breakpoints that have been set for a target instance.
`Connection`	• Connects this client instance to the Iris server. • Prints the client instance name and id.
`Disassembly`	• Prints the disassembly modes that are supported by a target instance. • Prints the current disassembly mode. • Disassembles a chunk of memory, or an individual opcode.

`ExecutionControl`	• Starts or stops the simulation.
	• Halts or resumes execution of a specific instance.
	• Provides an interactive mode, which in addition:
	  ◦ Prints the execution time and execution state of the simulation.
	  ◦ Performs instruction stepping.

`ListInstances`	• Prints a list of instances in the simulation and their properties. • Optionally filters the list of instances.

Example	Description
`Memory`	• Prints information about the memory spaces that are exposed by the target instance. • Prints the contents of memory that was read from a specific address, in a specific memory space.
`PrintCoreRegs`	• Prints a list of either all core registers, or a subset of them, and their values.
`RawEventBufferParsing`	• Manually parses the event objects in an event buffer while synchronously stepping the model.
`RawEventCallback`	• Receives events using a raw callback function which receives the event arguments and fields as an `IrisReceivedRequest`.
`Resource`	• Reads and writes various resources for the first core instance in the simulation, for example the PC, register X0, the stack pointer, and link register.
`ResourceTool`	• Prints information about all resources (registers and parameters) for each core in the system, or for a specific core. • Writes a value to a specific resource. • Reads a value from a specific resource. • Lists all instances in the system.
`Semihosting`	• Creates an event stream for `IRIS_SEMIHOSTING_OUTPUT` events. • Registers itself to receive callbacks for semihosting output events. • Receives semihosting output from the target and prints it.
`SimpleTraceClient`	• Registers itself to receive a specific trace source from all instances. The trace source is specified on the command line, or `INST` by default. • Creates an event stream for the trace source specified. • Implements a callback function that prints the contents of each trace event.
`SpawnAndConnect`	• Spawns a model as a child process and connects to it using UNIX domain sockets. • Performs common operations such as stepping, reading and writing registers, reading and writing memory, tracing event sources, and logging messages.

3.2 DummyModel example

DummyModel is an example of a complete Iris system, including the main server-side components that are required by Iris. Its purpose is only to demonstrate Iris, all other functionality in the example can be ignored.

DummyModel is aimed at:

- Simulator developers. It shows how to integrate Iris support into a simulation framework.
- Component developers. It shows how to use Iris to expose aspects of a component, for example registers, parameters, memory, and event sources.

It provides a simple Iris framework, so can also be used to test new Iris-related features and reproduce problems outside of a full simulation framework.

It consists of the following:

Simulation engine

Its main purpose is to maintain an event queue for Iris calls.

Main executable

Its main purpose is to instantiate components and load plug-in libraries.

Component

Uses Iris to expose aspects of a component.

This example takes the following command-line options:

`-p <port_number>`

Set the TCP server port. The default is the first free port in the range 7100-7109.

`-P`

Print the port number that the Iris server is listening to.

`-G`

Print a log of all Iris messages. This option can be specified multiple times, for example `-G -G` for log level 2.

`-S`

Enable verbose logging in the IrisTcpServer. This option can be specified multiple times, for example `-S -S` for log level 2.

`-A`

Allow remote connections from another machine to the Iris server. Defaults to not allowed.

`--list-params`

Print parameters and exit.

`--instantiate=[0,1]`

If 0, do not automatically instantiate the simulation. This allows a remote client to connect to and instantiate it. Defaults to 1.

`--plugin <plugin_name>`

Load a plug-in library.

`-C <param>=<value>`

Set a parameter.

3.3 Plug-in examples

The plug-in examples are located in `$IRIS_HOME/Examples/Plugin/`.

The following examples are DSO plug-ins that you can build, then load into a model using the `--plugin` option.

Table 3-2: Plug-in examples

Example	Description
`EnhanceInstance`	A plug-in that is tightly coupled with another instance. The plug-in uses the C++ interface of the target instance to add some registers to it.

Example	Description
`GenericTrace`	• Iris implementation of the GenericTrace MTI plug-in. • Prints a comma-separated list of trace sources specified on the command line (`INST` by default) to a file or to `stdout`. • Specify the trace sources of interest, and optionally the trace file to write to, as parameters to the plug-in. Each parameter is prefixed with `GenericTrace`, for example: `./isim_system --plugin $IRIS_HOME/…/GenericTrace.so -C GenericTrace.event=EXCEPTION,EXCEPTION_RETURN`
`ListInstances`	• Registers to receive `IRIS_SIM_PHASE_END_OF_ELABORATION` events. • At the end of elaboration, a callback prints to `stdout` details of all registered instances in the simulation.
`ListResources`	Configurable plug-in that can print to a file or to stdout any of the following information, in JSON format, for each instance in the simulation: • Instance name, id, and properties. • Event sources supported by the instance. • Parameters and registers that the instance exposes. Additionally, it can print information about the simulator and hidden data. Configure the plug-in using parameters. To see the list of plug-in parameters, run the model with the `-l` option. The plug-in parameters are prefixed with `ListResources`. For example, to output register information, use: `./isim_system --plugin $IRIS_HOME/…/ListResources.so -C ListResources.registers=1`
`SimPhaseEvents`	• Registers callback functions for `IRIS_SIM_PHASE_*` events. • Each callback prints the name of the event and the time it occurred.
`SimpleTrace`	Similar to the `GenericTrace` plug-in example, except it only traces a single trace source (`INST` by default) and prints to `stdout` only. Use the `SimpleTrace.event` parameter to specify the trace source, for example: `./isim_system --plugin $IRIS_HOME/…/SimpleTrace.so -C SimpleTrace.event=CORE_REGS`

3.4 Python examples

These examples demonstrate the `iris.debug` Python module. They are installed in `$IRIS_HOME/Python/Examples/`.

For more information about `iris.debug`, see Iris Python Debug Scripting User Guide.

- Before running these scripts, you must have added the directory that contains `iris.debug` to the `PYTHONPATH` environment variable.
- When launching the model to connect to, use the `--iris-connect` option to start the Iris server. For more information, see FVP command-line options.

Table 3-3: Python examples

Example	Description
`ConnectModel.py`	• Connects to a running model. • Prints the names of all target component instances. • Prints the CPU instance properties.
`DemoBreakpoints.py`	• Loads an application (`vectors.axf`) into the model. • Sets register, program, and memory breakpoints. • Runs the model and prints information about the breakpoints that were hit.
`DemoControl.py`	Connects to the model, then runs, stops, and steps it.
`DemoDisassembly.py`	Prints the disassembly for a range of instructions. Specify the start address and number of instructions to disassemble.
`DemoMemory.py`	• Loads an application (`endian.axf`) into the model. • Writes data to memory then reads it back as bytes and words, to show the effect of changing endianness.
`DemoNetworkInitializer.py`	Demonstrates how to use the `NetworkModelInitializer` class to create a connection between the debugger and an ISIM. Specify the full path to the ISIM to connect to.
`DemoParameters.py`	• Prints all the parameters for the first CPU in the model. • Changes a runtime parameter and prints the new value.
`DemoRegisters.py`	Modifies registers in the CPU in the target model and prints the values before and after the changes.
`LoadApplication.py`	• Loads an application (`demo.axf`) into the model. • Steps through the program. • Modifies and prints some register values.
`SemiHostConf.py`	• Loads an application (`semihostconf.axf`) into the model. • Handles semihosted I/O by printing the semihosting stderr and stdout of the CPU target to the console.

4. Generic function call interface

Iris interfaces are named functions that receive named arguments. The functions mostly receive and return structured data as objects that contain named values. In case of an error, they return an error code. This chapter describes how to access Iris interfaces from C++ or using IPC/TCP.

4.1 JSON data types

Iris interfaces use JSON data types. The JSON type system provides clarity and simplicity and is supported by all relevant programming languages.

In this topic, Value represents any of the following JSON types or constants:

- Object. A map from String to Value.
- Array. A list of Values, not necessarily of the same type.
- String.
- Number. Represents integer and floating point values of arbitrary precision. Iris avoids using the arbitrary Number type.
- Boolean.
- True.
- False.
- Null.

The term NumberU64 refers to a `uint64_t`, in the range 0 to 2^{64}-1.

The term NumberS64 refers to an `int64_t`, in the range -2^{63} to 2^{63}-1.

The term *Type*[] refers to an array of *Type* values. For example String[] is an array of strings. Value[] is semantically identical to Array.

The term Map[String]*Type* refers to a map or dictionary-like object where the type of the key is String and the type of the value is *Type*. For example, Map[String]NumberU64 is a map or dictionary object with String keys and NumberU64 values. Map keys are always Strings. Map[String]Value is semantically identical to Object.

The following table defines the implicit type conversions that are performed on the interface boundary. The first column contains the values to convert from:

Table 4-1: Implicit type conversions

Original value	To Number	To NumberU64	To NumberS64	To Boolean	To Object	To Array	To String
Number	✓	-/✓ (Round)(Range)	-/✓ (Round)(Range)	-/✓ (Round)(only 1/0)	-	-	-
NumberU64	✓	✓	-/✓ (Range)	-/✓ (only 1/0)	-	-	-
NumberS64	✓	-/✓ (Range)	✓	-/✓ (only 1/0)	-	-	-

Original value	To Number	To NumberU64	To NumberS64	To Boolean	To Object	To Array	To String
Boolean	✓ (to 1/0)	✓ (to 1/0)	✓ (to 1/0)	✓	-	-	-
Object	-	-	-	-	✓	-	-
Array	-	-	-	-	-	✓	-
String	-	-	-	-	-	-	✓

Key:

#	Implicitly converted.
-	Not converted. `E_*_type_mismatch` error.
(Round)	Floating point numbers are implicitly rounded to the nearest integer.
(Range)	Implicitly converted when in range, else `E_*_type_mismatch` error.
(only 1/0)	Numbers are converted to Booleans when they are 1 (True) or 0 (False), else `E_*_type_mismatch` error, which is stricter than C, C++, and Python.
(to 1/0)	Booleans are implicitly converted to numbers as 1 (True) or 0 (False), as in C, C ++, and Python.


Note

- The Iris interface only expects and produces U64 and S64 numbers. Other numbers can be passed to Iris functions and are converted according to this table.
- Null is not implicitly converted to or from anything else.

4.2 JSON-RPC 2.0 function call format

Iris interfaces use the JSON-RPC 2.0 format and semantics for function calls and responses.

JSON-RPC 2.0 is a lightweight *Remote Procedure Call* (RPC) mechanism that is easy to understand and implement.

In this documentation, the terms *request*, *notification*, and *response* refer to the Request, Notification, and Response Objects that are defined by JSON-RPC 2.0, see http://www.jsonrpc.org/specification.

All functions are called by name, and responses are associated with requests by using a request id, which the caller assigns to the request.

The JSON-RPC 2.0 standard supports various use patterns. For example, it supports argument passing by position or by name. Iris uses the following subset of, and extensions to, JSON-RPC 2.0:

Function arguments

Function arguments are passed by name, not by position. In other words, `params` is an object, not an array. The order of the arguments in the Iris API documentation is irrelevant.

When manually generating JSON or U64JSON requests, you can order function arguments alphabetically by name to speed up function call processing.

Request ids

The request id that is passed to a function call is a NumberU64. The caller specifies bits[31:0] of the request id. This allows the caller to match function return values with function calls. It is usually an integer that increases with every request. This increasing id can wrap around, but ids of ongoing function calls must not be reused. There is no requirement to use an increasing id or even unique ids.

The `instId` argument specifies the instance that the function operates on, similar to a `this` pointer in C++. For more information about `instId`, see 5.2 Instances on page 63. The caller must set bits[63:32] of the request id to the instance id, `instId`, of the caller. This part of the id is used to route responses back to the caller. The usage of bits[63:32] is an Iris-specific extension of JSON RPC 2.0 to support the Iris Object Model. For more information about the Object Model, see 5. Object model on page 63


Note

Notifications do not need to route a response back to the caller. Therefore, notifications do not use a request id.

Requests and notifications

All Iris functions can be sent either as a request or as a notification, unless otherwise stated in the API documentation:

- For requests, the caller always receives a response, even if the function is specified to have no return value. In this case, a Null value is returned.
- For notifications, the caller never receives a response and no value is returned, even if the function is specified to return one.

String encoding

All strings, including object member names, are encoded using UTF-8. All Iris function names, function argument names, and object member names are plain ASCII and are C identifiers. Iris does not use String to transport binary data, because String cannot represent all binary byte sequences. For example, Strings cannot contain NUL bytes.

Binary data

Binary data is transported as a NumberU64[] with an explicit size argument, if necessary.

Case sensitivity

The following are case sensitive:

- Function names.
- Argument names.
- Object member names.
- Instance names.
- Event source names.
- Event source field names.
- Any other names and textual identifiers.

- Type strings.
- Verbatim strings that are used in the interface.

Bi-directional calls

Functions can generally be called in both directions between two instances.

Batch requests

Iris does not support batch requests or batch responses, in other words, arrays of requests or arrays of responses. Independent function calls to independent instances do not map well onto the batch requests and batch responses as defined in JSON-RPC 2.0. However, IrisRpc uses persistent TCP connections, and sending individual requests has almost the same performance as sending them in an array as a batch request.

4.3 Synchronous and asynchronous behavior

When calling a function, you can generally choose either to generate a synchronous *request*, which will later be answered by the callee with a response, or you can generate an asynchronous *notification* for which no response is generated.

Requests enable the caller to know when the callee has finished with the function, while notifications do not. This is relevant in the following use-cases:

Synchronous or asynchronous event callbacks

When enabling an event callback, the event consumer can choose:

- Whether the event-generating instance should be blocked while the consumer processes the event. This is a synchronous callback, using a request and a response for each event, see `syncEc=True` argument to `eventStream_create()`.
- Whether the event-generating instance should continue running, without waiting for the event to be processed. This is an asynchronous callback, using a notification.

Overlapping function calls

In general it is unnecessary to wait for a response before issuing the next request, except for instances that generate an event callback when `syncEc=True`. This means that function calls can overlap.

For example, if a debugger wants to read all registers, some memory, and a table of information, it issues the following requests without waiting for them to complete:

- `resource_read()`, request id=707.
- `memory_read()`, request id=708.
- `table_read()`, request id=709.

It then waits for the responses to requests 707, 708, and 709 in any order. This reduces the round-trip latency, for example through a TCP connection, from three round trips to one round trip, but makes the code more complex.

Related information

eventStream_create() on page 171

4.4 Sending a request, a notification, and a response

This topic describes typical sequences of steps involved in sending a request, a notification, and a response.

Sending a request

Requests are defined in the JSON RPC 2.0 specification. For more information, see 4.2 JSON-RPC 2.0 function call format on page 31.

A request sent by the caller to the callee, and a response sent by the callee to the caller, are equivalent to a function call with a return value. The caller typically takes the following steps to complete a blocking function call:

Before carrying out these steps, the caller must know its own `instId`, by calling `instanceRegistry_registerInstance()`. Typically, the caller also must have called `instanceRegistry_getList()` to find out the id of the instance it is calling.

1. The caller chooses a 32-bit request id, which it will use to match responses to requests. It puts its own `instId`, which is also 32 bits wide, into the top 32 bits of the request id to form the 64-bit request id that is passed with the request. This is required by the global instance to route responses back to the caller.
2. The caller encodes the JSON RPC 2.0 request object in U64JSON.
3. The caller calls `irisHandleMessage()` on the `IrisInterface` that it is connected to. This is usually provided by `IrisCoreConnection` for in-process instances or `IrisClientConnection` for out-of-process instances. This forwards the request to the callee.
4. The caller can do other work or send other requests to the same instance or to other instances.
5. The caller receives the response, which comes through the `irisHandleMessage()` function of the `IrisInterface` of the caller.

In practice, these steps are handled by a support library and the caller is not exposed to them. Requests can be sent from different threads. The caller does not have to wait for a response before sending another request. Requests can overlap. Responses can come from different threads and in any order. The caller must use the request id to match the response to a request.

Sending a notification

Notifications are defined in the JSON RPC 2.0 specification. For more information, see 4.2 JSON-RPC 2.0 function call format on page 31. Notifications are used, for example, by non-blocking, asynchronous callbacks. Sending a notification differs from sending a request in the following ways:

- The caller does not specify a request id. This also means that the caller does not send its instance id to the callee.

- The caller does not receive any response, including any error response, not even `E_function_not_supported_by_instance`, `E_unknown_instance_id`, or any low-level I/O error codes from the transport layer. This might limit the usefulness of notifications.
- The callee does not send a response.

Sending a response

Responses are defined in the JSON RPC 2.0 specification. For more information, see 4.2 JSON-RPC 2.0 function call format on page 31. After processing the request, the callee takes the following steps to send a response to the request:

1. Extracts the `instId` of the caller from the request id of the request.
2. Constructs a JSON RPC 2.0 response object encoded in U64JSON using the caller's `instId` and the original 64-bit request id.

Related information

instanceRegistry_registerInstance() on page 212
instanceRegistry_getList() on page 212

4.5 U64JSON

This section defines the Iris-specific binary variant of JSON called U64JSON.

U64JSON uses a sequence of `uint64_t` values to represent JSON data. It is fully equivalent to JSON and can be converted into JSON and back without data loss. The U64JSON variant is used whenever in-process communication takes place and it can optionally be used over IPC.

The main motivation for U64JSON is fast generation and consumption of arbitrary structured data, function calls, and return values, especially in-process.

4.5.1 U64JSON format

In U64JSON, each JSON value is encoded as a sequence of `uint64_t` values.

This terminology is used in the following table:

MSB
: The most significant four bits or eight bits of each `uint64_t` value, in other words, bits[63:60], or bits[63:56]. The MSB determines the type and encoding of the value.

Container length
: The number of `uint64_t` values, including the leading MSB value, representing the Value. It is the number of `uint64_t` values that must be skipped when skipping the Value. If the container length is not specified in the table, it is one.

Array length
: The number of elements in an array, which is not the same as the container length.

Value

Any JSON value that is encoded according to this table.


Note

For examples of U64JSON, see 4.5.7 U64JSON examples on page 42.

Table 4-2: U64JSON format

MSB	JSON type	Meaning
`0x0`	`Number`	Positive integer Numbers from 0 to `0x0fffffffffffffff` (60 bits).
`0x1`	`Number`	Negative Numbers from `-0x1000000000000000` to -1. To convert such a negative 64-bit pattern to U64JSON, bits[63:60] (`0xf`) are replaced with `0x1`. To convert the U64JSON representation back to a 64-bit pattern, bits[63:60] (`0x1`) are replaced with `0xf`.

`0x2` to `0x7`	`String`	String. Short string, 255 or fewer bytes long, where `string[6]` is in `0x20-0x7f` if longer than 6 bytes. Format:
		
		`// nn = string length, s…+MM = string`
		
		`uint64_t msb_and_string_data = 0xMMss ssss ssss ssnn;`
		
		`uint64_t more_string_data_if_necessary[n >> 3]; // missing for nn <= 7`
		
		If the string is less than 7 bytes long, bits[63:56] (`MM`) are set to `0x20`. This makes the MSB `0x2-0x7`. String bytes are stored in little-endian format. All padding bytes are 0 bytes, except for the `0x20` in `MM` for short strings <= 6 bytes.
		
		The string can contain null bytes and is not zero-terminated. The string encoding is UTF-8.
		
		Note:
		• All ASCII strings that contain only printable characters, and therefore all C identifiers, that are 255 or fewer bytes long, belong to this class. This includes all Iris function names, argument names, object member names, and many transported strings, like resource names.
		• Strings with 15 or fewer bytes can be compared with one or two `uint64_t` compares.
		• Encoding and decoding on little-endian machines is efficient (string follows length byte).
		
		Container length: (`nn` >> 3) + 1.

`0x8`	`NumberU64[]`	Array of `NumberU64` values. Format:
		
		`uint64_t msb_and_array_length = 0x8nnn nnnn nnnn nnnn; // n… = array length`
		
		`uint64_t data[n];`
		
		Data is not encoded according to this table but rather stored as plain `uint64_t` values.
		
		Container length: `n`... + 1.

`0x9`	-	Reserved.

MSB	JSON type	Meaning

0xa	Array	Generic array which can contain anything. Format:
		
		`// x… = container length`
		
		`uint64_t msb_and_container_length = 0xaxxx xxxx xxxx xxxx;`
		
		`uint64_t array_length;`
		
		`Value elements[array_length];`
		
		Container length: x….

0xb	Object	Object container. Map from String to Value. Format:
		
		`// x… = container length`
		
		`uint64_t msb_and_container_length = 0xbxxx xxxx xxxx xxxx;`
		
		`uint64_t number_of_members;`
		
		`struct { String member_name; Value value; } members[number_of_members];`
		
		Container length: x….
		
		When converting from JSON, the object members should be sorted alphabetically by member name. This does not restrict or enhance JSON, because in JSON, object members have no defined order. When converting to JSON, the object members can be emitted in alphabetical order or in any other order.
		
		The reason for ordering object members is that U64JSON is used for time-critical, in-process function calls. Function arguments can be found faster in an ordered list than in an unordered list.
		
		Alphabetical ordering is used because function calls can be converted to and from JSON and the arguments are represented as an object in which no order can be relied upon. Alphabetical order can be mechanically re-established, regardless of the semantics of the Object.

0xc0	Number	64-bit `NumberU64`. Only used if the number cannot be represented using the MSB4=0 or MSB4=`0xf` formats. Format:
		
		`uint64_t msb = 0xc000 0000 0000 0000;`
		
		`uint64_t number;`
		
		Container length: 2.

0xc1	Number	64-bit `NumberS64`. Only used if the number cannot be represented using the MSB4=0, MSB4=`0x1`, or MSB8=`0xc0` formats. Format:
		
		`uint64_t msb = 0xc100 0000 0000 0000;`
		
		`uint64_t number;`
		
		Container length: 2.

0xc2 to 0xc9	-	Reserved, except `0xc9ffffffffffffff` is an invalid U64JSON encoding and causes an `E_u64json_encoding_error`. Implementations can use this internally to explicitly represent an invalid U64JSON value, without affecting future extensions.

MSB	JSON type	Meaning

0xca	Number	64-bit double-precision floating-point number. Format:
		
		`uint64_t msb = 0xca00 0000 0000 0000;`
		
		`double number;`
		
		Container length: 2.

0xcb	-	Reserved.

0xcc	String	String. All strings that are not represented using the MSB=0x2-0x7 format, that is, either of the following:
		• Strings that are 256 or more bytes long.
		• Strings that are 7 or more bytes long and `string[6]` not in 0x20-0x7f.
		
		Format:
		
		`uint64_t msb_and_string_length = 0xccnn nnnn nnnn nnnn; // n… = string length`
		
		`uint64_t string_data[(n + 7) >> 3]`
		
		String bytes are stored in little-endian format. Unused bytes, if any, must be set to zero. The string can contain null-bytes and is not zero-terminated. The string encoding is UTF-8.
		
		Container length: (n...+15) >> 3.

0xcd	Null	Null value. Format: `uint64_t msb = 0xcd00 0000 0000 0000;`
0xce	Boolean	Boolean value `False`. Format: `uint64_t msb = 0xce00 0000 0000 0000;`
0xcf	Boolean	Boolean value `True`. Format: `uint64_t msb = 0xcf00 0000 0000 0000;`
0xd	-	Reserved
0xe0	Request	Encodes an Iris request message.
		`uint64_t msb = 0xe0vv xxxx xxxx xxxx xxxx;` vv indicates the JSON-RPC version and is 0x20. x... is the container length.
		`uint64_t request_id; // request[1]` This is the same as the `id` field in a JSON-encoded request. The `request_id` is a plain `uint64` and is not encoded according to the Number format in this table.
		`uint64_t instId; // request[2]` Indicates the destination instance, in other words, the callee of the Iris function. Equivalent to the `instId` parameter that almost all Iris functions require. Setting `instId` to zero is equivalent to omitting the `instId` parameter, targeting the global instance. The `instId` is a plain `uint64` and is not encoded according to the Number format in this table.

MSB	JSON type	Meaning
		`String method; // request[3:n]` Equivalent to the `method` field in a JSON-encoded request. This field has a variable length and is encoded as a U64JSON string according to the format in this table. The offset `n` is given by the encoding of the string.
		`Object params; // request[n:m]` Equivalent to the `params` field in a JSON-encoded request. This field has a variable length and is encoded as a U64JSON object according to the format in this table. The offset `n` is given by the encoding of the previous field and m by the encoding of the `params` object.
`0xe1`	Notification	Encodes an Iris notification message. The encoding of a Notification is the same as a Request except for the following differences: • The MSB is `0xe1` instead of `0xe0`. • The `request_id` field is ignored and should be set to `0xffffffffffffffff`. All other fields are encoded in the same way as a Request.
`0xe2`	Response	Encodes an Iris response message.
		`uint64_t msb = 0xe2vv xxxx xxxx xxxx xxxx;` `vv` indicates the JSON-RPC version and is `0x20`. `x...` is the container length.
		`uint64_t request_id; // response[1]` This is the same as the `id` field in a JSON-encoded response. The `request_id` is a plain `uint64` and is not encoded according to the Number format in this table.
		`uint64_t instId; // response[2]` Indicates the destination instance, in other words, the caller of the Iris function. The `instId` is a plain `uint64` and is not encoded according to the Number format in this table.
		`int64_t error_code; // response[3]` If this is zero (`E_ok`), this response returns a result. Any other value is an Iris error code and this response returns an error. The value of this field determines the encoding of the rest of the Response. The error code is a plain `int64` and is not encoded according to the Number format in this table. See 7. Response error codes on page 242 for information about error codes.

		`Value result; // response[4:n]`
		
		or
		
		`String message; // response[4:m]`
		
		The type and meaning of this field depends on the value of the preceding `error_code` field. If `error_code` is `E_ok`, this field is the result of the call encoded as a U64JSON value. It can have any type. If `error_code` is not `E_ok`, this field is the response error object `message` field encoded as a U64JSON string.

		`Value data; // response[m:xx]` Optional error object `data` field. This field is only present in an error response, in other words, when `error_code` is not `E_ok`. It can be any value encoded as U64JSON according to this table. The data field is optional and can be omitted. In this case, the Response container ends at the end of the `message` field and `m == xx`.

MSB	JSON type	Meaning
`0xf`	`Number`	Positive integer Numbers from `0xf000000000000000` to `0xffffffffffffffff` (60 bits).

4.5.2 Container length

The type and total length of each JSON Value can be determined by looking at its first `uint64_t` value.

This means that any structured type, whether an object, array, or string, can be skipped in constant time because it does not need to be parsed. This enables access to any object member in linear or constant time.

For objects and the array variant `0xa`, the container length is explicit and is redundant. For all other value types, it is implicit.

4.5.3 Endianness

When used in-process, the `uint64_t` array is transported with the native endianness of each `uint64_t` value.

Values larger than `uint64_t` are created by using a sequence of `uint64_t` values in little-endian format, with the lowest `uint64_t` value first, independent of the host endianness. However, this is out of scope of this documentation.

When used over IPC, for instance over TCP, the `uint64_t` array is serialized in little-endian format.

4.5.4 Signedness and integer representation

JSON can unambiguously represent positive and negative integers of arbitrary size. U64JSON can represent all integers in the range -2^{63} to $2^{64}-1$ unambiguously.

Almost all Iris interfaces specify the signedness of each integer value, so it is clear whether it is a signed or unsigned integer. This means that programming languages can use any 64-bit data type to represent the 64-bit patterns transported through JSON or U64JSON. Applications must make sure that these 64-bit patterns are then suitably interpreted when processed further. There are very few interfaces in which integer values are allowed to cover the whole signed and unsigned range, for example in parameters. It is only necessary in these few cases to support signed and unsigned 64-bit integers at the same time. This can be achieved by storing an explicit type flag, for example `bool isSigned` in addition to the 64-bit pattern.

4.5.5 Numbers with arbitrary size and precision

JSON can represent numbers with arbitrary size and precision. U64JSON can only represent signed and unsigned 64-bit integers and 64-bit double-precision floating point values.

Interfaces that support larger numbers or bit patterns must represent them using JSON values that can hold an arbitrary amount of data. For example, `NumberU64[]` is used by the resources and memory interfaces to represent arbitrarily wide bit patterns.

4.5.6 Optimizations and normalized form

Some JSON values can be represented in more than one way in U64JSON.

- Numbers must be represented according to this list, with highest priority first:

  Small (60 bits) positive integers in the range 0 to 2^{60}-1

  MSB is `0x0`.

  Small (60 bits) negative integers in the range -2^{60} to -1

  MSB is `0x1`.

  Small (60 bits) positive integers in the range 2^{64}-2^{60} to 2^{64}-1 (`0xF000000000000000` to `0xFFFFFFFFFFFFFFFF`)

  MSB is `0xf`.

  Other positive 64-bit integers, in the range 2^{60} to 2^{64}-2^{60}-1 (`0x1000000000000000` to `0xEFFFFFFFFFFFFFFF`)

  MSB is `0xc0`.

  Other negative 64-bit integers, in the range -2^{63} to -2^{60}-1

  MSB is `0xc1`.

  All floating-point numbers that can be represented by a double

  MSB is `0xca`.

- Strings must be represented as follows:

  Strings <= 255 bytes that have a `0x20-0x7f` byte in `s[6]` if >= 6 bytes

  MSB is `0x2-0x7`.

  All other strings

  MSB is `0xcc`.

- Arrays must be represented as follows:

  Array of `uint64_t`

  MSB is `0x8`.

  Generic array

  MSB is `0xa`.

- U64JSON messages must be represented as a Request, Notification, or Response, and never as an Object. This is important for efficient routing and decoding. Any message that is encoded as an Object receives an `E_malformatted_request` response.
- For Object, Boolean, and Null, there is only one possible representation.

Interface functions, their arguments, and return data are defined in terms of JSON in this documentation, not U64JSON. The U64JSON encoding is a fully equivalent alternative for encoding JSON data.

4.5.7 U64JSON examples

The following table gives some examples of JSON values encoded in U64JSON.

Table 4-3: U64JSON examples

JSON value	U64JSON representation
`[1,2,3]`	`0x8000000000000003, 1, 2, 3`
`["1",2,3]`	`0xa000000000000005, 3, 0x2000 0000 0000 3101, 2, 3`
`"abc"`	`0x2000 0000 6362 6103`
`""`	`0x2000000000000000`
`"numbyte"`	`0x6574 7962 6d75 6e07`
`"numbytes"`	`0x6574 7962 6d75 6e08, 0x73`
`0`	`0`
`1`	`1`
`0xffff ffff ffff ffff`	`0xffff ffff ffff ffff` This is $+2^{64}$-1, not -1.
`-1`	`0x1fff ffff ffff ffff`
`0xaabb ccdd eeff 0011`	`0xc000 0000 0000 0000, 0xaabb ccdd eeff 0011`
`-0x1234 5678 9012 3456`	`0xc100 0000 0000 0000, 0xedcb a987 6fed cbaa`
`{"num":1,"b":2,"c":3}`	`0xb000 0000 0000 0008, 3, 0x2000 0000 6d75 6e03, 1, 0x2000 0000 0000 6201, 2, 0x2000 0000 0000 6301, 3` **Note:** 13 JSON tokens (26 chars) translate into 8 `uint64_t` values (64 bytes) in U64JSON.
`Null`	`0xcd00000000000000`
`False`	`0xce00000000000000`
`True`	`0xcf00000000000000`

4.6 Function call optimizations

This section describes some optimizations that implementations can use to call functions more efficiently.

4.6.1 Fast argument parsing using sorted arguments

The Iris function call mechanism passes function arguments by name. It also passes object members, for example members of passed or returned structs, by name.

Therefore, it is possible for the caller to order arguments or members differently in each call. If so, the callee must repeatedly search the list of arguments or members. This has a large performance impact, particularly because functions might accumulate many optional arguments over time.

To avoid this problem, the caller should list the arguments for a function in alphabetically ascending order and the callee should parse the arguments in this order. If the caller and callee follow this rule then the argument list only needs to be parsed once. This does not impose any overhead on the caller. However, the callee cannot always rely on a sorted argument list because this rule is not compulsory. The callee must support unsorted or incorrectly sorted lists.

4.6.2 String comparison and hashing

When an instance receives an incoming function call, in other words a request, it must first look up the function by name.

In U64JSON, all strings are sequences of 64-bit values. They have several properties that implementations can exploit to make function lookup more efficient:

- The first 64-bit value contains the first 7 characters and the length of the string.
- Most strings in Iris can be encoded using 1-6 `uint64_t` values, and most Iris function names can be encoded using 1-4 `uint64_t` values. It is possible to write explicit code for these four cases instead of using a generic loop.
- If the first 64-bit values of two strings are different, the two strings are different.
- If the first 64-bit values of two strings are the same, they are guaranteed not to be a prefix of each other, or the two strings are the same.

It is often possible to implement a function lookup that does not check for unknown functions in constant time by using closed hashing on the first 64-bit value and comparison of the second 64-bit value only if necessary. Checking for unknown functions can be a runtime option which then uses a slower decoder (debug mode).

4.7 IrisC interface

IrisC is the low-level C interface that is used between shared libraries in an Iris system. Typically, instances do not deal with IrisC directly but use a support library, such as `IrisSupportLib`, to provide a high-level abstraction.

4.7.1 Memory and interface ownership

Function pointers and context pointers that are passed to an IrisC function are owned by the instance that originated them and must stay valid for the lifetime of the instance.

All other memory that is passed to an IrisC function, for example a U64JSON-encoded message that is passed as a `uint64_t` pointer, is owned by the caller and must not be accessed by the callee after the call has returned. The callee must make a copy of memory if it needs to access it later.

4.7.2 IrisSupportLib lifecycle functions

IrisSupportLib defines these IrisCore and IrisClient functions to manage its lifecycle.

4.7.2.1 IrisCore_init()

`IrisCore_init()` function.

```
int64_t IrisCore_init(void **iris_core_context_out)
```

Initialises the GlobalInstance and provides an IrisC context pointer that should be used for all future calls to IrisC functions.

Arguments:

`iris_core_context_out`
: Output argument. The value of `*iris_core_context_out` is set to the IrisCore context pointer.

Return value:

An `IrisErrorCode` value indicating whether the call was successful.

4.7.2.2 IrisCore_shutdown()

`IrisCore_shutdown()` function.

```
int64_t IrisCore_shutdown(void *iris_core_context)
```

Destroys the GlobalInstance and shuts down Iris. All instances are unregistered and any running server is shut down. The context pointer passed in should not be used after this function returns.

Arguments:

`iris_core_context`
: Context pointer returned by `IrisCore_init()`.

Return value:

An `IrisErrorCode` value indicating whether the call was successful.

4.7.2.3 IrisClient_connect()

`IrisClient_connect()` function.

```
int64_t IrisClient_connect(void **iris_client_context_out, const char *hostname,
 uint16_t port);
```

Initialises an IrisTcpClient and connects it to an Iris server.

Arguments:

`iris_client_context_out`
: Output argument. The value of `*iris_client_context_out` is set to the IrisClient context pointer that the server was successfully connected to.

`hostname`
: Hostname of the server to connect to.

`port`
: Server port to connect to.

Return value:

An `IrisErrorCode` value indicating whether the call was successful.

4.7.2.4 IrisClient_disconnect()

`IrisClient_disconnect()` function.

```
int64_t IrisClient_disconnect(void *iris_client_context)
```

Disconnects and destroys an IrisTcpClient. If a client disconnects from the server spontaneously it should still call `IrisClient_disconnect()` to clean up any state allocated by the IrisTcpClient.

Arguments:

`iris_client_context`
: Context pointer returned by IrisClient.

Return value:

An `IrisErrorCode` value indicating whether the call was successful.

4.7.3 General IrisC functions

These IrisC functions are implemented by IrisSupportLib and some must also be implemented by users of IrisSupportLib.

4.7.3.1 handleMessage()

`handleMessage()` function.

```
int64_t handleMessage(void *handle_message_context, const uint64_t *message);
int64_t IrisCore_handleMessage(void *iris_core_context, const uint64_t *message);
int64_t IrisClient_handleMessage(void *iris_client_context, const uint64_t
 *message);
```

Passes a message to be routed or handled. IrisCore and IrisClient define `handleMessage()` functions to route a message to its destination instance by calling the `handleMessage()` function for that instance. If `handleMessage()` returns `E_ok`, this does not imply that a request was handled successfully or even that it has been handled at all. The response to a request is delivered by calling the `handleMessage()` function for the caller with a response message.

Arguments:

`handle_message_context`

The context pointer for the callee. For `IrisCore_handleMessage()`, this is the `iris_core_context` pointer provided by `IrisCore_init()`. For `IrisClient_handleMessage()`, this is the `iris_client_context` pointer provided by `IrisClient_connect()`. For other `handleMessage()` functions, this is the context pointer associated with that function.

`message`

A U64JSON-encoded message. This can be a request, a notification, or a response.

Return value:

An `IrisErrorCode` value indicating whether the call was successful.

4.7.3.2 registerChannel()

`registerChannel()` function.

```
int64_t IrisCore_registerChannel(void *iris_core_context, IrisC_CommunicationChannel
 *channel,uint64_t *channel_id);
int64_t IrisClient_registerChannel(void *iris_client_context, IrisC_CommunicationChannel
 *channel,uint64_t *channel_id);
```

In order for IrisCore and IrisClient to route messages to an instance they must know the `handleMessage()` function and context pointer to use to pass a message to that instance. These pointers are grouped together into the `IrisC_CommunicationChannel` structure and registered with the IrisC library by calling `registerChannel()`.

Arguments:

iris_core_context or iris_client_context

The context pointer for the callee. For `IrisCore_registerChannel()`, this is the `iris_core_context` pointer provided by `IrisCore_init()`. For `IrisClient_registerChannel()`, this is the `iris_client_context` pointer provided by `IrisClient_connect()`.

channel

An `IrisC_CommunicationChannel` struct for the channel being registered.

channel_id

Output argument. `*channel_id` is set to an id number used by IrisCore or IrisClient to identify the channel. This id is used when registering instances using the `instanceRegistry_registerInstance()` Iris function.

Return value:

An `IrisErrorCode` value indicating whether the call was successful.

4.7.3.3 unregisterChannel()

`unregisterChannel()` function.

```
int64_t IrisCore_unregisterChannel(void *iris_core_context, uint64_t channel_id);
int64_t IrisClient_unregisterChannel(void *iris_core_context, uint64_t channel_id);
```

Unregisters a previously registered channel when an instance disconnects from the Iris system.

Arguments:

iris_core_context or iris_client_context

The context pointer for the callee. For `IrisCore_unregisterChannel()`, this is the `iris_core_context` pointer provided by `IrisCore_init()`. For `IrisClient_unregisterChannel()`, this is the `iris_client_context` pointer provided by `IrisClient_connect()`.

channel_id

The id for the channel being unregistered. Any instances that have been registered using this channel are automatically unregistered if they have not already done so themselves.

Return value:

An `IrisErrorCode` value indicating whether the call was successful.

4.7.3.4 IrisC_CommunicationChannel structure

`IrisC_CommunicationChannel` structure.

```
struct IrisC_CommunicationChannel
{
    uint64_t CommunicationChannel_version;
    IrisC_HandleMessageFunction handleMessage_function;
    void *handleMessage_context;
};
```

Members:

`CommunicationChannel_version`

This member must be set to 0.

`handleMessage_function`

`handleMessage()` function pointer for this channel.

`handleMessage_context`

Context pointer to pass when calling `handleMessage_function`.

4.7.3.5 processAsyncMessages()

`processAsyncMessages()` function.

```
int64_t IrisCore_processAsyncMessages(void *iris_core_context, uint64_t flags);
int64_t IrisClient_processAsyncMessages(void *iris_client_context, uint64_t flags);
```

Processes any buffered messages for the current thread. If an instance is using thread marshalling to ensure that all messages are handled on the same thread, that instance must ensure that `processAsyncMessages()` is being called from that thread to forward marshalled messages.

Arguments:

`iris_core_context` Or `iris_client_context`

The context pointer for the callee. For `IrisCore_processAsyncMessages()`, this is the `iris_core_context` pointer provided by `IrisCore_init()`. For `IrisClient_processAsyncMessages()`, this is the `iris_client_context` pointer provided by `IrisClient_connect()`.

`flags`

Bitwise OR of `IrisC_AsyncMessage` flags.

Return value:

An `IrisErrorCode` value indicating whether the call was successful.

4.7.3.6 IrisC_AsyncMessage flags

`IrisC_AsyncMessage` flags.

`IrisC_AsyncMessage_Default`

Default non-blocking behavior. Returns immediately if there are no outstanding messages to process.

`IrisC_AsyncMessage_Blocking`

If there are no outstanding messages to process, block until there is one. This is useful when waiting for a response to a request. Call `processAsyncMessages()` as follows to wait for the response and also to avoid deadlock situations in which the recipient of your request makes a request that needs to be marshalled to the thread being blocked:

```
while (no_response_received)
    processAsyncMessages(context, IrisC_AsyncMessage_Blocking);
```

4.7.3.7 irisInitPlugin()

`irisInitPlugin()` function.

```
int64_t irisInitPlugin(IrisC_Functions *functions);
```

Iris plug-in entry point. This function should be exported by an Iris plug-in DSO.

Arguments:

`functions`

A pointer to an `IrisC_Functions` struct that contains pointers to IrisC functions so that the plug-in can register instances and interact with Iris.

Return value:

An error code indicating whether the call was successful.

4.7.3.8 IrisC_Functions structure

`IrisC_Functions` structure.

```
struct IrisC_Functions
{
    uint64_t Functions_version;
    void *iris_c_context;
    IrisC_RegisterChannelFunction registerChannel_function;
    IrisC_UnregisterChannelFunction unregisterChannel_function;
    IrisC_HandleMessageFunction handleMessage_function;
    IrisC_ProcessAsyncMessagesFunction processAsyncMessages_function;
};
```

Members:

`Functions_version`
: This member must be set to 0.

`iris_c_context`
: Context pointer to use when calling all IrisC functions.

`registerChannel_function`
: Pointer to an IrisC library `registerChannel()` function.

`unregisterChannel_function`
: Pointer to an IrisC library `unregisterChannel()` function.

`handleMessage_function`
: Pointer to an IrisC library `handleMessage()` function.

`processAsyncMessages_function`
: Pointer to an IrisC library `processAsyncMessages()` function.

4.7.4 Plug-in API

Plug-ins can play any role in a system, for example, a debugger, a client, a visualization tool, a trace receiver, a trace generator, a component, a part of a component, or any combination of these.

The plug-in API consists of the following:

- `irisInitPlugin()` entry point. This allows the plug-in to make and receive Iris function calls.
- Iris function calls, made in both directions.
- Iris initialization phase callbacks. These callbacks have names beginning `IRIS_SIM_PHASE_`. They allow the plug-in to hook into the initialization and shutdown processes.

`$IRIS_HOME/Examples/Plugin/` contains source code for some example Iris plug-ins.

4.7.4.1 Initialization phase callbacks

Initialization phase callbacks allow plug-ins, and any other instances, to hook into the initialization and shutdown stages. Depending on its role, a plug-in might perform initialization in different callbacks, in order to provide information to other parts of the system as early as possible.

The initialization phase callbacks are Iris events, without fields.


Note

For an example plug-in that registers callback functions for `IRIS_SIM_PHASE_*` events, see `$IRIS_HOME/Examples/Plugin/SimPhaseEvents/`.

This is the list of callbacks, in the order in which they are called on an instance:

IRIS_SIM_PHASE_INITIAL_PLUGIN_LOADING_COMPLETE

Called just after all plug-ins have been loaded on simulation startup. This is the earliest point in time at which all plug-ins can discover the presence of all other initial plug-in instances, because plug-ins register themselves as at least one instance in `irisInitDso()`.

Plug-ins can be loaded and unloaded dynamically afterwards. This callback is only called once, after the initial plug-in loading has completed.

IRIS_SIM_PHASE_INSTANTIATE_ENTER

Called just before `IRIS_SIM_PHASE_INSTANTIATE`. No component instances have been created yet.

IRIS_SIM_PHASE_INSTANTIATE

Called as part of the system instantiation phase. This is when all component instances are created. Plug-ins can use this step to emulate instantiating themselves at the same time as components.

IRIS_SIM_PHASE_INSTANTIATE_LEAVE

Called just after `IRIS_SIM_PHASE_INSTANTIATE`, which is just after all component instances have been instantiated. All component instances are usually connected, but are not yet initialized.

IRIS_SIM_PHASE_INIT_ENTER

Called just before `IRIS_SIM_PHASE_INIT`. Connections to other components are already established, but other components are not yet initialized.

IRIS_SIM_PHASE_INIT

Called as part of the `init()` phase of all components. A component typically initializes itself here. Other components might or might not be initialized yet.

IRIS_SIM_PHASE_INIT_LEAVE

Called just after `IRIS_SIM_PHASE_INIT`, which is after `init()` of all components. Other components are already initialized, in the sense of `init()`. This is the earliest point when all trace sources of all components can be discovered.

IRIS_SIM_PHASE_BEFORE_END_OF_ELABORATION

Called just after `IRIS_SIM_PHASE_INIT_LEAVE`. In SystemC contexts, this is called in `before_end_of_elaboration()`. This is also called in non-SystemC contexts.

IRIS_SIM_PHASE_END_OF_ELABORATION

Called just after `IRIS_SIM_PHASE_BEFORE_END_OF_ELABORATION`. In SystemC contexts, this is called in `end_of_elaboration()`. This is also called in non-SystemC contexts.

IRIS_SIM_PHASE_INITIAL_RESET_ENTER

Called just before `IRIS_SIM_INITIAL_PHASE_RESET`.

IRIS_SIM_PHASE_INITIAL_RESET

Called as part of the the first `reset()` phase of components. This is only called once, after `init()`.

IRIS_SIM_PHASE_INITIAL_RESET_LEAVE
Called just after `IRIS_SIM_PHASE_INITIAL_RESET`.

IRIS_SIM_PHASE_START_OF_SIMULATION
Called just after `IRIS_SIM_PHASE_INITIAL_RESET_LEAVE`. In SystemC contexts, this is called in `start_of_simulation()`. This is also called in non-SystemC contexts.

IRIS_SIM_PHASE_RESET_ENTER
Called just before `IRIS_SIM_PHASE_RESET`.

IRIS_SIM_PHASE_RESET
Called as part of the the `reset()` phase of components. This is called for every simulation reset, not hardware reset, after the first one. See `IRIS_SIM_PHASE_INITIAL_RESET` for the first invocation of `reset()` after `init()`. To achieve the semantics of component `reset()`, combine `IRIS_SIM_PHASE_INITIAL_RESET` and `IRIS_SIM_PHASE_RESET`.

IRIS_SIM_PHASE_RESET_LEAVE
Called just after `IRIS_SIM_PHASE_RESET`.

IRIS_SIM_PHASE_END_OF_SIMULATION
Called just before `IRIS_SIM_PHASE_TERMINATE_ENTER`. In SystemC contexts, this is called in `end_of_simulation()`. This is also called in non-SystemC contexts.

IRIS_SIM_PHASE_TERMINATE_ENTER
Called just before `IRIS_SIM_PHASE_TERMINATE`. This is the last chance to access components before the `terminate()` phase is called on them. This is generally the last chance to access components in a safe way.

IRIS_SIM_PHASE_TERMINATE
Called as part of the `terminate()` phase of components.

IRIS_SIM_PHASE_TERMINATE_LEAVE
Called just after `IRIS_SIM_PHASE_TERMINATE`. As components might already have freed their resources, it is not safe to access other components from this callback.

4.7.4.2 Plug-ins and callbacks

Different types of plug-in must do work in different callbacks.

Trace plug-ins and debugger plug-ins

To receive trace events from components, a trace plug-in typically does work in the following callbacks:

IRIS_SIM_PHASE_INIT_LEAVE
This corresponds to the MTI `registerSimulation()` callback. The plug-in can discover all trace sources here.

IRIS_SIM_PHASE_INITIAL_RESET_LEAVE
Here, all components are properly initialized and their register values are properly reset.

IRIS_SIM_PHASE_TERMINATE_ENTER
This is the last chance to read the final trace state of components.

Trace plug-ins should generally not do any work in the following callbacks because it is unclear which part of the observed components have completed these stages and which have not:

- `IRIS_SIM_PHASE_INSTANTIATE`.
- `IRIS_SIM_PHASE_INIT`.
- `IRIS_SIM_PHASE_RESET`.
- `IRIS_SIM_PHASE_TERMINATE`.

To provide debugger-like functionality or to simply observe the state of components, a plug-in typically does work in the same callbacks as trace plug-ins.

Special plug-ins

A plug-in can discover other plug-ins that were loaded at startup in `IRIS_SIM_PHASE_INITIAL_PLUGIN_LOADING_COMPLETE`, for example to print a list of all plug-in instances.


Note

The behavior of a plug-in should not depend on other plug-ins because this violates user expectations. Plug-ins should not influence each other, unless this influence is their main purpose.

4.7.4.3 SystemC simulation phases

The Iris initialization phase callbacks occur during the following SystemC simulation phases:

Table 4-4: Iris initialization phase callbacks and SystemC simulation phases

Iris initialization phase callback	SystemC simulation phase
`IRIS_SIM_PHASE_INITIAL_PLUGIN_LOADING_COMPLETE`	`sc_main()`, before `sc_start()`
`IRIS_SIM_PHASE_INSTANTIATE_ENTER`	`before_end_of_elaboration()`
`IRIS_SIM_PHASE_INSTANTIATE`	
`IRIS_SIM_PHASE_INSTANTIATE_LEAVE`	
`IRIS_SIM_PHASE_INIT_ENTER`	
`IRIS_SIM_PHASE_INIT`	
`IRIS_SIM_PHASE_INIT_LEAVE`	
`IRIS_SIM_PHASE_BEFORE_END_OF_ELABORATION`	
`IRIS_SIM_PHASE_END_OF_ELABORATION`	`end_of_elaboration()`
`IRIS_SIM_PHASE_INITIAL_RESET_ENTER`	`start_of_simulation()`
`IRIS_SIM_PHASE_INITIAL_RESET`	
`IRIS_SIM_PHASE_INITIAL_RESET_LEAVE`	
`IRIS_SIM_PHASE_START_OF_SIMULATION`	
`IRIS_SIM_PHASE_RESET_ENTER`	`sc_start()`, after `start_of_simulation()`, and before `end_of_simulation()`
`IRIS_SIM_PHASE_RESET`	

Iris initialization phase callback	SystemC simulation phase
IRIS_SIM_PHASE_RESET_LEAVE	
IRIS_SIM_PHASE_END_OF_SIMULATION	end_of_simulation()
IRIS_SIM_PHASE_TERMINATE_ENTER	
IRIS_SIM_PHASE_TERMINATE	
IRIS_SIM_PHASE_TERMINATE_LEAVE	

4.8 IrisRpc (RPC transport layer)

IrisRpc is the low-level protocol that allows Iris clients to connect to Iris servers and to exchange IrisRpc messages, which are used to make Iris function calls.

IrisRpc assumes a bi-directional byte stream between the client and the server. This section assumes a TCP connection is used, but any other bi-directional byte stream transport can be used instead, for example Unix pipes, or a serial line.

The version of the IrisRpc transport protocol that is described in this section is 1.0. This does not indicate an Iris interface version or a level of support for Iris functions. Support for Iris interfaces can be queried using 6.19.14 instance_checkFunctionSupport() on page 214.

In this section, the term *client* means an instance, for example a debugger, connecting to a running server, and *server* refers to, for example, the IrisTcpServer. The server represents the simulation executable. Multiple clients can connect to a server at any time.

The JSON RPC 2.0 specification uses the terms *client* and *server* to indicate the caller and callee, respectively. These semantics are not used in this documentation. An Iris client is both a JSON RPC 2.0 client and a JSON RPC 2.0 server. An Iris server is also both a JSON RPC 2.0 client and JSON RPC 2.0 server. Both clients and servers can send and receive functions calls.


Note

- The client and server side must both implement a JSON RPC 2.0 client and server. This is mandatory. This means both sides can call functions on the other side.

  Some functions in this documentation are called *callbacks*. This term refers to a function that is called in the other direction in a specific context. Callbacks are normal function calls.
- All interactive clients should be able to receive callbacks. To receive callbacks, clients must use a persistent connection.
- When a client disconnects, all its callbacks are automatically unregistered. The IrisTcpServer discards callbacks that should be sent to a disconnected client. This might happen if unregistering the callback was delayed.
- Killing the model and killing a client are first-class operations and must be supported seamlessly.

4.8.1 IrisRpc connection handshake

Clients use the IrisRpc protocol to initiate a connection to an Iris server, for example the IrisTcpServer that is running in the simulation.

The IrisRpc connection handshake allows the client to do the following:

- Verify that the server it is connecting to is an Iris server.
- Request a specific IrisRpc version.

It also allows the server to notify the client whether it supports the requested IrisRpc version.

For a TCP connection, it is assumed that the client knows the host IP and port number of the TCP server.

The following procedure is used to establish a connection:


Note

<CR> and <LF> represent ASCII 13 and 10 respectively.

- The client connects to the server, for example it connects to the TCP port.
- The client sends the following request to connect using IrisRpc version 1.0:

```
CONNECT / IrisRpc/1.0<CR><LF>
Supported-Formats: IrisJson, IrisU64Json, JsonRpcOverHttp<CR><LF>
<CR><LF>
```

- The server sends the following response to tell the client that the connection is established, the protocol is IrisRpc/1.0, and a list of supported message formats:

```
IrisRpc/1.0 200 OK<CR><LF>
Supported-Formats: IrisJson, IrisU64Json, JsonRpcOverHttp<CR><LF>
<CR><LF>
```

- After this step, the client and server can send and receive IrisRpc messages.

  At this point, all client instances, but usually just one, should call `instanceRegistry_registerInstance()` to register themselves in the instance registry. Other instances can then discover them and query their properties and name.
- The server keeps the connection open until the simulation executable terminates. The client keeps the connection open until it either terminates or it no longer needs the connection to the server.


Note

Closing the connection implicitly unregisters all client instances that used this connection from the instance registry, destroys all event streams, and unregisters all other callbacks and artefacts.

The start lines and the header fields must be formatted according to RFC 7230, Section 3, HTTP/1.1 Message Format. The client and the server must ignore any header fields they do not understand.

Related information

instanceRegistry_registerInstance() on page 212

4.8.2 Rejecting a connection request

A client might reject a server, or a server might reject a client, for the following reasons:

- If a client requests an IrisRpc protocol version that the server does not support, the server can send the following response after the CONNECT step:

  ```
  IrisRpc/0.1 505 IrisRpc version not supported<CR><LF>
  Error-Message: This IrisTcpServer only supports IrisRpc/0.x.<CR><LF>
  <CR><LF>
  ```

  The server, then the client, closes the connection.
- A server might reject a client because it does not support any of the formats that the client supports. The server responds with:

  ```
  IrisRpc/0.1 501 Format not supported<CR><LF>
  Error-Message: This IrisTcpServer only supports the formats IrisU64Json, IrisJson
   but the client does not support any of these.<CR><LF>
  <CR><LF>
  ```
- A client might reject a server because it does not support any of the formats that the server supports. In this case, the client closes the connection without any further communication with the server.


Note

The last two cases can only occur when the client was configured to force a format other than `IrisJson`, because all servers and clients support the `IrisJson` format.

4.8.3 Supported formats

The `Supported-Formats:` header in the `CONNECT` request or response can contain the following case-sensitive values.

Supporting a format means both for sending and receiving.

`IrisJson`
: IrisRpc protocol using JSON format.

`IrisU64Json`
: IrisRpc protocol using U64JSON format.

`JsonRpcOverHttp`
: JSON-RPC over HTTP. This format is initiated using a `HTTP POST` or `GET` request, not a `CONNECT` request. This format cannot be used after a `CONNECT` request.

All servers and clients must at least support the `IrisJson` format. Therefore, an incompatibility should not occur. Servers should support all of the formats listed.

4.8.4 IrisRpc message format

IrisRpc messages transport JSON RPC 2.0 function calls, responses, and notifications.

The IrisRpc message format provides the following functionality:

- Allows senders to send messages either in JSON, U64JSON, or another format.
- Allows receivers to detect whether a message is in JSON, U64JSON, or another format.
- Allows receivers to determine the length of a message, in order to efficiently read it without parsing the content of the message.
- Allows receivers to detect when they are out of sync, and re-sync.

IrisJson format:

`IrisJson:<ascii_decimal_content_length>:<content><LF>`

Where:

- *<ascii_decimal_content_length>* is the length of *<content>* in bytes as a decimal ASCII number. This must not contain any leading zeros and must be at most ten decimal digits.
- *<content>* is a JSON RPC 2.0-encoded function call, response, or notification.
- *<LF>* is a byte with the value of 10.

IrisU64Json format:

`IrisU64Json:<uint32_le_content_length><content><LF>`

Where:

- *<uint32_le_content_length>* is the length of *<content>* in bytes as a 32-bit little-endian unsigned integer.
- *<content>* is an array of little-endian encoded `uint64_t` values. It is a JSON RPC 2.0 and U64JSON-encoded request, response, or notification.

Senders must send messages in a format that is supported by the receiver. Senders know which formats are supported from the handshake. The format might change from message to message inside a session. An exception is connections that were initiated with `JsonRpcOverHttp`, which must use `JsonRpcOverHttp` by both sides for the session.

Receivers inspect the first few bytes of a received message to determine the format. When the format is unknown or not supported, they close the TCP connection immediately without reporting an error to the TCP peer.

4.8.5 TCP considerations

TCP sockets should be created with the `keep-alive` option, if possible. If not possible, the side that does not support `keep-alive` should call the `instance_ping(instId=0)` function, which does nothing, 3600s after the last function call. The default TCP `keep-alive` time is 7200s, or 2 hours, for Linux and Windows.

The two crossed JSON RPC 2.0 client and JSON RPC 2.0 server pairs share a single TCP connection. Function calls, responses, and notifications are sent over the same TCP connection in both directions.

Related information

instance_ping() on page 216

4.9 JSON-RPC 2.0 over HTTP

In addition to IrisRpc, Iris supports the HTTP standard transport for making functions calls. The IrisTcpServer supports it transparently.

Iris uses the specification http://www.simple-is-better.org/json-rpc/transport_http.html, although this section overrides some parts of the specification, in particular, persistent connections.

4.9.1 Recognizing a session as JSON-RPC HTTP

The IrisTcpServer recognizes an HTTP session by receiving a `POST` request line, instead of a `CONNECT` request line for IrisRpc. Clients do not have to do anything special.

- The IrisTcpServer only supports `POST` calls:
  - `Content-Type:` must be `application/json-rpc`.
  - `Content-Length:` must contain the correct length according to the HTTP specification.

    - `Accept:` must be `application/json-rpc`.
- The server responds to `GET` and `PUT` with `405 Method Not Allowed`.
- The URL for `POST` is `/`. The URL is neither used to identify functionality nor to identify a specific target in the simulation, nor to pass parameters. Everything is specified inside the JSON-RPC message. The HTTP wrapper contains no semantic information.

The server reads header fields that only relate to establishing the connection for the first message, and ignores them for any subsequent messages.

4.9.2 Persistent connections

The IrisTcpServer only supports keep-alive mode, which keeps the TCP connection open, even after responding to a request. Clients must send `Connection: keep-alive` in the header in every request. Clients can close the TCP connection at any time to end the session.

The IrisTcpServer does not support the no keep-alive mode, because closing the TCP connection implies the client is disconnecting. If a client calls `instanceRegistry_registerInstance()` without keep-alive, it would receive a response and would be assigned an instance id, but when the client or server closes the TCP connection, the client would automatically be removed from the instance registry and therefore could not make any more Iris function calls.

The IrisTcpServer accepts and produces chunked transfer encoding messages to implement bi-directional Iris messages. The client can send Iris messages either as a sequence of `POST` requests, or as a sequence of chunks of an initial `POST` request, or any combination. The IrisTcpServer responds with a sequence of chunks, until it receives a new `POST` request from the client. An end-of-chunks marker carries no semantic information. Switching between chunks and `POST` requests has no meaning. Clients must accept chunked transfer encoding. The IrisTcpServer does not send `HTTP` requests, for example `POST`, to the client.

As an alternative to using chunked transfer encoding, web sockets can be used to create a persistent connection between the client and the server.

Long polling cannot be used because it implies that a new TCP connection is created by the client to receive future events.

Related information

instanceRegistry_registerInstance() on page 212

4.10 Threading model and ordering

This section describes how Iris handles asynchronous functions, and gives rules for using synchronous event callbacks.

4.10.1 Asynchronous functions

All Iris functions are asynchronous, unless stated otherwise in the function description.

Functions can be called either as a request or as a notification:

- Functions that are called as a request, receiving a response, might or might not have an effect by the time `irisHandleMessage(request)` returns. The function is guaranteed to have completed from the caller's viewpoint by the time the caller's `irisHandleMessage(response)` was entered. `irisHandleMessage(response)` can be called at any point after `irisHandleMessage(request)` was entered. `irisHandleMessage(response)` can be called before or after `irisHandleMessage(request)` returned.
- Functions that are called as a notification do not receive a response. They can take effect any time after `irisHandleMessage(notification)` was entered and before or after `irisHandleMessage(notification)` returns.

In general, `irisHandleMessage()` might be called from any host thread. An instance that set `marshalRequests=true` when registering itself is only called on the thread from which it issued the `instanceRegistry_registerInstance()` call.

Related information

instanceRegistry_registerInstance() on page 212

4.10.2 Reentrancy

`irisHandleMessage()` implementations must support reentrancy. It can be called, and therefore reentered, by any number of pair-wise different host threads at the same time.

- `irisHandleMessage()` can be called, and therefore reentered, by its own thread. The `irisHandleMessage()` implementation must support reentrancy by the same thread and must hold mutexes only for short periods, when recursive reentrancy cannot happen, for example only when modifying local data structures and not when forwarding calls, to avoid deadlocks.
- Recursive mutexes should not generally be used, because mutexes protect invariants and recursive mutexes do not.
- Calling Iris functions while the simulation is running, for example from asynchronous `ec_FOO()` callbacks, is allowed. Reading state, for example, using `resource_read()` or `memory_read()` is allowed, but the results are random because the model state is fluctuating. It would not be possible to retrieve a consistent state across two or more Iris function calls. By the time a client receives an asynchronous `ec_FOO()` callback, the model might have progressed, and any observed state is unlikely to be related to the event. A typical use case is to indicate progress to the user by reading and displaying an instruction count.
- Calling back the simulation from within synchronous `ec_FOO()` callbacks is much more restricted than calling back from asynchronous `ec_FOO()` callbacks because Iris calls cannot be scheduled, but must complete while the simulation is blocked in the instance generating the event. This should only be done in very specific circumstances. The documentation of the Events API describes what functionality can be expected from within synchronous `ec_FOO()` callbacks. Also, not all event sources support synchronous `ec_FOO()` calls.

Calling back into the simulation from within a synchronous `ec_FOO()` callback of instance `A` has the following implications:

- If there are multiple parallel simulation threads, reading state from other instances might or might not be synchronous, for example when reading state from a completely unrelated instance that is still progressing. In this case, the Iris call is scheduled onto the other thread and is effectively asynchronous.
- If there is only a single simulation thread, the whole simulation is blocked by the synchronous event callback. All state is stable, but the state of instance `A` and all related instances might be inconsistent, depending on the nature of the event.
- As a guideline, data that is directly related to the event should be taken from the event fields rather than being read directly from the instance. For example, if the event is notifying about a bus fault, the `ec_FOO()` callback should not try to read fault registers, or registers and memory that are related to the current transaction. Instead, it should interpret the fields transported with the event and it can read unrelated state, for example the PC registers of all cores.
- Instances indicate that they do not support certain functions, or accessing certain state, while they are blocked in a synchronous event, by returning `E_not_supported_while_instance_is_blocked`.

Related information

ec_FOO() on page 166
memory_read() on page 105
resource_read() on page 83

4.10.3 Ordering rules for requests, notifications, and responses

Notifications and responses are asynchronous and can be called from any host thread. A response might be received before or after `irisHandleMessage(request)` returns.

The following ordering rules apply to requests, notifications, and responses:

- All requests, notifications, and responses from instance A to instance B arrive at instance B in the same order they were sent by instance A, if the order of these events was defined in A at all. If events E1 and E2 are generated in A with no implicit or explicit order, for example from two simulation threads without explicit synchronization, then the order of E1 and E2 is also undefined in B.
- All requests from instance A to instance B are completed in order at instance B. This means for function calls F1 and then F2 from A to B that F2 only starts to have an effect on B after F1 has completed, in other words, after B has sent the response for F1. F1 and F2 do not run concurrently.
- When instance A receives a response for function call F1 from instance B, function F1 has completed in B.
- When instance B receives the global event `ec_FOO(IRIS_SIMULATION_TIME_EVENT, RUNNING=False)`, which causes the simulation time to stop, it can be sure that it has received all requests and notifications that were generated up to and including this event.

These ordering rules have the following effects:

- Sending a sequence of requests or notifications from one instance to another without waiting for a response executes the requests or notifications in the order in which they were sent.
- Sending requests from one instance to another and waiting for the response to each request before sending the next request executes all requests in the order they were called.
- If instances A1 and A2 send notifications, for example events, to instance B, there are no guarantees about the order in which B receives the events. However, B receives all events from A1 in the order that A1 generated them, and all events from A2 in the order that A2 generated them. Also, if a transaction travels through A1 and A2 and back again using a causal path, then all events generated on the way arrive at instance B in the same causal order. B implicitly serializes these causally-related events in the correct order, by queuing incoming `IrisInterface::irisHandleMessage()S`.

Related information

ec_FOO() on page 166

5. Object model

Iris provides an object model in which all entities are represented by instances. Instances can discover other instances and can call functions on each other. For example, a debugger can read a register in a CPU model, and the CPU model can send trace data to the debugger. Both debugger and model are instances.

5.1 Object model overview

Iris uses a very simple object model:

- A system consists of a set of instances.
- Each instance has a unique numeric instance id, `instId`.
- Each instance has a unique instance name. This also implies a hierarchy.
- Each instance registers itself in a global instance registry, which assigns it an instance id.
- Each instance can query the list of instances and can also be notified when new instances are registered or unregistered.
- Instances communicate with each other by specifying the instance id.
- There are two special instances, the GlobalInstance, which has instance id 0, and the SimulationEngine, which has instance id 1. The GlobalInstance contains the global instance registry.

The object model does not have a hierarchy, but the instance names imply a hierarchy. The hierarchical instance names assign each instance to a specific class by specifying the class as the top-level hierarchy level. For example: `component.mainboard.cluster0.cpu3` is of class `component`. The following classes are defined:

- `component`
- `client`
- `framework`

For more information, see 6.19.1 Hierarchical instance names and instance classes on page 203.

5.2 Instances

JSON RPC 2.0 is a procedural interface, not an object-oriented interface. However, Iris extends it so that functions can be called on specific instances.

It achieves this by using the following extensions:

`instId` argument

All instance-specific functions have an `instId` argument, which identifies the instance that the function operates on. This argument is always named `instId`. It is used by framework components to route requests and notifications to their destination. This is similar to the `this` pointer in C++ or the `self` argument in Python. Callers must first query the list of instances using `instanceRegistry_getList()` from the global instance, whose `instId` is zero, to get the id of another instance.

Instance-specific request id

The request id contains the instance id of the caller in bits[63:32]. The request id is a `NumberU64`, for all requests. It is used by framework components to route responses from the callee back to the caller.

All instances in a system, for example components, plug-ins, remote clients, and framework instances, can discover and communicate symmetrically with all other instances in the system.

All instances register themselves in a central instance registry, which assigns instance ids. See 6.19 Instance registry, instance discovery, and interface discovery API on page 203 for details about the instance registry.

Instances can implement a subset of, or even a superset of, the functions that are defined in the Iris APIs. Instances that do not support a specific function must return `E_function_not_supported_by_instance` for that function. See 6.19.5 Interface discovery on page 208 for more information.

Few Iris functions do not have an `instId` argument. These functions apply globally rather than to a single instance, for example, `instanceRegistry_registerInstance()`. However, most functions are instance-specific.

Global functions are implemented by the global instance, which has the pre-defined instance id of zero. Specifying an `instId` argument of zero is equivalent to specifying no `instId` argument at all. For more details, see 6.3 instId argument on page 67.

Related information

instanceRegistry_getList() on page 212
instanceRegistry_registerInstance() on page 212

6. Iris APIs

This chapter describes the Iris APIs. It provides conceptual information for each API, followed by detailed reference information for each function, object, and event source in the API.

Functions can return a result or an error code. The function-specific error codes are listed for each function, although generic error codes, which any function can return, are not listed. All error codes are described in 7. Response error codes on page 242.

This documentation uses the syntax `foo()` to refer to a function called `foo`. The trailing parentheses are not part of the function name. They are only used in the documentation to identify function names.

6.1 Iris API documentation

This book uses the following conventions when referring to Iris functions and objects:

Intuitive type names

Objects that are used as arguments and return values have intuitive type names, for example `RegisterInfo`. These type names do not occur in the requests or responses themselves, but are used in the documentation to help to clarify the purpose and context of the data. They also define a name for derived interfaces like C++, which support type names.

Return values

Function calls in JSON RPC 2.0 either return a result or an error member in the response object. For each function, the documentation describes any Objects that it returns in the result and lists any function-specific error codes that it can return. All functions can also return one of the general error codes, which are not listed in the function documentation, for brevity.

Function call parentheses

The Iris documentation uses the syntax `foo()` to refer to a function called `foo`, although the trailing parentheses do not appear anywhere in JSON or in U64JSON-formatted function calls. The parentheses are used to intuitively identify function names. In practice, Iris functions are called by language bindings, for instance C++ or Python functions, which use the syntax with parentheses.

6.2 Naming conventions

This topic describes the naming conventions that Iris APIs use.

Table 6-1: Naming conventions for Iris functions, objects, and events

Identifier	Case	Example
Function name	lowerCamelCase	`instanceRegistry_registerInstance`
Function argument name	lowerCamelCase	`instId`
Object member name	lowerCamelCase	`bitWidth`
Object type name	UpperCamelCase	`RegisterInfo`
Event name	UPPERCASE_WITH_UNDERSCORES	`IRIS_BREAKPOINT_HIT`
Event field name	UPPERCASE_WITH_UNDERSCORES	`BPT_ID`
-	lowercase_with_underscores	Not used.

Acronyms are treated like normal words and are written in lowercase, but sometimes have an uppercase first letter, for example `isTcp`, `isCpp`, `isJson`.

Function names

Function names are hierarchical, with hierarchy levels separated by an underscore. All functions have at least two parts, namely the group or interface name, and the function name, for example `resource_read`. Function names might have more hierarchy levels to further group the functionality.

See also 6.19.8 Naming conventions for new functions on page 210 for the naming conventions to use when enhancing the interface.

Experimental functions

Experimental functions are prefixed by `experimental_` to avoid namespace pollution. Experimental functions are not part of the official Iris interface. Their semantics, arguments, and return values can change without notice. Experimental functions might become part of the Iris interface, and then lose the prefix, or might be removed without replacement.

Custom functions

Custom functions are prefixed by `custom_`*`companyName`* to avoid name clashes when multiple companies extend the Iris interface with their own functions. Introducing custom functions must be avoided if possible. It is preferable to use a combination of registers, memory spaces, tables, and event sources instead.

Function argument names

Function argument names should be short, if possible less than 24 bytes long, so that function implementations can compare argument names with one or three `uint64_t` compares.
Details about an argument can be put into a description string which is retrieved using `instance_getFunctionInfo()`, rather than in its name. However it is useful to indicate the units, for example bits, bytes, elements, or milliseconds, in the argument name if multiple interpretations are possible. For example, `tickHz` or `bitWidth`.

Object member names

Object member names, for example in return values or in complex arguments, should be less than 24 bytes long.

6.3 instId argument

An `instId` argument occurs in many different functions. In all cases, it defines the instance that a function call is sent to. It has a similar role to the `this` pointer in C++ and the `self` argument in Python.

For example, when the global instance receives the function call:

```
func(name="foo", instId=42, value=-1, bar=[1, "2", True])
```

it can infer that this function call must be sent to the instance with id 42, without knowing what `func()` does, or whether the instance supports `func()` at all.

The `instId` argument is used in a function-independent way by the following framework instances:

- The global instance uses `instId` to determine which connected component, plug-in, or Iris server it should route a function call to. It does this for all calls, no matter where they come from.
- The Iris server uses `instId` to select the connection, and therefore the client, that a function call should be sent to.

6.4 Compatibility rules for function callers and callees

Functions are called by name and function arguments are named, not positional. Function return values are often objects, or arrays of objects, that contain named values.

These principles allow Arm to enhance the interface in future without breaking compatibility. To achieve this, callers and callees must follow some rules.

Callers of functions must follow these rules:

- The argument list must contain all mandatory arguments.
- The argument list can contain any optional arguments.
- The argument list must not contain any arguments that are not listed in this document.
- The caller can rely on mandatory members in the return value objects.
- The caller must not rely on any optional members in the return value objects. If an optional return value member is missing, this must have the semantics described in this document.
- The caller must accept and ignore any unknown members in return value objects.

Callees, in other words function implementations, must follow these rules:

- If a mandatory argument is missing, an error must be returned.
- If an optional argument is missing, this must have the semantics described in this document.
- If an unknown argument is passed, an error must be returned.
- All mandatory members must be returned in the return value objects.
- Any set of optional members of return values can be returned in the return value objects.

These rules have the following implications:

- Callees can be enhanced to accept extra optional arguments.
- Callees can be enhanced to return extra return value members. Existing callers that are unaware of the new members will ignore them.
- Callers that rely on certain mandatory or optional arguments must reliably receive an error response if a new argument is not supported by the callee.

6.5 Iris-text-format

Some functions return format strings that allow clients to format and annotate data values into a compact string for display purposes. These format strings are in the *Iris-text-format*, which is described in this section.

6.5.1 Format strings

Format strings consist of literal characters and references to variables. The set of defined variables is specified by the function that returns the format string and is out of scope of this section. For example, these variables might be the fields of an event or of a table record.

6.5.2 References to variables

References to variables generally have the following syntax:

`%{`*`varname`*`[`*`optional_bitrange`*`]`*`optional_format_spec`*`}`

The percentage sign `%`, braces `{…}`, and square brackets `[…]` shown here are literal characters. In the rest of this topic, square brackets are used to indicate optional components.

`varname`
The set of defined variable names depends on the context in which the format string is returned. It might also be possible to access fields of sibling objects, in which case *`varname`* can contain dots as hierarchy level separators.

optional_bitrange
If this is included, the specified bits are extracted from the numeric variable, or the specified characters are extracted from a string variable. The syntax of *optional_bitrange* is:

range[.*range*]…

Where *range* is either:

pos
Extract a single bit at *pos*.

msb:lsb
Extract the range of bits from MSB to LSB, where *msb* >= *lsb*.

pos, *msb*, and *lsb* are positive decimal numbers. The dot is a literal character that separates multiple ranges.

optional_format_spec
The default is `:x` for numeric types and `:s` for strings. The syntax is:

:[*width*][.*precision*][*format_char*]

Or:

:(*enum_spec*[|*enum_spec*]…)

Where:

width
The minimum number of characters to be printed for a number or for a string. Unused leading characters are filled with zeros for `x` and `b` and with spaces for `d` and `u`. If *width* is less than zero, the value is left-adjusted and the rightmost characters are filled with spaces.

precision
For `e`, `f`, and `g`, the number of precision digits. For `s`, the maximum number of characters to print.

format_char
Specifies the format in which values are printed. It can be one of the following:

x
Hexadecimal, without the leading `0x`. The client decides whether to use uppercase or lowercase hex, the guideline is lowercase.

d
Signed decimal. Either a minus sign for negative numbers or no sign.

u
Unsigned decimal.

b
Binary.

`e`

Scientific notation.

`f` and `g`

Floating-point number. The value must be exactly 32 bits or 64 bits wide.

`y`

Exact symbol lookup. The value is looked up in the symbol table, with an exact match, but see the note following this list. If found, this is replaced by the symbol name. If not found, this is replaced by the hexadecimal value with a leading `0x`.

`Y`

Lower bound symbol lookup. The value is looked up in the symbol table, searching for the symbol that has the highest value that is less than or equal to the value of the specified symbol, see the note following this list. If found, which is usually the case, this is replaced by *`symbol_name+offset_in_hex`* or just *`symbol_name`* on an exact match. If not found, this is replaced by the hexadecimal value with a leading `0x`.

`s`

String. Can only be used for string types.


Note

Some contexts might require the lower bits of an address to be masked out, depending on the target instance and the symbol type, for example ignoring bit[0] for Arm® cores.

`enum_spec`

Instead of displaying the numeric value, display literal text. The format of *`enum_spec`* is:
`text``[=`*`number`*`]`

This allows you to specify dense or sparse enum symbols for numeric values. The counting of non-explicit enum numbers follows the C rules, starting at zero, and uses *`last_number`*+1 if no number is specified.

To output a literal `%`, use two percentage signs, `%%`. In addition, all percentage signs that are not followed by either `{` or `[` are treated as a literal `%`. Enum strings cannot contain the `|` or `)` characters.

Errors might occur if names are undefined, or if objects return an error when being read. In this case, the reference should be replaced with `(error: <`*`reason`*`>)`.

Examples

```
%{mode} -> Display variable 'mode' in hex according to its bitwidth.
%{fifo_len:u} -> Display variable as unsigned decimal integer.
%{address:4x} -> Display address as hex integer with 4 digits for N < 2**16 and > 4 digits for
 bigger values
%{perm:(---|--x|-w-|-wx|r--|r-x|rw-|rwx)} -> Display permissions as 'rwx' field.
%{status[7:0]} -> Display 2 hex digits for the 8-bit value taken from bits[7:0].
%{status[7:0.15:12]} -> Display 3 hex digits for the 12-bit value taken from bits[7:0] as msb
 and bits[15:12] as lsb
%{pc:y} -> Display symbol.
```

6.5.3 Conditional formatting

In some cases, the formatting of a variable might depend on the value of one or more bits in that variable or in another variable.

This can be expressed with the `map` statement:

`%[map|`*`varname`*`[`*`optional_bitrange`*`]|`*`default`*`|`*`key1=format1`*`[|`*`key2=format2`*`]…]`

The variable is replaced with either the default or any of the specified formats. It is replaced with the format that is defined for a specific numeric value (*`key`*) if the variable has this numeric value. If the variable has a value that is not listed in the mapping, then it is replaced with the default. *`default`* and all specified formats might in turn contain `map` statements and variable references. *`default`* and the formats might contain literal `=` characters.

For example, this statement prints either a 10-bit index or a 20-bit address in the status register, depending on bit[31] in the `status` register:

```
%[map|status[31]||0=index=status[11:2]|1=address=status[19:0]]
```

6.6 Resources API

A resource is either a parameter or a register. Parameters allow you to parameterize an instance, either at startup, these are called init-time parameters, or at run-time. Registers represent a piece of state of an instance that can be read and might be modifiable.

Clients first query a list of the available resources of an instance by calling `resource_getList()`.

In the Resources API, each resource is uniquely identified by an opaque resource id. The `resource_read()` and `resource_write()` functions accept lists of resource ids to allow efficient reading and writing of multiple resources.

Clients typically inspect the meta information of the `ResourceInfo` objects returned by `resource_getList()` and extract the resource ids of the resources they are interested in. These are the `ResourceInfo` fields that are typically used to discover or filter resources:

`registerInfo`
: If present, the resource is a register.

`parameterInfo`
: If present, the resource is a parameter.

`name`
: For registers, this is the architectural name.

`canonicalRn`

This field is usually set for core CPU registers, for instance DWARF register numbers, see 6.6.7 ElfDwarf scheme for canonical register numbers on page 77.

`tags.isPc` and other tags

These tags allow clients to understand the semantics of the most important registers found in CPU cores, for example PC, stack pointer, instruction counter.

To access resources by name or by `canonicalRn`, clients typically build maps from `name`s to resource ids or from `canonicalRn`s to resource ids, because the `resource_read()` and `resource_write()` functions only accept resource ids.

Clients can also query resource groups by calling `resource_getListOfResourceGroups()`. This function returns lists of resource ids that are suitable for reading or writing all resources of a group.

Target instances can expose zero or more resources. Target instances that expose no resources must either return `E_function_not_supported_by_instance` for all `resource_*()` functions or `resource_getList()` must return an empty list.

State that consists of smaller chunks that can be addressed and accessed in a uniform way should be represented as memory or a table instead of resources, see 6.7 Memory API on page 96 and 6.9 Tables API on page 119.

`$IRIS_HOME/Examples/Client/Register/` contains an example client application that demonstrates how to use this API.

6.6.1 Parameters and registers

A resource is either a parameter or a register, but not both.

`isParameter`

A resource is a parameter if and only if the `parameterInfo` object is present in the `ResourceInfo` object.

`isRegister`

A resource is a register if and only if the `registerInfo` object is present in the `ResourceInfo` object.

Components that implement a subset of the architectural registers should expose all of them, even if some are only implemented as stubs. The description of stub registers should indicate that they are stubs.

6.6.2 Resource groups

Every resource belongs to one or more resource groups. Resource group names are short, human-readable strings, for example `GPR` or `FPU Shadow`.

Query the list of resource groups using `resource_getListOfResourceGroups()`. Clients should display them as a flat list, in the same order as they appear in the array returned by `resource_getListOfResourceGroups()`.

A resource group must contain either registers or parameters, but clients must handle gracefully any resource group that contains both.

All parameters of an instance belong to a single group named `Parameters`, so you can query all parameters of an instance by calling:

```
resource_getList(group = "Parameters")
```

6.6.3 Registers with fields

Iris enables parts of registers to be exposed as child registers. Parent and child registers are linked by the `ResourceInfo.parentRscId` field.

A register either has no parent, in which case it is called a top-level register, and its `parentRscId` is missing, or it has one parent register, in which case it is a child of that parent. Child registers can have their own child registers, although instances should not expose a register hierarchy that is more than one or two levels deep. Clients should display child registers below their parents, in the order they appear in the `ResourceInfo` array returned by `resource_getList()`.

When reading or writing child registers, it is the responsibility of the instance to access the data in the correct location. The `ResourceInfo` might contain enough information to locate the child resource inside the parent, but clients can ignore this information and just present it as part of the description of a resource.

It is possible to represent parts of a parent register as a logical child register. Logical child registers have no `lsbOffset`, indicating that they are distributed across multiple, non-consecutive bit ranges inside their parent register. Logical child registers might also represent any other information that is related to their parent register. They can be a different type to their parent register and can be used to create a structure of registers underneath the register group level.

Clients can usually ignore the difference between logical child registers and non-logical child registers, but instance implementations might find it useful to expose this information.


Note

Parameters do not have child parameters.

6.6.4 Resource names

Parameter names must be unique within an instance. This means that clients can ignore the group name of a parameter. Clients must handle non-unique parameter names gracefully, for example by only using the first of the conflicting parameter names in the list returned by `resources_getList()`.

Register names of top-level registers, in other words registers without a parent, must be unique within a register group of an instance. Register names of child registers must be unique within their parent. Clients must handle violations of these rules gracefully.

Resource names (`ResourceInfo.name`) must only consist of printable ASCII characters, in the range `0x20-0x7e`. They can contain spaces, dots, and characters that are usually used as separators. `ResourceInfo.cname` must be a valid C identifier, that is, it must start with a letter or underscore and must consist of letters, digits, and underscores.

Resource group names must not conflict with resource names.

In scripts and other non-GUI contexts, it is often necessary to uniquely specify a resource. To do this, clients should ensure the following:

- All name matching must be case-sensitive.
- Hierarchical resource names are built by concatenating the individual components of the name, separated by dots.
- To make a resource name unique, it can optionally have a resource group name prepended to it, separated by a dot. If no group name is specified and the resource name is not unique, clients must access the first matching resource in the array returned by `resource_getList()`.
- Child resources require all parent resources up to the top-level resource to be prepended, separated by dots.

For example, to access a child register `c` in register `MMU Status-Flags` in register group `Control 0.0.1`, a script can use either of the following names:

- ```
  Control_0_0_1.MMU_Status_Flags.C
  ```
- ```
  MMU_Status_Flags.C
  ```

6.6.5 Reading a resource

The semantics of reading a resource are *peek* rather than architectural read. If possible, all instance implementations should try to achieve side-effect free reads. This is required for non-intrusive debug.

- The `resource_read()` function supports reporting bits in registers with an undefined value. It is optional for instances to support this.
- It is not always possible to return the exact value of a resource, for example when the instance that exposes the resource is not in a debuggable state. The `resource_read()` function supports reporting approximate values.

- The `resource_read()` function does not fail with an error for existing resources that could not be read. Instead, such read errors are reported in the `error` member of `ResourceReadResult`, for each resource.

Examples

`resource_read()` returns one `ResourceReadResult` object, which contains the read result for all resources that were read, comprising values and errors. Numeric resource values and string resource values are split into two different arrays. Numeric resource values occupy one or more `NumberU64` values in the array, depending on their width. For example:

- Reading 3 32-bit resources with the values 1, 2, and `0xf00daaaa` respectively:

```
ResourceReadResult.data = [1, 2, 0xf00daaaa]
```

- Reading one 8-bit, one 64-bit, and one 32-bit resource, with values 1, 2, and 3 respectively:

```
ResourceReadResult.data = [1, 2, 3]
```

- Reading one 132-bit wide resource which has the value `0x9_ffeeddcc_bbaa9988_77665544_33221100`:

```
ResourceReadResult.data = [0x7766554433221100, 0xffeeddccbbaa9988, 9]
```

- Reading a string resource containing the string `"abc"`:

```
ResourceReadResult.data = []
ResourceReadResult.strings = ["abc"]
```

- Reading a 32-bit resource with value 1, a string resource with value `"abc"`, and a 32-bit resource with value 3:

```
ResourceReadResult.data = [1, 3]
ResourceReadResult.strings = ["abc"]
```


Note

The following `resource_read()` operations give the same result as this example:

- Reading a string resource with value `"abc"`, a 32-bit resource with value 1, and a 32-bit resource with value 3.
- Reading a 32-bit resource with value 1, a 32-bit resource with value 3, and a string resource with value `"abc"`.

- Reading a 32-bit resource with value 1, a `noValue` resource, and a 32-bit resource with value 3:

```
ResourceReadResult.data = [1, 3]
```

6.6.6 Writing a resource

The semantics of writing a resource are *poke* rather than bus write.

Side effects

Writing a resource should generally cause the side effect that a debugger user would expect when modifying the resource value. Side effects should be useful and intuitive, and should be kept to a minimum.

For most register resources, the side effect is the same as an architectural write.

For all resources where writes have side effects, these side effects, or the absence of them, must be documented in the resource description. For resources that expose multiple useful layers of side effects, multiple resources with intuitive but different names should be exposed. For example:

- A `STATUS_CLEAR` register whose only purpose is to clear another register when written should have this effect when written with `resource_write()`.
- A `STATUS` register which clears itself when written to should not clear itself, but instead accept the value written to it. To clear the register, zero can be written to it.
- A `TIMER` register which you can modify to change the current timer value or which you can write to set a new reload value is best represented by three resources with different side effects:
  - `TIMER` for architectural writes.
  - `TIMER_value` to modify the timer value only.
  - `TIMER_reload` to modify the shadow timer reload register only.

Permissions and updating resources

Writing a resource should not be limited in any way. All bits that can architecturally change their value under certain conditions should be modifiable through `resource_write()`. However, writes that are architecturally forbidden and would lead to inconsistencies in the simulation state, should be ignored.

For example the following registers should be freely writable at all times:

- An EEPROM register containing a serial number which can normally only be programmed during a special reset procedure.
- A read-only flags register in which the flags can only be affected by executing instructions.
- A read-only cycle counter register, unless an update would cause inconsistent simulation state.
- An internal register that is architecturally inaccessible, for example an internal buffer or a shadow register.

Writes to read-only bits

Some or all bits of a resource might be read-only. Writes to these bits are ignored without error. If the whole resource is read-only, the `ResourceWriteResult.error` array should indicate this.

Write errors

`resource_write()` returns one `ResourceWriteResult` object. Errors that occurred while updating resources are returned in the `ResourceWriteResult.error` array. `resource_write()` never fails with an error when writing existing resources.

For examples of `data` and `strings` arguments, see 6.6.5 Reading a resource on page 74. If the values array is too long or too short for the specified resources, `resource_write()` returns `E_data_size_error`. In this case, the implementation might have updated any, or none of the specified resources.

6.6.7 ElfDwarf scheme for canonical register numbers

The ElfDwarf scheme is used for the `RegisterInfo.canonicalRn` field if the instance property `register.canonicalRnScheme` has the string value `ElfDwarf`.

The ElfDwarf scheme uses the DWARF register numbers defined for a specific architecture, combined with the value of the ELF header field, `e_machine`, which defines the architecture and is used as a namespace for the DWARF register numbers. This results in unique canonical register numbers across all architectures that ELF supports. The ElfDwarf scheme is defined for all architectures supported by ELF that define DWARF register numbers. See `/usr/include/elf.h` for a list of all possible values for `e_machine`.

Only a subset of the registers of an instance have an assigned DWARF register number. All other registers do not have a `RegisterInfo.canonicalRn` field and therefore cannot be discovered through the canonical register number. Instead, they can be discovered by inspecting `ResourceInfo.tags`, for instance `tags.isPc`, or `ResourceInfo.name`, which contains the architectural register name, if available.

The `RegisterInfo.canonicalRn` value is a 64-bit value with the following structure:

```
0x0000MMMM0000NNNN
```

Where:

Bits[15:0], *NNNN*

DWARF register number for the architecture that is defined in the ELF header field `e_machine`.

Bits[31:16], 0000

Reserved. Instances must set these bits to zero.

Bits[47:32], *MMMM*

ELF `EM_*` constant for the architecture, as defined by the ELF header field `e_machine`. This is the namespace for the DWARF register number specified in bits[15:0].

Bits[63:48], 0000

Reserved. Instances must set these bits to zero.

Related information

ElfDwarf canonical register numbers on page 78
ELF Header
DWARF for the ARM Architecture
DWARF for the ARM 64-bit Architecture (AArch64)

6.6.8 ElfDwarf canonical register numbers

This table lists the canonical register numbers that Arm® cores expose in `ResourceInfo.registerInfo.canonicalRn`, using the ElfDwarf scheme.


Note

- The C++ IrisSupportLib header file, `iris/IrisElfDwarfArm.h` contains symbolic constants for the canonical register numbers. They are listed in the *Constant* column.
- Only a small subset of the registers that Arm® cores expose have canonical register numbers and DWARF register numbers assigned. Other registers can be discovered by name, for example PC, or by tag, for example `ResourceInfo.registerInfo.tags.isPc`.

Table 6-2: ElfDwarf canonical register numbers for Arm® cores

canonicalRn value [1]	Register [2]	Arch name [3]	Arch number [4]	Dwarf register [5]	Constant [6]
0x2800000000+*n*	R*n* (*n*=0-15)	EM_ARM	40	0+*n*	iris::ElfDwarf::ARM_R*0+n*
0x2800000080	SPSR	EM_ARM	40	128	iris::ElfDwarf::ARM_SPSR
0x2800000081	SPSR_fiq	EM_ARM	40	129	iris::ElfDwarf::ARM_SPSR_fiq
0x2800000082	SPSR_irq	EM_ARM	40	130	iris::ElfDwarf::ARM_SPSR_irq
0x2800000083	SPSR_abt	EM_ARM	40	131	iris::ElfDwarf::ARM_SPSR_abt
0x2800000084	SPSR_und	EM_ARM	40	132	iris::ElfDwarf::ARM_SPSR_und
0x2800000085	SPSR_svc	EM_ARM	40	133	iris::ElfDwarf::ARM_SPSR_svc
0x2800000097	R8_fiq	EM_ARM	40	151	iris::ElfDwarf::ARM_R8_fiq
0x2800000098	R9_fiq	EM_ARM	40	152	iris::ElfDwarf::ARM_R9_fiq
0x2800000099	R10_fiq	EM_ARM	40	153	iris::ElfDwarf::ARM_R10_fiq
0x280000009a	R11_fiq	EM_ARM	40	154	iris::ElfDwarf::ARM_R11_fiq
0x280000009b	R12_fiq	EM_ARM	40	155	iris::ElfDwarf::ARM_R12_fiq
0x280000009c	R13_fiq	EM_ARM	40	156	iris::ElfDwarf::ARM_R13_fiq

[1] Canonical register number value in `ResourceInfo.registerInfo.canonicalRn`, according to the `ElfDwarf` scheme.
[2] Architectural register name.
[3] ELF EM_* constant name for the architecture for which the register is defined.
[4] Numerical value of the EM_* constant.
[5] DWARF register number defined for the architecture.
[6] Constant defined in `iris/ElfDwarfArm.h` for `canonicalRn` (`uint64_t`).

canonicalRn value [1]	Register [2]	Arch name [3]	Arch number [4]	Dwarf register [5]	Constant [6]
0x280000009d	R14_fiq	EM_ARM	40	157	iris::ElfDwarf::ARM_R14_fiq
0x280000009e	R13_irq	EM_ARM	40	158	iris::ElfDwarf::ARM_R13_irq
0x280000009f	R14_irq	EM_ARM	40	159	iris::ElfDwarf::ARM_R14_irq
0x28000000a0	R13_abt	EM_ARM	40	160	iris::ElfDwarf::ARM_R13_abt
0x28000000a1	R14_abt	EM_ARM	40	161	iris::ElfDwarf::ARM_R14_abt
0x28000000a2	R13_und	EM_ARM	40	162	iris::ElfDwarf::ARM_R13_und
0x28000000a3	R14_und	EM_ARM	40	163	iris::ElfDwarf::ARM_R14_und
0x28000000a4	R13_svc	EM_ARM	40	164	iris::ElfDwarf::ARM_R13_svc
0x28000000a5	R14_svc	EM_ARM	40	165	iris::ElfDwarf::ARM_R14_svc
0x2800000100+*n*	D*n* (*n*= 0-31)	EM_ARM	40	256+*n*	iris::ElfDwarf::ARM_D*0+n*
0xb700000000+*n*	X*n* (*n*=0-30)	EM_AARCH64	183	0+*n*	iris::ElfDwarf::AARCH64_X*0+n*
0xb70000001f	SP	EM_AARCH64	183	31	iris::ElfDwarf::AARCH64_SP
0xb700000021	ELR	EM_AARCH64	183	33	iris::ElfDwarf::AARCH64_ELR
0xb700000040+*n*	V*n* (*n*=0-31)	EM_AARCH64	183	64+*n*	iris::ElfDwarf::AARCH64_V*0+n*

Related information

ElfDwarf scheme for canonical register numbers on page 77
ELF Header
DWARF for the ARM Architecture
DWARF for the ARM 64-bit Architecture (AArch64)

6.6.9 Comparison of resource types

It is generally clear from the context whether a piece of state that an instance exposes is an init-time parameter, a run-time parameter, or a register. If it is unclear, see the following table.

In this table, if the criterion is true, the value can be modeled as shown, reading from left to right:

Table 6-3: Comparison of resource types

Criterion	Init-time parameter	Run-time parameter	Register
Is configurable at initialization time.	yes	yes	no
Is modifiable at runtime.	no	yes	yes
Is modifiable at runtime and generally does not change at runtime except when the user changes it.	no	yes	usually no

[1] Canonical register number value in `ResourceInfo.registerInfo.canonicalRn`, according to the `ElfDwarf` scheme.
[2] Architectural register name.
[3] ELF EM_* constant name for the architecture for which the register is defined.
[4] Numerical value of the EM_* constant.
[5] DWARF register number defined for the architecture.
[6] Constant defined in `iris/ElfDwarfArm.h` for `canonicalRn` (`uint64_t`).

Criterion	Init-time parameter	Run-time parameter	Register
Can change spontaneously, that is, without a parameter write, at runtime.	no	no	yes
Is an architectural register.	no	no	potentially
Has a reset value.	no	no	yes
Is reset during simulation reset.	no	no	yes
Corresponds to a design-time parameter of the hardware.	yes	no	no
Corresponds to a hardware register.	no	no	potentially
Can be modified by program code.	no	no	usually yes
Is artificial, not present in the hardware.	yes	yes	usually no
Can have fields.	no	no	yes
Is organized into groups.	no	no	yes

6.6.10 Exposure of parameters

Parameters are exposed through the following functions:

resource_getList()
: Returns all initialization-time parameters, run-time parameters, registers, and generic resources.

resource_read()
: Returns the current value of initialization-time parameters, run-time parameters, registers, and generic resources.

resource_write()
: Sets run-time parameters, registers, and generic resources. Returns `E_writing_init_time_parameter` in `ResourceWriteResult.error` when trying to write an initialization-time parameter.

simulation_getInstantiationParameterInfo()
: Returns all initialization-time parameters and all run-time parameters. Does not return non-parameter resources.

simulation_setInstantiationParameterValues()
: Sets initialization-time parameters and run-time parameters. Does not set non-parameter resources.

Initialization-time parameters are exposed by:

- `resource_getList()`
- `resource_read()`
- `simulation_getInstantiationParameterInfo()`
- `simulation_setInstantiationParameterValues()`
- `resource_write()` causes an error.

Run-time parameters are exposed by:

- `resource_getList()`
- `resource_read()`
- `resource_write()`
- `simulation_getInstantiationParameterInfo()`
- `simulation_setInstantiationParameterValues()`

Registers are exposed by:

- `resource_getList()`
- `resource_read()`
- `resource_write()`

Related information

simulation_getInstantiationParameterInfo() on page 228
simulation_setInstantiationParameterValues() on page 230

6.6.11 resource_getList()

Retrieves the static aspects of a resource. Debuggers usually call this function only once, after connecting to the target. If neither `group` nor `rscId` arguments are specified, all resources are returned.

Arguments

`group`

Type: `String`

Optional. Return information just for resources that are part of this resource group. If no such group is known, `E_unknown_resource_group` is returned. If a valid `rscId` is also specified, in addition to a group, only a single matching resource or an empty array (and no error) is returned.

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`rscId`

Type: `NumberU64`

Optional. Return information just for the resource with `rscId`. The return value is an array with a single element. If `rscId` is not known, `E_unknown_resource_id` is returned. If `group` is also specified, the resource is just searched for in the group. If a valid `rscId` is not part of the specified group, an empty array and no error is returned.

Return value

`ResourceInfo[]`

Zero or more `ResourceInfo` Objects.

Errors

- `E_unknown_instance_id`.
- `E_unknown_resource_id`.
- `E_unknown_resource_group`.

6.6.12 resource_getListOfResourceGroups()

Gets the meta information of all resource groups. Each resource group has a name, a description, and a list of ids of the resources in the group.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

`ResourceGroupInfo[]`

Zero or more `ResourceGroupInfo` Objects.

Errors

- `E_unknown_instance_id`.

6.6.13 resource_getResourceInfo()

Get the `ResourceInfo` object from a specific resource that belongs to a specific group.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`name`

Type: `String`

Name of the resource.

group

Type: `String`

Group which the resource belongs to.

Return value

`ResourceInfo`

Object that contains the resource information for the specified instId, name and group name. See ResourceInfo.

Errors

- `E_unknown_resource_group`.
- `E_unknown_resource_name`.

6.6.14 resource_read()

Reads the values of a set of resources. The semantics are `peek` rather than architectural read.

Arguments

instId

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

rscIds

Type: `NumberU64[]`

List of opaque resource ids uniquely identifying the resources within the target instance to be read. An empty array is valid and results in an empty result array. An `rscId` can occur multiple times, in which case the same resource is read multiple times.

Return value

`ResourceReadResult`

Resource data, undefined bits, and errors. See `ResourceReadResult`.

Errors

- `E_unknown_instance_id`.
- `E_unknown_resource_id`.

6.6.15 resource_write()

Writes values to a set of resources. The semantics are `poke` rather than architectural write.

Arguments

`data`

Type: `NumberU64[]`

List of numeric resource values to be written, in the order they are specified in the `rscIds` argument. See `ResourceReadResult.data` for the encoding. If this array does not match the number of resources being written, `E_data_size_error` is returned.

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`rscIds`

Type: `NumberU64[]`

List of opaque resource ids uniquely identifying the resources within the target instance to be written. An empty array is valid. The same `rscId` can occur more than once, in which case the same resource is written multiple times.

`strings`

Type: `String[]`

Optional. List of string resource values. Missing if no string resources are written. See `ResourceReadResult.strings` for the encoding. If this array does not match the number of resources being written, `E_data_size_error` is returned.

Return value

`ResourceWriteResult`

Write errors. See `ResourceWriteResult`.

Errors

- `E_unknown_instance_id`.
- `E_unknown_resource_id`.
- `E_data_size_error`.

6.6.16 ParameterInfo

ParameterInfo members:

`defaultData`

Type: `NumberU64[]`

Optional. Default value of the numeric parameter. Parameters for which no specific value was specified at init-time have this value. If this is not specified, a default value of 0 is used. This is only present for numeric parameters. Signed numeric values have the (unsigned) bit pattern in the default value. numericFp resources have floating-point bit patterns in the default value.

Numeric values are encoded right-aligned into the `NumberU64` elements and little-endian in the array (the same encoding when reading or writing resources). Instances must guarantee that the default value is consistent with the `min` and `max` values, but clients must not rely on this guarantee.

`defaultString`

Type: `String`

Optional. Default value of a string parameter. Parameters for which no specific value was specified at init-time have this value. If this is not specified, by default an empty string is used.

`initOnly`

Type: `Boolean`

Optional. Specifies when a parameter value can be set or written:

`True`

Init-time parameter

`False`

Run-time parameter. Default is false (run-time parameter).

Init-time parameter: The parameter can only ever be set before instantiation. The parameter is only settable through the function `simulation_setInstantiationParameterValues()`. It is not settable at run-time through the function `resource_write()`, which is only available after instantiation. The parameter behaves like a read-only resource after instantiation. After instantiation, it can be read through `resource_read()` like any other resource. The value of init-time parameters must be constant at run-time. Typical examples of init-time parameters are cache sizes or number of sub-units.

Run-time parameter: The parameter can be set at init-time and it can also be set at run-time. The parameter mostly behaves like a generic resource. As a guideline, the value of a run-time parameter must not change spontaneously at run-time other than through explicit `resource_write()` calls or equivalent explicit mechanisms, for example re-reading a config file. If it does change spontaneously at run-time, it is likely to be better modeled as a non-parameter resource.

Even if a parameter is only modifiable at run-time under very restricted circumstances, it must be a run-time parameter. Run-time parameters are not guaranteed to be modifiable at run-time, but init-time parameters are guaranteed to be constant at run-time.


Note

All parameters, regardless of the value of `initOnly`:

- Can always be set at init-time through `simulation_setInstantiationParameterValues()`.
- Can always be read at run-time through `resource_read()`.
- Are exposed through `simulation_getInstantiationParameterInfo()`.

`max`

Type: `NumberU64[]`

Optional. Maximum numeric value accepted (inclusive). Only used for numeric types.

`min`

Type: `NumberU64[]`

Optional. Minimum numeric value accepted (inclusive). Only used for numeric types.

6.6.17 RegisterInfo

RegisterInfo members:

`addressOffset`

Type: `NumberU64`

Optional. Address offset of a memory-mapped register, relative to the physical base address of the instance, for example a peripheral. This is informational only. A lot of factors affect the memory map of a system. Clients can safely ignore the value of `addressOffset` and usually just treat it as part of the register description.

`canonicalRn`

Type: `NumberU64`

Optional. Canonical register number. This number adheres to the scheme described by the register. canonicalRnScheme property returned by `instance_getProperties()`.

If register. canonicalRnScheme is `ElfDwarf` then bits[15:0] specify the `DWARF` register number for the architecture that is specified by bits[47:32]. The architectures are as defined in the ELF header field 'e_machine'. See section "ElfDwarf scheme for canonical register numbers" for details.

`lsbOffset`

Type: `NumberU64`

Optional. `LSB` offset of this register in its parent register specified by `parentRscId`. Together with `bitWidth` this describes the bit range covered by this register field in its parent register. If `lsbOffset` is present, `parentRscId` must also be set. For logical child registers, on the other hand, it is valid to have just `parentRscId` set and `lsbOffset` not present. This indicates that

this register is a logical child register of its parent, not covering a simple consecutive bit range. This can be used to cleanly expose child registers that are distributed across several bit ranges in the parent registers, reordering and splitting bits arbitrarily. It can also be used to expose logical parts of a parent register that do not appear in the bits of the parent register at all.

The special value 2^{64}-1 can be used synonymously to a missing value. This is for cases where not specifying `lsboffset` is not possible, for example arrays of the same object signature or C ++.

Clients can safely ignore the value of `lsbOffset` and usually just treat it as part of the register description. Clients do not need to interpret `lsbOffset` in any way to read and/or write register values. The target instance takes care of putting the right bits into the right location.

`resetData`

Type: `NumberU64[]`

Optional. Reset value for a numeric register. This is the value to which the resource is set at hardware reset. This is informational only. It is up to the instance implementation to implement a correct reset behavior. Registers that do not have a defined reset value must not have a `resetData` field. The value is encoded right-aligned inside each `NumberU64` and little-endian in the array, the same format that is used for resource values used by `resource_read()` and `resource_write()`. Clients can safely ignore the value of `resetData` and usually just treat it as part of the register description.

`resetString`

Type: `String`

Optional. Reset value for string resource. See `resetData`.

`writeMask`

Type: `NumberU64[]`

Optional. Write mask. Bits set in this mask can be written. Other bits cannot be modified. This is informational only. It is up to the instance implementation to enforce the write mask and is not guaranteed by the interface. Clients must not enforce the write mask when writing the resource. The value is encoded right-aligned inside each `NumberU64` and little-endian in the array, the same format that is used for resource values used by `resource_read()` and `resource_write()`. Clients can safely ignore the value of `writeMask` and usually just treat it as part of the register description.

`breakpointSupport`

Type: `String`

Optional. Breakpoint functionality support. This indicates the mode(s) on which a breakpoint can be set for the register. '?' is unknown, '' is no support, 'r' is read only, 'w' is write only, 'rw' is support on both read and write events.

Related information

ElfDwarf scheme for canonical register numbers on page 77

6.6.18 ResourceGroupInfo

ResourceGroupInfo members:

cname

Type: `String`

Name of the resource group in the context of expressions and in scripts. This is a valid C identifier that is unique within this instance and that also does not overlap with resource `cname` fields. Both `name` and `cname` are primary keys to identify groups. Instance implementations derive the `cname` from `name` according to the rules specified for `ResourceInfo.cname` if it is not explicitly specified when defining a resource. Clients must handle violations of these rules gracefully, converting `cname` to a C identifier according to the rules specfified in `ResourceInfo.cname` (which leaves all valid C identifiers untouched).

In case of conflicts with other groups' `cnames` only the first group within the array returned by `resource_getListOfResourceGroups()` with a specific `cname` must be accessible. In case of a conflict with resource `cnames` the group `cname` must always take precedence.

description

Type: `String`

Optional. Description of the resource group. Can contain linefeeds.

name

Type: `String`

Short string identifying the resource group. This is unique within this instance and must not overlap with resource `name` fields. Both `name` and `cname` are primary keys to identify groups.

resourceList

Type: `NumberU64[]`

List of resource ids of the resources that belong to this group. Must not be empty. Each resource must be in at least one group, and can be in more than one group. The array defines the order of the resources in each group that clients must use when displaying the resources of a group.

6.6.19 ResourceInfo

ResourceInfo members:

bitWidth

Type: `NumberU64`

Size of the resource in bits. Must be 0 for type="string" and type="noValue" resources. Must be > 0 for all other types of resources.

cname

Type: `String`

Name of the resource in the context of expressions and in scripts. This is a valid C identifier. For top-level resources this must be unique within each resource group this resource belongs to. For child resources this must be unique within the parent resource. Instance implementations derive the `cname` from `name` according to the following rules if no explicit `cname` is specified when defining a resource:

- All non-C identifier chars are replaced with underscores.
- If the first char is a digit, an underscore is prepended.

Clients must handle violations of these rules gracefully, by converting `cname` to a C identifier according to the rules specified above (which leaves all valid C identifiers untouched). In case of conflicts with other resource `cnames` only the first resource within the array returned by `resource_getList()` with a specific `cname` must be accessible.

Child registers do not contain the `cnames` of their parents in their `cname`. Clients that need a hierarchical C identifier for a child register must prepend the `cnames` of all parent registers, separated with an underscore (for instance 'FLAGS_X'), to create a hierarchical `cname`. See also `name`.

description

Type: `String`

Optional. Description of the semantics of the resource. Might contain linefeeds.

enums

Type: `EnumElementInfo[]`

Optional. Array of `EnumElementInfo` objects which describe symbols for numeric resource values. Debuggers can display these symbols (and potentially their description) in addition to the numeric value.

format

Type: `String`

Optional. Iris-text-format. This allows a client to format the value of this resource and the values of other resources in this instance (regardless of hierarchy) in a specific way. The value of this resource is referred to by the `value` variable in the Iris-text-format string. The values of other resources in this instance are referred to by their cname, optionally prefixed by their group cname and a dot (resource name without group name has priority).

Clients must allow the user to select whether the format must be used (if present at all) or whether the plain numeric value must be displayed. Clients must prefer the format if present.

Resources that only pull together information from other resources and do not have any value on their own can set type="noValue" to make this clear. This can for example be used to format bitfields in a descriptive way.

Cache line tag: "Addr=%{value[31:12]}000 %{value[11]:(clean|dirty)}".

Conditional formatting is also possible.

name

Type: `String`

Display name of the resource. For registers, this must be the architectural register name if available. For top-level resources this must be unique within each resource group this resource belongs to. For child resources this must be unique within the parent resource. Clients must handle non-unique register names gracefully. They must always use the first resource in the array returned by `resource_getList()` in case of a conflict.

The resource group name is not part of this resource `name`.

Child resources (which have a `parentRscId` field) specify only their own name in the `name` and `cname` fields, not including the names of their parents. Clients that need a hierarchical name for a child register must prepend the names of all parent registers, separated with a dot, to get a hierarchical name (for instance 'FLAGS.X').

See also `cname` which is used in expressions and scripts.

parameterInfo

Type: `ParameterInfo`

Optional. Iff this is present, this resource represents a parameter. Parameters generally behave like normal resources and have some additional semantics attached to them, like being settable at init-time. This `ParameterInfo` object contains parameter specific meta information. It also acts as the `isParameter` switch.

parentRscId

Type: `NumberU64`

Optional. If this is present, this is a child resource (for instance a field in a register) and this field contains the resource id of its parent resource. The `name` and `cname` fields of child resources only contain the names of the child resources, not of the parent resources.

Child resources might, in turn, have child resources. The nesting depth is not limited, but instances are encouraged to expose only shallow hierarchies (usually only one level). Instances must not expose loops in the parent graph. Clients must handle the situation where an instance exposes a loop in the parent graph gracefully, for instance by ignoring any parent pointer that points to a child. Clients must display child resources in the order they appear in the array returned by `resource_getList()` underneath a parent.

If `parentRscId` is missing this means that this is a top-level resource (which might or might not have children). All children of a specific parent resource must be in the same group as the parent resource.

registerInfo

Type: `RegisterInfo`

Optional. Iff this is present, this resource represents a register. Registers typically correspond to architectural or device registers in the component and have some additional metadata found in the `registerInfo` object.

`rscId`

Type: `NumberU64`

Opaque resource id uniquely identifying the resource within the target instance. Used to read/write the resource. This is the primary key to identify a resource. The value 2^{64}-1 is defined to be an invalid `rscId`.

`rwMode`

Type: `String`

Optional. Either `r`, `w`, or `rw` for read-only, write-only, or read-write (default). This is a hint for the debugger or user about which accesses on this resource are supported architecturally. However, it is always allowed to issue `resource_read()` and `resource_write()` calls on all resources, regardless of their `rwMode`. This must not cause an error in the `resource_read()` or `resource_write()` return value. This might or might not cause errors in the `ResourceReadResult.error` array (`E_error_reading_write_only_resource`, `E_error_writing_read_only_resource`, `E_error_reading_resource`, `E_error_writing_resource`).

Ultimately, the instance implementation decides what happens for a read or a write. Writes to read-only resources can be silently ignored or can return `E_error_writing_read_only_resource` and reads of write-only resources must return a useful value, for example the value of an internal latch, or can return `E_error_reading_write_only_resource`. `noValue` resources should not report this field and clients should always ignore this field for `noValue` resources because they have no value associated with them.

`subRscId`

Type: `NumberU64`

Optional. Additional resource id according to an instance-specific scheme defined by the instance. This is not required to be unique within an instance, nor is it required to be present for every resource of an instance. This is usually just used internally in an instance to identify registers in register access functions and is rarely useful for clients.


Note

For register resources, address offsets and canonical register numbers, which both are also suitable to identify registers, must go into the RegisterInfo `addressOffset` or `canonicalRn` fields, respectively. `subRscId` uses a scheme that is private to an instance.

`tags`

Type: `ResourceTags`

Optional. Object containing extra meta information about a resource, for example whether a register is the PC or stack pointer, see the `ResourceTags` object. If this is missing, this has the

same semantics as specifying an empty `ResourceTags` object. This means the resource is not tagged with anything, which is usually the case for most resources of an instance.

type

Type: `String`

Optional. Either `numeric`, `numericSigned`, `numericFp`, `string`, or `noValue`. Default is `numeric`.

numeric

The resource contains a bit-pattern of `bitWidth` bits. Clients must display this as hex by default and allow users to explicitly switch to other formats, for example decimal or floating point. This is the usual type for most resources. All other resource types are exotic.

numericSigned

Exotic. Same as `numeric` but in addition this gives a hint to the client that this resource always contains a signed integer. This is usually used for parameters that represent a signed integer value.

numericFp

Exotic. Same as `numeric` but in addition this gives a hint to the client that this resource always contains an IEEE 754 floating-point value. This is usually only useful for pure floating-point resources. Clients must display this as a floating-point number by default and allow users to switch explicitly to hex and other formats. This must only be used for `bitWidth` 32 (float) and `bitWidth` 64 (double). Clients must treat other bitWidths as `numeric`.

string

Exotic. The resource contains an `ASCII` string. Targets can use this type as a fallback to display arbitrary information in the debugger, or as parameters that have a string value, like filenames. `bitwidth` must be 0 for string resources. This must not be used to expose arbitrary length binary data. To expose arbitrary length binary data consider using a memory space or a table if the data is structured.

noValue

Exotic. No numeric or string value is associated with this resource. If this resource has a `format` then clients must display this format, usually by pulling together numeric information from other resources. `bitwidth` must be 0 and `rwMode` should not be reported. Reading a `noValue` resource always delivers zero `NumberU64` units in `ResourceReadResult.data` and `ResourceReadResult.undefinedBits`. Writing a `noValue` resource is always silently ignored. Clients might or might not allow editing of `noValue` resources that have a format string. Resource breakpoints can be supported for `noValue` resources.

Related information

Iris-text-format on page 68

6.6.20 ResourceReadResult

ResourceReadResult members:

`data`

Type: `NumberU64[]`

List of numeric resource values read, in the order they were specified in the `rscIds` argument of the `resource_read()` function. The encoding of the value depends on the type:

`numeric`, 0<bitWidth<=64

NumberU64, value right-aligned in the lowest bits, zero-extended to 64 bits.

`numeric`, bitWidth>64

Sequence of N*NumberU64 in little-endian, last element right-aligned in the lowest bits, zero-extended to N*64 bits, N = floor((bitWidth+63)/64).

`numericSigned`

Same as numeric except that the value is sign-extended instead of zero-extended.

`numericFp`

Same as numeric.

`string`

Not present in this array. Occupies zero elements in this array.

`noValue`

Not present in this array. Occupies zero elements in this array. All numeric resources read have a value in this array (potentially a dummy value), regardless of whether the read operation failed or succeeded (regardless of whether there is an entry for a resource in the "error" array). The layout of the data array can be interpreted in the same way, just based on the layout of the `rscIds` array in the `resource_read()`, regardless of the contents of `error`. The length of this array depends on the number and width of all numeric resources read.

`error`

Type: `NumberU64[]`

Optional. List of errors reported by resources that could not be read. Each entry in the list occupies two array elements: rscId and errorCode. The entries are sorted in the order of the `rscIds` argument of `resource_read()`. Resources that were successfully read do not appear in this list. An empty or missing list means "no error". This list only contains errors that happen because the callee is unable to provide the resource value of an existing resource, for example architectural errors. It does not contain errors caused by the caller doing something wrong, for example `E_unknown_instance_id` or `E_unknown_resource_id`. These errors are returned by `resource_read()` instead. The errors that are most likely to occur in this list are:

`E_approximation`

The resource value could be read but is only an approximation in some sense, for example because the instance is not in a debuggable-state.

`E_value_not_available`

The resource value is currently not available and cannot even be approximated, for example because the instance is not in a debuggable-state.

`E_error_reading_write_only_resource` or `E_error_reading_resource (catch-all)`

These errors must be shown as information to the user, similar to undefined bits, not as a user or implementation error. Errors returned in this array are valid resource read results and thus resource_read() will return E_ok even if this array is non-empty.

`strings`

Type: `String[]`

Optional. List of string resource values read, in the order they were specified in the `rscIds` argument of the `resource_read()` function. If no string resources were read, this array is missing. All string resources have a string value in this array, regardless of whether the read operation failed or not. See `data`.

`undefinedBits`

Type: `NumberU64[]`

Optional. List of resource masks that indicate undefined bits. This array has the same layout and length as `data`, even if only a subset of the read resources support undefined bits. A 1-bit means that the value is undefined, in which case the corresponding bit in `data` is 0 and must be ignored by clients. Undefined bits are only reported by instances that support it and only for resources that support it. A missing array is equivalent to an array containing all zeros (all bits defined).

6.6.21 ResourceTags

ResourceTags members:

`isPc`

Type: `Boolean`

Optional. If present and True, this is the register that represents the address that is executed next of a CPU or code-executing component. At most one register must have this set to True. Debuggers use this to find out which instruction or line is to be executed next. The `isPc` and the `isPcSpaceId` resources together describe the next execution location.

`isSp`

Type: `Boolean`

Optional. If present and True, this is the stack pointer of a CPU. At most one register must have this set to True.

`isLr`

Type: `Boolean`

Optional. If present and True, this is the link register of a CPU. At most one register must have this set to True.

isFramePointer

Type: `Boolean`

Optional. If present and True, this is the frame pointer register of a CPU. At most one register must have this set to True.

isPcSpaceId

Type: `Boolean`

Optional. If present and True, this resource contains the memory space id for the PC and for the link register. At most one resource must have this set to True. The `isPc` and the `isPcSpaceId` resources together describe the next execution location.

isSpSpaceId

Type: `Boolean`

Optional. If present and True, this resource contains the memory space id for the stack pointer and frame pointer. At most one resource must have this set to True.

isInstructionCounter

Type: `Boolean`

Optional. If present and True, this resource is the instruction counter. The instruction counter counts executed instructions linearly from 0. This is not the PC.

isArchitectural

Type: `Boolean`

Optional. If present and True, this resource is an architectural register. An architectural register is a register that is mentioned in the architecture reference manual for an instance. Architectural registers must use their architectural name.

Examples of architectural registers are the general purpose registers, the PC, and the flags register of a core. Examples of non-architectural register resources are artificial resources of simulation components that enable or disable certain features, count simulation events, or allow access to internal state, and registers that represent architectural information in a (potentially more convenient) non-architectural format. There is however no hard line between architectural and non-architectural registers, for example for internal shadow registers present in hardware and mentioned in the technical reference manual if an architecture reference manual is missing.

This flag is informational and clients can use it to extract the subset of architectural registers of an instance. It must be treated like a part of the description of a resource.

6.6.22 ResourceWriteResult

ResourceWriteResult members:

`error`

Type: `NumberU64[]`

Optional. List of errors reported by resources that could not be written. Each entry in the list occupies two array elements: rscId and errorCode. The entries are sorted in the order of the `rscIds` argument of `resource_write()`. Resources that were successfully written do not appear in this list. An empty or missing list means "no error".

This list only contains errors that happen because the callee is unable to write the resource value of an existing resource, for example architectural errors. It does not contain errors caused by the caller doing something wrong, for example `E_unknown_instance_id` or `E_unknown_resource_id`. These errors are returned by `resource_write()` instead.

The errors that are most likely to occur in this list are `E_error_writing_read_only_resource`, `E_writing_init_time_parameter` (when trying to write an init-time parameter), and `E_error_writing_resource` (catch-all). These errors should be shown as information to the user, similar to undefined bits, not as a user or implementation error. Errors returned in this array are valid resource write results and thus`resource_write()` will return `E_ok` even if this array is non-empty.

6.7 Memory API

The memory interface allows you to access data in the memory spaces that an instance exposes. All memory spaces are assumed to be byte-addressable, in the sense that each address refers to a byte location.

Clients first query a list of available memory spaces and their meta information by calling `memory_getMemorySpaces()`. Each memory space is identified by a memory space id. Memory is read or written by using the `spaceId` and the `memory_read()` or `memory_write()` function. The other memory functions provide less common functionality, for example address translations and retrieving sideband information.

`$IRIS_HOME/Examples/Client/Memory/` contains an example client application that demonstrates how to use this API.

6.7.1 Memory accesses

The interface supports access widths that are a power of two bytes, most commonly one, two, four, or eight bytes, as specified in the `byteWidth` argument to `memory_read()` and `memory_write()`.

Instances are not required to support all access widths for all addresses. They can either return an error if elements could not be read or written or they can return zero for reads, and ignore writes.

All accesses must be naturally aligned, or `E_unaligned_access` is returned.

Memory locations are read from lower addresses to higher addresses. Accessing memory does not stop on read or write errors.

If the `count` argument to `memory_read()` or `memory_write()` is greater than one, instances can convert debug accesses covering multiple elements into burst accesses, if the bus supports it. Buses must break debug burst accesses into individual accesses transparently, for example when passing accesses to peripheral buses that do not support bursts. To reduce the function call overhead, clients should generally make the access count as large as possible.

6.7.2 Errors

Reading and writing memory can fail for various reasons, including data aborts, translation errors, unsupported `byteWidth` values, or reading past the end of the memory space.

Such errors do not cause the `memory_read()` or `memory_write()` function to return an error, but instead are reported in the `error` member of the `MemoryReadResult` or `MemoryWriteResult` return value.

Reads and writes specify a start address, an access width for each element (`byteWidth`), and a number of elements (`count`). The start address must be within the range supported by the memory space, in other words between `minAddr` and `maxAddr` of the memory space, or `E_address_out_of_range` is returned. However, the end address can be beyond the end of the memory space. In other words, *`address`*`+(byteWidth*count)-1` is not required to be within `minAddr` to `maxAddr`. Reads and writes must return an error in the `error` member of the result for all elements that exceed the memory space address range.

Target instances that do not expose any memory must return `E_function_not_supported_by_instance` for the `memory_*()` functions.

6.7.3 Endianness

The target instance is responsible for using the endianness that is specified in the memory space when writing values to memory.

8-bit, 16-bit, and 32-bit numbers are packed into `NumberU64` values with the lowest address starting at bit[0], in other words, little-endian, regardless of the endianness of the memory space. Values that are greater than or equal to 128 bits are packed into a sequence of `NumberU64` with the lowest bits first, little-endian, regardless of the endianness of the memory space.

6.7.4 Memory spaces

All memory spaces are considered to be orthogonal to each other.

`minAddr` and `maxAddr` do not indicate the start and end of memory blocks inside a memory space, but rather the smallest and largest addresses supported by a memory space. This interface has no representation for memory blocks inside a memory space. Memory spaces usually start at address zero.

6.7.5 Side effects

The side effects of reading and writing memory are as follows:

- If possible, component creators should ensure that memory accesses are side-effect free. Side-effect free reads are a prerequisite for non-intrusive debug, although they might not be possible due to bugs in target instance implementations or bridges into environments that do not support them.
- Writing memory should be as free of side effects as possible. In other words, it should cause just enough side effects to keep the target and system state consistent. For memory-mapped registers, the side effect should be the same as calling `resource_write()`.
- Reading from cached memory must not allocate into the cache or change the cache tag in any way. It must follow the cache hierarchy until a hit is found and return the data.
- Writing to cached memory must update all cache lines that hold the written memory location. It must write through to all cache levels including main memory, regardless of the allocation strategy of the cache. Write accesses must never allocate into the cache or change the cache tag in any way. Writes never set dirty bits of caches. Writes cannot cause a cache inconsistency, but they can remove cache inconsistencies.

Related information

resource_write() on page 83

6.7.6 Canonical memory space number scheme

All Arm® components implement the canonical memory space number scheme `arm.com/memoryspaces`.

It allows debuggers to programmatically select a specific translation regime. The semantics of some memory spaces depend on the Arm® architecture version and even on the configuration of EL3.

The following ids are defined for the `canonicalMsn` member of `MemorySpaceInfo`:

Table 6-4: Canonical memory space number scheme arm.com/memoryspaces

canonicalMsn (NumberU64)	Architecture and configuration	Name	Semantics and translation regime
`0x1000`	Arm®v8 EL3=AArch64	Secure Monitor	Virtual memory as seen by code running at EL3. This is always secure. This is virtual memory as configured by TCR_EL3.

canonicalMsn (NumberU64)	Architecture and configuration	Name	Semantics and translation regime
	Arm®v7, Arm®v8, EL3=AArch32	Secure Monitor	Virtual memory as seen by code running at PL0 or PL1 on the secure side. This is always secure. This is virtual memory as configured by TTBCR (secure).
	Arm®v6, Arm®v7	Secure	Virtual memory as configured by TTBCR (secure).
0x1001	Arm®v8 EL3=AArch64	Guest	Virtual memory as seen by code running at EL0 or EL1. This can be secure or non-secure. This is virtual memory as configured by TCR_EL1/TTBCR (non-secure). **Note:** Although this is the non-secure bank of TTBCR, this does not make accesses non-secure in this configuration.
	Arm®v7, Arm®v8, EL3=AArch32	Guest	Virtual memory as seen by code running at PL0 or PL1 on the non-secure side. This is always non-secure. This is virtual memory as configured by TTBCR (non-secure).
	Arm®v6, Arm®v7	Normal	This is virtual memory as configured by TTBCR (non-secure).
0x1002	Arm®v7, Arm®v8	NS Hyp	Virtual memory as seen by code running at EL2/PL2, for AArch64/AArch32. This is always non-secure. This is memory as configured by TCR_EL2/HTCR, for AArch64/AArch32.
0x1003	Armv5, Arm®v6, Arm®v7	Memory	Virtual memory. Cores and other components that do not have TrustZone®.
0x1004	Arm®v7, Arm®v8	Hyp App	Virtual memory as seen from EL0 (32 or 64) running under a hypervisor with HCR.TGE=1. This has stage1 implicitly disabled but is still translated by stage2.
0x1005	Arm®v8.1	Host	Virtual memory as seen from EL0 (32 or 64) and EL2 (64) with HCR.E2H=1 and HCR.TGE=1. This has stage1 controlled by TCR_EL2 and implicitly disables stage2.
0x10ff	All	Current	Virtual memory view of the current exception level, protection level, or mode. The translation regime used follows the current state of the CPU.
0x1100	Arm®v7, Arm®v8	IPA	IPA memory view translated by stage2 using the current security state of EL1.
0x1200	Arm®v6, Arm®v7, Arm®v8	Physical Memory (Secure)	Physical memory, secure world.
0x1201	Arm®v6, Arm®v7, Arm®v8	Physical Memory (Non Secure)	Physical memory, non-secure world.
0x1202	Armv5, Arm®v6, Arm®v7	Physical Memory	Physical memory. Cores and components that do not have TrustZone®.
0x1203	Armv9	Physical Memory (Root)	For models using the RME extension.
0x1204	Armv9	Physical Memory (Realm)	For models using the RME extension.

Note

- Entries in the Name column are for information only and are not binding. They reflect the names that are used by existing models. The purpose of the `canonicalMsn` is for clients to use it to find a memory space with specific semantics.

- Arm®v8 instances support the AArch64 and AArch32 modes at runtime for the memory spaces with `canonicalMsn` = `0x1000`, `0x1001`, and `0x1002`. These memory spaces should have the static properties of AArch64, with 64-bit wide virtual addresses.

6.7.7 Memory access attributes

The set of memory access attributes that are available depends on the target instance and the memory space within it. The supported attributes and their semantics are listed in the target instance documentation and are also provided by the `attrib` and `attribDefaults` members of `MemorySpaceInfo`.

However, there are typical classes of instances and memory spaces that expose the same set of attributes. The following tables list all possible memory attributes as a guideline for instance implementations.


Note

There are no attributes for generic storage components like RAM, ROM, flash, and other backing storage.

The translation regimes that are implemented by the CPU should be exposed as memory spaces. All virtually-addressed regimes should be exposed, if applicable. In addition, a physical view of the memory should be exposed as a memory space, if applicable.

See 6.7.6 Canonical memory space number scheme on page 98 for a list of canonical memory spaces. Each memory space has a different set of default values for these attributes, which often define the semantics of the memory space.

Table 6-5: attrib object for Arm CPU components in virtually-addressed regimes

Name	Type	Description
`privileged`	Boolean	Access is privileged.
`instruction`	Boolean	For reads, access is on the instruction side if True, or data side if False.
`user`	NumberU64	User signaling (AXI4).

Table 6-6: attrib object for Arm CPU components in physically-addressed regimes

Name	Type	Description
`nonSecure`	Boolean	Access is non-secure if True, or secure if False.
`type`	String	Device or normal memory type. Must be one of the following: • `"Device-nGnRnE"` (strongly-ordered). • `"Device-nGnRE"` (device). • `"Device-nGRE"` (v8-specific). • `"Device-GRE"` (v8-specific). • `"Normal"` (innerCacheability, outerCacheability, and shareability define the attributes).

Name	Type	Description
`innerCacheability`	String	Cacheability for the inner domain. Must be one of: • `"NC"` (Non-Cacheable). • `"WT"` (Write-Through). • `"WB"` (Write-Back). This is only relevant for `type=Normal` and ignored for other types. These attributes are only used for routing the debug transaction. Debug accesses on caches have special semantics. For `WT` and `WB` there are no allocation hints for debug accesses as debug accesses never allocate. For more information, see 6.7.9 Reading and writing through caches and buffers on page 102.
`outerCacheability`	String	Cacheability for the outer domain. See `innerCacheability`.
`shareability`	String	Shareability. Must be one of: • `"nsh"` (Non-Shareable). • `"ish"` (Inner Shareable). • `"osh"` (Outer Shareable). This is only relevant for `type=Normal` and is ignored for other types. **Note:** When both `innerCacheability` and `outerCacheability` are `NC`, `shareability` is ignored and is Outer Shareable.

6.7.8 Reading and writing memory

The semantics of reading memory are *peek* rather than *bus read*. The semantics of writing memory are *poke* rather than *bus write*.

When reading, data is transferred in the `data` member of the `MemoryReadResult` object returned by `memory_read()` and when writing, data is transferred in the `data` argument of the `memory_write()` function. Both `data` fields use the same format to encode the data being transferred, see the documentation of `memory_write()` or `MemoryReadResult`.

Examples

These examples show how various `byteWidth` elements are packed into `NumberU64` elements.

All these examples are correct for big-endian and little-endian target memory and for big-endian and little-endian host memory. The representation is independent of the target or host endianness.

byteWidth=1

Reading 8 bytes with values 0x11, 0x22, 0x33, 0x44, 0x55, 0x66, 0x77, 0x88:

```
data[0] = 0x8877665544332211
```

byteWidth=2

Reading 4 16-bit words with values 0x1110, 0x2120, 0x3130, 0x4140:

```
data[0] = 0x4140313021201110
```

byteWidth=4

Reading 2 32-bit words with values 0x13121110, 0x23222120:

```
data[0] = 0x2322212013121110
```

byteWidth=8

Reading 1 64-bit word with value 0x8877665544332211:

```
data[0] = 0x8877665544332211
```

byteWidth=16

Reading 1 128-bit word with value 0x1f1e1d1c1b1a19181716151413121110:

```
data[0] = 0x1716151413121110, data[1] = 0x1f1e1d1c1b1a1918
```

6.7.9 Reading and writing through caches and buffers

This information applies to all types of buffer, for example caches, write buffers, and temporary data buffers.

Reads through a CPU component with caches must return dirty cache data and data in write buffers, if appropriate (programmer's view). The memory component can have its own memory view, but with physical addresses. Reads never change any cache state, for example they never allocate or flush. `memory_read()` means peek rather than bus read, for non-intrusive observation. Reads of any cache or buffer must return the data that an architectural read would see. Reads usually follow the same path as architectural reads.

Writes through a CPU component with caches must write the data through to all caches and to main memory, regardless of any write through policy or allocation policy. The data, but not the metadata, of write buffers and any other temporary buffers containing memory data, whether for read or write, must be updated, even data that architecturally cannot be modified. Writes only update data, not tags or metadata. Writes never allocate and never update the dirty bit of lines. Clean data is updated everywhere, and is therefore inherently clean after the write. Dirty data is also updated everywhere and so might no longer be dirty, or in other words different, after the write.

Writes on any cache and buffer must update all known locations that hold this data. Writes are usually very different from architectural writes.

The sequence `memory_write(address=A, data=memory_read(address=A))` has the side effect of propagating the programmer's view value of address A into all caches, buffers and into main memory.

6.7.10 Address translation

The `memory_translateAddress()` function is used to translate an address in one memory space into an address in another memory space. A common example is to convert a virtual address into a physical address.

A client can get a list of useful and supported translations by calling `memory_getUsefulAddressTranslations()`. It does not necessarily return all supported translations, but all returned translations are guaranteed to be supported by `memory_translateAddress()`.

Implementing `memory_getUsefulAddressTranslations()` is optional, even when `memory_translateAddress()` is implemented.

Address translation is usually only supported for specific pairs of memory spaces and only in specific directions. If the requested translation is not supported, `E_unsupported_translation` is returned. A translation might fail even if it is supported, for example because a certain address is not mapped in the output memory space. In this case, the returned `address` array is empty.

Clients can derive a short and consistent description for each supported translation by using the names of the memory spaces, for example "*memspace_name_in* -> *memspace_name_out*".

6.7.11 Memory sideband information

Instances can provide sideband information for addresses in a memory space using `memory_getSidebandInfo()`. GUIs can display this information in a tooltip when the user hovers over a memory cell, for example.

The following table describes all the sideband information fields that an instance might return in `memory_getSidebandInfo()`:

Table 6-7: Sideband information fields

Member	Type	Description
`regionStart`	`NumberU64`	The sideband information in this Object is valid for all addresses in the range `regionStart` to `regionEnd`, if they are present. However, there is no claim that this region is maximized, in other words, that it could not be further extended. Therefore, the model can return the page limits of a virtual page without looking at adjacent pages. If `regionStart` or `regionEnd` are missing, the sideband information is only valid for the requested address. The requested address is in the range `regionStart` to `regionEnd`.
`regionEnd`	`NumberU64`	End of the region for which the sideband information is valid.
`physicalAddress`	`NumberU64`	Physical address corresponding to the requested address.
`ipa`	`NumberU64`	Intermediate physical address corresponding to the requested address.
`noExecute`	`Boolean`	If `True`, the requested address cannot be used to execute code.
`ext_<Info>`	`Value`	Components can put arbitrary information here using the `ext_` prefix. Aspects that are supported consistently across multiple components can be added to this table in the future, without the `ext_` prefix.

6.7.12 memory_getMemorySpaces()

Gets a list of all memory spaces and their static information.

Arguments

instId

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

`MemorySpaceInfo[]`

List of `MemorySpaceInfo` Objects. Can be empty. If so, no memory can be read or written on this instance.

Errors

- `E_unknown_instance_id`.

6.7.13 memory_getSidebandInfo()

Gets sideband information for a specific memory address of a specific memory space.

Arguments

address

Type: `NumberU64`

Addresses to get sideband information for.

attrib

Type: `Map[String]Value`

Optional. Transaction attributes for the memory access. See `memory_read()` for details. The attributes might or might not be relevant to the returned sideband information.

instId

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

request

Type: `String[]`

Optional. If present, this specifies which sideband information fields must be filled in the return value. It can contain any subset of the field names. This can be used to suppress filling in members that are expensive to produce. The instance is free to fill in more members than

were requested. Unknown members are silently ignored and are not present in the result. If this is missing, all supported sideband information must be returned.

`spaceId`

Type: `NumberU64`

Opaque number uniquely identifying the memory space.

Return value

`Map[String]Value`

Object that contains the sideband information for the specified address.

Errors

- `E_unknown_instance_id`.
- `E_unknown_memory_space_id`.
- `E_address_out_of_range`.
- `E_unaligned_access`.
- `E_unsupported_attribute_name`.
- `E_unsupported_attribute_value`.
- `E_unsupported_attribute_combination`.

6.7.14 memory_getUsefulAddressTranslations()

Returns a list of useful address translations that are supported by `memory_translateAddress()`. It does not necessarily return all supported translations, but all returned translations are guaranteed to be supported by `memory_translateAddress()`.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

`MemorySupportedAddressTranslationResult[]`

List of useful and supported address translations. See `MemorySupportedAddressTranslationResult`.

Errors

- `E_unknown_instance_id`.

6.7.15 memory_read()

Reads data from the target's memory view of a given memory space. The semantics are `peek` rather than 'bus read'.

Arguments

`address`

Type: `NumberU64`

Start reading at this address. Must be within the range `minAddr` to `maxAddr` inclusive in the specified memory space, else `E_address_out_of_range` is returned. Must be naturally aligned according to `byteWidth`.

`attrib`

Type: `Map[String]Value`

Optional. Transaction attributes for the memory access. The attributes are represented as key/value pairs as members in the Object. All specified attributes override the respective default attributes of the selected memory space. A subset of all supported attributes can be specified, in which case only the specified attributes are overridden.

Specifying an empty object or omitting the `attrib` argument causes the default attributes of the selected memory space to be used. Specifying an unsupported or unknown attribute name results in an `E_unsupported_attribute_name` error. Specifying an unsupported or invalid value for a valid attribute name results in an `E_unsupported_attribute_value` error. Specifying an invalid combination of attributes (also with respect to default attributes that were not overridden) can result in `E_unsupported_attribute_combination`, but target instances are not obliged to detect all invalid attribute combinations.

The set of attributes supported by a memory space depends on the memory space and the target instance. The `MemorySpaceInfo` publishes all attributes and their default values in the `attrib` and `attribDefaults` fields.

`byteWidth`

Type: `NumberU64`

Access width in bytes. Must be a power of two (1, 2, 4, 8 ...), else `E_data_size_error` is returned. Accesses that fail because of a valid but unsupported access width record the error address in the `error` member of the result.

`count`

Type: `NumberU64`

Number of elements of `byteWidth` to read, starting at `address` and increasing the address for each element by `byteWidth`. Must be > 0, else `E_data_size_error` is returned. Models can transport accesses as bursts or individually, depending on the capabilities of the bus that is used internally.

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

spaceId

Type: `NumberU64`

Opaque number uniquely identifying the memory space.

Return value

`MemoryReadResult`

Object that contains the data and optional error indication for each element that was read. See `MemoryReadResult`.

Errors

- `E_unknown_instance_id`.
- `E_unknown_memory_space_id`.
- `E_data_size_error`.
- `E_address_out_of_range`.
- `E_unaligned_access`.
- `E_unsupported_attribute_name`.
- `E_unsupported_attribute_value`.
- `E_unsupported_attribute_combination`.

6.7.16 memory_translateAddress()

Translates an address of one memory space into an address of another memory space. This function is useful if the two memory spaces are associated with two different translation regimes, for example virtual and physical memory. A common example is to convert a virtual address into a physical address.

Arguments

instId

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

address

Type: `NumberU64`

Input address.

outSpaceId

Type: `NumberU64`

Desired output memory space. The address is translated from `spaceId` to `outSpaceId`.

spaceId

Type: `NumberU64`

Opaque number uniquely identifying the memory space of the input address.

Return value

`MemoryAddressTranslationResult`

Object that contains the result of the address translation. This is either the output address or an error. See `MemoryAddressTranslationResult`.

Errors

- `E_unknown_instance_id`.
- `E_unknown_memory_space_id`.
- `E_address_out_of_range`.
- `E_unsupported_translation`.

6.7.17 memory_write()

Writes data into the target's memory view of a given memory space. The semantics are poke rather than bus write.

Arguments

address

Type: `NumberU64`

Start writing bytes at this address. Must be within `minAddr` and `maxAddr` of the memory space.

attrib

Type: `Map[String]Value`

Optional. Transaction attributes for the memory access. The attributes are represented as key/value pairs as members in the object. All specified attributes override the respective default attributes of the selected memory space. A subset of all supported attributes can be specified, in which case only the specified attributes are overridden.

Specifying an empty object or omitting the `attrib` argument causes the default attributes of the selected memory space to be used. Specifying an unsupported or unknown attribute name results in an `E_unsupported_attribute_name` error. Specifying an unsupported or invalid value for a valid attribute name results in an `E_unsupported_attribute_value` error. Specifying an invalid combination of attributes (also with respect to default attributes that were not overridden) can result in `E_unsupported_attribute_combination`, but target instances are not obliged to detect all invalid attribute combinations.

The set of attributes supported by a memory space depends on the memory space and the target instance. The `MemorySpaceInfo` publishes all attributes and their default values in the `attrib` and `attribDefaults` fields.

byteWidth

Type: `NumberU64`

Access width in bytes. Must be 1, 2, 4, or 8, else `E_data_size_error` is returned. Accesses that fail because of a valid but unsupported access width record the error address in the `error` member of the result.

count

Type: `NumberU64`

Number of elements of `byteWidth` to write, starting at `address` and increasing the address for each element by `byteWidth`. Must be > 0, else `E_data_size_error` is returned. Models can transport accesses as bursts or individually, depending on the capabilities of the bus that is used internally.

data

Type: `NumberU64[]`

Data elements written to ascending addresses, packed into `NumberU64` types such that the lowest address is in the lowest bits:

byteWidth=1

8 bytes per `NumberU64`, lowest address in bits[7:0].

byteWidth=2

4 x 16-bit values per `NumberU64`, lowest address in bits[15:0].

byteWidth=4

2 x 32-bit values per `NumberU64`, lowest address in bits[31:0].

byteWidth=8

1 `NumberU64` per address.

byteWidth=16

2 `NumberU64` per address, lowest bits in the first one.

byteWidth=N

N/8 `NumberU64` per address, lowest bits in the first one. Elements of byteWidth >= 2 are read with the endianness of the memory space inside each element, but elements are stored with the lowest bits inside each `NumberU64` (for byteWidth < 8) and with the lowest bits first in sequences of `NumberU64` (for byteWidth > 8). Elements that caused an error while writing record the error address in the `error` member in the result. Padding bytes (unused high bits) must be set to zero. The array must have exactly N = floor((byteWidth*count+7) / 8) `NumberU64` elements (N is always >= 1).

instId

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

spaceId

Type: `NumberU64`

Opaque number uniquely identifying the memory space.

Return value

`MemoryWriteResult`

Object that contains error information. See `MemoryWriteResult` for details.

Errors

- `E_unknown_instance_id`.
- `E_unknown_memory_space_id`.
- `E_data_size_error`.
- `E_address_out_of_range`.
- `E_unaligned_access`.
- `E_unsupported_attribute_name`.
- `E_unsupported_attribute_value`.
- `E_unsupported_attribute_combination`.

6.7.18 MemoryAddressTranslationResult

MemoryAddressTranslationResult members:

address

Type: `NumberU64[]`

List of addresses in memory space `outSpaceId` that correspond to `address` in `spaceId`. If this array is empty then `address` is not mapped in `outSpaceId`. If the array contains exactly one element then the mapping is unique. If it contains multiple addresses then `address` is accessible in the same way under all of these addresses in `outSpaceId`.

6.7.19 MemoryReadResult

MemoryReadResult members:

data

Type: `NumberU64[]`

Data elements read from ascending addresses, packed into `NumberU64` types such that the lowest address is in the lowest bits:

byteWidth=1

8 bytes per `NumberU64`, lowest address in bits[7:0].

byteWidth=2

4 x 16-bit values per `NumberU64`, lowest address in bits[15:0].

byteWidth=4

2 x 32-bit values per `NumberU64`, lowest address in bits[31:0].

byteWidth=8

1 `NumberU64` per address.

byteWidth=16

2 `NumberU64` per address, lowest bits in the first one.

byteWidth=N

N/8 `NumberU64` per address, lowest bits in the first one. Elements of byteWidth >= 2 are read with the endianness of the memory space inside each element, but elements are stored without endianness inside each `NumberU64` (for byteWidth < 8) and with the lowest bits first in sequences of `NumberU64` (for byteWidth > 8). Elements that could not be read have a value of zero and their address is recorded in the `error` array. Padding bytes (unused high bits) are always zero. Array length is always exactly N = floor((byteWidth*count+7) / 8) `NumberU64` elements (N is always >= 1).

error

Type: `NumberU64[]`

Optional. List of addresses and `E_*` error codes for memory locations that could not be read. Each entry in the list occupies two array elements: address and then errorCode. This only returns errors that happen because the callee is unable to provide the memory value, for example architectural errors. This does not return errors that are caused by the caller doing something wrong, for example `E_unknown_memory_space_id`. These errors are returned by `memory_write()` instead. The errors that are most likely to occur in this list are:

E_error_memory_abort

The memory value could not be read because the memory operation was aborted by the memory subsystem. A load instruction from this address would have also failed. The corresponding bits in `data` must be ignored.

E_approximation

The memory value could be read but is only an approximation, for example because one of the instances is not in a debuggable-state. A load instruction from this address would have succeeded.

E_value_not_available

The memory value is currently not available and cannot even be approximated. A load instruction from this address would have succeeded. This can happen for example when an instance is not in a debuggable-state and a `TLB` entry is updated half-way. Addresses that failed with an error might or might not have been updated. Addresses that did not fail with an error also might or might not have been updated (for example, a read-only register that silently ignores writes, ROM).

6.7.20 MemorySpaceInfo

MemorySpaceInfo members:

attrib

Type: `Map[String]AttributeInfo`

Optional. Attributes of this memory space. Object that maps attribute names onto `AttributeInfo` objects, which contain their type and description. The attribute names are the same as used for the `attrib` argument of `memory_read()` and `memory_write()`. It is valid for a memory space and instance not to define any attributes, in which case this member might be missing. The actual set of attributes and their semantics are described in the documentation of the target instance.

attribDefaults

Type: `Map[String]Value`

Optional. Object that maps attribute names in this memory space to their default values. The type of the default value must be valid for `memory_read()` and `memory_write()` and must be consistent with the type advertised in `attrib`.

Some memory spaces use dynamic values for some or all attributes, for example attributes derived from the current state of a CPU. Attributes that are taken from the current dynamic state are missing in `attribDefaults`. Thus an empty or missing `attribDefaults` object indicates that all attributes are dynamic.

The value of `attribDefaults` can be passed directly into the `attrib` argument of `memory_read()` and `memory_write()`. Doing so has the same effect as specifying no `attrib` argument or an empty `attrib` object, because this overrides the defaults with the defaults.

canonicalMsn

Type: `NumberU64`

Optional. Canonical memory space number. This number adheres to the scheme described by the `memory.canonicalMsnScheme` member returned by `instance_getProperties()`.

description

Type: `String`

Optional. Description of the memory space. Might contain linefeeds.

endianness

Type: `String`

Optional. Hint for clients about which endianness to use to interpret wider-than-byte memory values. Possible values:

little

Little-endian format (default when endianness is not present).

big
: Big-endian format (also sometimes called "byte invariant big endian format").

be32
: big-endian word invariant endianness

variable
: The endianness can change at runtime. The client determines the current endianness by other means if it can, for example by reading a register.

none
: The memory space does not define any endianness. Clients must use little-endianness by default and allow the user to select the endianness. Regardless of the value of the endianness field, clients must allow the user to override the endianness when displaying memory.

maxAddr

Type: `NumberU64`

Optional. Maximum address in this address space (inclusive). Default is 2^{64}-1. Must be >= `minAddr`.

minAddr

Type: `NumberU64`

Optional. Minimum address in this address space (inclusive). Default is 0. It is very exotic to have a memory space with `minAddr` != 0. Memory spaces must not represent blocks of memory.

name

Type: `String`

Short string identifying the memory space. If available, this is the architectural memory space name.

spaceId

Type: `NumberU64`

Opaque memory space id uniquely identifying the memory space within the target instance. Used to read and write memory locations.

supportedByteWidths

Type: `NumberU64`

Optional. Set of supported byteWidth values supported by `memory_read()` and `memory_write()` for this memory space. This is the outer envelope of all supported byteWidth values for all addresses for read and write. Some addresses and/or read and/or write may only support a subset of these byteWidths. This is a bit mask where bit N==1 means that byteWidth 1 << N is supported. For example: 31 means that byteWidths 1, 2, 4, 8 and 16 are supported.

6.7.21 MemorySupportedAddressTranslationResult

MemorySupportedAddressTranslationResult members:

`description`

Type: `String`

Description of this translation. This also explains artefacts, for example non-uniqueness and unsupported cases.

`inSpaceId`

Type: `NumberU64`

Input memory space id.

`outSpaceId`

Type: `NumberU64`

Output memory space id.

6.7.22 MemoryWriteResult

MemoryWriteResult members:

`error`

Type: `NumberU64[]`

Optional. List of addresses and `E_*` error codes for memory locations that could not be written. Each entry in the list occupies two array elements: address and then errorCode. This only returns errors that happen because the callee is unable to write the memory value, for example architectural errors. This does not return errors that are caused by the caller doing something wrong, for example `E_unknown_memory_space_id`. These errors are returned by `memory_read()` instead. The errors that are most likely to occur in this list are:

`E_error_memory_abort`

The memory value could not be written because the memory operation was aborted by the memory subsystem. A store instruction to this address would have also failed.

6.8 Disassembly API

Some instances can provide a disassembled view of their memory. Because disassembly is just a form of `memory_read()`, a memory space id must be provided.

The main interface function is `disassembler_getDisassembly()`, which offers a disassembled view of a memory location. The other disassembler functions offer more exotic functionality, for example querying disassembler modes and disassembling individual opcodes.

Target instances that do not support disassembly must return `E_function_not_supported_by_instance` for the `disassembler_*()` functions.

`$IRIS_HOME/Examples/Client/Disassembly/` contains an example client application that demonstrates how to use this API.

Related information

memory_read() on page 105

6.8.1 Disassembling chunks of memory

Use the `disassembler_getDisassembly()` function to disassemble a chunk of memory.

This function returns lines of disassembled instructions. The number of lines that are returned is specified by the `count` argument. The amount of memory that a chunk represents depends on the encoding of the instruction set being disassembled. The address of the next instruction following a disassembled chunk is given by the `address` field of the last `DisassemblyLine` element of the result value. This function returns `count` lines, unless an error occurred.

This function can return the following errors:

- When `address` is out of the range `minAddr` to `maxAddr` for the memory space, it returns `E_address_out_of_range`.
- When reading past `maxAddr`, which is the end of the memory space, no error is returned. In this case, fewer disassembly lines than requested are returned.
- When the memory subsystem cannot read a byte value, for example due to a permission fault or a translation table fault, no error is returned. In this case, the `opcode` string in `DisassemblyLine` must be empty and the disassembly string must have the format `"(error: foo)"` where *`foo`* describes the error that occurred. Disassembly must continue by increasing the address by one unit of the alignment constraint until `count` elements are returned.

6.8.2 Disassembling opcodes

Instead of retrieving the disassembly for a specific memory location, it is possible to retrieve the disassembly for an individual opcode, using the `disassembler_disassembleOpcode()` function.

Disassembling an opcode never fails because of an invalid opcode. Instead, `opcode=""` and `disass="`*`hex_constant_definition_in_assembler_syntax`*`"` are returned in the `DisassemblyLine` object.

6.8.3 disassembler_disassembleOpcode()

Retrieves the disassembly for an individual opcode.

Arguments

`address`

Type: `NumberU64`

Context for the disassembly. Address of the opcode, for example for addresses of relative branches. If unknown, specify 0.

`context`

Type: `Object`

Optional. More context information for the disassembly. The contents of this object depend on the instance and the selected mode. When this is missing, reasonable defaults are to be used.

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`mode`

Type: `String`

Mode name to use for disassembling. This must either be one of the modes returned by `disassembler_getModes()` or the special mode `Current` which selects the mode currently returned by `disassembler_getCurrentMode()`.

`opcode`

Type: `NumberU64[]`

Opcode to disassemble, in 64-bit units in little-endian format.

Return value

`DisassemblyLine`

`DisassemblyLine` object containing the disassembly.

Errors

- `E_unknown_instance_id`.
- `E_unknown_disassembly_mode`.

6.8.4 disassembler_getCurrentMode()

Gets a hint from the target about which disassembly mode is best suited to disassemble the memory around the current PC location of the target. It has similar semantics to `resource_read()`. Debuggers can use this function to implement an `auto` mode which always displays disassembly in the current mode.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

`String`

Name of the current mode. This is the mode that is best suited to disassemble the current PC location. If the target does not support disassembly, this is an empty string.

Errors

- `E_unknown_instance_id`.

6.8.5 disassembler_getDisassembly()

Disassembles a chunk of memory.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`address`

Type: `NumberU64`

Start disassembling at this address. Must be within `minAddr` and `maxAddr` in the memory space. If the set of implemented architectures has strong per-instruction alignment requirements which are not met by `address`, `E_unaligned_access` must be returned.

`attrib`

Type: `Object`

Optional. Transaction attributes for the memory read access. The attributes are represented as key/value pairs as members in the object. See `memory_read()` for details.

`count`

Type: `NumberU64`

Maximum number of lines to disassemble. Must be > 0.

`maxAddr`

Type: `NumberU64`

Optional. Stop disassembling at or shortly after `maxAddr`. One element is returned that is >= `maxAddr`. In any case, no more than `count`+1 elements are returned.

`mode`

Type: `String`

Mode name to use for disassembling. This must either be one of the modes returned by `disassembler_getModes()` or the special mode `Current` which selects the mode returned by `disassembler_getCurrentMode()`.

spaceId

Type: `NumberU64`

Opaque number uniquely identifying the memory space.

Return value

`DisassemblyLine[]`

List of `DisassemblyLine` Objects containing the disassembly. The length of this array is one element more than the number of returned disassembly lines ([0 to `count`] + 1). A trailing `DisassemblyLine` element is appended which only has a valid address member containing the next address to start disassembling from. The `opcode` and `disass` members are invalid, and might be missing, for this last element.

Errors

- `E_unknown_instance_id`.
- `E_unknown_memory_space_id`.
- `E_data_size_error`.
- `E_unknown_disassembly_mode`.
- `E_address_out_of_range`.
- `E_unaligned_access`.
- `E_unsupported_attribute_name`.
- `E_unsupported_attribute_value`.
- `E_unsupported_attribute_combination`.

6.8.6 disassembler_getModes()

Retrieves a list of supported disassembly modes. The mode name string is used to identify the disassembly mode.

Arguments

instId

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

`DisassemblyMode[]`

List of supported disassembly modes. Empty if the target does not support disassembly. If the target supports disassembly, this must contain at least one element. See `DisassemblyMode`.

Errors

- `E_unknown_instance_id`.

6.8.7 DisassemblyLine

DisassemblyLine members:

`address`
: Type: `NumberU64`

  Start address of this disassembled instruction.

`disass`
: Type: `String`

  Disassembly of this instruction. It is a single line without linefeeds, or multiple lines with linefeeds (LF, 0xa) but without a trailing linefeed. The returned string does not contain any symbols.

`opcode`
: Type: `String`

  Opcode of the disassembled instruction in hexadecimal format, using uppercase letters, without the leading 0x. It can contain spaces for readability. Clients are suggested to display the opcode string as returned by the target. It is a single line without linefeeds, or multiple lines with linefeeds (LF, 0xa) but without a trailing linefeed.

6.8.8 DisassemblyMode

DisassemblyMode members:

`description`
: Type: `String`

  Description of this disassembly mode.

`name`
: Type: `String`

  Short name identifying the disassembly mode.

6.9 Tables API

The tables interface allows an instance to expose an ordered series of records that all have the same fields.

Clients first call `table_getList()` to get a list of tables exposed by the instance. Then they call `table_read()` or `table_write()` to read or write the contents of the table cells.

This interface can be used to expose arbitrary information in tabular form. If it is more appropriate to represent the information as a resource, memory space, or disassembly, they should be used instead, because they contain semantic information.

Table rows are accessed by a densely allocated index. Each index uniquely corresponds to one table row. So, for example, index range 4-8 is 5 table rows.

Information that has a non-dense key, for example addresses, or that uses non-unique keys, for example addresses in translation tables, can expose this non-dense or non-unique key as a column and hide the index column. Then the index becomes an opaque id of a display slot.

As for resources and memory, the semantics are *peek* rather than *bus read* and *poke* rather than *bus write*, and reads and writes should be as side-effect free as possible.

6.9.1 Table cell types

The following types are allowed in table cells and all clients must support them:

- `String`
- `NumberU64`
- `NumberS64`
- `Boolean`
- `NumberU64[]`

`NumberU64[]` is used to represent binary data which exceeds 64 bits, for example cache line data.

The cell values returned or specified must be consistent with the cell type specified in the `TableColumnInfo`. The `NumberU64[]` in a column has the same length for all rows. The length is specified in the `TableColumnInfo`. Clients must handle inconsistent types gracefully.

6.9.2 table_getList()

Gets the static meta information of all tables exposed by an instance. This information can be used to retrieve the actual volatile data and render this data in a client in a suitable form.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

`TableInfo[]`

List of tables that are exposed by this instance. The client must honor the order of this list when displaying a list of tables. See `TableInfo`.

Errors

- `E_unknown_instance_id`.

6.9.3 table_read()

Reads data from a table in order to display it to the user. The semantics are `peek` rather than 'bus read'. This must be as free of side effects as possible.

Arguments

`count`

Type: `NumberU64`

Optional. Number of records to read, starting at `index`. Default is 1. The index `index+count-1` must be in the range minIndex to maxIndex, else `E_index_out_of_range` is returned.

`index`

Type: `NumberU64`

The row number from which to start reading. This must be in the range minIndex to maxIndex, else `E_index_out_of_range` is returned.

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`tableId`

Type: `NumberU64`

Opaque table id of the table to read from.

Return value

`TableReadResult`

List of table records that were read from the table. This is an array even if only one record was read. The size of the array is always the same as `count`. See `TableReadResult`.

Errors

- `E_unknown_instance_id`.
- `E_unknown_table_id`.
- `E_index_out_of_range`.

6.9.4 table_write()

Writes individual fields in individual table records. The semantics are `poke` rather than 'bus write'. This must be as free of side effects as possible while keeping all simulation state consistent.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`records`

Type: `TableRecord[]`

List of table records to be written. This is an array even if only one record is written. The size of the array determines how many records are written. It is valid to specify a subset of the values of a record to write a subset of table cells, potentially only one.

`tableId`

Type: `NumberU64`

Opaque table id of the table to write to.

Return value

`TableWriteResult`

`An` object that contains errors, if any occurred when writing cells. See `TableWriteResult`.

Errors

- `E_unknown_instance_id`.
- `E_unknown_table_id`.
- `E_index_out_of_range`.

6.9.5 TableCellError

TableCellError members:

errorCode

Type: `NumberS64`

Numeric `E_*` error code.

index

Type: `NumberU64`

Index in table (row number).

name

Type: `String`

Column name (field name) as in `TableColumnInfo`.

6.9.6 TableColumnInfo

TableColumnInfo members:

description

Type: `String`

Description of the record field, describing the semantics of the record fields in free form. Can contain linefeeds.

format

Type: `String`

Optional. Iris-text-format. The value of a cell is referred to by the `value` variable in the Iris-text-format string. The values of other cells are referred to by their column title, and the values of resources in the same instance are referred to by their resource name optionally prefixed by a resource group name and a dot.

formatLong

Type: `String`

Optional. Iris-text-format specification when displaying the value in textual form. Can contain multiple lines and must be self-descriptive. This is intended to be displayed for example in bubble help when hovering over a table cell. Must be present iff `formatShort` is present.

formatShort

Type: `String`

Optional. Iris-text-format specification when displaying the value in textual form. Ignored for type `String`. Must only be a single line and must be short. This is intended to be displayed in

a table cell. Values are referred to by their column `name`. The index can be referred to by the `index` variable in the Iris-text-format string.

`name`

Type: `String`

Column title and record field name. This must be a short capitalized string uniquely identifying the column in the table.

`rwMode`

Type: `String`

Optional. Either "r" or "rw" for read-only or read-write (default). Clients must not try to write to read-only locations. Components must silently ignore writes to read-only locations.

`bitWidth`

Type: `NumberU64`

The interpretation of `bitWidth` depends on the value of `type`:

`NumberU64`, `NumberS64`

Size of the value in bits. The actual value is always zero-extended or sign-extended to 64 bits. This is the number of bits that are relevant to the user.

`NumberU64[]`

Size of the value in bits. The encoding is the same as for resources. The least significant bit is in bit[0] of the first `NumberU64`, the following `NumberU64` values contain the more significant bits (little-endian encoding with 64-bit quantities).

`Boolean`

`bitWidth` must be 1.

`String`

`bitWidth` must be 0 and must be ignored by clients.

`type`

Type: `String`

Value type of this record field (of the table cells in this column). Must be one of the following:

- `NumberU64`.
- `NumberS64`.
- `NumberU64[]`.
- `Boolean`.
- `String`.

Related information

Iris-text-format on page 68

6.9.7 TableInfo

TableInfo members:

`columns`

Type: `TableColumnInfo[]`

List of meta information for the columns in the table. This describes the fields in each record. The order in this list must be preserved by clients when displaying information.

`description`

Type: `String`

Description of the table, describing the semantics of the table in free form. Can contain linefeeds.

`formatLong`

Type: `String`

Optional. Global Iris-text-format. Long version of `formatShort` intended to be displayed in a bubble help when hovering over a table row. This must be specified iff `formatShort` is specified.

`formatShort`

Type: `String`

Optional. Global Iris-text-format. If present, clients must format the data of each row according to this format and must not (by default) show the individual columns. This short variant must be single line and is intended to be displayed in the table cells. Values are referred to by their column `name`. The index can be referred to by `index`. If missing, the table is shown as specified in `columns`.

`indexFormatHint`

Type: `String`

Optional. Hint for clients on how to display the index of a record. If present this must be one of the following:

`hide`

Hide the numeric index of records. Display the first column as row index.

`dec`

Display the row index preferably in decimal (but allow the user to override this).

`hex`

Display the row index preferably in hexadecimal (but allow the user to override this). This is useful if the index represents an address-like entity. Default is "hex".

`maxIndex`

Type: `NumberU64`

Optional. Maximum row index (inclusive). If the number of records is not known statically this must be set to 2^{64}-1. It is valid to set this to very high numbers such as 2^{64}-1. Clients must not blindly try to retrieve all rows of a table. Default is 2^{64}-1.

minIndex

Type: `NumberU64`

Optional. Minimum row index (inclusive). This is usually 0. Default is 0.

name

Type: `String`

Name of the table. This must be a short string uniquely identifying the table in the instance.

tableId

Type: `NumberU64`

Opaque table id used to read and write table contents.

Related information

Iris-text-format on page 68

6.9.8 TableReadResult

TableReadResult members:

data

Type: `TableRecord[]`

The actual data read from the table.

error

Type: `TableCellError[]`

Optional. List of errors that occurred while reading one or more table cells. This only returns errors that happen because the callee is unable to read the table cell value of an existing table cell, for example architectural errors. This does not return errors caused by the caller doing something wrong, for example `E_index_out_of_range`. These errors are returned by `table_read()` instead. This array is either missing, in case of no such error, or non-empty, in case of errors.

6.9.9 TableRecord

TableRecord members:

index

Type: `NumberU64`

Index of this record.

row

Type: `Map[String]Value`

Object with key-value pairs as described in the corresponding `TableColumnInfo` objects.

6.9.10 TableWriteResult

TableWriteResult members:

error

Type: `TableCellError[]`

Optional. List of errors that occurred while writing one or more table cells. This only returns errors that happen because the callee is unable to write the table cell value of an existing table cell, for example architectural errors. This does not return errors caused by the caller doing something wrong, for example `E_index_out_of_range`. These errors are returned by `resource_write()` instead. This array is either missing, in case of no such error, or non-empty, in case of errors.

6.10 Image loading and saving API

This section describes the image loading and saving interface. The `image_load*()` functions load images into a target instance.

In a typical implementation:

- Only target instances that have the `executesSoftware=1` property support the `image_*()` functions.
- Cores and CPUs support the `image_*()` functions.
- Memory components, for example RAMDevice, only support the `memory_*()` functions, not the `image_*()` functions.

6.10.1 Loading an image

Select from the following functions to load an image:

image_loadFile()

Loads an image into a target instance from a file. The file must be accessible under `path` on the host that runs the target instance. If the file is only guaranteed to be accessible on the host that runs the client, clients should use `image_loadData()` instead, and load the file in the client.

`image_loadData()`

Loads image data into a target instance. Clients can use this function to push an image into an instance with a single function call. This function is intended for images that are small enough to be transferred as one uninterruptible chunk, typically up to a few megabytes. To load an image from the client side that is larger than that, use `image_loadDataPull()`.

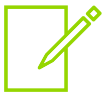
`image_loadDataPull()`

Loads image data into a target instance. This is semantically equivalent to `image_loadData()`, except that the image data is not provided as an argument but is pulled by the target instance from the client by calling the callback function `image_loadDataRead()`. This interface enables:

- Interruptible transfers of large images.
- Format loaders, for example an ELF loader, to only read specific parts of images, or to skip some data, for example debug information.
- Format loaders to read data whose size is unknown or hard to determine.

`memory_write()`

This is the primary method of writing raw byte data into memory at a specific address.


Note

- The `image_load*()` functions can optionally load arbitrary raw binary data, which is unformatted and without a header, into memory, by using the `rawAddr` and `rawSpaceId` arguments.
- Target instances must return `E_function_not_supported_by_instance` for any `image_load*()` functions that they do not support.

Related information

memory_write() on page 108

6.10.2 Saving an image

Use the following functions to save an image:

- `memory_read()` and `resource_read()` inspect the state of the target instance. The client is responsible for formatting this data into the required image format and writing it to a file.
- It is not possible to use the `image_*()` interface to write an image into a file that is accessible to the target instance. In other words, there is no `image_saveFile()` functionality.

Related information

memory_read() on page 105
resource_read() on page 83

6.10.3 image_loadDataRead() callback

The callee of `image_loadDataPull()`, the *consumer*, calls this function on the caller of `image_loadDataPull()`, the *client*, to retrieve a chunk of data. The consumer determines the read position and the size of each chunk.

Consumers should not use this function for fine-grain parsing, for example to parse a symbol table, symbol by symbol. The function call overhead should not become significant, even for IPC connections, so very small chunks should not be used. On the other hand, very large chunks should also not be used, because they block the IPC connection for the transfer of a single block. The chunk size should be between 100KB and 10MB, typically around 1MB.

On reaching the end of the file, the client returns fewer bytes than requested, possibly zero bytes, and returns `E_ok`. Reading past the end of the file is not treated as an `E_io_error`.

The client can return `E_operation_interrupted` if a user interrupted or canceled loading a large image. The implementation of `image_loadData()` should then stop calling `image_loadDataRead()` and should return `E_operation_interrupted`.

If a read error occurs, for example an error from the host OS while reading a file, the client returns `E_io_error`. Since a function can either return an error code or a result object, it does not return `ImageReadResult` nor any bytes. The implementation of `image_loadData()` should then stop calling `image_loadDataRead()` and should return `E_io_error`.

6.10.4 image_clearMetaInfoList()

Clears the list of meta information for the loaded images in the target instance.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.

6.10.5 image_getMetaInfoList()

Gets image filenames and other meta information as loaded by the client using `image_loadData()`, or by the target instance using `image_loadFile()`, since the list of meta information was last reset using `image_clearMetaInfoList()`.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

`ImageMetaInfo[]`

List of image meta information records of images loaded since the last call to `image_clearMetaInfoList()`. See `ImageMetaInfo`.

Errors

- `E_unknown_instance_id`.

6.10.6 image_loadData()

Loads an image from a data buffer.

Usage

Loading an image might cause some state to be modified, for example the start address in the PC register, or the symbol table. This function is semantically equivalent to `image_loadFile()` except that this function does not open a file. Instead, it expects the image contents as an argument.

Arguments

`data`

Type: `ByteArray`

Image data to be pushed into the target instance. If `rawAddr` is not specified, this byte sequence is the complete image, for example a complete ELF file. A non-raw image file, for example an ELF file, cannot be pushed into the target in multiple chunks using this function. Use `image_loadDataPull()` instead to achieve a chunked read of huge ELF files. Multiple ELF files can, of course, be loaded by calling `image_loadData()` multiple times.

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

path

Type: `String`

Optional. Hint to the target instance about the original client-side filename. The target instance must not use this filename to open a file. The path only makes sense on the host of the client. It might still be useful to show this path to the user, with a note that this is a path on the client side.

rawAddr

Type: `NumberU64`

Optional. If specified, treat the data as a contiguous chunk that starts at byte position 0 and load it to `rawAddr` and `rawSpaceId`. A format-specific loader, for example an ELF loader, is not used to load the data, even if it has a valid format signature. If not specified, the data is loaded according to its format signature, see the `path` argument to `image_loadFile()`.

rawSpaceId

Type: `NumberU64`

Optional. Memory space id to load raw data into. This must be present iff `rawAddr` is present, otherwise `E_unknown_memory_space_id` is returned.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_image_format`.
- `E_image_format_error`.
- `E_unsupported_argument_name`.

6.10.7 image_loadDataPull()

Loads an image from a data buffer.

Usage

Loading an image might cause some state to be modified, for example the start address in the PC register, or the symbol table. This function is semantically equivalent to `image_loadData()` except that the image data is not provided as an argument. Instead, the target instance pulls the image data from the client by calling the callback function `image_loadDataRead()`.

Arguments

instId

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

path

Type: `String`

Optional. Hint to the target instance about the original client-side filename. The target instance must not use this filename to open a file. The path only makes sense on the host of the client. It might still be useful to show this path to the user, with a note that this is a path on the client side.

rawAddr

Type: `NumberU64`

Optional. If specified, treat the data as a contiguous chunk that starts at byte position 0 and load it to `rawAddr` and `rawSpaceId`. A format-specific loader, for example an ELF loader, is not used to load the data, even if it has a valid format signature. If not specified, the data is loaded according to its format signature, see the `path` argument to `image_loadFile()`.

rawSpaceId

Type: `NumberU64`

Optional. Memory space id to load raw data into. This must be present iff `rawAddr` is present, otherwise `E_unknown_memory_space_id` is returned.

tag

Type: `NumberU64`

Opaque tag provided by the caller which is passed back to the callback function `image_loadDataRead()` so the caller can match the callbacks to the correct call, like a stream id. The instance id of the caller is in the top 32 bits of the request "id" (for all function calls).

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_image_format`.
- `E_image_format_error`.
- `E_unsupported_argument_name`.
- `E_operation_interrupted`.

6.10.8 image_loadDataRead()

Reads and returns a chunk of data. This is the callback function of `image_loadDataPull()`.

Arguments

`end`

Type: `Boolean`

Optional. If this is present and true, this is the last callback for this tag. The client will not be called back again for this tag/image. The client must still return data if `size` > 0.

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance. This is the instance id of the caller of `image_loadDataPull()`.

`position`

Type: `NumberU64`

Absolute read position in bytes, relative to the start of the image. Consumers might read the data in any order, might skip data, and might read data again. This might be any byte position and is not guaranteed to be aligned to any boundary. `position` might be equal to or exceed the image size. Neither is an error and an empty `ImageReadResult` is returned in this case.

`size`

Type: `NumberU64`

Size of the chunk to read in bytes. This might be 0 and the position + size might exceed the image size (which is unknown to the caller).

`tag`

Type: `NumberU64`

This is the value of the `tag` argument of the `image_loadDataPull()` call for which this is a callback. It allows clients to match `image_loadDataRead()` callbacks to the original `image_loadDataPull()` calls.

Return value

`ImageReadResult`

`An` object containing the chunk of data that was read. See `ImageReadResult`.

Errors

- `E_unknown_instance_id`.
- `E_io_error`.
- `E_operation_interrupted`.

6.10.9 image_loadFile()

Loads an image from a file. Loading an image might cause some state to be modified, for example the start address in the PC register, or the symbol table. The file must be accessible under `path` on the host that runs the target instance.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`path`

Type: `String`

Path of the image file to load. It can be absolute or relative to the current working directory. This path must be on a filesystem that is accessible to the callee, but is not necessarily accessible to the client that calls the function.

Multiple image file formats are usually supported. The image file format is auto-detected, based on the content of the file. If the image format is unknown, `E_unknown_image_format` is returned. If the image format is known but the image could not be loaded because of unsupported content or a malformatted image, `E_image_format_error` is returned. The instance property `loadfileExtension` provides a hint to clients about which filename extensions are supported.

`rawAddr`

Type: `NumberU64`

Optional. If specified, treat the file content as a contiguous chunk of data, ignoring any format signature, and load it to `rawAddr` and `rawSpaceId`. A format-specific loader, for example an ELF loader, is not used to load the data, even if it has a valid format signature. If not specified, the file is loaded according to its format signature, see `path`.

`rawSpaceId`

Type: `NumberU64`

Optional. Memory space id to load raw data into. This must be present iff `rawAddr` is present, otherwise `E_unknown_memory_space_id` is returned.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_image_format`.
- `E_image_format_error`.

- `E_error_opening_file`.
- `E_io_error`.
- `E_unknown_memory_space_id`.

Related information

Instance properties on page 206

6.10.10 ImageMetaInfo

ImageMetaInfo members:

`instId`

Type: `NumberU64`

Instance id of the instance that called the `image_load*()` function. In other words, the client that triggered loading the image. This id can be used by clients to determine whether an image was loaded by this client or by other clients.

`instanceSideFile`

Type: `Boolean`

Iff True the file was loaded by the target instance (using `image_loadFile()`), else it was loaded by a client (using `image_loadData()`). Note that different clients can run on separate hosts (separate from the target instance and separate from each other), seeing different filesystems, so it is not guaranteed that every client can see all files marked with `instanceSideFile=False`.

`path`

Type: `String`

Path passed to the `image_load*()` functions. Clients must only use this for informational purposes or for coarse loading heuristics, for example automatically loading debug information from the image when possible, as clients cannot be sure to have access to the file when running on a different host to the simulation.

`rawAddr`

Type: `NumberU64`

Optional. Base address of loaded data in memory. Only present if the image was loaded with a `rawAddr` argument.

`rawSpaceId`

Type: `NumberU64`

Optional. Only present iff `rawAddr` is present. This is the id of the memory space that `rawAddr` belongs to.

6.10.11 ImageReadResult

ImageReadResult members:

data

Type: `ByteArray`

Data bytes returned by the read operation.

6.11 Simulation time execution control API

Simulation time execution control allows a client to stop and resume the progress of simulation time. After stopping simulation time, the client can inspect the state of the simulation. Simulation time execution control should be non-intrusive, in other words, it should not affect the behavior of the simulation.

`$IRIS_HOME/Examples/Client/ExecutionControl/` contains an example client application that demonstrates how to use this API.

6.11.1 Starting and stopping simulation time

Clients can use `simulationTime_run()` and `simulationTime_stop()` to start and stop simulation time.

These functions return asynchronously to the point in time when the simulation time starts or stops progressing. `simulationTime_run()` can return:

- Before the simulation time starts progressing.
- After the simulation time starts progressing.
- After the simulation time briefly started to progress, then stopped again, for example when running to a nearby breakpoint.

`simulationTime_stop()` can return before or after the simulation time stops progressing.

Callers must monitor the `IRIS_SIMULATION_TIME_EVENT` event source to find out when the simulation time starts or stops progressing.

Simulation time progresses until one of the following events happen:

- A breakpoint that stops the simulation time is hit.
- An event counter overflow occurs, with `counterMode.overflowStopSim=True`.
- `simulationTime_stop()` is called.
- An instance has executed the steps specified in `step_setup()`.

Any kind of stepping, for example instruction stepping, is achieved by calling `step_setup()` followed by calling `simulationTime_run()`.

Related information

step_setup() on page 147

6.11.2 simulationTime_get()

Gets the current simulation time in ticks and the run/stop state.

Arguments

`instId`

Type: `NumberU64`

Optional. Clients must omit this argument or specify 0 because this is a global function.

Return value

`SimulationTimeObject`

Object containing the current simulation time in ticks, the tick resolution, and the run/stop state. See `SimulationTimeObject`.

6.11.3 simulationTime_notifyStateChanged()

Notify client instances of a change to an instance's state. State includes, for example, the values of resources, memory, tables, or disassembly but does not include meta-information like resource names.

Arguments

`instId`

Type: `NumberU64`

Optional. Clients must omit this argument or specify 0 because this is a global function.

Return value

Function has no return value.

6.11.4 simulationTime_run()

Requests to resume the progress of simulation time soon. If simulation time is already running, this function is silently ignored.

Arguments

`instId`

Type: `NumberU64`

Optional. Clients must omit this argument or specify 0 because this is a global function.

Return value

Function has no return value.

6.11.5 simulationTime_stop()

Requests to stop the progress of simulation time soon. If simulation time is already stopped, this function is silently ignored.

Arguments

`instId`

Type: `NumberU64`

Optional. Clients must omit this argument or specify 0 because this is a global function.

Return value

Function has no return value.

6.11.6 Event source IRIS_SIMULATION_TIME_EVENT

This event is emitted when the simulation time starts or stops progressing. It gives the reason why simulation time stopped. It is provided by the `framework.SimulationEngine` instance, not by individual instances.

Table 6-8: Event source IRIS_SIMULATION_TIME_EVENT

Field	Type	Description
`TICKS`	`NumberU64`	Current simulation time in ticks. One tick is 1/`TICK_HZ` seconds long. The elapsed simulation time is `TICKS`/`TICK_HZ` seconds.
`TICK_HZ`	`NumberU64`	Time resolution of the `TICKS` value in Hz. For example, 1000 means that 1 tick = 1ms.

Field	Type	Description
RUNNING	Boolean	True if and only if the simulation is running, else False. **Note:** This information might already be out of date when the callback is received. When multiple simulation controllers start and stop the simulation, for example if multiple debuggers are connected, there is no way to reliably know whether the simulation is currently running or stopped. In this case, this field is only a hint.
REASON	NumberU64	Optional. This field is only present when the simulation is stopped, in other words, when RUNNING=False. It gives the reason why simulation time stopped. If there are multiple reasons, only one IRIS_SIMULATION_TIME_EVENT is generated. The reason is only a coarse classification and can usually be ignored by clients. **Bit[0]** UNKNOWN. **Bit[1]** STOP. simulationTime_stop() was called. **Bit[2]** BREAKPOINT. A breakpoint was hit. Details about hit breakpoints are transmitted with the instance-specific IRIS_BREAKPOINT_HIT event source. IRIS_BREAKPOINT_HIT is emitted before IRIS_SIMULATION_TIME_EVENT. **Bit[3]** EVENT_COUNTER_OVERFLOW. An event counter overflow occurred, with counterMode.overflowStopSim. **Bit[4]** STEPPING_COMPLETED. **Bit[5]** REACHED_DEBUGGABLE_STATE. For more information, see 6.12 Debuggable state API on page 139. **Bit[6]** EVENT. The simulation stopped because of an event in an event stream that was created with stop=True. Details about which event caused the stop are transmitted with the event callback. For example, ec_FOO for event FOO. The event callback happens before IRIS_SIMULATION_TIME_EVENT. **Bit[7]** STATE_CHANGED. Emitted when an instance calls simulationTime_notifyStateChanged() to notify client instances of a change to an instance's state. State includes, for example, the values of resources, memory, tables, or disassembly but does not include meta-information like resource names. All other bits are reserved and must be zero.
INST_ID	NumberU64	Optional. If available, this contains the instance id that originally caused the simulation time event.

Related information

Event source IRIS_BREAKPOINT_HIT on page 160

6.12 Debuggable state API

Debuggable state is the state of an instance in which its registers, memory, and other resources can be freely inspected and manipulated.

Programmer's view simulations are usually in a debuggable state. They execute atomic transitions from one debuggable state to another. They generally do not implement the debuggable state API.

In less abstract simulation environments, for example RTL simulations, or in real hardware, a target instance might not always be in a state in which registers and memory can be freely inspected and manipulated. In such environments, instances might need to execute some simulation time to

get into a debuggable state, in order to expose a consistent view of registers, memory, and other resources.

When not in a debuggable state, an instance might respond to resource reads and memory reads with approximate values and return `E_approximation` in the error field in `ResourceReadResult` and `MemoryReadResult`. It might be unable to provide a value at all, and return `E_value_not_available`. Or, it might respond with the actual value. Similarly, writes might fail when not in a debuggable state.

Related information

Function-specific error codes on page 242
MemoryReadResult on page 110
ResourceReadResult on page 92

6.12.1 Debuggable state flags

Instances that support debuggable state maintain the following flags:

Debuggable-state-request flag

The client sets or clears this flag in a specific instance by calling `debuggableState_setRequest()`. Only `debuggableState_setRequest()` can change this flag. The flag is per-instance and not per-client. Setting the flag changes how the instance behaves as simulation time passes in the following ways:

- If the request was not yet acknowledged, the instance progresses towards a debuggable state, for example by flushing pipelines and moving register values to their final location.
- When the request has been acknowledged, the instance is halted. It stops progressing while simulation time passes and while the request flag is set. This is necessary to be able to bring more than one instance into a debuggable state.

Debuggable-state-acknowledge flag

The instance automatically sets or clears this flag when it reaches or leaves a debuggable state. Typically, the instance reaches a debuggable state after setting the `debuggable-state-request` flag and executing some simulation time, usually by calling `simulationTime_runUntilDebuggableState()`.

Typically, the instance leaves a debuggable state when simulation time progresses after the `debuggable-state-request` flag has been cleared.

The `debuggableState_getAcknowledge()` function queries this flag. This function has no side effects on the instance.

These flags have similar semantics to a debug request pin and a debug acknowledge pin found on some CPUs.

6.12.2 Reaching debuggable state

The global, non-instance-specific function, `simulationTime_runUntilDebuggableState()` advances simulation time until all instances for which a debuggable state is currently requested, have acknowledged it.

This function is a variant of `simulationTime_run()`. They generally have the same semantics, except that this function sets up a global state in which simulation time stops automatically when all instances that have the `debuggable-state-request` flag set also have the `debuggable-state-acknowledge` flag set.

This is a global function and so does not take an `instId` argument.

The simulation time might stop before reaching a debuggable state for the same reasons as for `simulationTime_run()`, for example hitting breakpoints, or calling `simulationTime_stop()`.

To find out whether a debuggable state was reached, enable the `IRIS_SIMULATION_TIME_EVENT` event source. The `REACHED_DEBUGGABLE_STATE` bit in the `REASON` field indicates whether a debuggable state was reached.


Note

- After requesting one or more instances enter a debuggable state, if you then call `simulationTime_run()` instead of `simulation_runUntilDebuggableState()`, this does not cause the simulation time to stop progressing when all the instances enter a debuggable state.
- Simulation time progresses while bringing an instance into a debuggable state, so it is intrusive. The state of an instance in the system might change as a result of bringing an instance into a debuggable state.

Related information

simulationTime_run() on page 137
simulationTime_stop() on page 138

6.12.3 Testing whether a model has reached debuggable state

Follow these steps to inspect a model that supports debuggable state:

Procedure

1. Call `debuggableState_setRequest(request = true)` on all instances to be inspected and that support the `debuggableState_setRequest()` function.
2. Call `simulationTime_runUntilDebuggableState()`.
3. Wait until an `IRIS_SIMULATION_TIME_EVENT` occurs.
4. Inspect the `REACHED_DEBUGGABLE_STATE` bit of the `REASON` field of the `IRIS_SIMULATION_TIME_EVENT` to find out whether a debuggable state was reached. If not, ignore or re-iterate depending on the desired behavior.

5. Call `debuggableState_setRequest(request = false)` on all instances for which the request was previously set to true.
6. Inspect and manipulate the state.

Related information

Event source IRIS_SIMULATION_TIME_EVENT on page 138

6.12.4 Support for the debuggable state API

The `debuggableState_*()` functions are typically only supported by instances that can be in a non-debuggable state.

This means:

- They are usually only supported by simulations below the programmer's view abstraction level, for example cycle-accurate simulations and RTL simulations.
- They are typically implemented by core or CPU-like instances. However, they can also be implemented by other instances that have complex behavior, for example interconnects.
- Instances that do not implement them are assumed to always be in a debuggable state.
- The global function `simulationTime_runUntilDebuggableState()` is usually only supported if and only if there are one or more instances in the system that support the `debuggableState_*()` functions.

6.12.5 debuggableState_getAcknowledge()

Queries the debuggable-state-acknowledge flag of an instance.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

`Boolean`

Returns true iff the instance is in a debuggable state, else false.

Errors

- `E_unknown_instance_id`.

6.12.6 debuggableState_setRequest()

Sets or clears the debuggable-state-request flag in a specific instance. This flag is changed only by this function, and does not change spontaneously.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`request`

Type: `Boolean`

Optional. If missing or true, set the debuggable-state-request flag, that is, request to go into a debuggable state. If present and false, clear the debuggable-state-request flag, that is, resume normal execution. Default is true.

Default: `True`

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.

6.12.7 simulationTime_runUntilDebuggableState()

A variant of `simulationTime_run()` and generally has the same semantics, except that this function sets up a global state in which the progress of simulation time stops automatically when all instances that have the debuggable-state-request flag set also have the debuggable-state-acknowledge flag set.

Arguments

`instId`

Type: `NumberU64`

Optional. Clients must omit this argument or specify 0 because this is a global function.

Return value

Function has no return value.

6.13 Stepping API

The `step_*()` functions allow you to progress the global simulation time so that a specific instance advances by a number of steps. They only set or query state that is used for stepping. They do not resume simulation time.

Stepping is non-intrusive. In other words, the execution result is the same whether code is freely running or being stepped through.

Stepping does not just advance the state of the stepped instance, it advances the global simulation time for all instances.

When the specified instance has executed the specified number of steps, the progress of simulation time is stopped and an `IRIS_SIMULATION_TIME_EVENT` with the `STEPPING_COMPLETED` bit in the `REASON` field is generated.

Related information

Event source IRIS_SIMULATION_TIME_EVENT on page 138

6.13.1 Step units

The `step_*()` functions use a generic concept of *steps*.

The meaning of a step is defined by the `unit` argument, which can have the following values:

`unit = "instruction"`
: One step corresponds to one executed instruction. This unit should be supported by all types of CPU models, regardless of the simulation technology.

`unit = "cycle"`
: One step corresponds to one executed clock cycle of the target instance. Not all models support this value.

6.13.2 Step counters

Each instance that supports stepping maintains the following counters:

- A global *step counter*. This counts the steps in an increasing and wrapping 64-bit counter.
- A global *remaining steps* counter. This counts down the remaining steps during stepping. If it transitions from one to zero, the simulation is stopped. If it is zero, no stepping is performed. The remaining steps counter of an instance is shared by all clients. Therefore, only one connected client can step an instance.
  When the simulation time stops, for any reason, the remaining steps counter of all instances is automatically set to zero to disable stepping. For example, this might happen when:

- A breakpoint is hit.
- A stepping operation of another instance has completed.
- `simulationTime_stop()` was called.

Related information

simulationTime_stop() on page 138

6.13.3 Stepping examples

To step an instance, a client first calls `step_setup()` on it to set the *remaining steps* counter. This function does not execute any steps and does not start or resume the progress of simulation time.

To execute the remaining *N* steps of a specific instance, the progress of simulation time must be resumed explicitly, for example with the following function calls:

```
step_setup(instId=<instId>, steps=<N>, unit="instruction");
simulationTime_run();
```

Stepping only one core instance, or a subset of core instances is achieved by combining stepping with per-instance execution control, see 6.14 Per-instance execution control API on page 150. The following example progresses one specific core in a system that contains multiple cores, by *N* steps, using per-instance execution control:

```
step_setup(instId=<instId>, steps=<N>, unit="instruction");
perInstanceExecution_setStateAll(instanceSet=[<instId>], enable = True);
simulationTime_run();
```


Note

The order of `step_setup()` and `perInstanceExecution_setStateAll()` does not matter, because they only set state.

The simulation might be stopped before the specified number of steps have been executed, for example because a breakpoint is hit or `simulationTime_stop()` was called. In this case, the remaining steps counter is cleared, and resuming the simulation time does not resume the stepping operation, instead it freely runs the simulation.

Related information

simulationTime_run() on page 137
simulationTime_stop() on page 138

6.13.4 step_getRemainingSteps()

Queries the current 'remaining steps' counter value of an instance. A value of zero means that the instance is not stepping, but is running freely.

Arguments

instId

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

unit

Type: `String`

Optional. Unit of the return value. See `unit` argument of `step_setup()`.

Return value

`NumberU64`

Number of remaining steps to execute before stopping the simulation time. If zero, this instance is currently not stepping in this unit.

Errors

- `E_unknown_instance_id`.
- `E_unit_not_supported`.

6.13.5 step_getStepCounterValue()

Queries the current 'step counter' value of an instance in the specified units.

Usage

This can be used to query and monitor the current instruction count or cycle count of an instance. The step counter is a 64-bit unsigned value that is always increasing and silently wrapping around, so it must always be assumed to have an unknown offset. It can still be used to measure relative step counts.

Arguments

instId

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

unit

Type: `String`

Optional. Unit of the return value. See `unit` argument of `step_setup()`.

Return value

`NumberU64`

Number of total elapsed steps in this instance so far. This wraps around and so always has an unknown offset. It is still useful to get relative readings.

Errors

- `E_unknown_instance_id`.
- `E_unit_not_supported`.

6.13.6 step_setup()

Tell an instance to stop after `steps` steps next time `simulationTime_run()` is called. Sets the 'remaining steps' counter to N steps for a specified instance. Steps are measured in the specified `units`.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`steps`

Type: `NumberU64`

Optional. Number of steps to perform before stopping the simulation time (default is one step). This overwrites the previous 'remaining steps' counter of the instance. A value of zero cancels a currently running stepping operation.


Note

To run the simulation time (to perform the actual stepping), `simulationTime_run()` must be called after calling this function.

`unit`

Type: `String`

Optional. Unit for steps. Must be one of:

`instruction`

A step is one executed instruction (default). Typically, all core models support this unit.

`cycle`

A step is one cycle. Not all core models support this unit.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unit_not_supported`.

6.13.7 step_syncStep()

Execute a synchronous step (or multiple steps) on the target instance.

Usage

This function blocks until the step is complete. The simulation time must be stopped when this function is called. If the simulation is running `E_stepping_blocked` is returned.

This function must not be called from the simulation thread because all functions called from the simulation thread must return before simulation time can make progress, and this function waits for simulation time to make progress before it returns and so a deadlock would occur.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`steps`

Type: `NumberU64`

Optional. Number of steps to perform. Default is 1.

`unit`

Type: `String`

Optional. Unit for steps. Must be one of:

`instruction`

A step is one executed instruction (default). Typically, all core models support this unit.

`cycle`

A step is one cycle. Not all core models support this unit.

Return value

`SyncStepResult`

The returned `SyncStepResult` object contains all events that were recorded in the event buffer during the step.

Errors

- `E_unknown_instance_id`.
- `E_unit_not_supported`.
- `E_stepping_blocked`.

6.13.8 step_syncStepSetup()

Set up synchronous stepping on an instance.

Usage

Call this function once to set parameters used during the step execution, before issuing `step_syncStep()` calls on an instance. In particular the event buffer which is returned after every step is returned. This function might be called at any point in time between `step_syncStep()` calls to change the parameters. Not calling this function before the the first `step_syncStep()` call is allowed and the default values of all arguments take effect (no events are recorded and returned).

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`evBufId`

Type: `NumberU64`

Optional. Event buffer id of the event buffer that is returned by every `step_syncStep()` call.

Return value

`SyncStepSetupResult` object.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_buffer`.

6.13.9 SyncStepResult

SyncStepResult members:

`events`

Type: `EventData[]`

Optional. List of events that occurred during a synchronous step (step_syncStep()). Events are recorded in the list in the order of their occurrence. Events are enabled by setting up an event buffer using eventBuffer_create() and step_syncStepSetup().

6.14 Per-instance execution control API

Per-instance execution control allows clients to enable or disable execution of individual targets. The per-instance execution state is maintained in each instance and is shared by all callers and clients.

Execution of an instance can only progress while the simulation time of the whole system progresses. Therefore, the per-instance execution control cannot progress the state of individual components when the simulation time is stopped.

To achieve the effect of progressing execution of a single instance only, the per-instance execution of all other instances that support this feature is disabled and then the simulation time is progressed, either by free running it or by letting it run to a breakpoint.

Updating the per-instance execution state of one or more instances while the simulation time is running is allowed, but has undefined results, because the instances might detect the state change after an undefined delay. Updating the per-instance execution state is only guaranteed to work deterministically while the simulation time is stopped.

`$IRIS_HOME/Examples/Client/ExecutionControl/` contains an example client application that demonstrates how to use this API.

6.14.1 perInstanceExecution_getState()

Gets the current per-instance execution state of a specific instance.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

`Object`

Object containing one member, `enable` (Boolean), which is True iff execution is enabled in this instance.

Errors

- `E_unknown_instance_id`.

6.14.2 perInstanceExecution_getStateAll()

Gets the execution state of all instances in the system that support per-instance execution control. This is a convenience function, calling `perInstanceExecution_getState()` on all instances in the system that support it.

Return value

`Object`

Object containing two members: `enabledSet` and `disabledSet`. Each member is an array of `NumberU64` containing the set of instance ids for which execution is enabled or disabled, respectively.

6.14.3 perInstanceExecution_setState()

Sets the current per-instance execution state of a specific instance.

Arguments

`enable`

Type: `Boolean`

Iff True, enable execution of instructions or processing of work items.

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.

6.14.4 perInstanceExecution_setStateAll()

Updates the execution state of all instances in the system that support per-instance execution control. This is a convenience function, calling `perInstanceExecution_setState()` on all instances in the system that support it.

Arguments

`enable`

Type: `Boolean`

Iff True, enable execution of instructions or processing of work items for instances in `instanceSet` and disable execution for all other instances. Iff False, disable execution for instances in `instanceSet` and enable execution for all other instances.

`instanceSet`

Type: `NumberU64[]`

List of instance ids for which execution must be enabled or disabled, depending on `enable`. All instances that are not in this list are set to the opposite state. Can be empty.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.

6.15 Breakpoints API

Clients manipulate breakpoints in an instance by using the `breakpoint_set()` and `breakpoint_delete()` functions.

Clients are encouraged to use the `breakpoint_getList()` function to display all breakpoints, instead of maintaining their own list of breakpoints. This ensures that breakpoints that are set by other clients are visible to the user, and avoids the program stopping on breakpoints that are invisible and undeletable by the user. The use of `breakpoint_getAdditionalConditions()` is exotic.

The term *breakpoint* is used here to refer to all types of breakpoints, including watchpoints and trigger points, which stop the entire simulation. When debugging an application that is running on an OS in a simulation, you usually would not use these breakpoints. This use case normally requires the simulation, and therefore the simulated OS, to continue running. Instead, you would use a debug server in the simulated world to stop the execution of the simulated application only. Iris does not support this type of application debugging.

Breakpoints and breakpoint ids are specific to the target instance that contains them, not to the client that sets them.

The target instance implementation must ensure that after a breakpoint is hit, stopping the simulation time, it is not immediately hit again when resuming the simulation time, for example by implementing a micro step.

Instances that support the breakpoint interface must also support the event interface. This allows clients to enable `IRIS_BREAKPOINT_HIT` events for an instance.

Debug accesses do not trigger breakpoints.


Note

`$IRIS_HOME/Examples/Client/Breakpoints/` contains an example client application that demonstrates how to use this API.

6.15.1 Breakpoint actions and trace points

Optionally, a single action can automatically be performed when a breakpoint is hit, using the `action` argument of `breakpoint_set()`. This action is performed before the `IRIS_BREAKPOINT_HIT` callback is called.

Breakpoint actions are useful for breakpoints that do not stop the simulation time, which is controlled by the `dontStop` argument of `breakpoint_set()`. The action is performed without involving the client, which reduces latency.

The `action` argument of `breakpoint_set()` supports the following values:

`action=eventStream_enable`
: Enable the event stream `esId`. Ignored if the event stream is already enabled. The event stream `esId` must have been created before this breakpoint is set.

`action=eventStream_disable`
: Disable the specified event stream `esId`. Ignored if the event stream is already disabled.

These two actions can be used to implement *trace points*. For more information, see About trace support in the Arm Development Studio User Guide.

Only a single action is supported for each breakpoint, but you can set multiple identical breakpoints with different actions. The actions are executed in an undefined order.

Breakpoints can trigger arbitrary actions by implementing them in the client in the `IRIS_BREAKPOINT_HIT` callback. To execute the action synchronously with the breakpoint hit, set the breakpoint with `syncEc=true` to achieve a synchronous `IRIS_BREAKPOINT_HIT` callback. Depending on the frequency of the breakpoint hit events, this might severely affect performance, especially for clients connected using IPC.

6.15.2 Other ways to stop simulation time

In addition to `IRIS_BREAKPOINT_HIT` events, there are other ways to stop simulation time:

Event breakpoints
: Events in enabled event streams that were created with `eventStream_create(stop=True)` stop the simulation time whenever they are generated. These stopping events do not generate `IRIS_BREAKPOINT_HIT` events, but they do generate event callbacks, see 6.16.3 Event callback functions on page 164.

Stepping

The stepping functionality stops the simulation time after a specified number of steps, see 6.13 Stepping API on page 143.

Debuggable state

The debuggable state functionality allows clients to stop simulation time when one or more instances reaches a debuggable state, see 6.12 Debuggable state API on page 139.

6.15.3 breakpoint_delete()

Deletes the specified breakpoint.

Arguments

`bptId`

Type: `NumberU64`

Breakpoint id of the breakpoint to delete.

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_breakpoint_id`.
- `E_error_deleting_breakpoint`.

6.15.4 breakpoint_getAdditionalConditions()

Discovers any component-specific breakpoint conditions that are supported by an instance.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`type`

Type: `String`

Optional. If present, return only conditions that are applicable to the specified breakpoint type. Must be one of: `code`, `data`, or `register`. See `breakpoint_set()`.

Return value

`BreakpointConditionInfo[]`

List of `BreakpointConditionInfo` objects indicating additional conditions that can be configured.

Errors

- `E_unknown_instance_id`.
- `E_unsupported_breakpoint_type`.

6.15.5 breakpoint_getList()

Gets information about one or all breakpoints that have been set.

Arguments

`bptId`

Type: `NumberU64`

Optional. If specified, just return the information for the specified breakpoint. If not specified, return the information for all breakpoints.

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

`BreakpointInfo[]`

List of `BreakpointInfo` Objects that contain information about one or all breakpoints.

Errors

- `E_unknown_instance_id`.
- `E_unknown_breakpoint_id`.

6.15.6 breakpoint_set()

Sets and adds a breakpoint on a specific instance.

Arguments

`action`

Type: `BreakpointAction`

Optional. Perform the specified action whenever the breakpoint is hit. There are actions defined to enable or disable event streams. See `BreakpointAction` Object.

address

Type: `NumberU64`

Optional. Address or start address of a range for code and data breakpoints. Mandatory for code and data breakpoints. Ignored for other breakpoint types.

conditions

Type: `Map[String]Value`

Optional. Key-value pairs specifying additional component-specific breakpoint conditions. See `breakpoint_getAdditionalConditions()`.

dontStop

Type: `Boolean`

Optional. Iff present and true, do not stop the simulation on breakpoint hit, but still generate an `IRIS_BREAKPOINT_HIT` event with field DONTSTOP=true. This feature is used to implement trace trigger points. Together with `syncEc=True`, this can be used to check for arbitrary conditions in the client before stopping the simulation, or for causing other effects at runtime, for example enabling or disabling trace, or writing resources.

noCallback

Type: `Boolean`

Optional. Iff present and true, do not generate an `IRIS_BREAKPOINT_HIT` event when the breakpoint is hit. A breakpoint action and simulation stop is still executed regardless of this option. This feature is useful for breakpoints that have a `eventStream_insertTrigger` action to avoid generating unnecessary `IRIS_BREAKPOINT_HIT` callbacks.

instId

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

rscId

Type: `NumberU64`

Optional. Resource id for register breakpoints. Mandatory for register breakpoints, ignored for other breakpoint types.

rwMode

Type: `String`

Optional. Either `r`, `w`, or `rw` for read-only, write-only, or read-write (default). Only relevant for data and register breakpoints, ignored for other breakpoint types.

Default: `rw`

size

Type: `NumberU64`

Optional. Size of address range in bytes for code and data breakpoints. Ignored for other breakpoint types. The default is 0 which means to hit when the access or execution addresses match exactly. For size > 0, breakpoints hit when the access or execution is in the inclusive range [address to address+size-1].

spaceId

Type: `NumberU64`

Optional. Memory space id for code and data breakpoints. Mandatory for code and data breakpoints, ignored for other breakpoint types.

syncEc

Type: `Boolean`

Optional. Iff present and true, call the `IRIS_BREAKPOINT_HIT` callback synchronously for this breakpoint. If this is true this overrides the `syncEc` setting given in `eventStream_create(IRIS_BREAKPOINT_HIT)`. This allows breakpoint-hit callbacks to be generally asynchronous and the synchronous behavior can be switched on for specific breakpoints only. The default is false. See `syncEc` argument of `eventStream_create()` function.

Default: `False`

type

Type: `String`

Breakpoint type. Must be one of code, data, or register:

`code` (Disassembly breakpoint)

Hit just before the instruction at `address` in memory space `spaceId` is executed. When `size` is specified and > 0, hit just before any instruction in the range [address to address +size-1] is executed.

`data` (Watchpoint)

Hit while or shortly after `address` in memory space `spaceId` was accessed with an access matching `rwMode`. When `size` is specified and > 0, hit while or shortly after an address in the range [address to address+size-1] was accessed. Setting a data breakpoint implicitly requests a syncLevel of 2 (`POST_INSN_IO`).

`register`

Hit while or shortly after register `rscId` was accessed with an access matching `rwMode`. If the type of breakpoint is not supported by the instance, `E_unsupported_breakpoint_type` is returned.

Return value

`NumberU64`

Breakpoint id (`bptId`). This is specific to the instance.

Errors

- `E_unknown_instance_id`.
- `E_unsupported_argument_combination`.
- `E_invalid_rwMode`.
- `E_invalid_breakpoint_condition`.
- `E_error_setting_breakpoint`.

6.15.7 BreakpointAction

BreakpointAction members:

`action`

Type: `String`

Action that is executed when the breakpoint is hit. It might be:

`eventStream_enable`

Enable the event stream specified by `esId`.

`eventStream_disable`

Disable the event stream specified by `esId`.

eventStream_*

Any other action starting with 'eventStream_' supported by the event stream specified by `esId`.

`esId`

Type: `NumberU64`

Optional. Event stream id for eventStream_* actions.

6.15.8 BreakpointConditionInfo

BreakpointConditionInfo members:

`name`

Type: `String`

Name of the condition.

`type`

Type: `String`

Type of the condition value, for example `String` or `NumberU64`.

description

Type: `String`

A description of the condition. This indicates the circumstances that cause the breakpoint to trigger.

bptTypes

Type: `String[]`

Optional. List of breakpoint types (`code`, `data`, or `register`) that this condition is applicable to. If omitted, all types are supported.

6.15.9 BreakpointInfo

BreakpointInfo members:

bptId

Type: `NumberU64`

Breakpoint id.

type

Type: `String`

Breakpoint type. Is one of `code`, `data`, or `register`.

address

Type: `NumberU64`

Optional. Address or start address of the range for code and data breakpoints.

size

Type: `NumberU64`

Optional. Size of address range in bytes for code and data breakpoints. Ignored for register breakpoints. The default is 0 which means to hit when the access or execution address match exactly. For size > 0, breakpoints hit when the access or execution is in the inclusive range [address to address+size-1].

spaceId

Type: `NumberU64`

Optional. Memory space id for code and data breakpoints.

rscId

Type: `NumberU64`

Optional. Resource id for register breakpoints.

rwMode

Type: `String`

Optional. Either `r`, `w`, or `rw` for read-only, write-only, or read-write (default). Only relevant for data and register breakpoints.

`dontStop`

Type: `Boolean`

Optional. Iff present and true, do not stop simulation on breakpoint hit, but still generate an `IRIS_BREAKPOINT_HIT` event with field DONTSTOP=true.

`noCallback`

Type: `Boolean`

Optional. Iff present and true, do not generate an `IRIS_BREAKPOINT_HIT` event when the breakpoint is hit. A breakpoint action and simulation stop is still executed regardless of this option. This feature is useful for breakpoints that have a `eventStream_insertTrigger` action to avoid generating unnecessary `IRIS_BREAKPOINT_HIT` callbacks.

`instId`

Type: `NumberU64`

Instance id of the instance that created the breakpoint.

`conditions`

Type: `Object`

Optional. Key-value pairs indicating values of any additional conditions set on this breakpoint.

6.15.10 Event source IRIS_BREAKPOINT_HIT

This event is generated whenever a breakpoint is hit.

Breakpoints can only be hit while the simulation time is running. Normally the simulation time is stopped when a breakpoint is hit, unless `dontStop=true` was set on `breakpoint_set()`. In this case, the `IRIS_BREAKPOINT_HIT` event is generated but the simulation time continues running.

To receive this event from an instance, clients must explicitly call `eventStream_create(IRIS_BREAKPOINT_HIT)` once on that instance.

Multiple breakpoints might be hit before the simulation time is stopped. It is guaranteed that all `IRIS_BREAKPOINT_HIT` callbacks are called, and therefore all breakpoint hit information is present, before `IRIS_SIMULATION_TIME_EVENT(running=False)` is called.

This event source is instance-specific, unlike `IRIS_SIMULATION_TIME_EVENT`, which is global.

Table 6-9: Event source IRIS_BREAKPOINT_HIT

Field	Type	Description
`BPT_ID`	`NumberU64`	Breakpoint id of the breakpoint that was hit.
`PC`	`NumberU64`	PC value when the breakpoint was hit.
`PC_SPACE_ID`	`NumberU64`	Memory space id of the PC value when the breakpoint was hit.

Field	Type	Description
ACCESS_ADDR	NumberU64	Optional. Address of the access that hit a data breakpoint. Mandatory for data breakpoints. Not present for other breakpoint types.
ACCESS_SIZE	NumberU64	Optional. Size in bytes of the access that hit a data breakpoint. Mandatory for data breakpoints. Not present for other breakpoint types.
ACCESS_RW	String	Optional. Either "r" or "w". The rwMode of the access that hit a data or register breakpoint. Mandatory for these breakpoint types. Not present for other breakpoint types.
ACCESS_DATA	NumberU64[]	Optional. Transferred read data or write data of the access that hit a data or register breakpoint. Mandatory for these breakpoint types. Not present for other breakpoint types.
TYPE	String	Breakpoint type. One of: • code • data • register See breakpoint_set().
DONTSTOP	Boolean	Optional. If and only if present and True, the simulation time did not stop because of this breakpoint hit, although it might be stopped because of other breakpoints that were hit.

Related information

Event source IRIS_SIMULATION_TIME_EVENT on page 138

6.16 Events and trace API

All Iris events are handled through this interface.

Target instances can expose zero or more event sources. Event sources emit:

- Trace events, for example INST events for each executed instruction.
- Simulation events, for example IRIS_BREAKPOINT_HIT events.
- Other events, for example events defined by a custom GUI.

An instance that produces events is called an *event producer*, or *trace producer*. It implements the event_*() functions.

An instance that receives event callbacks is called an *event consumer*, or *trace consumer*. It must implement the callbacks for the events it requested, for example ec_INST() and ec_IRIS_BREAKPOINT_HIT().

Instances that do not expose any event sources must either return E_function_not_supported_by_instance for the event_*() functions, or return an empty list of event sources. In practice, however, all instances that implement Iris interfaces that might generate events, must also implement the event interface to expose them, and allow clients to receive them.

In particular, instances that support the breakpoint interface or the semihosting interface must implement the event interface.

Most clients only need to call the following functions:

`event_getEventSources()`
: Get a list of all events that an instance supports.

`eventStream_create()`
: Enable receiving the specified event.

`eventStream_destroy()`
: When the events are no longer required.

Alternatively, clients can enable or disable events by calling `eventStream_enable()` or `eventStream_disable()`. These functions might provide a performance benefit over `eventStream_create()` and `eventStream_destroy()` when repeatedly enabling and disabling the same event stream.

The client implements the event callback functions `ec_*()`, as needed.

The other functions in this API are more unusual and deal with ringbuffering events, counter events, and reading the state of an event.

`$IRIS_HOME/Examples/Client/SimpleTraceClient/` contains an example client application that demonstrates how to use this API.

Related information

Event source IRIS_BREAKPOINT_HIT on page 160

6.16.1 References in event source fields

Event sources must follow these rules when referring to fields or to resources.

Identifying resources and memory spaces

Event sources that refer to a resource or to a memory space should use the numeric resource id, `ResourceInfo.rscId` or `MemorySpaceInfo.spaceId`, not the resource name string. If resource names are reported, which is discouraged, they must be consistent with the `ResourceInfo.name` or `MemorySpaceInfo.name` field.

Syntax of references in the format string

A format string can refer to values in this and other instances, with the following syntax and semantics. In the following list, variables are enclosed by angle brackets, <...>, and optional items are enclosed by square brackets, `[...]`. This list is ordered roughly from more common to less common references:

`%{<field_name>...}`
: Refers to a field in this event source. The client must make sure the field is enabled.

%{:resource.[*<group_name>*.]*<resource_name>*…}

Refers to a resource in this instance. Only well-defined for synchronous event sources, otherwise the results are undefined.

%{:event.*<event_source_name>*.*<event_field>*…}

Refers to a field in another, previous, event. The client must make sure the other event and field are enabled and must buffer the values of these fields. The semantics are only well-defined for event sources with a defined ordering relationship. Because event sources can only refer to past events, not future events, usually only the last event in a causal event chain can refer to all fields of that event chain. Clients are not expected to wait until data is available. Using this reference requires detailed knowledge of the ordering of the event sources involved.

%{:instance.*<instance_path>*:resource.[*<group_name>*.]*<resource_name>*…}

Refers to a resource in another instance. This is only well-defined for synchronous events where other instances are stable and are causally connected to this instance. For example an event source from a downstream cache might be able to refer to resources in its parent cache or parent core if they are causally connected. In some cases, an approximation of otherwise hard to produce data might still be useful, for example acquiring the approximate PC value of an otherwise unrelated sibling core to debug multithreading problems. Using this reference requires detailed knowledge of the causal relationship between instances and their events.

%{:instance.*<instance_path>*:event.*<event_source_name>*.*<event_field>*…}

Refers to an event field in a previous event of another instance. The client must make sure the event and field are enabled in the other instance and the client must buffer the values of these fields. This is only well-defined if the events involved have a strict ordering relationship and if the instances involved are strongly causally connected. This might be the case, for example, when transactions flow through multiple components of a memory subsystem. Using this reference requires very detailed knowledge about the causal relationship between instances and their events.

<instance_path>

This is always relative to the instance that contains the format string. The semantics are similar to C++ namespace scoping semantics. It starts at the path of the instance that contains the format string, tries to find *instance_path*, and if that fails, repeatedly goes one level up, until it is found. This enables references to children, siblings, and parent instances without needing to specify absolute paths. The special token "PARENT" can be used as an explicit inverse scope to reach parents without specifying the parent's name. It can be specified multiple times, but only at the beginning of the path.

6.16.2 Creating and destroying event streams

`eventStream_create()` creates a new event stream, which is identified by an event stream id, `esId`. Event streams are destroyed by `eventStream_destroy()` or by calling `instanceRegistry_unregisterInstance()` either explicitly or implicitly.

By default, `eventStream_create()` enables event generation for the selected event. The `ec_<eventName>` callback is called on the instance specified by `ecInstId`, which is usually the client creating the event stream, with the requested event source fields, or a superset of them.

There are internal checks and states associated with an event stream that might suppress event generation:

- Enable flag. An event stream can be enabled or disabled. This state is controlled by:
  - The `disable` argument of `eventStream_create()`.
  - The functions `eventStream_enable()` and `eventStream_disable()`.
  - Trace point breakpoints. These are breakpoints with `action=eventStream_enable` or `eventStream_disable`, see the `BreakpointAction` object.
- Range check. An enabled event stream might only emit the events that match the ranges for a specific event source field, or the PC. See `eventStream_setTraceRanges()`.
- Latency. `eventStream_create()` and `eventStream_destroy()` do not take effect until the next sync point, in other words, the point at which a stop can be detected. Therefore, event generation might be delayed after calling `eventStream_create()`, depending on the sync level of the event-producing instance and on the nature of the events, for example `INST` events, which are generated by instruction execution. Stopping event generation might also be delayed after calling `eventStream_destroy()`. For more information, see 6.18 Simulation accuracy (sync levels) API on page 197.

To stop generating events for a specific event stream that was previously started with `eventStream_create()`, a client can call either:

- `eventStream_destroy()`. The event stream id, `esId`, is no longer valid after entering this function.
- `instanceRegistry_unregisterInstance()`. This unregisters instance *x* and automatically destroys all event streams that were sent to instance *x*, that is, event streams that were created using `eventStream_create(ecInstId=X)`.

Use the following guidelines on whether to use `eventStream_create()` and `eventStream_destroy()` or `eventStream_enable()` and `eventStream_disable()`:

- Use `eventStream_create()` and `eventStream_destroy()` to enable and disable events interactively, at a low frequency. These functions might have some latency until events are generated, depending on the current sync level and the nature of the events. Only `eventStream_destroy()` ensures all event generation overhead is removed. Use these functions if you can, or if you are unsure.
- Use `eventStream_enable()` and `eventStream_disable()` to enable and disable event generation at a high frequency, for example while the simulation is running. Trace points are an example of this. These functions usually have the lowest possible latency until event generation starts or stops. A disabled event stream might have a significant runtime overhead, depending on the frequency of the event. Use these functions only if you must.

Related information

eventStream_setTraceRanges() on page 179
instanceRegistry_unregisterInstance() on page 213

6.16.3 Event callback functions

Event callback functions are called for each event in an event stream that was previously created and enabled by `eventStream_create()`.

The function name `ec_FOO()` is used as a placeholder for the real callback function name. The real name is specified with the `ecFunc` argument of the `eventStream_create()` call. If the `ecFunc` argument was not specified, then the function name is `ec_<EventSourceInfo.name>`, for example `ec_INST` for the `INST` event source.

When calling `eventStream_create()`, if `syncEc` is not specified or False, which is usually the case, the callback function is called asynchronously to the thread causing the event. If `syncEc` is True, the callback is called synchronously. This blocks the calling thread from executing in the target instance.

6.16.4 Event counter

To count events in an event stream without the runtime overhead of using event callbacks, set the optional `counter` argument of the `eventStream_create()` function to True.

This argument has the following effects:

- An internal counter is incremented for each event. This counter is specific to an event stream and client. In other words, it is specific to each `eventStream_create()` call.
- No normal `ec_FOO()` callbacks are generated, but see `counterMode.nonOverflowTrace`.

The `counter` is initially set to the `startVal` argument that is passed to `eventStream_create()`, or to zero if `startVal` is not specified. Together with the `counterMode` argument, `startVal`, which is of type `NumberU64`, can be used to trigger an action after *N* events by setting it to `0xffffffffffffffff`-*N*+1.

The `counterMode` argument determines what happens when the counter overflows from `0xffffffffffffffff` to 0 and what happens on non-overflow events. Several orthogonal actions can be selected by setting flags in `counterMode`, see `EventCounterMode` for details.

In addition to causing actions on counter overflow and counter events, the `counter` value of a counting event stream can be read by using `eventStream_getCounter()`.

In the counter mode that is created using `eventStream_create(counter=True)`, the counter counts from 0 to 2^{64}-1 and then automatically wraps to 0. This overflow can safely be ignored in all cases. The difference between two 64-bit counter values is the number of ticks between the counter values if fewer than 2^{64} ticks occurred between reading the counter values.

For `counterMode.overflowReload`, clients must also enable `counterMode.overflowTrace` to determine the number of wraparounds that occurred.

6.16.5 Proxy events

The Iris global instance proxies Iris simulation engine events and simulation time events.

This means that the global instance Id (`instId` = 0) can be used as the `instID` in event APIs when working with simulation engine and simulation time events.


Note

You can alternatively use `IrisInstIdSimulationEngine` (`instId` = 1) for these events.

6.16.6 ec_FOO()

Event callback function.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance to which this event is sent. This is not the source of the event, see `sInstId`. This argument can safely be ignored by the client (callee). This argument is used to route the events to the correct receiving instance.

`esId`

Type: `NumberU64`

Event stream id.

`fields`

Type: `Map[String]Value`

Object that contains the names and values of all event source fields requested by the `eventStream_create()` call. This can be a superset of fields requested by the `eventStream_create()` call. It is guaranteed to contain all fields requested by `eventStream_create()`. Counter overflow events have an additional implicit `overflowTrace` field in the fields array in the `ec_FOO()` callback, with value True, to clearly identify this callback as an overflow event.

`sInstId`

Type: `NumberU64`

Source `instId`. The instance that generated and sent this event.

`syncEc`

Type: `Boolean`

Optional. Synchronous callback behavior. If this is present and True, this invocation of `ec_FOO()` blocks the execution of the thread that generated the event. Otherwise the execution of the thread that generated the event resumes before this `ec_FOO()` call returned. This is only True iff it was set to True in `eventStream_create()`.

Default: `False`

`time`

Type: `NumberU64`

Simulation time timestamp of the event. This is local simulation time, if available, using the terminology of temporal decoupling, or otherwise the best approximation of simulation time available to the instance. The units of this integer timestamp are called ticks and are defined by the simulation environment. The semantics are identical to `simulationTime_get()`.ticks. Instances must report a timestamp. If they are not able to produce a timestamp, they must set this to `simulationTime_get()`.ticks when generating the event.

Return value

Function has no return value.

6.16.7 eventBuffer_create()

Creates a new event buffer and enables the requested event streams to fill the newly created buffer.

Usage

It can enable event streams of the target instance and also of any other instance in the system. When this event buffer is used with synchronous stepping, by calling step_syncStepSetup(evBufId=...), the current content of the event buffer is always returned from the step_syncStep() function.

Arguments

`instId`

Type: `NumberU64`

Optional. Opaque number uniquely identifying the target instance.

`eventStreamInfos`

Type: `EventStreamInfo[]`

Array of event streams to create which fill the event buffer. All of these event streams are created opaquely inside the target instance. None of the streams directly reach the calling instance.

`mode`

Type: `String`

Optional. Specify what must happen when the buffer content gets >= bufferSize:

send

Send event buffer content to ebcFunc+ebcInstId when full and clear event buffer. This is the default.

overwrite

Circular buffer. Old events are dropped so that the buffer content is just >= bufferSize.

drop

One-shot buffer: Drop all new events when the event buffer gets full and keep the old events in the buffer.

For modes `overwrite` and `drop`, the event buffer content is not sent spontaneously to ebcFunc. `eventBuffer_flush()` is used to send the current content of the event buffer to ebcFunc.

bufferSize

Type: `NumberU64`

Optional. Buffer size of the event buffer in bytes. Events are stored in U64JSON format and one event typically takes 100-1000 bytes of buffer space. The default buffer size is 1MB. Useful buffer sizes are in the range of 10KB-1GB. Note that the maximum event buffer size is effectively limited by the maximum size of an Iris message across TCP in some implementations (for example, 4095MB). This is a non-limiting buffer size in the sense that the event buffer is considered to be full when it contains >= bufferSize bytes (events can be of arbitrary size and so a maximum event buffer size cannot be enforced). The `mode` argument specifies what happens when the event buffer gets full.

ebcFunc

Type: `String`

Optional. Name of the callback function to call when the event buffer gets full or when `eventBuffer_flush()` gets called. It is not necessary to specify a callback function when the event buffer is used for synchronous stepping when the event buffer is big enough to hold all events for the executed steps..

When this is not specified, the default function `ebc_default` is called. When an error message "Function 'ebc_default' not supported by instance" is printed this usually means that the ebcFunc argument was erroneously missing in the `eventBuffer_create()` call.

ebcInstId

Type: `NumberU64`

Optional. Instance id which receives `ebcFunc` callbacks. The default is the caller of the `eventBuffer_create()` function.

syncEbc

Type: `Boolean`

Optional. Enable synchronous callback behavior. Callbacks are notifications (and so do not block) by default. If this is present and True, the event buffer callback function blocks the execution of the calling thread in the target instance until the callback function returns.

Synchronous callbacks have a performance impact and must only be enabled when necessary. Synchronous callbacks enabled by out-of-process clients over IPC have a disastrous performance impact due to network latencies.

Return value

`EventBufferInfo`

`EventBufferInfo` object which contains the event buffer id (evBufId) which can be used to access the event buffer in following `eventBuffer*()` calls, and `eventStreamInfos`, which is an array of `EventStreamInfo` objects. This has the same layout as the `eventStreamInfos` argument of `eventStream_create()`. The `EventData.esInfoId` member is an index into this array.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_source_id`.
- `E_unknown_event_field`.
- `E_unknown_callback_instance_id`.
- `E_unsupported_option_name`.
- `E_unsupported_option_value`.
- `E_unsupported_option_combination`.
- `E_syncEc_mode_not_supported`.
- `E_unknown_mode`.
- `E_error_creating_event_stream`.
- `E_error_enabling_event_stream`.

6.16.8 eventBuffer_destroy()

Destroys the event buffer and all internally-created event streams in it. The `evBufId` is no longer valid after this call.

Arguments

`instId`

Type: `NumberU64`

Optional. Opaque number uniquely identifying the target instance.

`evBufId`

Type: `NumberU64`

Event buffer which is to be destroyed.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_buffer_id`.
- `E_unknown_event_stream_id`.
- `E_error_destroying_event_stream`.

6.16.9 eventBuffer_flush()

Flushes the content of the event buffer.

Usage

If a callback function was specified (`ebcInstId` and `ebcFunc`) the content of the event buffer is sent to it. Then the event buffer is cleared, also if no callback function was specified.

This is a race-free way to read the content of the event buffer when `mode=send` is enabled. The callback function transports a `reason=flush` argument to indicate that no further callbacks will occur if the simulation is stopped. When this function is called on an empty event buffer the callback function will still be called.

Arguments

`instId`

Type: `NumberU64`

Optional. Opaque number uniquely identifying the target instance.

`evBufId`

Type: `NumberU64`

Event buffer which is to be flushed.

`mode`

Type: `String`

Optional. New event buffer mode. This can be either `send` or `drop` to enable capturing events that occur around an interesting point in time. Calling this function at that point in time captures past events and tells the event buffer what to do with future events.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.

- `E_unknown_event_buffer_id`.
- `E_unknown_mode`.

6.16.10 eventStream_action()

Execute an action on the event stream. This is called by breakpoint actions with a `BreakpointAction` object and is normally not called directly by clients.

Arguments

`instId`

Type: `NumberU64`

Optional. Opaque number uniquely identifying the target instance.

`esId`

Type: `NumberU64`

Id of the event stream to execute the action on. This is the return value of `eventStream_create()`.

`action`

Type: `BreakpointAction`

Object specifying the action to be executed.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_stream_id`.
- `E_not_supported_for_event_source`.

6.16.11 eventStream_create()

Creates a new event stream and returns its `esId`.

Arguments

`instId`

Type: `NumberU64`

Optional. Opaque number uniquely identifying the target instance.

`counter`

Type: `Boolean`

Optional. Iff True, this event stream counts events and does not emit any `ec_FOO()` callbacks for events. It can emit counter overflow events. See also the `startVal` and `counterMode` arguments. If the event source does not support counter mode, `E_counter_mode_not_supported` is returned.

counterMode

Type: `EventCounterMode`

Optional. Only relevant if `counter==True`. Defines what happens when the counter overflows from 0xffff ffff ffff ffff to 0 and what happens on non-overflow events.

disable

Type: `Boolean`

Optional. Iff present and True, do not enable event generation. Event generation can later be enabled with `eventStream_enable()` or with breakpoints that have action==eventStream_enable. If this argument is missing or False, event generation is enabled.

ecFunc

Type: `String`

Optional. Name of the callback function to call on instance `ecInstId`. This must start with `ec`, for 'event callback'. See `ec_FOO()` for a description of this callback function. The default when not specified is `ec_<EventSourceInfo.name>`, for example `ec_INST` for the `INST` event source. Multiple event streams can send their events to the same callback function. The callback function can demultiplex events based on the event stream id. The client implementation must decide which events are sent to which function.

ecInstId

Type: `NumberU64`

Callback `instId`. Events are sent to this instance whenever they occur.

evSrcId

Type: `NumberU64`

Id of the event source to start tracing. This must be one of the `EventSourceInfo.evSrcId` values returned by `event_getEventSources()`.

fields

Type: `String[]`

Optional. List of requested event source fields. The array can be empty, in which case only the event is reported. Omit this argument to conveniently select all event fields. An event producer must generate all the requested fields, and can generate a superset of them, but it must avoid generating unrequested fields that are expensive to generate.

startVal

Type: `NumberU64`

Optional. Only relevant if `counter==True`. Set the start value of the counter. Default is zero. This is useful to trigger overflow events after N events by setting `startVal` to -N. This is silently ignored if `counter==False`.

`stop`

Type: `Boolean`

Optional. Iff present and True, stop the simulation time for each event while the event stream is enabled. The simulation time is not stopped while the event stream is disabled. An `IRIS_SIMULATION_TIME_EVENT` is generated for each stopping event. This option implements event breakpoints.

`syncEc`

Type: `Boolean`

Optional. Synchronous callback behavior. If this is present and True, the event callback function `ec_FOO()` blocks the execution of the calling thread in the target instance until the callback function returns. Synchronous callbacks have a performance impact and must only be enabled when necessary. Synchronous callbacks enabled by out-of-process clients over IPC have a disastrous performance impact due to network latencies.

If this is missing or False, the event callback function `ec_FOO()` might be queued and called from another thread to the simulation thread that encountered the event. In any case, the execution of the calling thread in the target instance resumes before the callback returns. This mode must be used for all normal tracing activity, which usually does not require the synchronous callback behavior.

`options`

Type: `Map[String]Value`

Optional. Object specifying event source-specific options for the event stream. The supported options (if any) are described in `EventSourceInfo.options` of the event source. `E_unsupported_option_name`, `E_unsupported_option_value`, or `E_unsupported_option_combination` is returned if a specified option is unknown, its value is unsupported, or the combination of options is not supported, respectively.

Some event sources support the `useByteArray` option to select the data type of variable sized data or data that is longer than 8 bytes: `useByteArray=true` sends the data as ByteArray and `useByteArray=false` sends the data as uint64_t[] array plus explicit byte size (old-style byte array).

`minEsId`

Type: `NumberU64`

Optional. Minimum event stream `ID`. It is expected that the event stream `ID` (`esId`) returned by this API will be greater than or equal to `minEsId`.

This is an internal infrastructure parameter. Clients never need to use this parameter.

isProxy

Type: `Boolean`

Optional. Represents whether the event is registered as a proxy in the caller instance.

This is an internal infrastructure parameter. Clients never need to use this parameter.

Return value

`NumberU64`

Event stream id (`esId`). This id uniquely identifies the event stream created by this call. It is used to manipulate and stop this event stream. Trace streams are specific to a given `ecInstId`. Each client has its own private event stream ids.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_source_id`.
- `E_unknown_event_field`.
- `E_unknown_callback_instance_id`.
- `E_unsupported_option_name`.
- `E_unsupported_option_value`.
- `E_unsupported_option_combination`.
- `E_syncEc_mode_not_supported`.
- `E_counter_mode_not_supported`.
- `E_error_creating_event_stream`.
- `E_error_enabling_event_stream`.

6.16.12 eventStream_destroy()

Stops generating events for a specific event stream and destroys the event stream.

Arguments

instId

Type: `NumberU64`

Optional. Opaque number uniquely identifying the target instance.

esId

Type: `NumberU64`

Id of the event stream to be destroyed. This is the return value of `eventStream_create()`.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_stream_id`.
- `E_error_destroying_event_stream`.

6.16.13 eventStream_destroyAll()

Disable and destroy all event streams. Any errors while disabling and destroying the event streams are silently ignored.

Arguments

`instId`

Type: `NumberU64`

Optional. Opaque number uniquely identifying the target instance.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.

6.16.14 eventStream_disable()

Disables an existing event stream. If the event stream is already disabled, this function is silently ignored. The event stream is not destroyed and can be re-enabled later by calling `eventStream_enable()`.

Arguments

`instId`

Type: `NumberU64`

Optional. Opaque number uniquely identifying the target instance.

`esId`

Type: `NumberU64`

Id of the event stream to be enabled. This is the return value of `eventStream_create()`.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_stream_id`.

6.16.15 eventStream_enable()

Enables an existing event stream. If the event stream is already enabled, this function is silently ignored.

Arguments

`instId`

Type: `NumberU64`

Optional. Opaque number uniquely identifying the target instance.

`esId`

Type: `NumberU64`

Id of the event stream to be enabled. This is the return value of `eventStream_create()`.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_stream_id`.

6.16.16 eventStream_flush()

Flushes any potentially buffered data for an event stream by emitting all pending data via an event callback.

Usage

This is an exotic function since most event streams issue events as they happen, unbuffered. This is only meaningful and only implemented for event streams that buffer data, or that emit events in a buffered way. Event callbacks generated by an `eventStream_flush()` call get passed an additional field 'FLUSH_REQUEST_ID' which contains the request id of the `eventStream_flush()` call that caused the event callback. Note that the event callback will generally happen asynchronously to the `eventStream_flush()` callback. This function might also be called while the event stream is disabled and will then also generate an event callback.

Arguments

`instId`

Type: `NumberU64`

Optional. Opaque number uniquely identifying the target instance.

`esId`

Type: `NumberU64`

Id of the event stream to be flushed. This is the return value of 'eventStream_create()'.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_stream_id`.
- `E_not_supported_for_event_source`.

6.16.17 eventStream_getCounter()

Gets the current event counter value for a specific event stream.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`esId`

Type: `NumberU64`

Event stream id of the counter to be returned. The event stream must have been started with `counter=True`. Trace streams with `counter=False` return `E_not_a_counter`.

Return value

`NumberU64`

Current counter value of the requested event stream id.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_stream_id`.
- `E_not_a_counter`.

6.16.18 eventStream_getState()

Queries the current state of the resource associated with an event stream.

Arguments

instId

Type: `NumberU64`

Optional. Opaque number uniquely identifying the target instance.

esId

Type: `NumberU64`

Id of the event stream to be queried. This is the return value of `eventStream_create()`.

Return value

`EventState`

Object that contains the fields of the event. The fields represent the current state of the resource. See `EventState`.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_stream_id`.
- `E_not_supported_for_event_source`.

6.16.19 eventStream_setOptions()

Set options for an event stream. This is used to change the options of an existing event stream. This is an exotic function since most event streams do not support any options.

Arguments

instId

Type: `NumberU64`

Optional. Opaque number uniquely identifying the target instance.

esId

Type: `NumberU64`

Id of the event stream to set the options on. This is the return value of 'eventStream_create()'.

options

Type: `Map[String]Value`

Object specifying event source specific options for the event stream. Only specific event sources support options. The supported options (if any) are described in 'EventSourceInfo.options' of the event source. This is exotic. 'E_unsupported_option_name', 'E_unsupported_option_value' or 'E_unsupported_option_combination' is returned if a specified option is unknown, its value is unsupported or the combination of options is not supported, respectively.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_stream_id`.
- `E_not_supported_for_event_source`.
- `E_unsupported_option_name`.
- `E_unsupported_option_value`.
- `E_unsupported_option_combination`.

6.16.20 eventStream_setTraceRanges()

Sets a number of ranges and masks/values for an event stream. Events are only generated when a specific aspect, for example the PC of a core, matches any of the ranges or mask/value tuples.

Arguments

`aspect`

Type: `String`

Can be any event source field name, or ':pc':

`:pc`

Enable tracing if the associated PC is in one of the masked ranges. The PC does not have to be, but can be, a field of the event sources.

`any field name`

Enable event generation if the value of the field matches any of the masked ranges. The field must have been enabled in the `fields` argument of `eventStream_create()`. If `aspect` is not supported for the selected event source, `E_not_supported_for_event_source` is returned. If the field was not enabled for the selected event stream, `E_unknown_event_field` is returned.

`esId`

Type: `NumberU64`

Event stream id to be gated by the trace ranges.

instId

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

ranges

Type: `NumberU64[]`

List of (start, end, mask) tuples. The array length must be dividable by 3. Tracing is enabled iff (general case):

(start & mask) <= (aspect & mask) <= (end & mask)

Standard case: Match against [start, end]:

(start, end, 2^{64}-1)

Standard case: Match against mask/value:

(value, value, mask)

An empty array is valid and enables tracing permanently, as if no trace range was specified. Event generation is enabled if one of the specified ranges matches.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_stream_id`.
- `E_not_supported_for_event_source`.
- `E_unknown_event_field`.

6.16.21 event_getEventSource()

Gets information about an event source by its name. This function also returns hidden event sources, if their name is known to the caller.

Arguments

instId

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

name

Type: `String`

Name of the requested event source.

Return value

`EventSourceInfo`

Metadata about the requested event source. See `EventSourceInfo`.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_source`.

6.16.22 event_getEventSources()

Retrieves a list of all event sources that are supported by a target instance. This function does not return any hidden event sources. Use `event_getEventSource()` for this.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

`EventSourceInfo[]`

Zero or more `EventSourceInfo` Objects containing the metadata for all event sources offered by this instance.

Errors

- `E_unknown_instance_id`.

6.16.23 event_registerProxyEventSource()

Register a proxy event which transparently forwards all calls on such events to a target instance.

Usage

This can be used to expose an event on a proxy instance while it is implemented in the target instance. The main use-case is to add global events to the global instance and implement them in another instance. This function is an internal infrastructure function. Clients never need to call this function. Calling this function for an already registered event (proxy or normal event) returns `E_event_source_already_registered`. The target instance must already be registered in the global instance and the event must already be added to the target instance before calling this function.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the proxy instance.

`name`

Type: `String`

Name of the proxy event. If this event is not implemented by the target instance, `E_unknown_event_source` is returned.

`targetInstId`

Type: `NumberU64`

Optional. Calls for the proxy event are transparently forwarded to this instance. If this is not a valid instance id, `E_unknown_instance_id` is returned. If this is missing, the instance id in the request id is used as the target instance.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_source`.
- `E_event_source_already_registered`.

6.16.24 event_unregisterProxyEventSource()

Unregister proxy event. This is the counterpart of `event_registerProxyEventSource()`. This function is an internal infrastructure function. Clients never need to call this function.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the proxy instance.

`name`

Type: `String`

Name of the proxy event. If this event was not registered as a proxy event, `E_unknown_event_source` is returned.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_event_source`.

6.16.25 logger_logMessage()

Emits a log message with a severity level.

Arguments

`message`

Type: `String`

The log message to emit.

`severityLevel`

Type: `String`

Severity level of the message. Must be one of DEBUG, INFO, WARNING, ERROR, FATAL_ERROR.

Return value

Function has no return value.

Errors

- `E_unsupported_argument_value`.
- `E_internal_error`.

6.16.26 EventBufferInfo

EventBufferInfo members:

`evBufId`

Type: `NumberU64`

Event buffer id of the described/new event buffer. This is allocated and returned by `eventBuffer_create()`.

`eventStreamInfos`

Type: `EventStreamInfo[]`

Array of `EventStreamInfo` objects. This has the same layout as the `eventStreamInfos` argument of 'eventStream_create()'. The 'EventData.esInfoId' member is an index into this array.

6.16.27 EventData

EventData members:

fields

Type: `Object`

Contains the field values of the event, for example PC for INST trace events.

time

Type: `NumberU64`

Simulation time in ticks when event occurred.

esInfoId

Type: `NumberU64`

Index into the `eventStreamInfos` array passed into `eventBuffer_create()`, uniquely identifying the event type/stream. This allows access to `sInstId` and `evSrcId`.

6.16.28 EventCounterMode

EventCounterMode members:

nonOverflowTrace

Type: `Boolean`

Optional. Iff present and True, call `ec_FOO()` callback for all non-overflow events. For example, this feature can be used to automatically trace the next 100 events. If `nonOverflowTrace` and `overflowTrace` are both set, all events are emitted similarly to normal non-counter event sources.

overflowDisableTrace

Type: `Boolean`

Optional. Iff present and True, disable event on overflow. The event stream is not destroyed. The client must call `eventStream_destroy()` to destroy the event stream.

overflowReload

Type: `Boolean`

Optional. Iff present and True, set internal counter value to `startVal` on overflow. If this is False or missing, the counter wraps from 0xffff ffff ffff ffff to 0.

overflowStopSim

Type: `Boolean`

Optional. Iff present and True, stop simulation on overflow.

overflowTrace

Type: `Boolean`

Optional. Iff present and True, call `ec_FOO()` callback on overflow. The `fields` argument has an additional implicit `overflowTrace` field (with value True) to clearly identify this callback as an overflow event.

6.16.29 EventSourceFieldInfo

EventSourceFieldInfo members:

description

Type: `String`

Optional. Description of the event source field. Can contain linefeeds.

enums

Type: `EnumElementInfo[]`

Optional. Array of `EnumElementInfo` objects which describe symbols for numeric event field values. Debuggers can display these symbols (and potentially their description) in addition to the numeric value.

name

Type: `String`

Name of the event source field. This name is used to uniquely identify the event source field within an event source. By convention, all field names are uppercase with underscores. Field names must not start with a colon. Names starting with a colon are reserved.

size

Type: `NumberU64`

Size of the field value in bytes. Permissible sizes depend on the type, see `type`. 0 means variable size, where the actual size is defined by the actual value for "type=string" (text string) and "type=uint" (ByteArray).

type

Type: `String`

Type of this event source field:

uint

Unsigned integer, either of fixed size (`size` > 0, typically 1, 2, 4, or 8, but may also be wider) or ByteArray with variable size (`size` == 0). (Legacy byte array support: Some events support a `useByteArray` option which can be used to (de)select the lecacy format for byte arrays in events which is `NumberU64[] array` together with an explicit size field (usually FOO__size or FOO_SIZE for field FOO).)

int
: Signed integer (`size` > 0).

bool
: Boolean value (`size` == 1).

float
: IEEE 754 floating-point value (`size` is 4 or 8).

string
: The value is a string of variable size (`size` == 0). The string should be interpreted as UTF-8 encoded text, not as binary data. Use `uint` and `size` == 0 for binary data (ByteArray).

Use `int` or `uint` together with `enums` to model an enum type.

6.16.30 EventSourceInfo

EventSourceInfo members:

counter
: Type: `Boolean`

Optional. If present and True, this event source supports the counter features, see arguments `counter`, `startVal`, and `counterMode` for `eventStream_create()`, and the `counter` argument for `eventStream_create()`, if present, can be True or False. If this is False or missing, the `counter` argument for `eventStream_create()` must be False or missing.

hasSideEffects
: Type: `Boolean`

Optional. If present and True, creating event streams of this event source has side effects. The normal expectation for any event source is that creating an event stream has no side effects since it just enables a client to observe a certain event which happens whether the event stream is enabled or not (hasSideEffects=false, default). Certain event sources, for example ones that relate to semihosting, intentionally alter the behavior of the target when an event stream is created. These event sources are marked with hasSideEffects=true.

description
: Type: `String`

Optional. Description of the event source. Can contain linefeeds.

evSrcId
: Type: `NumberU64`

Opaque event source id. This id is used to identify the event source in other event functions.

fields
: Type: `EventSourceFieldInfo[]`

Metadata for the fields of this event. Event sources that do not have any fields, which is rare, return an empty array.

format

Type: `String`

Optional. Iris-text-format. The format can refer to fields of this event source, to resources of this and other instances, and to the fields in other event sources of this and other instances.

name

Type: `String`

Name of the event source. This name is used to uniquely identify the event source within a target instance. By convention, all event source names are uppercase and can contain underscores. Event source names must be chosen so that wildcard matching is possible. In particular, generic parts of event source names like `_START` and `_END` must be suffixes. Alphabetic sorting of event source names must group related event sources together, if possible. Event source names must not start with a colon. Names starting with a colon are reserved.

options

Type: `Map[String]AttributeInfo`

Optional. Object mapping the names of all available event source-specific options (passed in the `options` argument of `eventStream_create()`) onto `AttributeInfo` objects. The `AttributeInfo` objects specify details of each option like type, description, and enum values. This is only present for event sources that accept options, which is exotic.

Related information

Iris-text-format on page 68

6.16.31 EventState

EventState members:

esId

Type: `NumberU64`

Event stream id.

fields

Type: `Object`

Same semantics as `ec_FOO(fields)`, except that the values of the fields represent the current state of the underlying resource and no actual event happened.

time

Type: `NumberU64`

Same semantics as `ec_FOO(timestamp)`.

sInstId

Type: `NumberU64`

Same semantics as `ec_FOO(sInstId)`.

6.16.32 EventStreamInfo

EventStreamInfo members:

sInstId

Type: `NumberU64`

Instance id of the instance that emits the event stream.

evSrcId

Type: `NumberU64`

Optional. Id of the event source. This must be one of the `EventSourceInfo.evSrcId` values returned by `event_getEventSources()` or by `event_getEventSource()`.

evSrcName

Type: `String`

Optional. Name of the event source. For `eventBuffer_create()`, either `evSrcId` or evSrcName must be specified. If both are specified, `evSrcId` takes precedence. evSrcName is only used when `evSrcId` is either missing or 2^{64}-1.

fields

Type: `String[]`

Optional. Requested event source fields. The array can be empty, in which case only the event is reported. Omit this member to conveniently select all event fields. An event producer must generate all the requested fields, and can generate a superset of them, but it must avoid generating unrequested fields that are expensive to generate.

options

Type: `Map[String]Value`

Optional. Object specifying event source-specific options for the event stream. Only specific event sources support options. The supported options (if any) are described in `EventSourceInfo.options` of the event source. This is exotic. `E_unsupported_option_name`, `E_unsupported_option_value`, or `E_unsupported_option_combination` is returned if a specified option is unknown, its value is unsupported, or the combination of options is not supported, respectively.

disable

Type: `Boolean`

Optional. Iff present and True, do not enable event generation. Event generation can later be enabled with `eventStream_enable()` or with breakpoints that have

action==eventStream_enable. If this argument is missing or False, event generation is enabled.

counter

Type: `Boolean`

Optional. Iff True, this event stream counts events and does not emit any `ec_FOO()` callbacks for events. It can emit counter overflow events. See also the `startVal` and `counterMode` arguments. If the event source does not support counter mode, `E_counter_mode_not_supported` is returned.

counterMode

Type: `EventCounterMode`

Optional. Only relevant if `counter==True`. Defines what happens when the counter overflows from `0xffff ffff ffff ffff` to 0 and what happens on non-overflow events.

ecFunc

Type: `String`

Optional. Name of the callback function to call on instance `ecInstId`. This must start with `ec`, for 'event callback'. See `ec_FOO()` for a description of this callback function. The default when not specified is `ec_<EventSourceInfo.name>`, for example `ec_INST` for the `INST` event source. Multiple event streams can send their events to the same callback function. The callback function can demultiplex events based on the event stream id. The client implementation must decide which events are sent to which function.

ecInstId

Type: `NumberU64`

Callback `instId`. Events are sent to this instance whenever they occur.

startVal

Type: `NumberU64`

Optional. Only relevant if `counter==True`. Set the start value of the counter. Default is zero. This is useful to trigger overflow events after N events by setting `startVal` to -N. This is silently ignored if `counter==False`.

stop

Type: `Boolean`

Optional. Iff present and True, stop the simulation time for each event while the event stream is enabled. The simulation time is not stopped while the event stream is disabled. An `IRIS_SIMULATION_TIME_EVENT` is generated for each stopping event. This option implements event breakpoints.

syncEc

Type: `Boolean`

Optional. Synchronous callback behavior. If this is present and True, the event callback function `ec_FOO()` blocks the execution of the calling thread in the target instance until the

callback function returns. Synchronous callbacks have a performance impact and must only be enabled when necessary. Synchronous callbacks enabled by out-of-process clients over IPC have a disastrous performance impact due to network latencies.

If this is missing or False, the event callback function `ec_FOO()` might be queued and called from another thread to the simulation thread that encountered the event. In any case, the execution of the calling thread in the target instance resumes before the callback returns. This mode must be used for all normal tracing activity, which usually does not require the synchronous callback behavior.

esId

Type: `NumberU64`

Optional. Event stream id of this event stream.

6.16.33 TraceEventData

TraceEventData members:

esId

Type: `NumberU64`

Event stream id.

fields

Type: `Object`

Object that contains the names and values of all event source fields requested by the `eventStream_create()` call. See `ec_FOO()`.

sInstId

Type: `NumberU64`

Source `instId`. The instance that generated and sent this event.

time

Type: `NumberU64`

Simulation time timestamp of the event. See `ec_FOO()`.

6.17 Semihosting API

Iris provides basic support for stdin, stdout, and stderr. It also supports the addition of new semihosting functions and the replacement of the existing ones.

Clients enable semihosting by creating event streams for the `IRIS_SEMIHOSTING_*` events. The `semihosting_*()` functions implemented by the target instance provide dedicated feedback from the client to the target instance and are usually only called from within the callback function

implemented by the client. Only `semihosting_provideInputData()` can be called from outside of callback functions.

`$IRIS_HOME/Examples/Client/Semihosting/` contains an example client application that demonstrates how to use this API.

6.17.1 Basic stdin, stdout, and stderr support

Clients can capture semihosting output through the stdout and stderr file descriptors, and semihosting applications can read input from stdin.

Semihosting output through stdout and stderr

Semihosting output is implemented as an event source, `IRIS_SEMIHOSTING_OUTPUT`. To receive semihosting output, clients must activate this event source using `eventStream_create()`. Multiple clients can request semihosting output at the same time. All of them receive the same semihosting output.

If no client requests semihosting output, the global instance must either print all semihosting output to the simulation process's host stdout file descriptor, or make it visible through another mechanism. If a client has requested semihosting output, the global instance must not print semihosting output to stdout.

Target instances that do not support any semihosting output must not expose an `IRIS_SEMIHOSTING_OUTPUT` event source.

Semihosting input through stdin

Semihosting input is more complex than output because it requires more cooperation between the user, the client, and the simulated application. The process of receiving semihosting input generally involves the following steps:

1. The simulated application tells the semihosting interface that it wants to receive user input.
2. The simulated application waits for semihosting input, either because the read call is blocked or because it actively waits.
3. The user enters data.
4. The user tells the user interface that data entry is complete.
5. The client provides the data to the simulated application.
6. The simulated application tells the semihosting interface that it is no longer waiting for semihosting input.

Target instances that do not support any semihosting input must not expose the `IRIS_SEMIHOSTING_INPUT_*` event sources. The implementation of `semihosting_provideInputData()` must return `E_function_not_supported_by_instance`.

The simulation and all interfaces involved must stay responsive during semihosting input. Semihosting input must not change the simulation state. A simulator that is blocked in a

semihosting input operation is still considered to be running if it was running previously. It can be stopped and resumed when in this state.

Related information

eventStream_create() on page 171

6.17.2 Enabling semihosting input

Enabling semihosting input typically involves the following steps:

Procedure

1. The client activates the `IRIS_SEMIHOSTING_INPUT_REQUEST` event source and optionally `IRIS_SEMIHOSTING_INPUT_UNBLOCKED` using `eventStream_create()`. This step tells the global instance that this client is able to provide semihosting input. If multiple clients activate these event sources, they all receive these events. The input that they provide might be interleaved and unsynchronized.
2. When the application requires user input, it causes the semihosting implementation to issue an `IRIS_SEMIHOSTING_INPUT_REQUEST` event. The client might then read from the console or open a terminal window UI, for example. Applications that do not require input do not issue these events.
3. When the user has entered a character or a line of data, the client passes this data to the semihosting interface using the function `semihosting_provideInputData()`.
4. If the simulated application requires more data, the client waits for user input and sends it to the semihosting interface when it is available. If the application does not require more data, for example it is no longer blocked in a `read()` call, the semihosting implementation issues an `IRIS_SEMIHOSTING_INPUT_UNBLOCKED` event. The client can then close the terminal window or simply ignore this event.
5. The client can send user input to the semihosting implementation using `semihosting_provideInputData()` at any time, even if the application is not waiting for data, in other words before an `IRIS_SEMIHOSTING_INPUT_REQUEST` or after an `IRIS_SEMIHOSTING_INPUT_UNBLOCKED` event. In these cases, the semihosting implementation must buffer the data for subsequent reads. Sending user input to the model before the first `IRIS_SEMIHOSTING_INPUT_REQEST` must assume that the `IRIS_SEMIHOSTING_INPUT_REQUEST RAW` field is False. This means user input should be passed to the model when the user presses the `Enter` key, in other words terminal *cooked* mode.
   The following rules apply to buffering the data that is provided by `semihosting_provideInputData()`. They are only relevant when the semihosting implementation must handle megabytes of input data, for example from streams or files. For interactive user input, they are not relevant and can be ignored:
   - The target must not impose a limit on the buffer.
   - The client is responsible for not pushing too much data to the model before the model has processed it. The client should send a maximum of 1MB of data to the simulation before receiving an `IRIS_SEMIHOSTING_INPUT_REQUEST` event. After receiving this event, the client can send a maximum of `SIZEHINT` + 1MB of data, because this event indicates that all previous data has been consumed. This ensures that the model only needs to buffer at

most 1MB in addition to the currently requested data size, assuming only a single client is pushing data. The client effectively controls the buffer size in the model. The advantage over the model limiting the data size is that the client can choose a suitable behavior when more data becomes available. For example, it can block the thread that produces the data, or it can discard unwanted data.

Related information

eventStream_create() on page 171

6.17.3 Extending or replacing the semihosting implementation

Targets can contain a semihosting implementation that provides `libc` functionality. Applications can use this functionality without a simulated operating system.

Such an implementation can be enabled using suitable CPU parameters. No external interface is involved in making it work. However, the concept of offloading work from the simulation to the host is generic and can be used beyond the `libc` set of functions.

Functions that need to return more data than an integer should write it directly into memory using `memory_write()`. A buffer consisting of a memory address and length is usually passed to the called function as an argument for this purpose.

Related information

memory_write() on page 108

6.17.4 semihosting_notImplemented()

If a client has registered the `IRIS_SEMIHOSTING_CALL_EXTENSION` event source but only wants to override a subset of the semihosting functions, it can call `semihosting_notImplemented()` from within the `ec_FOO()` callback function for `IRIS_SEMIHOSTING_CALL_EXTENSION`.

Usage

This indicates that the function was not yet executed and that it must be handled by another client or by the original built-in function. This function is called in the same context as, and instead of, `semihosting_return()`.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance. This must be the `instId` argument of the current `ec_FOO()` callback.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_invalid_context`.

6.17.5 semihosting_provideInputData()

Feeds user input as a sequence of bytes into the model for a semihosted read.

Arguments

`data`

Type: `ByteArray`

Bytes to be provided to the file descriptor `fDes` as input data. This must not be empty.

`fDes`

Type: `NumberU64`

File descriptor number used for input. This is usually 0, meaning stdin. This value must be passed to the `semihosting_provideInputData()` function when passing data.

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance to which the input data must be sent.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_file_descriptor`.
- `E_data_size_error`.

6.17.6 semihosting_return()

Returns a value from a semihosting override function. This function must be called from within the event callback of the `IRIS_SEMIHOSTING_CALL_EXTENSION` event, before returning from the callback. It must not be called from any other event callback. If called from outside of an `IRIS_SEMIHOSTING_CALL_EXTENSION` event, `E_invalid_context` is returned.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance to which the return value must be sent. This must be the `instId` argument of the current `ec_FOO()` callback.

`retval`

Type: `NumberU64`

Return value of the function being called. The semantics depend on the function being called.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_invalid_context`.

6.17.7 Event source IRIS_SEMIHOSTING_OUTPUT

This event is generated by the target instance to emit bytes of semihosting output.

Table 6-10: Event source IRIS_SEMIHOSTING_OUTPUT

Field	Type	Description
`DATA`	`NumberU64[]`	Characters (bytes) that are to be written to stdout or stderr. It can include bytes with the value of zero, and is not zero-terminated. It must not be empty. The encoding is 8 bytes for each array element, with the first byte in the lowest bits, in other words, little-endian. The last element contains 1-8 bytes in the lowest bits.
`SIZE`	`NumberU64`	Number of bytes in `DATA`.
`FDES`	`NumberU64`	File descriptor number that is used for output. 1 means stdout and 2 means stderr. Other values have a meaning that is specific to the target instance or target application.

6.17.8 Event source IRIS_SEMIHOSTING_INPUT_REQUEST

This event is issued whenever the semihosting implementation starts blocking on a blocking read operation or returns no data for a non-blocking read operation. It indicates that an application requests some data.

Table 6-11: Event source IRIS_SEMIHOSTING_INPUT_REQUEST

Field	Type	Description
`FDES`	`NumberU64`	File descriptor number used for input. This is usually 0, meaning stdin. This value should be passed to the `semihosting_provideInputData()` function when passing data.
`NONBLOCK`	`Boolean`	Optional. If present and True, this request is caused by a non-blocking read operation. Otherwise, the target instance remains in a blocking read until it receives enough data.

Field	Type	Description
RAW	Boolean	Optional. If True, all subsequent user input should be fed into the model immediately when it becomes available, as if a terminal is switched to raw I/O. When this field is missing, or False, user input should be fed into the model when the user presses the Enter key, in other words terminal *cooked* mode. The user interface can allow editing the line before sending it to the model. The raw or cooked mode should stay active until the next IRIS_SEMIHOSTING_INPUT_REQUEST or IRIS_SEMIHOSTING_INPUT_UNBLOCKED event for this file descriptor.
SIZEHINT	NumberU64	Number of bytes that the model consumes immediately.

6.17.9 Event source IRIS_SEMIHOSTING_INPUT_UNBLOCKED

This event is issued whenever a blocking semihosting read operation is unblocked.

It does not mean that no more input is required in the future. It is only a hint that the target instance is not currently blocked because of missing input. Non-blocking read operations never send this event because they never block. The raw or cooked mode should be set to cooked, see the RAW field of IRIS_SEMIHOSTING_INPUT_REQUEST.

Table 6-12: Event source IRIS_SEMIHOSTING_INPUT_UNBLOCKED

Field	Type	Description
FDES	NumberU64	File descriptor number used for input. This is usually 0, which means stdin.

6.17.10 Event source IRIS_SEMIHOSTING_CALL

This event is issued just before a semihosting function is called. It can be used to monitor semihosting call usage.

Activating it does not affect the model behavior. It cannot be used to re-implement the built-in semihosting calls or to extend semihosting.

Table 6-13: Event source IRIS_SEMIHOSTING_CALL

Field	Type	Description
OPERATION	NumberU64	The operation number of the built-in or user semihosting call according to the semihosting specification. This is the value of the operation number register when the target issues the semihosting trap instruction.
PARAMETER	NumberU64	Register argument for the called function. This is the value of the parameter register when the target issues the semihosting trap instruction. This either contains an argument value for the called function, or it contains the virtual address of a data structure. This decision and the semantics depend on OPERATION. In case of a memory address, the semihosting implementation must read the memory using the memory_read() function.

6.17.11 Event source IRIS_SEMIHOSTING_CALL_EXTENSION

This event source is intrusive. Activating it changes the model behavior. When it is active, this event is issued instead of a built-in semihosting function call.

The receiver of this event is expected to implement and execute the semihosting call from within the event callback. This event source should be activated with `eventStream_create(syncEc=True)`.


Note

All synchronous event activity across IPC has a severe performance impact.

The `ec_FOO()` callback must do one of the following:

- Execute the semihosting function, and therefore override the built-in implementation. In this case it must call `semihosting_return()`. `semihosting_return()` must not be called from any other event callback, otherwise `E_invalid_context` is returned. Functions that need to return more data than an integer should write it directly into memory using `memory_write()`. A buffer consisting of a memory address and length is usually passed to the called function as an argument for this purpose.
- Leave execution to the built-in implementation, and therefore do not override it. In this case, it must call `semihosting_notImplemented()`.
- Leave execution to the next client that registered this event source. If multiple clients have registered this event source, any of them might be called first and have the choice to implement the function or pass it to the next one, in no defined order. This enables different plug-ins to override separate, non-overlapping, sets of functions.

Table 6-14: Event source IRIS_SEMIHOSTING_CALL_EXTENSION

Field	Type	Description
`OPERATION`	`NumberU64`	The operation number of the built-in or user semihosting call according to the semihosting specification. This is the value of the operation number register when the target issues the semihosting trap instruction.
`PARAMETER`	`NumberU64`	Register argument for the called function. This is the value of the parameter register when the target issues the semihosting trap instruction. This either contains an argument value for the called function, or it contains the virtual address of a data structure. This decision and the semantics depend on `OPERATION`. In case of a memory address, the semihosting implementation must read the memory using the `memory_read()` function.

6.18 Simulation accuracy (sync levels) API

Some target instances support adjusting the trade-off between simulation speed and accuracy, by using a synchronization level or *sync level*.

The `syncLevel_request()` and `syncLevel_release()` functions request and release a minimum sync level. Calling `syncLevel_request(N)` ensures that the effective sync level is at least *N*.

`syncLevel_release(N)` must be called for every call to `syncLevel_request(N)` when the requested sync level is no longer required. This might cause the sync level to decrease, and therefore increase the simulation speed, depending on the sync levels requested by other users.

Requesting and releasing a sync level of zero is valid but has no effect. The sync level of a particular target instance is a shared resource. It is not possible to set a specific sync level, except the highest one, because another client might be using a higher sync level.

Target instances that do not support requesting sync levels must return `E_function_not_supported_by_instance` for the `syncLevel_*()` functions.

6.18.1 Sync points

A sync point is a point at which the simulation can detect whether it needs to stop and at which it can start and stop producing trace and events. The sync level determines where the sync points are in terms of simulated time.

Table 6-15: Sync levels and sync points

Sync level	Description
0	`OFF`. Maximum simulation speed. No accuracy guarantees. In particular, the simulation cannot be stopped immediately, even from synchronous callbacks or model code, and the values of the PC and instruction count registers are generally out of date, even when read from synchronous callbacks or model code. Use cases: • Simulations that do not require immediate stopping of any kind. • Free-running simulations that are used for software development. • Normal debugging sessions when no watchpoint is set. The sync point is the end of the current quantum.
1	`SYNC_STATE`. Slightly slower than 0. It is possible to read up-to-date resource values from synchronous callbacks (`syncEc=True`) from the model and model code, for example the PC register. The simulation cannot be stopped immediately from within synchronous callbacks or model code. Use cases: • External breakpoints that block the simulation. • Inspecting the processor state from within peripheral accesses.
2	`POST_INSN_IO`. Similar to 1 but slightly slower, and the simulation can be stopped immediately while executing I/O (LD/ST) instructions from within synchronous callbacks and model code by using the `simulationTime_stop()` function. The simulation stops after the currently executed I/O (LD/ST) instruction has completed. Use cases: • Watchpoints. • External breakpoints, in other words, breakpoints that are set in peripherals, behind a bridge. • Complex breakpoints built from LD/ST-related events. The sync point is the same as for sync level 1, but additionally after every I/O instruction.

Sync level	Description
3	`POST_INSN_ALL`. Similar to 2 but slightly slower, and the simulation can be stopped immediately, independently of the instruction being executed. The simulation stops after the currently executed instruction has completed. Use case: • Complex breakpoints that are built from arbitrary events. The sync point is the same as for sync level 2, but additionally after every instruction.

Some use cases that require specific sync levels:

- Watchpoints, or memory breakpoints, require sync level 2. This is handled transparently by the model and the sync level does not need to be requested by the watchpoint setter.
- External breakpoints that can stop the simulation use sync level 2.
- Trace event-based breakpoints usually require sync level 2 or 3.
- Events that inspect the state of cores, in particular the PC and instruction count, from within the `ec_FOO()` callback require sync level 1.

Related information

simulationTime_stop() on page 138
ec_FOO() on page 166

6.18.2 syncLevel_get()

Queries the current sync-level state. This is only provided for debugging purposes. Clients must not rely on the values returned by this function because other clients might explicitly change the sync level, or might implicitly change it using watchpoints.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

`SyncLevelState`

Current sync-level value and the number of registered users for each sync level. See `SyncLevelState`.

Errors

- `E_unknown_instance_id`.
- `E_unknown_sync_level`.

6.18.3 syncLevel_release()

Releases a previous request for a minimum sync level. This signals that the client no longer requires that the sync level of the instance goes no lower than the released level.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`syncLevel`

Type: `NumberU64`

Requested minimum sync level:

"0" ("OFF")

Maximum simulation speed. No accuracy guarantees. In particular, the simulation cannot be stopped immediately, even from synchronous callbacks or model code, and the values of the PC and instruction count registers are generally out of date, even when read from synchronous callbacks or model code.

Use cases: Simulations that do not require immediate stopping of any kind. Free-running simulations used for software development. Normal debugging sessions when no watchpoint is set.

The sync point, which is the point at which the simulation can detect that it needs to stop and can start and stop generating trace and events, is the end of the current quantum.

"1" ("SYNC_STATE")

Slightly slower than 0. It is possible to read up-to-date resource values from synchronous callbacks from the model (`syncEc=True`) and model code, for example the PC register. The simulation cannot be stopped immediately from within synchronous callbacks or model code.

Use cases: External breakpoints that block the simulation. Inspecting the processor state from within peripheral accesses.

Sync point is the same as for sync level 0.

"2" ("POST_INSN_IO")

Slightly slower than 1. Like 1 but the simulation can be stopped immediately while executing I/O (LD/ST) instructions from within synchronous callbacks and model code, using the `simulationTime_stop()` function. The simulation stops after the currently executing I/O (LD/ST) instruction has completed.

Use cases: Watchpoints. External breakpoints (breakpoints in peripherals). Complex breakpoints built from LD/ST-related events.

Sync point is the same as for sync level 1 plus after every I/O instruction.

"3" ("POST_INSN_ALL")

Slightly slower than 2. Like 2 but the simulation can be stopped immediately, independently of the instruction currently executing. The simulation stops after the currently executing instruction has completed.

Use cases: Complex breakpoints built from arbitrary events.

Sync point is the same as for sync level 2 plus after every instruction.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_sync_level`.

6.18.4 syncLevel_request()

Requests a minimum sync level. This signals that the sync level of the instance must go no lower than the level requested.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`syncLevel`

Type: `NumberU64`

Requested minimum sync level:

"0" ("OFF")

Maximum simulation speed. No accuracy guarantees. In particular, the simulation cannot be stopped immediately, even from synchronous callbacks or model code, and the values of the PC and instruction count registers are generally out of date, even when read from synchronous callbacks or model code.

Use cases: Simulations that do not require immediate stopping of any kind. Free-running simulations used for software development. Normal debugging sessions when no watchpoint is set.

The sync point, which is the point at which the simulation can detect that it needs to stop and can start and stop generating trace and events, is the end of the current quantum.

"1" ("SYNC_STATE")

Slightly slower than 0. It is possible to read up-to-date resource values from synchronous callbacks from the model (`syncEc=True`) and model code, for example the PC register. The simulation cannot be stopped immediately from within synchronous callbacks or model code.

Use cases: External breakpoints that block the simulation. Inspecting the processor state from within peripheral accesses.

Sync point is the same as for sync level 0.

"2" ("POST_INSN_IO")

Slightly slower than 1. Like 1 but the simulation can be stopped immediately while executing I/O (LD/ST) instructions from within synchronous callbacks and model code, using the `simulationTime_stop()` function. The simulation stops after the currently executing I/O (LD/ST) instruction has completed.

Use cases: Watchpoints. External breakpoints (breakpoints in peripherals). Complex breakpoints built from LD/ST-related events.

Sync point is the same as for sync level 1 plus after every I/O instruction.

"3" ("POST_INSN_ALL")

Slightly slower than 2. Like 2 but the simulation can be stopped immediately, independently of the instruction currently executing. The simulation stops after the currently executing instruction has completed.

Use cases: Complex breakpoints built from arbitrary events.

Sync point is the same as for sync level 2 plus after every instruction.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_sync_level`.

6.18.5 SyncLevelState

SyncLevelState members:

`counts`

Type: `NumberU64[]`

Current number of requests for sync levels 0, 1, 2, and 3 respectively. The count for sync level 0 is always 0. Array length is always four.

syncLevel

Type: `NumberU64`

Current effective sync level. This is the highest requested sync level.

6.19 Instance registry, instance discovery, and interface discovery API

All entities in Iris are represented by instances. Instances must first be registered in the global instance registry. Instances can discover and communicate with other instances, and can check which functions they support.

6.19.1 Hierarchical instance names and instance classes

Every entity in a simulation is uniquely identified by a hierarchical instance name string. Hierarchy levels are separated by dots.

The first hierarchy level in the string defines the instance class that this instance belongs to. It can be one of the following:

component

An entity that primarily is controlled and observed, typically:

- Components that are part of the component tree of the system and that model a specific piece of hardware, for example a core, memory, or peripheral.
- In-process plug-ins or out-of-process clients that model a component.

Following `component.` is the name of the top-level component of the component tree, or `root` if it has no name. This is followed by the instance names of all components in the hierarchical path up to and including the instance name that is being registered, for example `component.cluster0.cpu0`.

client

An entity that primarily observes other instances or controls the simulation. Typically:

- Debuggers.
- Trace consumers.
- In-process plug-ins that primarily observe and control. In other words, DSOs that are loaded using the `FM_PLUGINS` environment variable, or built-in plug-ins that are statically linked into the simulator executable.
- Out-of-process clients, in other words, anything that connects to the `IrisTcpServer`.

Following `client.` is the instance name of the client, which might or might not be hierarchical, for example `client.plugin.ListInstances`.

framework

An entity that is part of the simulation framework. The following instance names are defined for this instance class:

- `framework.GlobalInstance`.
- `framework.SimulationEngine`.

- All instances can discover and communicate with all other instances. The instance class only gives an indication of the role of the instance to other instances. It does not limit what the instance can do, for example only producing or only consuming events.
- Physical entities, for example DSO plug-ins, can register multiple instances, for example one or more components, and also a client, if the entity contains one.

6.19.2 Registering instances

The global function `instanceRegistry_registerInstance()` registers a new instance in the global instance registry and assigns an instance id, `instId`, to it.

A call to this function to register instance `foo.bar`, has the following effects:

- The instance is registered under its path name `foo.bar` and a unique `instId` is assigned to it, which the function returns. The list of all registered instances can be queried using `instanceRegistry_getList()`.
- All framework instances can use the `instId` to route requests and responses to `foo.bar`.

`instanceRegistry_registerInstance()` must be called as a request, not as a notification. When it is called as a notification, the call is ignored and no instance is registered. Instances must call it before calling any other Iris function because their instance id must be included in all request ids. When calling it, instances do not yet have an instance id assigned, so they cannot set their instance id in bits[63:32] of the request id. Instead, they set bits[63:32] of the request id to zero. The caller can freely choose bits[31:0], as for normal requests.

The `IrisSupportLib` library normally takes care of constructing request objects for you, so unless you are implementing your own library, you do not need to create request ids yourself.

The following restrictions apply to registering instances:

- The top-level in the hierarchical instance name must be one of the instance classes, for example `component`.
- Instances must register themselves as early as possible, in other words as soon as they exist and an `IrisInterface` can send the `instanceRegistry_registerInstance()` call.

See 6.19.3 Unregistering instances on page 205 for restrictions on unregistering instances.

The hierarchy does not indicate dependencies. Children do not depend on the presence of their parents. So, the following actions are valid:

- Registering `component.foo.bar` without having registered `component.foo` beforehand.
- Unregistering `component.foo` before unregistering `component.foo.bar`, assuming both have previously been registered.

6.19.3 Unregistering instances

`instanceRegistry_unregisterInstance()` unregisters an instance from the instance registry. It undoes all the effects of `instanceRegistry_registerInstance()`.

When `instanceRegistry_unregisterInstance()` returns, the instance is no longer visible to `instanceRegistry_getList()`. Functions that receive an `instId` argument fail with `E_unknown_instance_id` if they are called with an unregistered `instId`.

Calling `instanceRegistry_unregisterInstance(instId)` and waiting for its response is the only way to make sure the `IrisInterface` of the instance with `instId` is no longer in use.

Side effects of unregistering an instance:

- Unregistering instance *x* using `instanceRegistry_unregisterInstance()` automatically destroys all event streams that are sent to instance *x*. That is, event streams that were created with `eventStream_create(ecInstId=X)`.
- Unregistering an instance does not affect any breakpoints that the instance has set.

The following constraints apply when unregistering instances:

- Instances must unregister themselves as late as possible, in other words just before or during destruction, as long as an `IrisInterface` can send the `instanceRegistry_unregisterInstance()` function call.
- Constraints on communication during unregistering:
  - Before sending the `instanceRegistry_unregisterInstance()` request, the instance can call functions normally, and it must accept function call responses and respond to function calls normally.
  - After sending the `instanceRegistry_unregisterInstance()` request and before receiving a response to the request, the instance must not call any functions. It must accept function call responses and respond to function calls normally.
  - After receiving the response to the `instanceRegistry_unregisterInstance()` request, the instance must not call any functions. It must assume that `irisHandleMessage()` on its `IrisInterface` interface will not be called after this point. It can destroy itself and the `IrisInterface` after this point.
- Instances that receive a function call for an unregistered `instId` must return `E_unknown_instance_id`.
- At any time, other instances can call functions for a specific `instId`. They either receive an OK response, or an error response from the destination instance or from a message-routing instance, for example the GlobalInstance. If the instance no longer exists, they receive an

`E_unknown_instance_id` error. This is normal behavior and must not cause any side effects, for example closing the simulation. The caller is responsible for handling this error in a suitable way.

If an instance fails to call `instanceRegistry_unregisterInstance(instId)` before destroying itself:

- If the instance is in-process, that is, connected using the C++ `IrisInterface` interface, this is considered to be as severe a programming error as using a freed C++ object, and is explicitly forbidden.
- If the instance is out-of-process, that is, connected using a TCP socket or any other mechanism, this is considered normal behavior. For example, this might happen if the remote process crashes or the TCP connection closes from the remote side. The message-routing instance that provided the connection is able to detect such a loss of connection. It must then:
  - Synthesize a call to `instanceRegistry_unregisterInstance()` into the rest of the system.
  - Send `E_unknown_instance_id` error responses to all pending function calls that it is handling for the instance that was destroyed.

Related information

eventStream_create() on page 171

6.19.4 Instance properties

The function `instance_getProperties()` gets detailed information that is inherent to the instance and does not change, for example the type of component and whether certain features are supported or not. Properties should not be confused with parameters, which are variable characteristics of a component, set at compile time or runtime.

`instance_getProperties()` returns a set of arbitrary key/value pairs. The following tables describe all properties that have defined semantics in Iris. Instances can report additional properties that are not described here. All instance properties except `instId` and `instName` are optional.

Table 6-16: Instance properties defined by Iris

Property	Type	Description
`instId`	`NumberU64`	Instance id as reported by instanceRegistry_getList().
`instName`	`String`	Instance name as reported by instanceRegistry_getList().
`register.canonicalRnScheme`	`String`	Canonical register number scheme used by the `canonicalRn` member of `RegisterInfo`. Canonical register numbers are intended to be target-specific numbers that identify registers in the device. The format of this field is `domain_name/string`. The `domain_name` is that of the organization specifying the scheme. The organization specifies the `string`. Arm® components use `arm.com/registers`, if they expose registers. **Note:** This property is only defined for component instances.

Property	Type	Description
`memory.canonicalMsnScheme`	`String`	Canonical memory space number scheme used by the `canonicalMsn` member of `MemorySpaceInfo`. Canonical memory space numbers are intended to be target-specific numbers that identify memory spaces in the device. The format of this field is `domain_name/string`. The `domain_name` is that of the organization specifying the scheme. The organization specifies the `string`. Arm® components use `arm.com/memoryspaces`, if they expose memory spaces, see 6.7.6 Canonical memory space number scheme on page 98. **Note:** This property is only defined for component instances.


Note

The properties in the following table extend the set of properties for a component that are described in Table 6-16: Instance properties defined by Iris on page 206.

Table 6-17: Instance properties defined by LISA+, typically only for `component` instances

Property	Type	Description
`componentName`	`String`	The name of the component that this is an instance of. For example, `RAMDevice`. The `componentName` must uniquely identify a given instance type within a given framework, for example Fast Models. Two instances that have the same `componentName`: • Represent separate instances of the same component model. • Can expose different interfaces because of differences in how the separate component model instances have been configured.
`version`	`String`	Component version, as defined in the LISA+ properties section.
`componentType`	`String`	Component type. For example: • `Bridge` • `Bus` • `Clocking` • `Core` • `Media` • `Other` • `Peripheral` • `Signals` • `SystemIP` Components can report other component types. If a strong classification is needed for these, they should be included in the same class as `Other`. The LISA+ name is `component_type`.
`description`	`String`	Short description of the functionality of the component. Can contain linefeeds, but is usually just a single line of text.
`documentationFile`	`String`	Filename of the documentation for this component. A user interface can open this file upon request. The LISA+ name is `documentation_file`.

Property	Type	Description
`executesSoftware`	`NumberU64`	A hint that is set to 1 if the component can execute software. Clients can take this as a hint that this component is a CPU-like debug target, in contrast to a peripheral, which might also be inspected but which generally does not execute software. The LISA+ name is `executes_software`.
`loadfileExtension`	`String`	A hint for clients about which filename extensions are usually suitable for the `image_loadFile()` function. Clients should offer them to users in addition to `All Files`. Clients that use their own loader and always send binary data to the target should ignore this property. The list contains glob-style wildcard expressions, separated by semicolons, for example `"*.txt"` or `"*.axf;*.elf"`. The LISA+ name is `loadfile_extension`.


Note

The properties in the following table extend the set of properties that are described in Table 6-16: Instance properties defined by Iris on page 206.

Table 6-18: Instance properties for `client` instances and for instances connected using IPC

Property	Type	Description
`name`	`String`	Human readable name of a client. Single line, usually prettier than the instance name, for example `"Arm Development Studio v1.0"`. This does not need to be unique for different clients, if they are of the same type.
`description`	`String`	Multiple-line description of this client.
`connectionInfo`	`String`	Single line that describes the way this instance is connected to the simulation. This can be either: **`"in-process"`** For DSO plug-ins, for example. This should be the default interpretation when this property is missing. **`"iris://<ip>:<port>"`** For an IPC client on <*ip*> and <*port*>.

Related information

RegisterInfo on page 86
MemorySpaceInfo on page 112
image_loadFile() on page 134

6.19.5 Interface discovery

Instances can support any subset of Iris functions. It is possible to check whether an instance supports a specific function or set of functions. It is also possible to get a list of all functions that a specific instance supports.

It is not mandatory to check whether a function is supported before calling it. Functions that are not supported by an instance return `E_function_not_supported_by_instance`. Interface discovery is mandatory for all instances. In other words, `instance_checkFunctionSupport()` and `instance_getFunctionInfo()` must not return `E_function_not_supported_by_instance`.

6.19.6 Use cases for instance_ping()

This function has no effect on the instance. It is intended to be a no-op.

It has the following use cases:

- A dummy operation to simulate keep-alive. To keep the TCP connection open without disturbing the other side of the connection, this function can be called at regular intervals, for example every 7200s. However, it is preferable to use the TCP keep-alive socket options, if available, instead. The ping should be addressed at an instance on the other side, for example the `IrisTcpServer` instance from a client or the client instance from the `IrisTcpServer`.
- Benchmarking. Ping can optionally return a dummy payload, which could, for example, be any or all of the following:
  - Sequence count.
  - Timestamp.
  - Dummy data that is used by a benchmark to measure the transport performance.

Instances that do not support `instance_ping()` must return `E_function_not_supported_by_instance`, although instances are encouraged to implement this trivial function.

6.19.7 Interface versioning

Interface versioning is implicit and per-function in the Iris interfaces. Explicit interface versioning is not necessary for Iris interfaces and therefore is not provided.

Versioning works as follows:

- Use `instance_checkFunctionSupport()` to determine whether a specific function or set of functions is supported. You can also use `instance_getFunctionInfo()` to check which mandatory and optional arguments are supported by a specific function.
- Callers only take the information they need from return value objects. They must ignore all object members they do not know about.
- New functionality might be added to Iris without breaking existing clients in the following ways:
  - If new details are returned, for example static register information, the return value objects are extended with new members. Existing clients will ignore these additions and new clients can reliably see them.
  - If new optional features are added to a function call, they are added as optional arguments, with a default value that is fully compatible with the previous behavior of the function. Existing clients will not specify these new arguments and will receive the previous behavior.
  - If the semantics of a function change so significantly that it cannot remain compatible with the previous behavior by adding optional arguments, a new function with a new name must be added. Existing clients will not know about this new function and will call the existing function. If the existing function is no longer supported, they will find out reliably.

- New orthogonal functions are added, extending the target without breaking existing clients.

For a new feature to become useful and usable, it must be supported by both the client and the target.

6.19.8 Naming conventions for new functions

When adding new functions that replace or extend existing functions, use the following naming conventions.

- Only add new functions if the same effect cannot be achieved by extending an existing function with new return value members or with new optional arguments.
- All orthogonal changes or additions can be achieved with new optional arguments. Adding new functions to replace or enhance existing ones is not necessary.

Assuming the existing function is called `breakpoint_set()`, and a new non-orthogonal feature, `foo`, must be added, which cannot be supported by extending `breakpoint_set()` with optional arguments, for example `breakpoint_set(enableFoo=True, ...)`, new versions of this function should be named, in the following order, from most to least preferred:

`breakpoint_setFoo()`
: Use this format when `Foo` is a suitable description of the new non-orthogonal feature. If the feature is orthogonal to existing functionality, an argument `foo={"space":42, "index":6}` or `enableFoo=True` should be added to the existing `breakpoint_set()` function, rather than introducing a new function.

`breakpoint_set_armCortexA53()`
: Use this format when the behavior is processor-specific, and cannot be generalized. Generalizing is preferred if possible, preferably in an orthogonal way, so that introducing a new function is not necessary. For example:
`breakpoint_set(addressArmCortexA53UtlbTag=<something_very_complex>)`

`experimental_breakpoint_set_armCortexA53()`
: Use this format when the function is experimental and should only be used by an experimental client.

`breakpoint_foo()`
: Use this format when the new functionality is breakpoint-related, but does not have *set* semantics but *foo* semantics instead.

`foo_bar()`
: Use this format when this is entirely new functionality, not related to breakpoints at all.

`breakpoint_set2()`

Use this format when this function has the same semantics as `breakpoint_set`, but has a better interface with incompatible arguments or incompatible return value and therefore enhancing the argument list or return value is not an option.

See also 6.2 Naming conventions on page 65 for general naming conventions.

6.19.9 instanceRegistry_getInstanceInfoByInstId()

Gets the instance name for an instance id.

Arguments

`aInstId`

Type: `NumberU64`

Instance id of the instance to look up. This argument is intentionally not called `instId` because this function is not targeted at the instance identified by this argument, but is targeted at the instance registry.

Return value

`InstanceInfo`

`InstanceInfo` object containing the name and `instId` of an instance.

Errors

- `E_unknown_instance_id`.

6.19.10 instanceRegistry_getInstanceInfoByName()

Gets the instance Id for a named instance.

Arguments

`instName`

Type: `String`

Instance name of the instance to look up.

Return value

`InstanceInfo`

`InstanceInfo` object containing the name and `instId` of an instance.

Errors

- `E_unknown_instance_name`.

6.19.11 instanceRegistry_getList()

Gets a list of all instances, optionally filtered by a specific prefix.

Usage

Optionally also get the instance properties of all returned instances. This allows you to conveniently inspect the instance properties, for example to extract all core/CPU components, without first manually needing to call `instance_getProperties()` on all instances.

Arguments

`prefix`

Type: `String`

Optional. Only return instances whose hierarchical instance name starts exactly with `prefix` or is exactly `prefix`. Only complete parts of the hierarchical names are matched, that is, prefix="component.root.ram" does not match "component.root.ramdevice", but does match "component.root.ram.bank0" and also matches "component.root.ram".

The primary use case of `prefix` is to conveniently query only a specific class of instances, for example all components of a simulation using prefix="component".

If this is missing or empty, all instances are returned. If no matching instance is found, an empty list is returned, rather than an error.

`getProperties`

Type: `Boolean`

Optional. Include instance properties in the returned instance infos. By default instance properties are not returned, just `instId` and instName. This is a convenience feature. Requesting properties calls `instance_getProperties()` on all returned instances since instance properties are not stored in the instance registry.

Return value

`InstanceInfo[]`

`InstanceInfo` Objects describing the instances matching `prefix`, optionally including instance properties.

6.19.12 instanceRegistry_registerInstance()

Registers a new instance in the global instance registry and assigns an instance id (`instId`) to it.

Arguments

`instName`

Type: `String`

Hierarchical instance name. Hierarchy levels are separated by dots ('.'). The first hierarchy level defines the class this instance belongs to, namely `component`, `client`, or `framework`. Instance names must not start or end with a dot and must not contain two adjacent dots. The instance name elements that are separated by dots must be C identifiers. For invalid instance names, `E_invalid_instName` is returned.

`channelId`

Type: `NumberU64`

Optional. For in-process instances, this is mandatory. It indicates the IrisInterface communication of the caller of this function. For out-of-process instances, for example ones that are connected using TCP, this is ignored and must be omitted.

`uniquify`

Type: `Boolean`

Optional. Iff True, uniquify name if `instName` already exists, by appending a suffix to `instName` such that `instance` + `suffix` is a unique instance name. This must only be used by `client` instances, for example debuggers and plug-ins, not by `component` instances, which must choose a unique name based on the system hierarchy. Instances must use a meaningful stem as `instName`, for example the name of a debugger or a plug-in instance name.

Default: `False`

Return value

`InstanceInfo`

Object containing the `instId` and the `instName` of the registered instance. The opaque instance id uniquely and globally identifies the instance in the simulation until it is unregistered using `instanceRegistry_unregisterInstance()`. See `InstanceInfo`.

Errors

- `E_invalid_instName`.
- `E_instance_already_registered`.

6.19.13 instanceRegistry_unregisterInstance()

Unregisters an instance from the instance registry.

Arguments

`aInstId`

Type: `NumberU64`

Opaque number uniquely identifying the instance to be unregistered. This argument is intentionally not called `instId` because this function is not targeted at the instance identified by this argument, but is targeted at the instance registry.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.

6.19.14 instance_checkFunctionSupport()

Checks whether a specific instance supports a specific set of functions and, optionally, function arguments. If a Boolean result is not sufficient, use `instance_getFunctionInfo()` to retrieve a list of all supported functions and their arguments. This function does not return errors for unknown functions or arguments listed in `functions`.

Arguments

`functions`

Type: `FunctionSupportRequest[]`

List of function names with optional argument list per function.

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the instance.

Return value

`Boolean`

True: Instance supports all functions and all their arguments that are specified in `functions`. The instance might support functions not specified in `functions` and might also support more arguments than are specified in `functions`. False: Instance either does not support at least one of the specified functions or it does not support at least one of the specified function arguments.

Errors

- `E_unknown_instance_id`.

6.19.15 instance_getCppInterfaceIrisInstance()

Get a host pointer to the C++ `iris::IrisInstance` implementing an instance.

Usage

This is an exotic function which must generally not be used.

This function is only supported by instances that use the C++ IrisSupportLib class `iris::IrisInstance`. If this function is present it always returns a non-null pointer.

The caller of this function must make sure that the caller and callee use the same C++ interface class layout and run in the same process. This effectively means that they both must be compiled using the same compiler using the same header files. The returned pointer is only meaningful if caller and callee run in the same process.

The meta-information provided alongside the returned pointer in `CppInterfacePointer` can (and must) be used to do minimal compatibility checking between caller and callee.

- Instances do not have to be implemented using `iris::IrisInstance`, thus not all instances will support this function.
- This function must only be used by instances that are tightly coupled because the use of this function creates a binary dependency between the instances.
- Using this function is very exotic and must be avoided if possible.
- Normal Iris function calls must always be preferred over direct C++ communication between instances.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

`CppInterfacePointer`

Pointer to the C++ `iris::IrisInstance` (and associated meta-information) of this instance. See `CppInterfacePointer`.

Errors

- `E_unknown_instance_id`.

6.19.16 instance_getFunctionInfo()

Returns a list of all functions supported by a specific instance and their meta information, for example the description, the mandatory and optional arguments, and the type of the return value.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the instance to query. Specifying the value 0 queries the list of functions supported by the global instance, for example `instanceRegistry_registerInstance()`.

prefix

Type: `String`

Optional. Get FunctionInfo only for functions whose name starts with `prefix`. If this argument is missing or empty, all supported functions are returned.

Return value

`Map[String]FunctionInfo`

Object that maps function names onto `FunctionInfo` Objects. The map might be empty, for example if `prefix` does not match any function.

Errors

- `E_unknown_instance_id`.

6.19.17 instance_getProperties()

Gets detailed information about an instance. This information is inherent to the instance and does not change, for example the type of a component or whether certain features are supported or not.

Arguments

instId

Type: `NumberU64`

Opaque number uniquely identifying the instance.

Return value

`Map[String]Value`

Object containing all properties and their values. Numeric values can be stored as a number or as a `String` in this object.

Errors

- `E_unknown_instance_id`.

6.19.18 instance_ping()

Ping instance. This function has no effect on the instance, it is a no-op. It is primarily used to test and benchmark the Iris infrastructure. Optionally a payload can be sent to the target instance, and the target instance returns this payload in the return value.

Arguments

instId

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

payload

Type: `Value`

Optional. If present, this value is returned. If not present, Null is returned.

Return value

`Value`

If `payload` is present, it is returned, else Null is returned.

Errors

- `E_unknown_instance_id`.

6.19.19 instance_ping2()

Ping instance.

Usage

This function differs from `instance_ping()` in the following ways:

- It returns a `PingResult` object which contains the payload and information about success or errors in any recursive ping calls.
- It supports reverse pings (the callee pings the caller), also recursively. In addition, the number of pings for the innermost recursion level can be specified so that 'reverse ping' benchmarks can be run.

`E_io_error` is returned when for any recursive ping the returned payload did not match the passed payload.

Example: Simple ping like instance_ping():

```
instance_ping2()
```

Reverse ping, calling back the caller 1000 times:

```
instance_ping2(recursive = 1, nCalls = 1000, seqNr = 0)
```

Passing seqNr = 0 is optional and enables setting the seqNr fields in the inner PingResults which is useful when debugging but which costs some performance in contrast to not passing/returning it.

Testing whether at least 10 recursion levels are supported when calling Iris functions:

```
instance_ping2(recursive = 10).
```

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`payload`

Type: `Value`

Optional. If present, this value is returned in `PingResult.payload`.

`recursive`

Type: `NumberU64`

Optional. If present and > 0 then the callee will call back the caller with instance_ping2(recursive = recursive -1, ...). This allows the caller to issue a reverse ping (recursive = 1 and nCalls = number of reverse ping calls to make), or to cause deeply nested callbacks from within callbacks (recursive > 1).

`nCalls`

Type: `NumberU64`

Optional. This only has an effect if recursive is >= 1. If present and > 0, issue nCalls ping calls on the innermost recursion level. A total number of 'nCalls + recursive - 1' ping calls are called. If recursive is >= 1 and nCalls is missing then nCalls = 1 is assumed.

`seqNr`

Type: `NumberU64`

Optional. If present, this value is returned in the PingResult return value to allow easy association of calls and return values (requests and responses). If this is not specified in the initial ping call it is also not returned by any inner PingResult. This value is otherwise ignored.

Return value

`PingResult`

Payload (if specified) and potentially information about the success and errors of inner ping calls. In addition, recursive and seqNr are returned (unmodified) when they were specified. This allows an observer of the Iris communication (for example, through an Iris communication log) to match Iris messages for recursive calls and their corresponding return values. See `PingResult`.

Errors

- `E_unknown_instance_id`.
- `E_io_error`.

6.19.20 instance_registerProxyFunction()

Register a proxy function which transparently forwards all calls to a target instance.

Usage

This can be used to expose a function on a proxy instance while it is implemented in the target instance. The main use case is to add global functions to the global instance and implement them in another instance.

This function is an internal infrastructure function. Clients never need to call it.

Calling this function for an already registered function (proxy or normal function) returns `E_function_already_registered`. The target instance must already be registered in the global instance and the function must already be registered in the target instance before calling this function.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the proxy instance.

`name`

Type: `String`

Name of the proxy function. If this function is not supported by the target instance, `E_unknown_function_name` is returned.

`targetInstId`

Type: `NumberU64`

Optional. Calls to the proxy function are transparently forwarded to this instance. If this is not a valid instance id, `E_unknown_instance_id` is returned. If this is missing, the instance id in the request id is used as the target instance.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_function_name`.
- `E_function_already_registered`.

6.19.21 instance_unregisterProxyFunction()

Unregister proxy function. This is the counterpart of `instance_registerProxyFunction()`. This function is an internal infrastructure function. Clients never need to call it.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the proxy instance.

`name`

Type: `String`

Name of the proxy function. If this function was not registered as a proxy function, `E_unknown_function_name` is returned.

Return value

Function has no return value.

Errors

- `E_unknown_instance_id`.
- `E_unknown_function_name`.

6.19.22 AttributeInfo

AttributeInfo members:

`defval`

Type: `Value`

Optional. Default value for optional attributes. If not specified, the default values are 0, false, empty string, empty object, empty array, or null for number, boolean, string, object, array, and value respectively. Must be missing for mandatory arguments.

`description`

Type: `String`

Optional. Free-form description of the semantics and the structure of the argument. The format is the same as for the `description` member in `FunctionInfo`.

`enums`

Type: `EnumElementInfo[]`

Optional. List of valid enum values if this attribute is an enum. The position of the `EnumElementInfo` has no semantics. `EnumElementInfo` objects always contain the value they describe.

optional

Type: `Boolean`

Optional. If present and True, this attribute is optional. If False or missing, this attribute is mandatory.

type

Type: `String`

Specifies the type of the attribute. Can be one of: Number, `NumberU64`, `NumberS64`, `String`, Boolean, Object, Array, or Value, or the name of a specified object format. Arrays are indicated by suffixing the type with `[]` (that is an array of `NumberU64` would be `NumberU64[]`) and map-like objects are indicated by `Map[<key-type>]value-type` (that is `Map[String]NumberU64`). The map key type is always `String`.

6.19.23 CppInterfacePointer

CppInterfacePointer members:

pointer

Type: `NumberU64`

Host pointer of the C++ interface. This is a pointer to a class that supports runtime-type-information (`RTTI`). The pointer value is represented as a `NumberU64`.

The consumer of this pointer must use the meta-information provided in this object to do a minimal check that it is safe to use the pointer value in the current context.

The checks associated with `typeidName`, `typeidHashCode` and `sizeof` are insufficient to guarantee that the producer and consumer have compatible class layouts but are better than not doing any check at all. The consumer must also use other means to ensure compatibility with the producer, for example by being built into the same executable or set of executables.

typeidName

Type: `String`

The value of the expression `typeid(*pointer).name()` associated with `pointer`. This must be used by the consumer to verify that the producer and the consumer of the pointer have been compiled against the same source code using the same compiler.

typeidHashCode

Type: `NumberU64`

The value of the expression `typeid(*pointer).hash_code()` associated with `pointer`. This must be used by the consumer to verify that the producer and the consumer of the pointer have been compiled against the same source code using the same compiler.

sizeof

Type: `NumberU64`

The value of the expression `sizeof(*pointer)` associated with `pointer`. This must be used by the consumer to verify that the producer and the consumer of the pointer have been compiled against the same source code using the same compiler.

pid

Type: `NumberU64`

Process id associated with `pointer`. This must be used by the consumer to verify that the producer and the consumer of the pointer run in the same process. The pointer is only valid when used within the same process.

6.19.24 EnumElementInfo

EnumElementInfo members:

description

Type: `String`

Optional. Free-form description of the semantics and the structure of the argument. The format is the same as for the `description` member in `FunctionInfo`.

symbol

Type: `String`

Optional. Symbolic value, usually a C identifier, associated with a numeric value. This is mandatory for numeric values. This must not be present for enums of type `String` where the string value is the symbol's value.

value

Type: `Value`

Value of the enum element. This is usually either a `String`, `NumberU64`, or `NumberS64` value. The type must match the type of the attribute this enum is associated with.

6.19.25 FunctionInfo

FunctionInfo members:

args

Type: `Map[String]AttributeInfo`

Object mapping the names of all arguments onto `AttributeInfo` objects. The `AttributeInfo` objects specify details of each formal argument like type, description, and enum values.

description

Type: `String`

Free-form description of this function. Must start with a capital letter and end with a dot. Can contain multiple lines (separated by `LF`). If so, the first line is a summary and is separated from the detailed description by an empty line.

errors

Type: `String[]`

The names of error codes that this function might respond with.

retval

Type: `AttributeInfo`

`AttributeInfo` object describing the return value (type, description).

6.19.26 FunctionSupportRequest

FunctionSupportRequest members:

args

Type: `String[]`

Optional. List of formal argument names to check for. At least the specified argument must be supported. More arguments can be supported. The default is not to check for any arguments, which is the same as an empty list.

name

Type: `String`

Name of a function to check for.

6.19.27 InstanceInfo

InstanceInfo members:

instId

Type: `NumberU64`

Opaque id uniquely identifying the instance.

instName

Type: `String`

Hierarchical instance name of the instance.

properties

Type: `Map[String]Value`

Optional. Instance properties as reported by `instance_getProperties()`. This is only returned by `instanceRegistry_getList(getProperties=true)`, otherwise this is missing.

`connectionInfo`

Type: `String`

Optional. Describes how the instance is connected to the global instance:

- `local`: In-process with the global instance.
- `plugin:<PLUGIN-PATH>`: Plugin. Also in-process with the global instance.
- `socket:tcpclient=IP:PORT` or `socket:socketfd=N`: Connected via TCP or `UNIX` domain socket. Out-of-process.

6.19.28 PingResult

PingResult members:

`payload`

Type: `Value`

Optional. Returns the payload argument passed to an `instance_ping2()` call. This is only present if a payload argument was passed to `instance_ping2()`.

`seqNr`

Type: `NumberU64`

Optional. Sequence number of the returning inner `instance_ping2()` call. This is only present when a seqNr argument (of any value < 2^{64}-1) was specified in the original call to `instance_ping2()`.

`recursive`

Type: `NumberU64`

Optional. Recursion level this return value belongs to, where the innermost level is 0. This is only present when recursive >= 1 was specified when calling `instance_ping2()`.

`numCallsOk`

Type: `NumberU64`

Optional. Total number of successful recursive calls to `instance_ping2()`. This is only present when recursive >= 1 was passed to `instance_ping2()`.

This counts all calls including the intermediate recursive calls and the calls made on the innermost recursion level on behalf of `nCalls`. When calling `instance_ping2(recursive=R, nCalls=N)` then `numCallsOk = R - 1 + N` is expected (-1 just because N includes the innermost recursion level. That is, R=1 and N=1 issue exactly one recursive call and `numCallsOk=1`). The top-most call to `instance_ping2()` is not counted, only the recursive calls issued by `instance_ping2()` are counted to make them observable by the caller.

errors

Type: `NumberU64[]`

Optional. List of error codes that occurred in any of the recursive calls. This is only present if an error occurred. If this is missing or empty, no error occurred.

6.19.29 Event source IRIS_INSTANCE_REGISTRY_CHANGED

This event is generated when the list of registered instances has changed, shortly after the change was applied to the instance registry.

This event source is only provided by `framework.GlobalInstance`, not by individual instances.

Table 6-19: Event source IRIS_INSTANCE_REGISTRY_CHANGED

Field	Type	Description
`EVENT`	`String`	The event that occurred. Possible values: **`"added"`** Added a new instance to the instance registry. **`"removed"`** Removed an instance from the instance registry.
`INST_ID`	`NumberU64`	Instance id of the instance that was added or removed.
`INST_NAME`	`String`	Instance name of the instance that was added or removed.

6.20 Simulation instantiation and discovery API

This section describes the functionality to instantiate simulations and discover running simulations.

There are two main use cases when using simulations:

- Connecting to a running simulation using IPC.
- Instantiating a new simulation, in-process.

Most functions described in this section have a different scope to other Iris functions. Most Iris functions assume a pre-existing communication channel between instances in a pre-existing simulation, and this communication channel, regardless of its transport, is specific to one instantiated simulation.

Instead, the functions in this section deal with situations where a simulation is about to be instantiated or where a communication channel to an existing simulation is about to be established. The available functionality strongly depends on whether a caller connects using IPC or instantiates a new simulation in-process.

6.20.1 Connecting to a running simulation using IPC

Communicating with a running simulation typically involves these basic steps:

1. Optionally get a list of all available running simulations.
2. Connect to a specific simulation.
3. Use Iris to inspect and manipulate the simulation and the instances in it.
4. Disconnect from the simulation. Optionally request simulation shutdown.

6.20.2 Instantiating a new simulation, in-process

A client that does not yet have an instantiated simulation to communicate with is called a *pre-instantiation client*.

Examples of pre-instantiation clients:

- `main()` function of a standalone, non-SystemC, simulator executable.
- DSO entry point of a standalone, non-SystemC, simulator DSO.

Instantiating a new simulation follows this sequence:

1. Optionally get instantiation parameter meta-information, for example name, type, and description, from the simulator.
2. Optionally get instantiation parameter values from the user.
3. Optionally set instantiation parameter values.
4. Instantiate a simulation with instantiation parameter values.
5. Use Iris to inspect and manipulate the simulation and the instances in it.
6. Optionally request simulation shutdown.

6.20.3 Instantiation parameters

The parameters that are exposed through `simulation_getInstantiationParameterInfo()` are called *instantiation parameters*.

Instantiation parameters are used to initialize the initialization-time and runtime parameters of each instance during instantiation. After the system is instantiated, the instantiation parameter values are exposed through the `resource_*()` functions of each instance.

Instantiation parameters are exposed as a flat list of parameters. The full instance path is prepended to the parameter name, to indicate the hierarchy of the not-yet-instantiated system:

<instance_path>.<parameter_name>

This parameter will later on be exposed by instance *<instance_path>* as parameter *<parameter_name>*.

There are subtle differences between instantiation parameters and the instance-specific initialization-time and runtime parameters:

- Instantiation parameters have a hierarchical name and are exposed through `simulation_getInstantiationParameterInfo()`. They can only be set by using `simulation_setInstantiationParameterValues()`. At instantiation, there is no functional difference between initialization-time and runtime parameters. The instantiation parameters are the sum of all initialization-time and runtime parameters, but with hierarchical names.
- Instantiation parameters are global and their association with a specific, future, instance is only implied through their hierarchical parameter name. Instantiation parameters use `ResourceInfo` metadata, the function `simulation_getInstantiationParameterInfo()`, which is similar to `resource_getList()`, and the function `simulation_setInstantiationParameterValues()`, which is similar to `resource_write()`.
- The main difference between instantiation parameters and the per-instance initialization-time and runtime parameters is that instantiation parameters are only identified by their hierarchical name string and do not have a resource id (`rscId`) or instance id (`instId`).
- Initialization-time parameters can only be set before instantiation and cannot be changed later. Before instantiation, they are exposed globally as instantiation parameters, with a hierarchical parameter name, and after instantiation they are exposed as resources with `parameterInfo.initOnly = True`. That is, they are exposed only by the instance they belong to, with a non-hierarchical name.
- Runtime parameters can be set before instantiation and can also be changed later. Before instantiation, they are exposed globally as instantiation parameters, with a hierarchical parameter name, and after instantiation they are exposed as resources with `parameterInfo.initOnly = False`. That is, they are exposed only by the instance they belong to, with a non-hierarchical name.

Related information

Resources API on page 71
ResourceInfo on page 88

6.20.4 Setting instantiation parameter values

Pre-instantiation clients can optionally call `simulation_setInstantiationParameterValues()` to initialize all init-time and runtime parameters for all instances during the instantiation of the simulation.

This function modifies state that exists before the simulation is instantiated, it does not instantiate the simulation. It can be called multiple times. Each invocation can set all of the instantiation parameters or a subset of them. Any parameters that this function does not set keep their default values. Each invocation can overwrite parameter values that were set with previous invocations of `simulation_setInstantiationParameterValues()`.

An implementation can defer any errors, for example `E_unknown_parameter_name` or `E_type_mismatch`, until instantiation. These deferred errors are then returned by `simulation_instantiate()`.

6.20.5 simulation_getInstantiationParameterInfo()

Gets the meta information of all instantiation parameters of a not-yet-instantiated simulation.

Usage

Calling this function is optional. If a pre-instantiation client already knows which parameters exist, it can instantiate the simulation without first getting the meta information using this function, for example when reading parameter values from a config file. This function has no side effects.

Arguments

`instId`

Type: `NumberU64`

Optional. Clients must omit this argument or specify 0 because this is a global function.

`prefix`

Type: `String`

Optional. Only return parameters whose hierarchical name starts exactly with `prefix` or is exactly `prefix`. Only complete parts of the hierarchical names are matched, that is, prefix="component.root.ram" does not match "component.root.ramdevice", but does match "component.root.ram.bank0" and also matches "component.root.ram". If this is missing or empty, all parameters are returned. If no matching parameter is found, an empty list is returned rather than an error.

Return value

`ResourceInfo[]`

List of meta information for instantiation parameters as an array of `ResourceInfo` objects. The semantics of these ResourceInfo entries differ slightly from instance-specific ResourceInfo entries:

- The list of instantiation parameters is global and an association with a specific future instance is only implied by its hierarchical name.
- `ResourceInfo.rscId` is missing. (Instantiation parameters are identified by their hierarchical name.).
- `ResourceInfo.name` contains the hierarchical name of the instantiation parameter, with the format <instance_path>.<parameter_name>.
- `ResourceInfo.cname` is missing. Instantiation parameters do not have valid C identifiers and are always identified by their `name` string.

6.20.6 simulation_instantiate()

Pre-instantiation clients use this function to instantiate the simulation. It implicitly uses the parameter state that was set up by `simulation_setInstantiationParameterValues()`.

Arguments

`instId`

Type: `NumberU64`

Optional. Clients must omit this argument or specify 0 because this is a global function.

Return value

`InstantiationResult`

List of errors and warnings that occurred during instantiation. This includes invalid parameter values and license checking errors. See `InstantiationResult`.

6.20.7 simulation_requestShutdown()

Requests that the simulation destroys itself cleanly. The shutdown might be delayed and is likely to happen after this function returns. Receiving a response to this function call does not mark any special event and does not mean the simulation has been shut down.

Arguments

`instId`

Type: `NumberU64`

Optional. Clients must omit this argument or specify 0 because this is a global function.

Return value

Function has no return value.

6.20.8 simulation_reset()

Resets the simulation to exactly the same state it had after instantiation, see `simulation_instantiate()`.

Usage

Some simulations might require simulation time to be stopped before they can be reset. These simulations respond with the error code `E_simulation_running` if `simulation_reset()` is called while simulation time is progressing. For simulations that can be reset while simulation time is progressing, the simulation is stopped automatically before resetting the system. Simulation time is not resumed after the reset is done. After `simulation_reset()` completes, the simulation is always stopped.

Arguments

`instId`

Type: `NumberU64`

Optional. Clients must omit this argument or specify 0 because this is a global function.

`allowPartialReset`

Type: `Boolean`

Optional. If present and true, perform a partial simulation reset for simulations that do not support a full reset. This might be because some components in a simulation do not support reset functionality. By setting `allowPartialReset` to true, a client acknowledges that it accepts the consequences of not resetting the whole simulation.

Default: `False`

Return value

Function has no return value.

Errors

- `E_full_reset_not_supported`.
- `E_simulation_running`.

6.20.9 simulation_setInstantiationParameterValues()

Sets the instantiation parameter values. These values are used to initialize all init-time and run-time parameters of all instances during the instantiation of the simulation. This function modifies a state that exists before the simulation is instantiated. It does not instantiate the simulation.

Arguments

`instId`

Type: `NumberU64`

Optional. Clients must omit this argument or specify 0 because this is a global function.

`data`

Type: `InstantiationParameterValue[]`

List of instantiation parameter values.

Return value

Function has no return value.

Errors

- `E_unknown_parameter_name`.

- `E_type_mismatch`.

6.20.10 simulation_waitForInstantiation()

This function can be used by clients that connect to a simulation to make sure that the simulation has been instantiated and all components have been initialized.

Usage

It can be called at any time during the simulation. If called before the simulation has been instantiated the response will only be sent after the simulation has been instantiated. If called after instantiation it will return immediately.

Arguments

`instId`

Type: `NumberU64`

Optional. Clients must omit this argument or specify 0 because this is a global function.

Return value

Function has no return value.

6.20.11 InstantiationError

InstantiationError members:

`code`

Type: `String`

Error or warning code as a string symbol. This is one of the following:

License checking errors and warnings:

- "error_license_found_but_expired".
- "error_license_not_found".
- "error_license_count_exceeded".
- "error_cannot_contact_license_server".
- "warning_license_will_expire_soon".
- "error_general_license_error" for other license-related errors.

Parameter-related errors:

- "error_parameter_type_mismatch". Specified a `String` value for a non-String parameter or vice versa.
- "error_parameter_value_invalid". The value for a parameter is invalid.

- "error_unknown_parameter". Parameter name is unknown.
- "error_general_parameter_error" for other parameter-related errors.

General errors or warnings:

- "error_general_error" for all other errors.
- "error_general_warning" for all other warnings.

message

Type: `String`

Free-format error or warning message, potentially multiple lines long. This must repeat the error or warning reason given in `code`.

parameterName

Type: `String`

Optional. Name of the offending parameter for parameter-related errors. Mandatory for parameter-related errors. Must not be present for other errors or warnings.

severity

Type: `String`

Severity of the error or warning. This is one of the following:

error

This is an error. The simulation was not instantiated because of this error, and possibly other errors.

warning

This is a warning. Warnings do not prevent the simulation from being instantiated but they might provide useful information to the user about potential problems.

6.20.12 InstantiationParameterValue

InstantiationParameterValue members:

name

Type: `String`

Hierarchical name of the parameter to set. This is the same as the `ResourceInfo.name` value returned by `simulation_getInstantiationParameterInfo()` or `plugin_getInstantiationParameterInfo()`.

value

Type: `Value`

Value of the parameter. Type is either a `String` for string parameters, or NumberU64[] for numeric parameters.

6.20.13 InstantiationResult

InstantiationResult members:

`errors`

Type: `InstantiationError[]`

List of errors and warnings that occurred during instantiation.

`success`

Type: `Boolean`

If True, the simulation was instantiated successfully. In this case, `errors` is either empty or only contains warnings. If False, the simulation was not instantiated. In this case, `errors` contains at least one error.

6.20.14 SimulationTimeObject

SimulationTimeObject members:

`ticks`

Type: `NumberU64`

Current simulation time in ticks. One tick is 1/tickHz seconds long. The elapsed simulation time is ticks/tickHz seconds.

`tickHz`

Type: `NumberU64`

Time resolution of the `ticks` value in Hz. For example, 1000 means that 1 tick = 1 ms.

`running`

Type: `Boolean`

Iff True, the simulation time is running, else it is stopped. Note that this information can already be outdated when the caller receives the response. When multiple simulation controllers start and stop the simulation, for example when multiple debuggers are connected, there is no way to reliably know whether the simulation is currently running or stopped. In this case, this is just a hint.

6.20.15 Event source IRIS_SIMULATION_SHUTDOWN_ENTER

This global event is generated when the simulation is about to enter its shutdown procedure. This is the earliest point at which instances can know that the simulation is about to exit. This event source has no fields.

If the event receiver activated this event source with `syncEc=True`, the shutdown procedure is not entered until the `ec_FOO()` function returns. This enables clients to perform last-minute operations, for example reading the final state of registers.

The global instance might impose a global timeout for progressing with the shutdown sequence, to handle stalled or blocked clients. The shutdown sequence should only be paused for a few milliseconds, and as a guideline, not for more than 1000ms.

Instances must not unregister themselves from the instance registry using `instanceRegistry_unregisterInstance()` in response to this event, because other instances might want to continue to communicate with them during the shutdown phase.

If this event was requested with `syncEc=True`, the requesting instance should not make any Iris calls after returning from `ec_FOO()`. This is possible in a race-free way. If this event was requested with `syncEc=False`, the requesting instance should not make any Iris calls after this event was received. This is inherently racy. Any Iris calls made while or after this event was received with `syncEc=False` might return `E_unknown_instance_id`.

For in-process instances, the C++ `IrisInterface` pointers of the instance and of the global instance stay valid and can be used even when returning from this event.

Related information

ec_FOO() on page 166
instanceRegistry_unregisterInstance() on page 213

6.20.16 Event source IRIS_SIMULATION_SHUTDOWN_LEAVE

This global event is generated when the simulation shutdown procedure is complete. After receiving this event, instances cannot communicate with each other. This event source has no fields.

This event is issued only after all instances that requested `IRIS_SIMULATION_SHUTDOWN_ENTER` with `syncEc=True` have returned from their `ec_FOO()` callback.

Instances can consider themselves to have been unregistered from the instance registry when they receive this event, so they should not call `instanceRegistry_unregisterInstance()` after receiving it. They are guaranteed not to receive any more Iris calls or responses after receiving it.

This event can be used by instances to destroy themselves. The C++ `IrisInterface` pointers must no longer be used after returning from `IrisInterface::irisHandleMessage()`. This is always possible race-free.

Related information

ec_FOO() on page 166

6.21 Plug-in loading and instantiation API

Plug-in instantiation is similar to simulation instantiation but with the following differences:

- Plug-ins can be instantiated more than once. When `plugin_instantiate()` is called on a plug-in factory, it creates an instance of the plug-in. The same factory instance can be used to create multiple instances of the plug-in with the same or different parameter values.
- The parameter names that are given by `plugin_getInstantiationParameterInfo()` are not hierarchical, but are relative to the plug-in instance. They are the same as the parameter names returned by calling `resource_getList()` on the plug-in instance.

Related information

resource_getList() on page 81

6.21.1 plugin_getInstantiationParameterInfo()

Gets the list of ParameterInfo used to instantiate instances of a plug-in.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

Return value

`ResourceInfo[]`

ResourceInfo for the instantiation parameters of the plug-in.

Errors

- `E_unknown_instance_id`.

6.21.2 plugin_instantiate()

Instantiates a plug-in instance.

Arguments

`instName`

Type: `String`

Optional. Used to construct the instance name for the new instance. The instance name is "client.plugin.<instName>". If omitted, the plug-in factory chooses a suitable instance name.

`paramValues`

Type: `InstantiationParameterValue[]`

Optional. List of instantiation parameter values to use when instantiating the plug-in instance. Any parameters can be omitted and the `paramValues` argument can be omitted entirely. Any parameters that do not have a value set use their default value.

Return value

`InstantiationResult`

Indicates whether instantiation was successful and lists any errors and warnings that occurred during instantiation. See `InstantiationResult`.

Errors

- `E_unknown_instance_id`.

6.21.3 plugin_load()

Loads a plug-in library.

Arguments

`path`

Type: `String`

Path to plug-in library to be loaded.

Return value

`InstanceInfo[]`

List of InstanceInfo for instances registered by this plug-in.

Errors

- `E_error_loading_plugin`.

6.22 TCP server management API

The global instance manages the Iris TCP server.

The TCP server can be started or stopped at any time during the simulation but typically is started at the beginning of the simulation and stopped automatically when the simulation is shut down. If it is stopped while there are remote instances still connected to it, all those instances are automatically unregistered.

6.22.1 tcpServer_getPort()

Gets the TCP port number that the Iris server is listening on.

Return value

`NumberU64`

TCP port number that the server is listening on.

Errors

- `E_server_not_running`.

6.22.2 tcpServer_start()

Start the Iris server. This can be either a TCP server (by specifying connectionSpec=tcpserver) or the server is directly connected to a UNIX domain socket (by specifying connectionSpec=socketfd=N).

Arguments

`connectionSpec`

Type: `String`

Specify the type of server and its parameters. Supported connection types:

`tcpserver[,port=PORT][,endport=ENDPORT][,allowRemote]`

Start TCP server on the first free port in the range [PORT..ENDPORT]. Default for `PORT` is 7100. Default for `ENDPORT` is `PORT` + 63. Only local connections are allowed, unless allowRemote is specified.

`socketfd=FD`

Use socket file descriptor `FD` as an established UNIX domain socket connection.

General parameters:

`verbose=N`

Increase verbose level of server to level N (0..3).

Return value

`TcpServerStartResult`

Parameters of the started server. TCP port number that the TCP server is listening on. See `TcpServerStartResult`.

Errors

- `E_server_already_running`.
- `E_data_size_error`.

6.22.3 tcpServer_stop()

Stops the running Iris server. Any instances connected using TCP are automatically unregistered in the process.

Return value

Function has no return value.

Errors

- `E_server_not_running`.

6.22.4 service_connect()

Connects to a local or remote Iris service server.

Arguments

`hostname`

Type: `String`

Hostname of IrisService to connect to.

`port`

Type: `NumberU64`

Port of IrisService to connect to.

Return value

Function does not return a value.

Errors

- `E_already_connected`.
- `E_unknown_hostname`.
- `E_socket_error`.

- `E_not_compatible`.
- `E_connection_refused`.
- `E_timeout`.

6.22.5 service_disconnect()

Disconnects from an already connected Iris service server.

Arguments

`hostname`

Type: `String`

Hostname of the service to disconnect from.

`port`

Type: `NumberU64`

Port of the service to disconnect from.

Return value

Function does not return a value.

Errors

- `E_socket_error`.
- `E_not_connected`.

6.22.6 TcpServerStartResult

TcpServerStartResult members:

`port`

Type: `NumberU64`

Optional. TCP port the server was started on.

6.23 Checkpointing API

The Checkpointing API allows you to save and restore the state of an instance.

Not all Iris components support checkpointing in this release.

6.23.1 checkpoint_save()

Saves a checkpoint on a specific instance.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`checkpointDir`

Type: `String`

Directory to which the checkpoint is saved. This directory is always on the machine on which the target instance is running, which is not necessarily the machine on which the caller of this function is running.

Return value

Function has no return value.

Errors

- `E_error_saving_checkpoint`.

6.23.2 checkpoint_restore()

Restores a checkpoint on a specific instance.

Arguments

`instId`

Type: `NumberU64`

Opaque number uniquely identifying the target instance.

`checkpointDir`

Type: `String`

Directory from which the checkpoint is restored.

Return value

Function has no return value.

Errors

- `E_error_restoring_checkpoint`.

7. Response error codes

This chapter describes the error codes that Iris defines. These are in addition to those defined in the JSON-RPC 2.0 specification.

Function calls in Iris are made according to the JSON-RPC 2.0 specification. This specification requires that a function call must return a response object, which must either contain a `result` member, if no error occurred, or an `error` object, if an error occurred.

Error objects have the following mandatory members:

- code
- message

7.1 Function-specific error codes

The following table describes error codes that might be returned by specific functions only. These error codes are listed in the Errors section for each function that might return them.

Table 7-1: Function-specific error codes

Error code	Value	Meaning
`E_unknown_resource_id`	`0xE101`	The `rscId` argument does not specify an existing resource for the specified target instance.
`E_data_size_error`	`0xE102`	The `data` argument, or one of the `data` arguments, if there are more than one, does not match the size that is expected by that function. Either the function expects data with a certain minimum or maximum size, or the size of an array or string is inconsistent with other parameters.
`E_unknown_memory_space_id`	`0xE103`	The `spaceId` argument does not specify a valid memory space for the target instance.
`E_unknown_event_source`	`0xE104`	The `name` argument does not specify a valid event source for the target instance.
`E_unknown_event_field`	`0xE105`	The `field` or `fields` argument contains an unknown event field for the specified event source.
`E_unknown_event_stream_id`	`0xE106`	The `esId` argument does not specify a valid event stream id, that is, one that was previously created with `eventStream_create()`.
`E_unknown_disassembly_mode`	`0xE107`	The `mode` argument specifies an unknown disassembly mode.
`E_unknown_callback_instance_id`	`0xE108`	The callback instance id, `ecInstId`, is unknown.
`E_syncEc_mode_not_supported`	`0xE109`	The specified event source or function does not support synchronous callbacks.
`E_counter_mode_not_supported`	`0xE10A`	An unknown event counter id was passed to an event counter function.
`E_unknown_file_descriptor`	`0xE10B`	An unknown file descriptor was passed to the `semihosting_provideInputData()` function.

Error code	Value	Meaning
E_invalid_context	0xE10C	The function must not be called in this context. For example, the semihosting_return() function must only be called from within synchronous invocations of the ec_FOO() callback for the IRIS_SEMIHOSTING_CALL_EXTENSION event source.
E_unknown_sync_level	0xE10D	Unknown sync level value.
E_invalid_instName	0xE10E	The instance name is invalid. Either the class, that is, the first part of the hierarchical instance name, is unknown, or the dots separating the hierarchy levels have caused a formatting error.
E_instance_already_registered	0xE10F	The instance could not be registered because another instance with the same instName was already registered.
E_address_out_of_range	0xE113	The specified address is outside of the range minAddr to maxAddr for the specified memory space.
E_unknown_resource_group	0xE114	The specified resource group name is unknown.
E_unknown_event_source_id	0xE115	The specified event source id is unknown.
E_io_error	0xE116	An operation on a file or a socket on the callee side returned an I/O error, for example for image_loadFile(). End-of-file never results in E_io_error.
E_unknown_image_format	0xE117	The format of an image passed to image_loadFile() or image_loadData() is not recognized so it cannot be loaded.
E_image_format_error	0xE118	The format of an image passed to image_loadFile() or image_loadData() is recognized, but the image is either malformatted or contains unsupported constructs.
E_error_opening_file	0xE119	The file passed to image_loadFile() cannot be opened for reading.
E_not_supported_for_event_source	0xE11B	One of the following: • A trace range or trace start point or stop point was set on an event source that does not support this feature. • The trace range does not support the selected aspect. • The event source does not support eventStream_getState().
E_not_a_counter	0xE11C	eventStream_getCounter() was called on an event stream that was not started as a counter, in other words, it was created with eventStream_create(counter = False).
E_unaligned_access	0xE11D	memory_read() or memory_write() was called with a start address that is not naturally aligned to the byteWidth argument.
E_unsupported_attribute_name	0xE11E	memory_read() or memory_write() was called with an unknown or unsupported attribute name in the attrib argument.
E_unsupported_attribute_value	0xE11F	memory_read() or memory_write() was called with a valid attribute name, but the value specified is unsupported or invalid, regardless of the values of other attributes, or has the wrong type.
E_unsupported_attribute_combination	0xE120	memory_read() or memory_write() was called with a combination of attributes that does not make sense or is otherwise unsupported. **Note:** Target instances are not required to detect all invalid attribute combinations.
E_unsupported_breakpoint_type	0xE121	breakpoint_set() was called with an unknown or unsupported breakpoint type.
E_unsupported_argument_combination	0xE122	A function was called with a combination of optional arguments that is either unsupported or does not make sense. This includes missing optional arguments that are mandatory under some circumstances.

Error code	Value	Meaning
E_invalid_rwMode	0xE123	breakpoint_set() was called with an rwMode argument that is not "r", "w", or "rw".
E_unknown_breakpoint_id	0xE124	The specified breakpoint id, bptId, is not known by the instance.
E_unsupported_translation	0xE125	memory_translateAddress() was called with an unsupported pair of memory spaces. Models usually only support translations for very specific pairs of memory spaces and only in certain directions, for example only virtual to physical.
E_unit_not_supported	0xE126	A step function was called with a unit that is not supported by the instance.
E_unknown_function_name	0xE127	A function name was passed as an argument to another function, but the function is not known by the associated instance. This error is different to E_function_not_supported_by_instance in that the function in question is not the function currently being called, but is referred to by other means.
E_writing_ init_time_parameter	0xE128	resource_write() was called on an initialization-time parameter, which can only be set before simulation instantiation and are read-only after that.
E_not_connected	0xE129	The client, for example IrisTcpClient, is not connected to a simulation and so the call cannot be sent anywhere. This is only returned by IrisTcpClient or similar clients.
E_index_out_of_range	0xE12A	The specified index is out of range, for example for table_read().
E_unknown_table_id	0xE12B	A table function was called with an unknown table id.
E_unsupported_mode	0xE12E	A function was called with an unknown or unsupported mode argument.
E_unknown_instance_name	0xE12F	Function instanceRegistry_getInstanceInfoByName() was called with an unknown instance name. The class of the instance must be part of the instance name, for example component.cluster0 instead of just cluster0. Also, the presence of component.*a.b.c* does not guarantee the presence of component.*a.b*.
E_connection_refused	0xE130	Tried to connect to a server but there is no Iris server running on that port.
E_timeout	0xE131	A function that supports a timeout was called and it timed out.
E_unknown_hostname	0xE132	Tried to connect to a host using a hostname, but the hostname is not known.
E_socket_error	0xE133	A low level read, write, or configuration operation failed on the TCP socket.
E_thread_error	0xE134	A low-level threading function failed.
E_not_compatible	0xE135	Tried to connect to a server, but the server is not compatible with this client.
E_already_connected	0xE136	Tried to connect to a server but the client is already connected to one. Disconnect the client first.
E_error_reading_ write_only_resource	0xE137	resource_read() returns this error code in the error member of the returned ResourceReadResult for write-only resources that were read. resource_read() does not return it as the error code. **Note:** It is valid, and encouraged, for registers that are architecturally write-only to return a useful value when read through resource_read(). resource_read() is not an architectural register read and does not have to follow architectural rules, including architectural semantics and permissions.

Error code	Value	Meaning
E_error_writing_read_only_resource	0xE138	resource_write() returns this error code in the error member of the returned ResourceWriteResult for read-only resources that were written. resource_write() does not return it as the error code. **Note:** Some registers that are architecturally read-only might be writable through resource_write() because resource_write() is not an architectural write.
E_error_reading_resource	0xE139	resource_read() returns this error code in the error member of the returned ResourceReadResult when the value of a resource cannot be determined, or it produced an error that cannot be represented in a better way. resource_read() does not return it as the error code. This is a catch-all error for resource reads that failed.
E_error_writing_resource	0xE13A	resource_write() returns this in the error member of the returned ResourceWriteResult for resources that could not be written, or writing it produced an error. resource_write() does not return it as the error code. This is a catch-all error for resource writes that failed.
E_operation_interrupted	0xE13C	An operation was interrupted by an end user. This is usually only returned by specific callbacks that are implemented by clients to allow chunked transfers of data. This error code tells the original operation, for example image_loadDataPull(), to stop. The interrupted operation in turn returns E_operation_interrupted.
E_error_setting_breakpoint	0xE13D	A breakpoint could not be set because the breakpoint logic that is internal to a specific instance failed.
E_error_deleting_breakpoint	0xE13E	A breakpoint could not be deleted because the breakpoint logic that is internal to a specific instance failed.
E_error_creating_event_stream	0xE13F	An event stream could not be created because the event logic that is internal to the instance failed.
E_error_enabling_event_stream	0xE140	An event stream could not be enabled because the event logic that is internal to the instance failed.
E_error_disabling_event_stream	0xE141	An event stream could not be destroyed because the event logic that is internal to the instance failed.
E_error_memory_abort	0xE142	Only returned in the error field in MemoryReadResult or MemoryWriteResult. The memory value could not be read because the memory subsystem aborted the operation. A load instruction from this address would also have failed. The corresponding bits in data should be ignored.
E_approximation	0xE143	Only returned in the error field in MemoryReadResult or ResourceReadResult. The memory value could be read but is only an approximation, for example because one of the instances is not in a debuggable state. A load instruction from this address would have succeeded.
E_value_not_available	0xE144	Only returned in the error field in MemoryReadResult or ResourceReadResult. The memory value is currently not available and cannot even be approximated. A load instruction from this address would have succeeded. For example, this can happen when an instance is not in a debuggable state.
E_current_thread_does_not_have_a_message_queue	0xE145	Returned by IrisC_processAsyncMessages() functions when called from a thread that is not synchronous to the simulation thread.
E_server_already_running	0xE146	Returned by tcpServer_start() when a server is already running.
E_server_not_running	0xE147	Returned by tcpServer_getPort() or tcpServer_stop() if no server is running.
E_error_loading_dso	0xE148	Could not load a DSO. This might be because the specified file could not be found or it was not a valid DSO.
E_invalid_plugin	0xE149	Returned by plugin_load() if the plug-in path does not refer to a valid Iris plug-in.

Error code	Value	Meaning
`E_plugin_already_loaded`	`0xE14A`	Returned by `plugin_load()` if the plug-in path refers to a plug-in that has already been loaded.
`E_error_writing_read_only_cell`	`0xE14B`	Returned when trying to write a read only table cell.
`E_invalid_breakpoint_condition`	`0xE14C`	One or more breakpoint condition was invalid. This might be because the condition was not recognized, or it was the wrong type, or it was not applicable to the breakpoint type being set.
`E_full_reset_not_supported`	`0xE14D`	Not all parts of the simulation could be reset by the SimulationEngine. It might still be possible to partially reset the simulation by calling `simulation_reset()` with `allowPartialReset=true`.
`E_simulation_running`	`0xE14E`	The request cannot be carried out while the simulation is running. The caller must stop the simulation and try again.
`E_function_already_registered`	`0xE14F`	A function with the same name is already registered in an instance.
`E_event_source_already_registered`	`0xE150`	An event source with the same name is already registered in an instance.
`E_error_saving_checkpoint`	`0xE151`	`checkpoint_save()` was unable to save the checkpoint, for example because a directory was not writable.
`E_error_restoring_checkpoint`	`0xE152`	`checkpoint_restore()` was unable to restore the checkpoint, for example because a file was not found.
`E_unsupported_option_name`	`0xE153`	An unsupported option name was specified in an `options` argument.
`E_unsupported_option_value`	`0xE154`	An unsupported option value was specified in an `options` argument.
`E_unsupported_option_combination`	`0xE155`	An unsupported combination of optional values was specified in an `options` argument.
`E_unknown_resource_name`	`0xE157`	The specified resource name is unknown.
`E_unknown_event_buffer_id`	`0xE158`	An unknown event buffer id was specified. Event buffer ids are created by `eventBuffer_create()` and destroyed by `eventBuffer_destroy()` and they must not be used after destruction.

7.2 Function-independent error codes

The following table describes the error codes that any function might return. These error codes are not listed in the Errors sections, for brevity.

Table 7-2: Function-independent error codes

Symbol	Value	Meaning
`E_u64json_encoding_error`	`-0xB0`	One of the following: • An invalid 64-bit code was found while parsing a U64JSON value. • The explicit size of an array, which was used to skip the array, is inconsistent with the array contents. • The explicit size of an object, which was used to skip the object, is incorrect. • Duplicate keys appear in an object. • The container length exceeds the length of the available data or the container length is shorter than the available data. • A number as a string has a parse error.
`E_malformatted_request`	`-0xB1`	A malformatted request was received. For example, the `params` member is an array instead of an object. This error is only returned when the request is sufficiently well-formatted to identify that it is a request, for example it contains a `method` member, and to enable the return path to be traced back. Requests that contain an invalid or missing method, `instId`, or request id might not be able to respond to the caller.
`E_malformatted_response`	`-0xB2`	A malformatted response was received. For example, this is returned when a response was received that contains both an `error` member and a `result` member.
`E_ok`	0	Indicates no error. This is never returned by JSON RPC 2.0 calls because they only return an error object if an error occurred. This value is reserved for the OK case for C++ interfaces or for variables that need to hold a non-error state.
`E_no_response_yet`	1	No error. No response was received yet for a request. This is never returned by Iris functions and is only used in the Iris framework state machines.
`E_unknown_instance_id`	`0xE100`	The `instId` argument does not specify an existing target instance.
`E_function_not_supported_by_instance`	`0xE110`	A function was called with a valid `instId` argument, but the instance does not support the function that was called. This error applies only to the function name, not to arguments or their values. This error is also returned when an unsupported global function, without an `instId`, was called.
`E_unsupported_argument_name`	`0xE111`	A function received one or more argument names that it does not support. This error tells the caller that the expected functionality is not available in the function. The caller can fall back to a simpler function call with fewer parameters, if it is designed to do so. The callee must put an object `{"name": X}` into `error.data` of the response object, where `X` is one of the unsupported argument names. This does not imply that other argument names are valid.
`E_unsupported_argument_value`	`0xE112`	A function received an unsupported value for one or more arguments. This is a catch-all error code, which should only be used if a more specific error code is not available. The callee must put an object `{"name": X}` into `error.data` of the response object, where `X` is the name of one of the arguments containing an unsupported value. This does not imply that other argument values are valid.

Symbol	Value	Meaning
`E_missing_mandatory_argument`	`0xE11A`	A function was called without a mandatory argument. The callee must put an object `{"name": X}` into `error.data` of the response object, where `X` is one of the missing argument names. This does not imply that all other arguments are present.
`E_argument_type_mismatch`	`0xE12C`	A value of an incompatible type was specified for a function parameter. This includes types of object members that are passed into functions. See 4.1 JSON data types on page 30 for type compatibility and conversion rules. The callee must put an object `{"name": X}` into `error.data` of the response object containing the parameter name of one of the errors encountered. This does not imply that other parameters are valid. It is undefined whether the request was ignored or partially completed. Clients should assume that the request was ignored and should repeat the request.
`E_not_supported_while_instance_is_blocked`	`0xE12D`	A function *`F`* was called by instance *`A`* on instance *`B`* while instance *`B`* is blocked in a synchronous function call to instance *`A`*, for example in a synchronous `ec_FOO()` call. Instance *`B`* cannot complete function *`F`* while it is blocked in the call to instance *`A`*.
`E_not_implemented`	`0xE13B`	The function being called or the feature being requested or used is not implemented. A common use case is to return this in the `error` member of a `ResourceReadResult` or `ResourceWriteResult` for resources that are known to an instance but are not implemented. It might be more useful to return `E_not_implemented` rather than returning dummy values for partially implemented interfaces during development. Iris functions should generally not return this error for functionality that will never be implemented. `E_function_not_supported_by_instance` or the `E_*unsupported*` errors should be preferred if they are more appropriate.
`E_syntax_error`	`0xE159`	A function that expects specific syntax for a string argument has detected invalid syntax, for example inconsistent braces or invalid characters in numeric constants. This generic error code is returned for example by IrisSupportLib functions that accept complex patterns for finding resources or events, or that set numeric parameters with strings.
`E_help_message`	`0xE160`	The client specified `help` as the connection specification string when starting the Iris server. The server returns a list of supported connection types and their syntax, as an `E_help_message` error.