Device Developer's Guide

User Manual

Reference	TLT-0784-MAN-DeviceDevGuide
Revision	4.1-Bdraft1

Confidentiality & Intellectual Property

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1 Document Conventions

1.1 Bibliography

[JVM]	Tim Lindholm & Frank Yellin, The Java™ Virtual Machine Specification, Second Edition, 1999
[EDC]	Embedded Device Configuration: ESR 021, http://www.e-s-r.net
[B-ON]	Beyond: ESR 001, http://www.e-s-r.net
[SNI]	Simple Native Interface for Green Threads: ESR 012, http://www.e-s-r.net
[SP]	Shielded Plug: ESR 014, http://www.e-s-r.net
[MUI]	Micro User Interface: ESR 002, 2009, http://www.e-s-r.net
[U61]	The Unicode Standard, Version 6.1, 2012
[KF]	Kernel & Features: ESR 020, 2013, http://www.e-s-r.net

1.2 Glossary

MicroEJ Vee	MicroEJ Virtual Execution Environment (Vee) is a scalable runtime for resource-constrained embedded and IoT devices running on 32-bit microcontrollers or microprocessors. MicroEJ Vee allows devices to run multiple and mixed Java and C software applications.
MicroEJ Application	A MicroEJ application (or app) is a software program that runs on the MicroEJ Vee.
MicroEJ Workbench	MicroEJ Workbench is the full set of tools built on Eclipse for device software development.
MicroEJ Architecture	MicroEJ Architecture is the MicroEJ Vee port to a target instruction set architecture (ISA) and native compiler.
MicroEJ Platform	MicroEJ Platform is the MicroEJ core engine and Libraries running on a specific target board support package (BSP, with or without RTOS).
MicroEJ Firmware	MicroEJ Firmware is a binary instance of MicroEJ Vee for a target hardware board.
MicroEJ Simulator	MicroEJ Simulator allows running MicroEJ Applications on a target hardware simulator running MicroEJ Vee on the developer's desktop computer.
Foundation Library	A MicroEJ Foundation Library is a MicroEJ Core library that provides core runtime APIs or hardware-dependent functionality.
Add-On Library	A MicroEJ Add-On Library is a MicroEJ Core library that is implemented on top of MicroEJ Foundation Libraries (100% full Java code).

2 Introduction

2.1 Scope

This document explains how the core features of MicroEJ architecture are accessed, configured and used by the MicroEJ platform builder. It describes the process for creating and augmenting a MicroEJ architecture. This document is concise, but attempts to be exact and complete. Semantics of implemented foundation libraries are described in their respective specifications. This document includes an outline of the required low level drivers (LLAPI) for porting the MicroEJ architectures to different real-time operating systems (RTOS).

MicroEJ architecture is state-of-the-art, with embedded MicroEJ runtimes for MCUs. They also provide simulated runtimes that execute on workstations to allow software development on "virtual hardware."

2.2 Intended Audience

The audience for this document is software engineers who need to understand how to create and configure a MicroEJ platform using the MicroEJ platform builder. This document also explains how a MicroEJ application can interoperate with C code on the target, and the details of the MicroEJ architecture modules, including their APIs, error codes and options.

2.3 MicroEJ Architecture Modules Overview

MicroEJ architecture features the MicroEJ core engine: a tiny and fast runtime associated with a smart RAM optimizer. It provides four built-in foundation libraries :

- [B-ON]
- [EDC]
- [SNI]
- [SP]

Figure 2.1 shows the components involved.

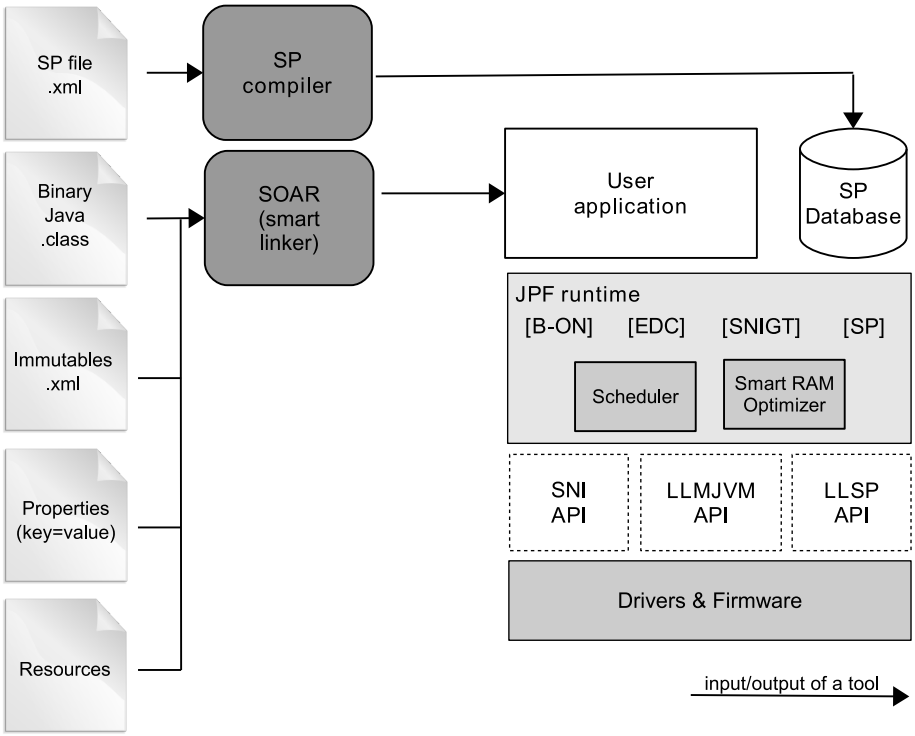


Figure 2.1. MicroEJ Architecture Runtime Modules: Tools, Libraries and APIs

Three APIs allow the device architecture runtime to link with (and port to) external code, such as any kind of RTOS or legacy C libraries. These three APIs are

- Simple Native Interface (SNI)
- Low Level MicroEJ core engine (LLMJVM)
- Low Level Shielded Plug (LLSP)

MicroEJ architecture features additional foundation libraries and modules to extend the kernel:

- serial communication,
- UI extension (User Interface)
- networking
- file system
- etc...

Each additional module is optional and selected on demand during the MicroEJ platform configuration.

2.4 Scheduler

The MicroEJ architecture features a green thread platform that can interact with the C world [SNI]. The (green) thread policy is as follows:

- preemptive for different priorities,
- round-robin for same priorities,
- "priority inheritance protocol" when priority inversion occurs. [1]

MicroEJ stacks (associated with the threads) automatically adapt their sizes according to the thread requirements: Once the thread has finished, its associated stack is reclaimed, freeing the corresponding RAM memory.

2.5 Smart RAM Optimizer

The MicroEJ architecture includes a state-of-the-art memory management system, the Garbage Collector (GC). It manages a bounded piece of RAM memory, devoted to the Java world. The GC automatically frees dead Java objects, and defragments the memory in order to optimize RAM usage. This is done transparently while the MicroEJ applications keep running.

[1] This protocol raises the priority of a thread (that is holding a resource needed by a higher priority task) to the priority of that task.

3 Features

3.1 Platform Architecture and Modules

Feature	Version
Core Architecture	9.0.2
UI Extension	9.0.2
Network Extension	6.1.4
File System Extension	3.0.0
HAL Extension	1.0.4

Table 3.1. Platform Architecture and Modules

3.2 Foundation Libraries

Name	Reference	Versions
BON	[B-ON]	1.2
DEVICE		1.0
ECOM		1.1
ECOM-COMM		1.1
EDC	[EDC]	1.2
FS		2.0
HAL		1.0
KF	[KF]	1.4
MICROUI	[MUI]	2.0
NET		1.1
NLS		2.0
SNI	[SNI]	1.2
SP	[SP]	2.0
SSL		2.0

Table 3.2. Foundation Libraries

3.3 Platform Characteristics

Name	Item	MicroEJ platform Characteristics	MicroEJ simulator Characteristics	User Configurable
RAM Optimizer	Heap Partition	1	1	
	Immortal Space	Yes	Yes	Yes
	Immutable Space	Yes (static)	Yes (static)	
Debug	Symbolic	No	JDWP (Socket)	Yes
MicroEJ Code	Location	In Flash (in place execution)	n/a	

Table 3.3. Platform Characteristics

4 Process Overview

This section summarizes the steps required to build a MicroEJ platform and obtain a binary file to deploy on a board.

Figure 4.1 shows the overall process. The first three steps are performed within the MicroEJ platform builder. The remaining steps are performed within the C IDE.

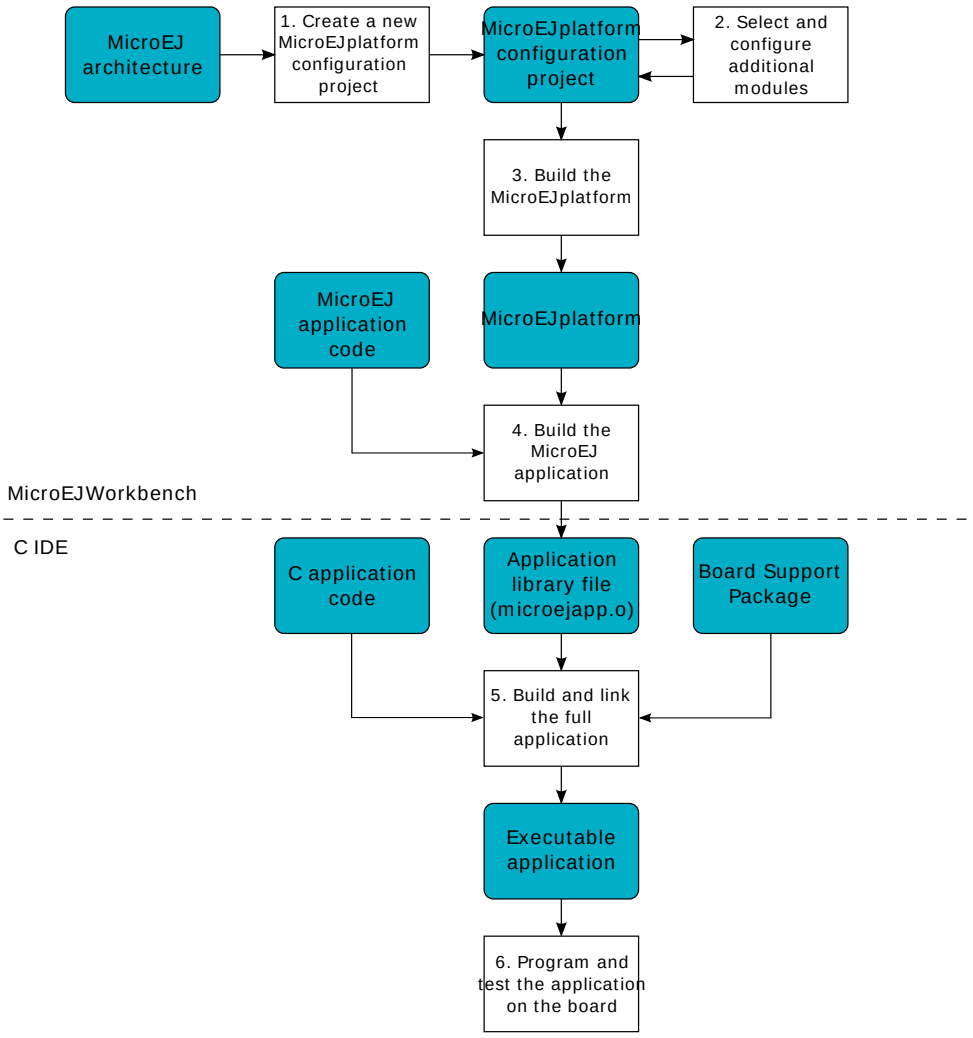


Figure 4.1. Overall Process

1. Step 1 consists in creating a new MicroEJ platform configuration project. This project describes the MicroEJ platform (MicroEJ architecture, metadata, etc.).

2. Step 2 allows you to select which modules available in MicroEJ architecture will be installed in the MicroEJ platform.

3. Step 3 builds the MicroEJ platform according to the choices made in steps 1 and 2.

4. Step 4 compiles a MicroEJ application against the MicroEJ platform in order to obtain an application file to link in the BSP.

5. Step 5 consists in compiling the BSP and linking it with the MicroEJ application that was built previously, in step 4.

6. Step 6 is the final step: Deploy the binary application onto a board.

5 Concepts

5.1 MicroEJ Platform

A MicroEJ platform includes development tools and a runtime environment.

The runtime environment consists of:

- A MicroEJ core engine.
- Some foundation libraries.
- Some C libraries.

The development tools are composed of:

- Java APIs to compile MicroEJ application code.
- Documentation: this guide, library specifications, etc.
- Tools for development and compilation.
- Launch scripts to run the simulation or build the binary file.
- Eclipse plugins.

5.2 MicroEJ Platform Configuration

A MicroEJ platform is described by a .platform file. This file is usually called [name].platform, and is stored at the root of a MicroEJ platform configuration project called [name]-configuration.

The configuration file is recognized by the MicroEJ platform builder. The MicroEJ platform builder offers a visualization with two tabs:

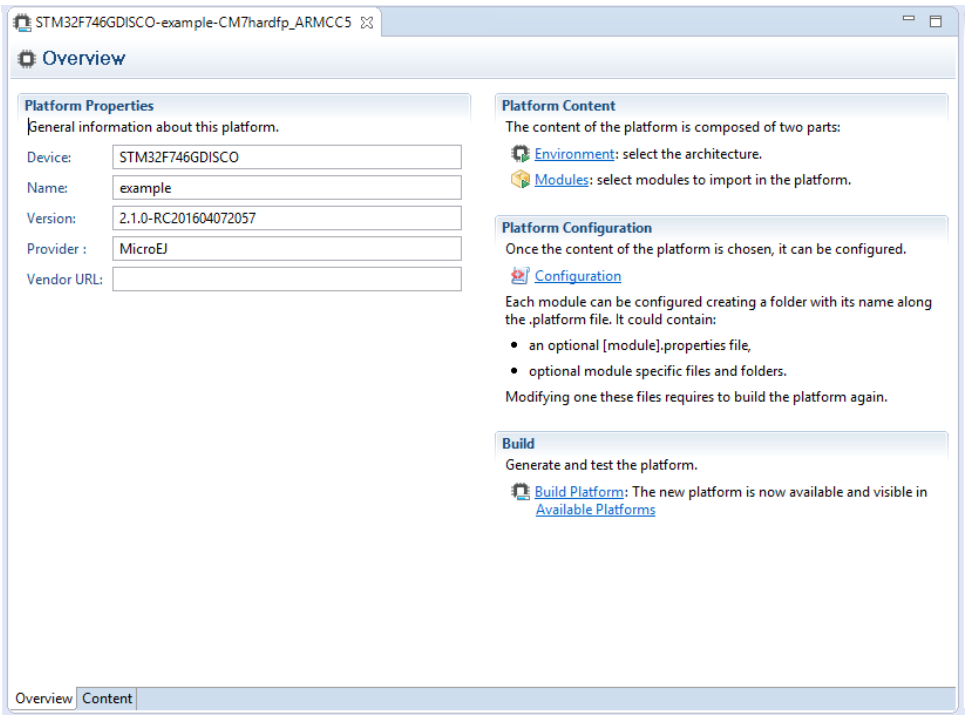


Figure 5.1. MicroEJ Platform Configuration Overview Tab

This tab groups the basic platform information used to identify it: its name, its version, etc. These tags can be updated at any time.

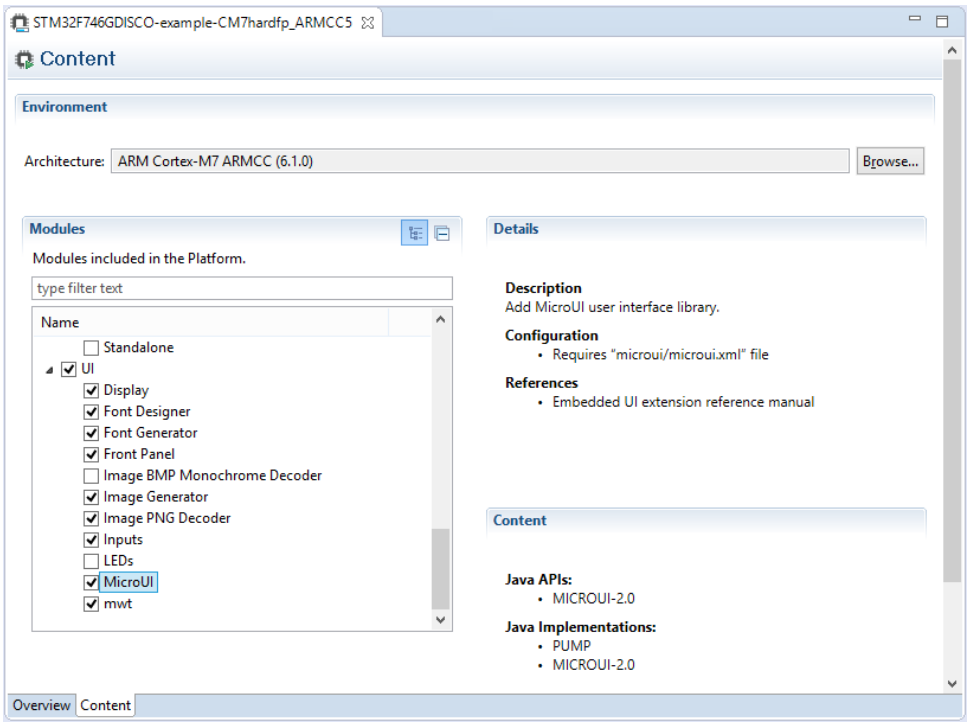


Figure 5.2. MicroEJ Platform Configuration Content Tab

This tab shows all additional modules (see “Modules”) which can be installed into the platform in order to augment its features. The modules are sorted by groups and by functionality. When a module is checked, it will be installed into the platform during the platform creation.

5.3 Modules

The primary mechanism for augmenting the capabilities of a “MicroEJ Platform” is to add modules to it.

A MicroEJ module is a group of related files (foundation libraries, scripts, link files, C libraries, simulator, tools, etc.) that together provide all or part of a platform capability. Generally, these files serve a common purpose. For example, providing an API, or providing a library implementation with its associated tools.

The list of modules is in the second tab of the platform configuration tab. A module may require a configuration step to be installed into the platform. The Modules Detail view indicates if a configuration file is required.

5.4 Low Level API Pattern

5.4.1 Principle

Each time the user must supply C code that connects a platform component to the target, a *Low Level API* is defined. There is a standard pattern for the implementation of these APIs. Each interface has a name and is specified by two header files:

- [INTERFACE_NAME].h specifies the functions that make up the public API of the implementation. In some cases the user code will never act as a client of the API, and so will never use this file.
- [INTERFACE_NAME]_impl.h specifies the functions that must be coded by the user in the implementation.

The user creates *implementations* of the interfaces, each captured in a separate C source file. In the simplest form of this pattern, only one implementation is permitted, as shown in the illustration below.

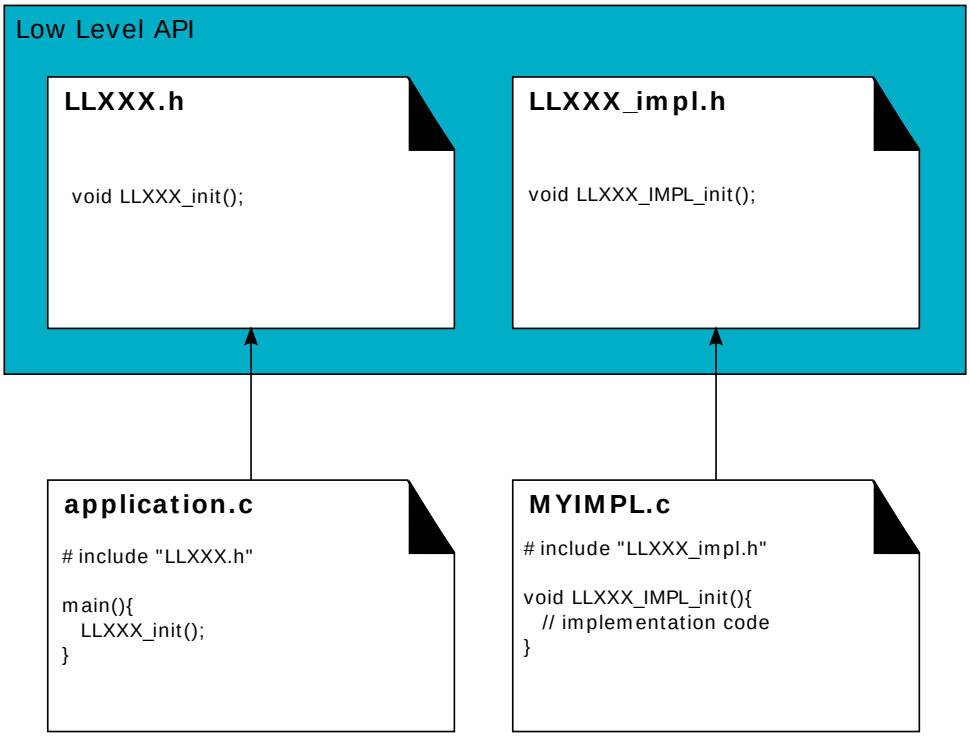


Figure 5.3. Low Level API Pattern (single implementation)

The following figure shows a concrete example of an LLAPI. The C world (the board support package) has to implement a send function and must notify the library using a receive function.

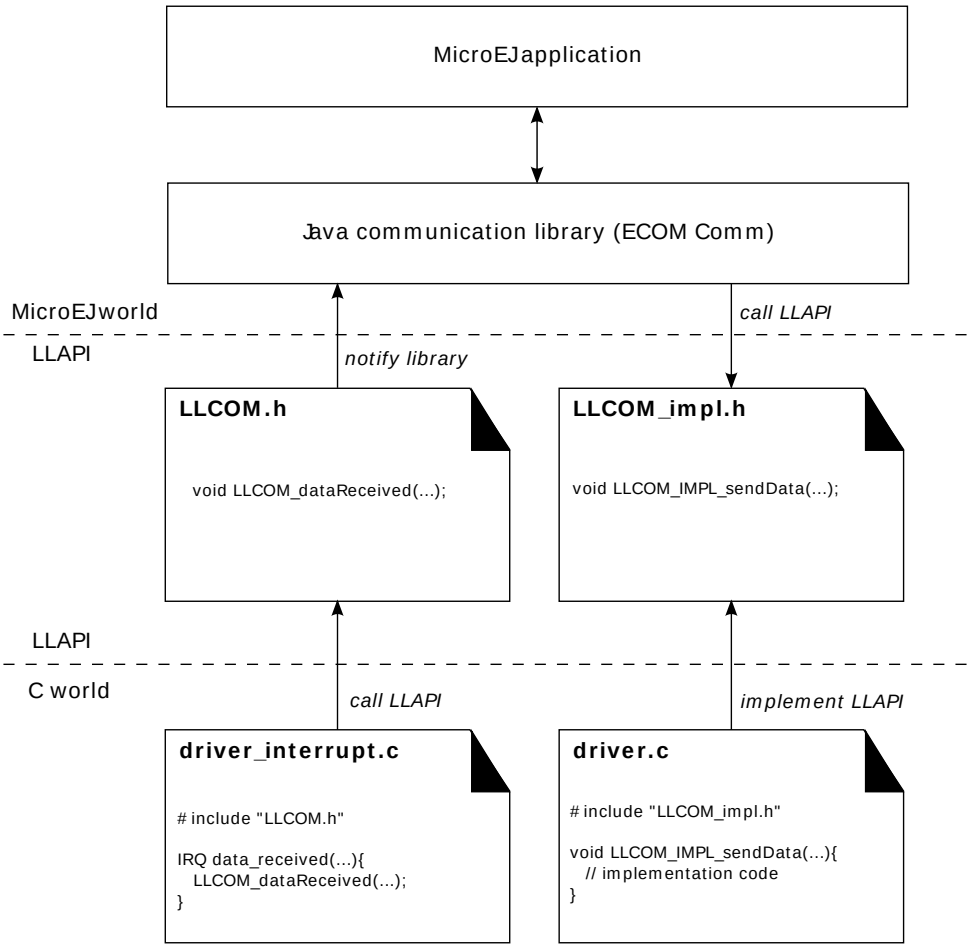


Figure 5.4. Low Level API Example

5.4.2 Multiple Implementations and Instances

When a Low Level API allows multiple implementations, each implementation must have a unique name. At run-time there may be one or more instances of each implementation, and each instance is represented by a data structure that holds information about the instance. The address of this structure is the handle to the instance, and that address is passed as the first parameter of every call to the implementation.

The illustration below shows this form of the pattern, but with only a single instance of a single implementation.

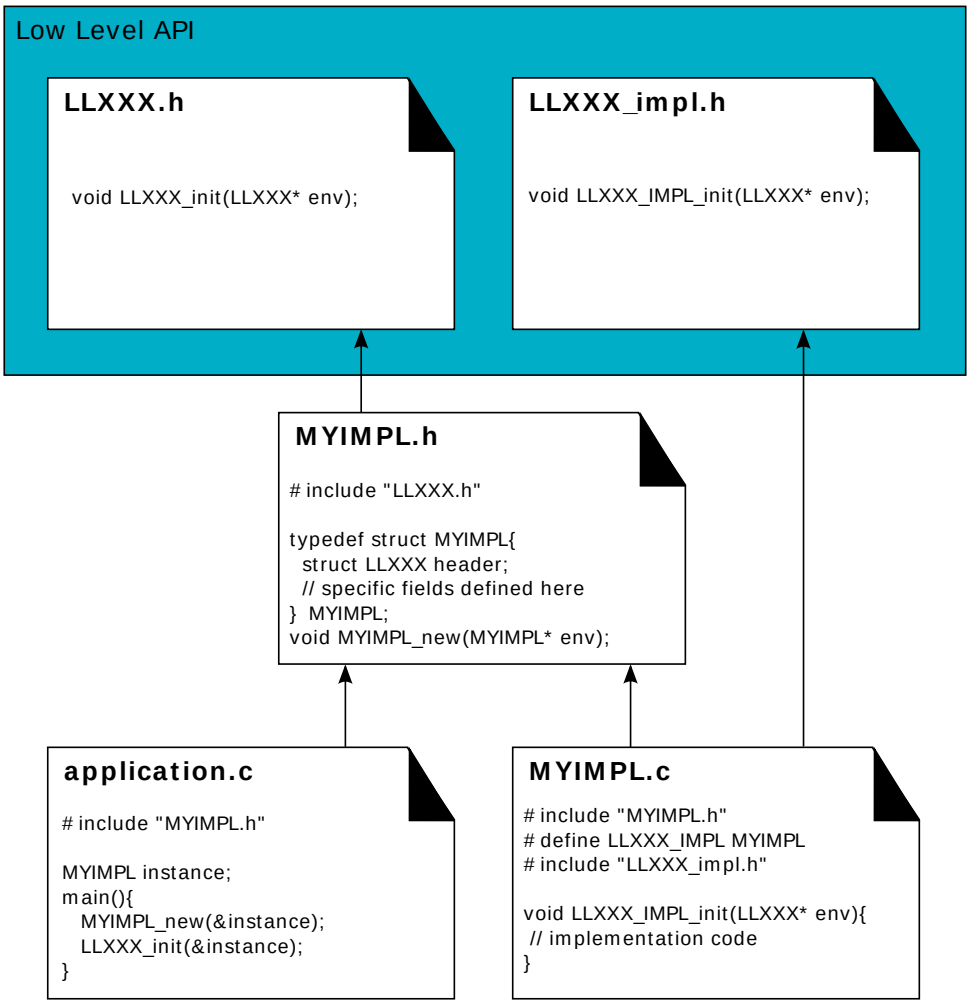


Figure 5.5. Low Level API Pattern (multiple implementations/instances)

The #define statement in MYIMPL.c specifies the name given to this implementation.

5.5 MicroEJ Applications

MicroEJ applications are developed as standard Java applications on Eclipse JDT, using foundation libraries. MicroEJ workbench allows you to run / debug / deploy MicroEJ applications on a MicroEJ platform.

5.6 MicroEJ Launch

The MicroEJ launch configuration sets up the “MicroEJ Applications” environment (main class, resources, target platform, and platform-specific options), and then launches a MicroEJ launch script for execution.

Execution is done on either the MicroEJ platform or the MicroEJ simulator. The launch operation is platform-specific. It may depend on external tools that the platform requires (such as target memory programming). Refer to the platform-specific documentation for more information about available launch settings.

5.6.1 Main Tab

The Main tab allows you to set in order:

1. The main project of the application.

2. The main class of the application containing the main method.

3. Types required in your application that are not statically embedded from the main class entry point. Most required types are those that may be loaded dynamically by the application, using the Class.forName() method.

4. Binary resources that need to be embedded by the application. These are usually loaded by the application using the Class.getResourceAsStream() method.

5. Immutable objects' description files. See the [B-ON 1.2] ESR documentation for use of immutable objects.

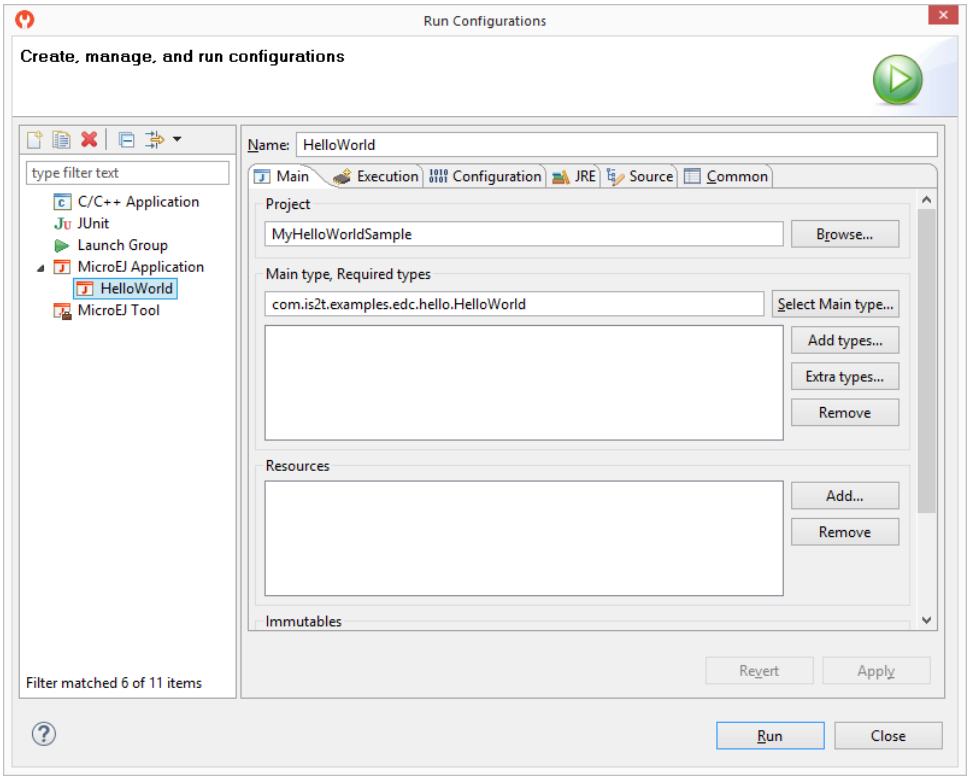


Figure 5.6. MicroEJ Launch Application Main Tab

5.6.2 Execution Tab

The next tab is the Execution tab. Here the target needs to be selected. Choose between execution on a MicroEJ platform or on a MicroEJ simulator. Each of them may provide multiple launch settings. This page also allows you to keep generated, intermediate files and to print verbose options (advanced debug purpose options).

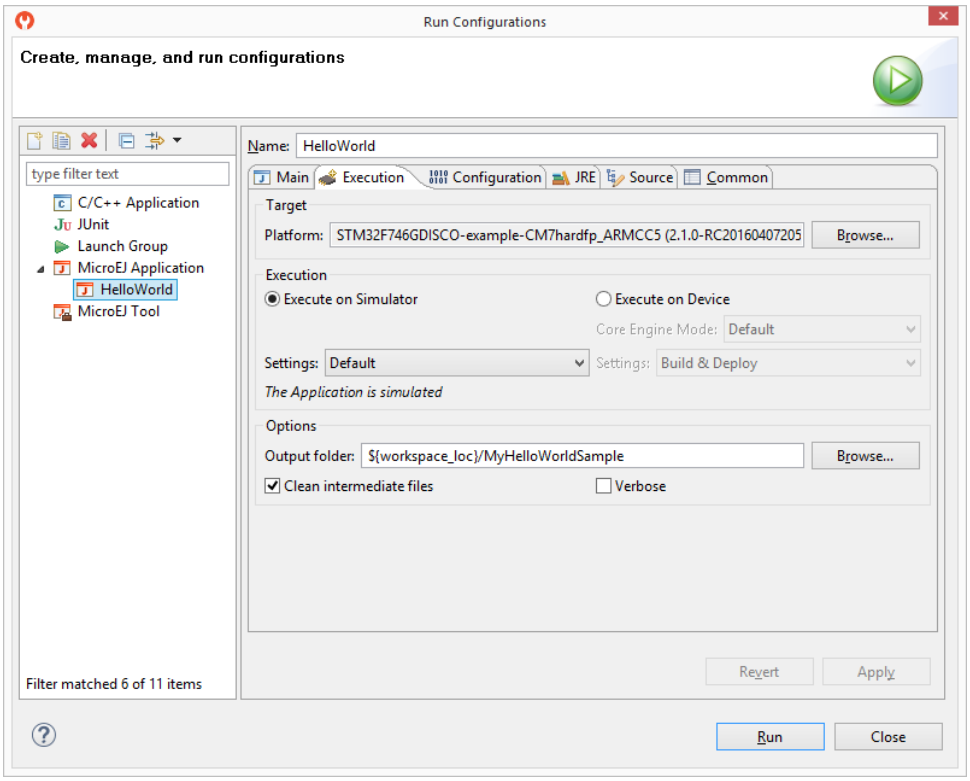


Figure 5.7. MicroEJ Launch Application Execution Tab

5.6.3 Configuration Tab

The next tab is the Configuration tab. This tab contains all platform-specific options.

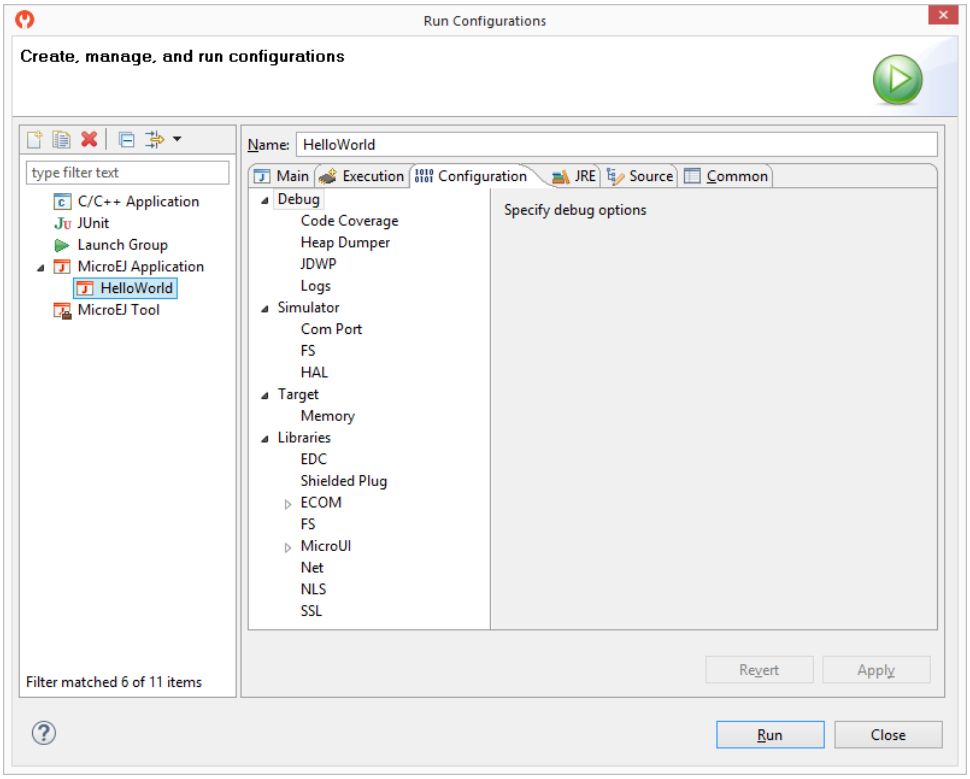


Figure 5.8. Configuration Tab

5.6.4 JRE Tab

The next tab is the JRE tab. This tab allows you to configure the Java Runtime Environment used for running the underlying launch script. It does not configure the MicroEJ application execution. The VM Arguments text field allows you to set vm-specific options, which are typically used to increase memory spaces:

- To modify heap space to 1024MB, set the -Xmx1024M option.
- To modify string space (also called PermGen space) to 256MB, set the -XX:PermSize=256M -XX:MaxPermSize=256M options.
- To set thread stack space to 512MB, set the -Xss512M option.

5.6.5 Other Tabs

The next tabs (Source and Common tabs) are the default Eclipse launch tabs. Refer to Eclipse help for more details on how to use these launch tabs.

5.7 MicroEJ Tool

A MicroEJ platform contains a number of tools to assist with various aspects of development. Some of these tools are run using **MicroEJ Tool** configurations, and created using the **Run Configurations** dialog of the workbench. A configuration must be created for the tool before it can be used.

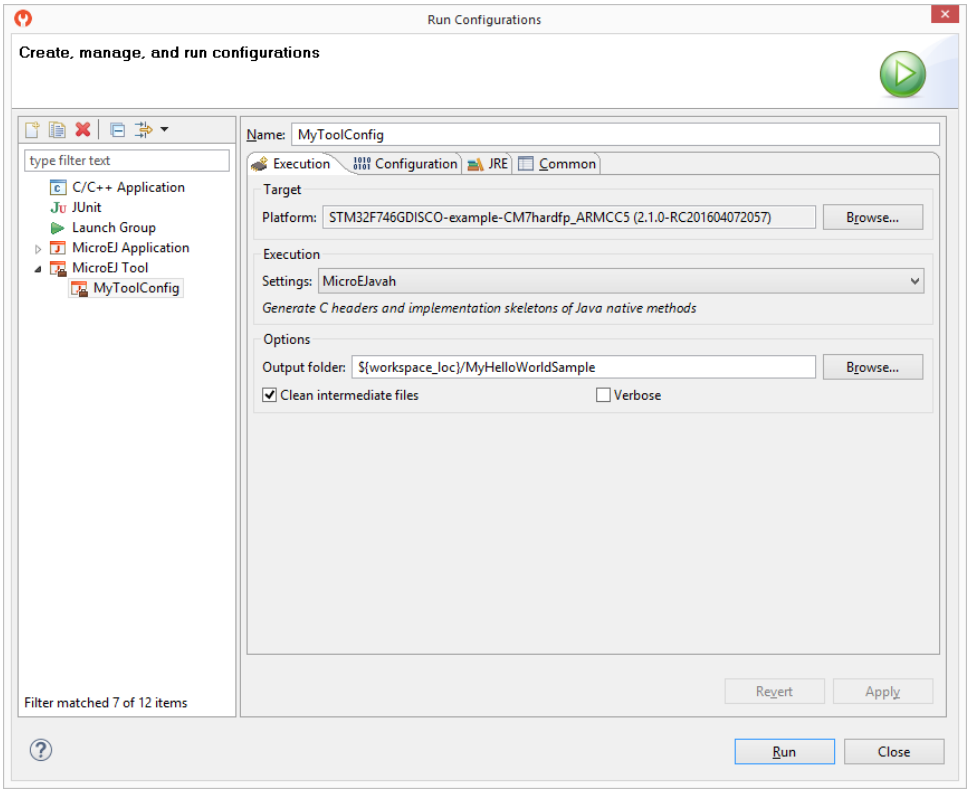


Figure 5.9. MicroEJ Tool Configuration

Figure 5.9 shows a tool configuration being created. In the figure, the MicroEJ platform has been selected, but the selection of which tool to run has not yet been made. That selection is made in the **Execution Settings...** box. The **Configuration** tab then contains the options relevant to the selected tool.

6 Building a MicroEJ Platform

6.1 Create a New MicroEJ Platform Configuration

The first step is to create a MicroEJ platform configuration:

- Select **File** > **New** > **Project...**, open MicroEJ category and select **MicroEJ Platform Project.**
- Click on **Next.** The **Configure Target Architecture** page allows to select the MicroEJ architecture that contains a minimal MicroEJ platform and a set of compatible modules targeting a processor architecture and a compilation toolchain. This environment can be changed later.
  - Click on **Browse...** to select one of the installed MicroEJ architecture.
  - Check the **Create from a platform reference implementation** box to use one of the available implementation. Uncheck it if you want to provide your own implementation or if no reference implementation is available.
- Click on **Next.** The **Configure platform properties** contains the identification of the MicroEJ platform to create. Most fields are mandatory, you should therefore set them. Note that their values can be modified later on.
- Click on **Finish.** A new project is being created containing a [name].platform file. A platform description editor shall then open.

6.2 Groups / Modules Selection

From the platform description editor, select the **Content** tab to access the platform modules selection. Modules can be selected/deselected from the **Modules** frame.

Modules are organized into groups. When a group is selected, by default, all its modules are selected. To view the modules making up a group, click on the **Show/Hide modules** icon on the top-right of the frame. This will let you select/deselect on a per module basis. Note that individual module selection is not recommended.

The description and contents of an item (group or module) are displayed beside the list on item selection.

All the checked modules will be installed in the platform.

6.3 Modules Customization

Each selected module can be customized by creating a [module] folder named after the module beside the [name].platform definition. It may contain:

- An optional [module].properties file named after the module name. These properties will be injected in the execution context prefixed by the module name. Some properties might be needed for the configuration of some modules. Please refer to the modules documentation for more information.
- Optional module specific files and folders.

Modifying one of these files requires to build the platform again.

6.4 Platform Customization

Platform can be customized by creating a configuration.xml script beside the [name].platform file. This script can extend one or several of the extension points available.

Configuration project (the project which contains the [name].platform file) can contain an optional dropins folder. The contents of this folder will be copied integrally into the final platform. This feature allows to add some additional libraries, tools etc. into the platform.

The dropins folder organization should respect the final platform files and folders organization. For instance, the tools are located in the sub-folder tools. Launch a platform build without the dropins folder to see how the platform files and folders organization is. Then fill the dropins folder with additional features and build again the platform to obtain an advanced platform.

The dropins folder files are kept in priority. If one file has the same path and name as another file already installed into the platform, the dropins folder file will be kept.

Modifying one of these files requires to build the platform again.

6.5 Build MicroEJ Platform

To build the MicroEJ platform, click on the **Build Platform** link on the platform configuration **Overview**.

It will create a MicroEJ platform in the workspace available for the MicroEJ project to run on. The MicroEJ platform will be available in: **Window > Preferences > MicroEJ > Platforms in workspace**.

6.6 BSP Tool

6.6.1 Principle

When the MicroEJ platform is built, the user can compile a MicroEJ application on that platform. However, the result of this compilation is not sufficient. A third-party C project is required to obtain the final binary file to flash on a board.

This third-party C project is usually configured to target only one board. It contains some C files, header directories, C libraries, etc. Using this C project, the user can build (compile and link) a binary file which contains the specific MCU and board libraries, the foundation libraries, and the MicroEJ application.

The BSP tool configures the third-party project, updating the third-party C-IDE project file, adding some C libraries and filling some header directories.

6.6.2 Third-party C Project

The BSP tool is able to configure automatically the board C project. Fill the bsp > bsp.properties properties file to enable the third-party C project configuration during the MicroEJ platform build.

The properties file can contain the following properties:

- project.file [optional, default value is "" (*empty*)]: Defines the full path of the C project file. This file will be updated with the platform libraries. If not set or empty, no C project is updated.
- project.libs.group.name [optional, default value is "" (*empty*)]: Defines the libraries group name of the C project file. This property is required if property project.file is set.
- project.includes.output.dir [optional, default value is "" (*empty*)]: Defines the full path of the C project's other header files (*.h) output directory. All platform header files (*.h) will be copied into that directory. If not set or empty, no header platform files are copied.

6.6.3 BSP Files

The MicroEJ platform needs some information about the board project (the BSP). This information is required for building a MicroEJ application that is compatible with the BSP.

Some BSP files (XML files) are required to configure the MicroEJ platform modules. The name of these files must be bsp.xml. They must be stored in each module's configuration folder.

This file must start with the node <bsp>. It can contain several lines like this one: <nativeName="A_LLAPI_NAME" nativeImplementation name="AN_IMPLEMENTATION_NAME"/> where:

- A_LLAPI_NAME refers to a Low Level API native name. It is specific to the MicroEJ C library which provides the Low Level API.
- AN_IMPLEMENTATION_NAME refers to the implementation name of the Low Level API. It is specific to the BSP; and more specifically, to the C file which does the link between the MicroEJ C library and the C driver.

Example:

```
<bsp>
 <nativeImplementation name="COMM_DRIVER" nativeName="LLCOMM_BUFFERED_CONNECTION"/>
</bsp>
```

The BSP tool converts these files into an internal format during the MicroEJ platform build.

6.6.4 Dependencies

No dependency.

6.6.5 Installation

The BSP tool is automatically called during the MicroEJ platform build.

7 MicroEJ Core Engine

The MicroEJ Core Engine (also called the platform engine) and its components represent the core of the platform. It is used to compile and execute at runtime the MicroEJ application code.

7.1 Functional Description

Figure 7.1 shows the overall process. The first two steps are performed within the MicroEJ Workbench. The remaining steps are performed within the C IDE.

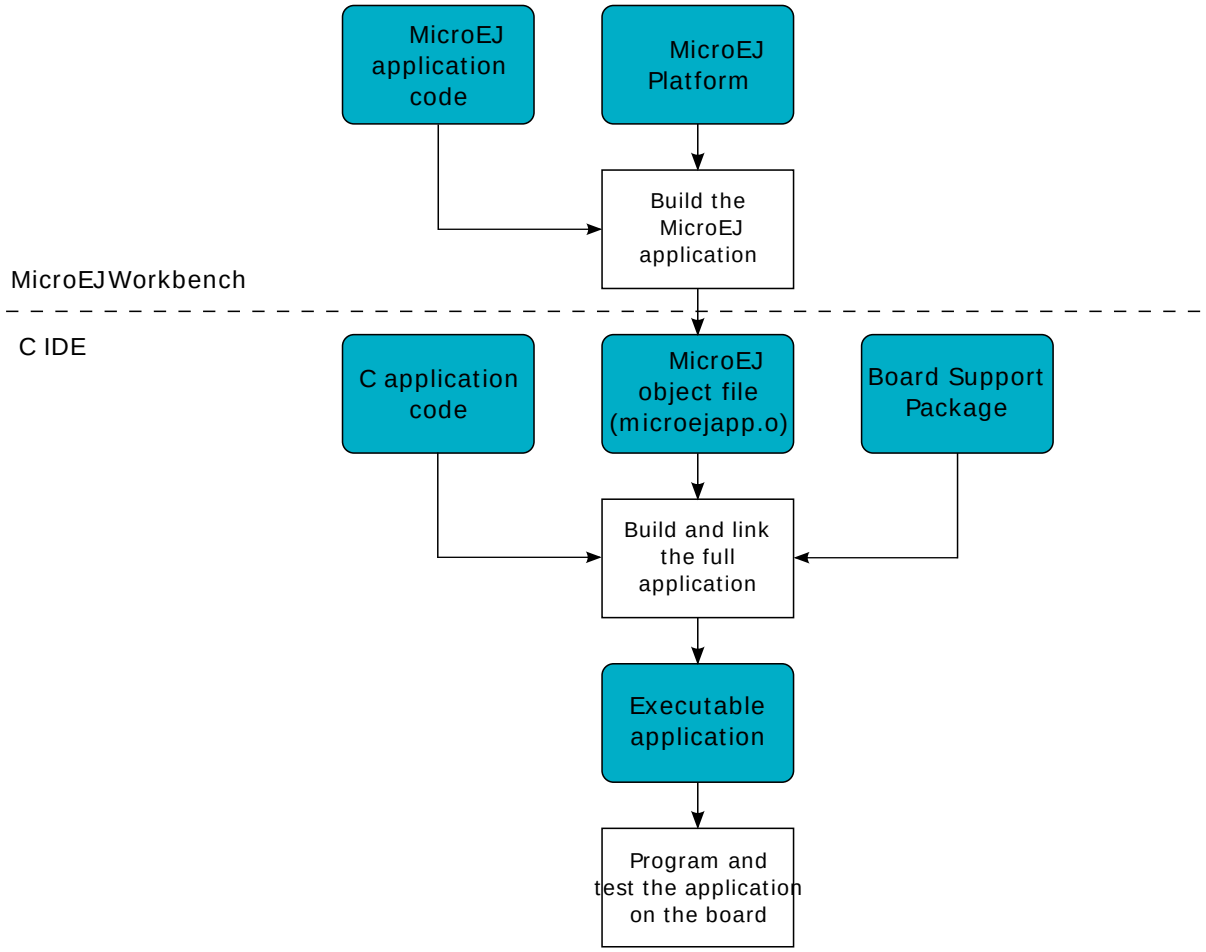


Figure 7.1. MicroEJ Core Engine Flow

1. Step 1 consists in writing a MicroEJ application against a set of foundation libraries available in the platform.

2. Step 2 consists in compiling the MicroEJ application code and the required libraries in an ELF library, using the Smart Linker.

3. Step 3 consists in linking the previous ELF file with the MicroEJ Core Engine library and a third-party BSP (OS, drivers, etc.). This step may require a third-party linker provided by a C toolchain.

7.2 Architecture

The MicroEJ Core Engine and its components have been compiled for one specific CPU architecture and for use with a specific C compiler.

The architecture of the platform engine is called green thread architecture, it runs in a single RTOS task. Its behavior consists in scheduling MicroEJ threads. The scheduler implements a priortiy preemptive scheduling policy with round robin for the MicroEJ threads with the same priority. In the

following explanations the term "RTOS task" refers to the tasks scheduled by the underlying OS; and the term "MicroEJ thread" refers to the thread scheduled by the MicroEJ Core Engine.

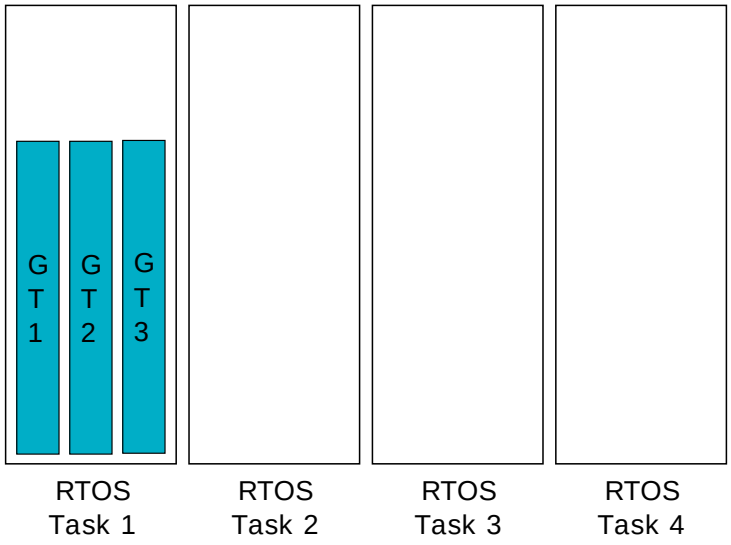


Figure 7.2. A Green Threads Architecture Example

The activity of the platform is defined by the MicroEJ application. When the MicroEJ application is blocked (when all MicroEJ threads are sleeping), the platform sleeps entirely: The RTOS task that runs the platform sleeps.

The platform is responsible for providing the time to the MicroEJ world: the precision is 1 millisecond.

7.3 Capabilities

MicroEJ core engine defines 3 exclusive capabilities:

- Single application: capability to produce a monolithic firmware (default one).
- Multi applications: capability to produce a extensible firmware on which new applications can be dynamically installed. See section “Multi Applications”.
- Tiny application: capability to produce a compacted firmware (optimized for size). See section “Tiny Application”.

All MicroEJ Core Engine capabilities may not be available on all architectures. Refer to section “Supported MicroEJ Core Engine Capabilities by Architecture Matrix” for more details.

7.4 Implementation

The platform implements the [SNI] specification. It is created and initialized with the C function SNI_createVM. Then it is started and executed in the current RTOS task by calling SNI_startVM. The function SNI_startVM returns when the MicroEJ application exits. The function SNI_destroyVM handles the platform termination.

The file LLMJVM_impl.h that comes with the platform defines the API to be implemented. The file LLMJVM.h that comes with the platform defines platform-specific exit code constants. (See “LLMJVM: MicroEJ core engine ”.)

7.4.1 Initialization

The Low Level MicroEJ core engine API deals with two objects: the structure that represents the platform, and the RTOS task that runs the platform. Two callbacks allow engineers to interact with the initialization of both objects:

- LLMJVM_IMPL_initialize: Called once the structure representing the platform is initialized.
- LLMJVM_IMPL_vmTaskStarted: Called when the platform starts its execution. This function is called within the RTOS task of the platform.

7.4.2 Scheduling

To support the green thread round-robin policy, the platform assumes there is an RTOS timer or some other mechanism that counts (down) and fires a call-back when it reaches a specified value. The platform initializes the timer using the LLMJVM_IMPL_scheduleRequest function with one argument: the absolute time at which the timer should fire. When the timer fires, it must call the LLMJVM_schedule function, which tells the platform to execute a green thread context switch (which gives another MicroEJ thread a chance to run).

7.4.3 Idle Mode

When the platform has no activity to execute, it calls the LLMJVM_IMPL_idleVM function, which is assumed to put the RTOS task of the platform into a sleep state. LLMJVM_IMPL_wakeupVM is called to wake up the platform task. When the platform task really starts to execute again, it calls the LLMJVM_IMPL_ackWakeup function to acknowledge the restart of its activity.

7.4.4 Time

The platform defines two times:

- the application time: The difference, measured in milliseconds, between the current time and midnight, January 1, 1970, UTC.
- the system time: The time since the start of the device. This time is independent of any user considerations, and cannot be set.

The platform relies on the following C functions to provide those times to the MicroEJ world:

- LLMJVM_IMPL_getCurrentTime: Depending on the parameter (true / false) must return the application time or the system time. This function is called by the MicroEJ method System.currentTimeMillis(). It is also used by the platform scheduler, and should be implemented efficiently.
- LLMJVM_IMPL_getTimeNanos: must return the system time in nanoseconds.
- LLMJVM_IMPL_setApplicationTime: must set the difference between the current time and midnight, January 1, 1970, UTC.

7.4.5 Example

The following example shows how to create and launch the MicroEJ core engine from the C world. This function (mjvm_main) should be called from a dedicated RTOS task.

```
#include <stdio.h>
#include "mjvm_main.h"
#include "LLMJVM.h"
#include "sni.h"

void mjvm_main(void)
{
 void* vm;
 int32_t err;
 int32_t exitcode;

 // create VM
 vm = SNI_createVM();

 if(vm == NULL)
 {
  printf("VM initialization error.\n");
 }
 else
 {
  printf("VM START\n");
  err = SNI_startVM(vm, 0, NULL);

  if(err < 0)
  {
   // Error occurred
   if(err == LLMJVM_E_EVAL_LIMIT)
   {
    printf("Evaluation limits reached.\n");
   }
   else
   {
    printf("VM execution error (err = %d).\n", err);
   }
  }
  else
  {
   // VM execution ends normally
   exitcode = SNI_getExitCode(vm);
   printf("VM END (exit code = %d)\n", exitcode);
  }

  // delete VM
  SNI_destroyVM(vm);
 }
}
```

Example 7.1. MicroEJ Core Engine Creation

7.4.6 Debugging

The internal MicroEJ Core Engine function called `LLMJVM_dump` allows you to dump the state of all MicroEJ threads: name, priority, stack trace, etc. This function can be called at any time and from an interrupt routine (for instance from a button interrupt).

This is an example of a dump:

```
============ VM Dump ============
2 java threads
--------------------------------
Java Thread[3]
name="SYSINpmp" prio=5 state=WAITING

java/lang/Thread:
   at com/is2t/microbsp/microui/natives/NSystemInputPump.@134261800
 [0x0800AC32]
   at com/is2t/microbsp/microui/io/SystemInputPump.@134265968
 [0x0800BC80]
   at ej/microui/Pump.@134261696
 [0x0800ABCC]
   at ej/microui/Pump.@134265872
 [0x0800BC24]
   at java/lang/Thread.@134273964
 [0x0800DBC4]
   at java/lang/Thread.@134273784
 [0x0800DB04]
   at java/lang/Thread.@134273892
 [0x0800DB6F]
--------------------------------
Java Thread[2]
name="DISPLpmp" prio=5 state=WAITING

java/lang/Thread:
   at java/lang/Object.@134256392
 [0x08009719]
   at ej/microui/FIFOPump.@134259824
 [0x0800A48E]
   at ej/microui/io/DisplayPump.134263016
 [0x0800B0F8]
   at ej/microui/Pump.@134261696
 [0x0800ABCC]
   at ej/microui/Pump.@134265872
 [0x0800BC24]
   at ej/microui/io/DisplayPump.@134262868
 [0x0800B064]
   at java/lang/Thread.@134273964
 [0x0800DBC4]
   at java/lang/Thread.@134273784
 [0x0800DB04]
   at java/lang/Thread.@134273892
 [0x0800DB6F]
================================
```

Example 7.2. MicroEJ Core Engine Dump

See “Stack Trace Reader” for additional info related to working with VM dumps.

7.5 Java Language

The MicroEJ Core Engine is compatible with the Java language version 7.

7.6 Smart Linker (SOAR)

Java source code is compiled by the Java compiler[2] into the binary format specified in [JVM]. This binary code needs to be linked before execution. The MicroEJ platform comes with a linker, named the SOAR. It is in charge of analyzing .class files, and some other application-related files, to produce the final application that the MicroEJ platform runtime can execute.

SOAR complies with the deterministic class initialization (<clinit>) order specified in [B-ON]. The application is statically analyzed from its entry points in order to generate a clinit dependency graph. The computed clinit sequence is the result of the topological sort of the dependency graph. An error is thrown if the clinit dependency graph contains cycles.

[2]The JDT compiler from the Eclipse IDE.

An explicit clinit dependency can be declared by creating an XML file with the .clinitdesc extension in the application classpath. The file has the following format:

```
<?xml version='1.0' encoding='UTF-8'?>
<clinit>
   <type name="T1" depends="T2"/>
</clinit>
```

where T1 and T2 are fully qualified names on the form a.b.C. This explicitly forces SOAR to create a dependency from T1 to T2, and therefore cuts a potentially detected dependency from T2 to T1.

A clinit map file (ending with extension .clinitmap) is generated beside the SOAR object file. It describes for each clinit dependency:

- the types involved
- the kind of dependency
- the stack calls between the two types

7.7 Foundation Libraries

7.7.1 Embedded Device Configuration (EDC)

The Embedded Device Configuration specification defines the minimal standard runtime environment for embedded devices. It defines all default API packages:

- java.io
- java.lang
- java.lang.annotation
- java.lang.ref
- java.lang.reflect
- java.util

7.7.2 Beyond Profile (B-ON)

B-ON defines a suitable and flexible way to fully control both memory usage and start-up sequences on devices with limited memory resources. It does so within the boundaries of Java semantics. More precisely, it allows:

- Controlling the initialization sequence in a deterministic way.
- Defining persistent, immutable, read-only objects (that may be placed into non-volatile memory areas), and which do not require copies to be made in RAM to be manipulated.
- Defining immortal, read-write objects that are always alive.

7.8 Properties

Properties allow the MicroEJ application to be parameterized using the System.getProperty API. The definition of the properties and their respective values can be done using files. Each filename of a properties file must match with *.system.properties and must be located in the properties package of the application classpath. These files follow the MicroEJ property list specification: key/value pairs.

```
microedition.encoding=ISO-8859-1
```

Figure 7.3. Example of Contents of a MicroEJ Properties File

MicroEJ properties can also be defined in the launch configuration. This can be done by setting the properties in the launcher with a specific prefix in their name:

- Properties for both the MicroEJ platform and the MicroEJ simulator: name starts with microej.java.property.*
- Properties for the MicroEJ simulator: name starts with sim.java.property.*
- Properties for the MicroEJ platform: name starts with emb.java.property.*

For example, to define the property myProp with the value theValue, set the following option in the VM arguments field of the JRE tab of the launch configuration:

```
-Dmicroej.java.property.myProp=theValue
```

Figure 7.4. Example of MicroEJ Property Definition in Launch Configuration

7.9 Generic Output

The System.err stream is connected to the System.out print stream. See below for how to configure the destination of these streams.

7.10 Link

Several sections are defined by the MicroEJ core engine. Each section must be linked by the third-party linker.

Section name	Aim	Location	Alignment (in bytes)
.bss.features.installed	Resident applications statics	RW	4
.bss.soar	Application static	RW	8
.bss.vm.stacks.java	Application threads stack blocks	RW	8
ICETEA_HEAP	MicroEJ core engine internal heap	Internal RW	8
_java_heap	Application heap	RW	4
_java_immortals	Application immortal heap	RW	4
.rodata.resources	Application resources	RO	16
.rodata.soar.features	Resident applications code and resources	RO	4
.shieldedplug	Shielded Plug data	RO	4
.text.soar	Application and library code	RO	16

Table 7.1. Linker Sections

7.11 Dependencies

The MicroEJ Core Engine requires an implementation of its low level APIs in order to run. Refer to the chapter “Implementation” for more information.

7.12 Installation

The MicroEJ Core Engine and its components are mandatory. In the platform configuration file, check Multi Applications to install the MicroEJ Core Engine in "Multi applications" mode. Otherwise, the "Single application" mode is installed.

7.13 Use

A MicroEJ classpath variable named EDC-1.2 is available, according to the selected foundation core library. This MicroEJ classpath variable is always required in the build path of a MicroEJ project; and all others libraries depend on it. This library provides a set of options. Refer to the chapter “Appendix E: Application Launch Options” which lists all available options.

Another classpath variable named BON-1.2 is available. This variable must be added to the build path of the MicroEJ application project in order to access the B-ON library.

8 Multi Applications

8.1 Principle

The Multi Applications capability of the MicroEJ core engine allows a main application (called standalone application) to install and execute at runtime additional applications (called sandboxed applications).

The MicroEJ core engine implements the [KF] specification. A Kernel is a standalone application generated on a multi applications-enabled platform. A Feature is a sandboxed application generated against a Kernel.

A sandboxed application may be dynamically downloaded at runtime or integrated at build-time within the executable application.

Note that the Multi Applications is a capability of the MicroEJ core engine. The MicroEJ simulator always runs an application as a standalone application.

8.2 Functional Description

The Multi applications process extends the overall process described in Section 4.

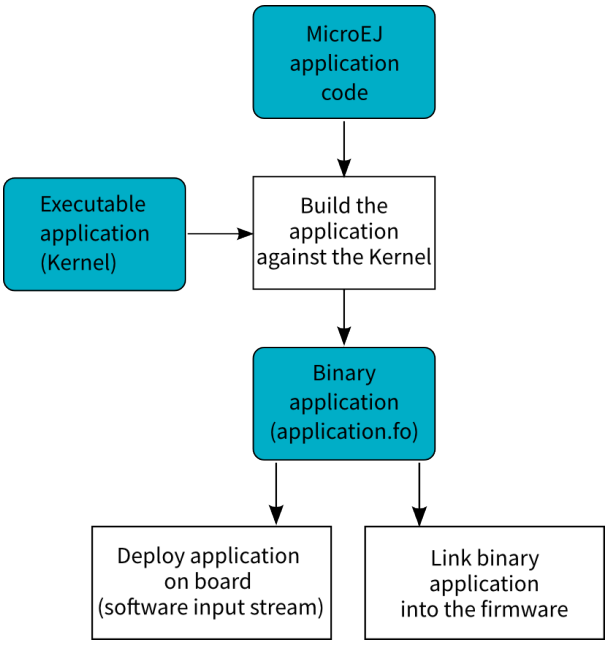


Figure 8.1. Multi Applications Process

Once a Kernel has been generated, additional MicroEJ application code (Feature) can be built against the Kernel by :

- Creating one launch configuration per feature.
- Setting the Settings field in the Execution tab of each feature launch configuration to Build Dynamic Feature.
- Setting the Kernel field in the Configuration tab of each feature launch configuration to the .

using the MicroEJ application launch named **Build Dynamic Feature.** The binary application file produced (application.fo) is compatible only for the Kernel on which it was generated. Generating a new Kernel requires that you generate the Features again on this Kernel.

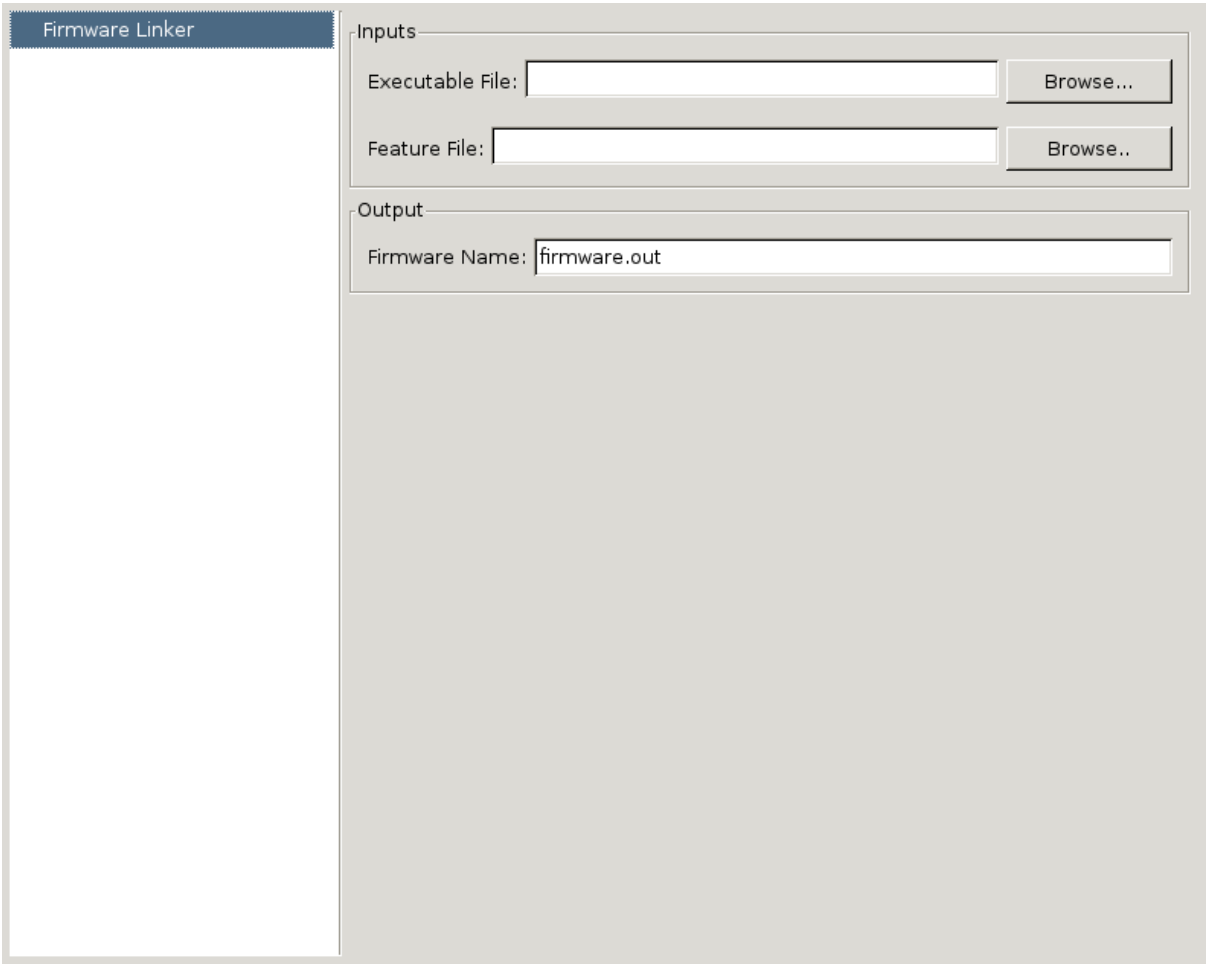
The Features built can be deployed in the following ways:

- Downloaded and installed at runtime by software. Refer to the [KF] specification for ej.kf.Kernel install APIs.
- Linked at build-time into the executable application. Features linked this way are then called Installed Features. The Kernel should have been generated with options for dimensioning the maximum size (code, data) for such Installed Features. Features are linked within the Kernel using the Firmware linker tool.

8.3 Firmware Linker

A MicroEJ tool is available to link Features as Installed Features within the executable application. The tool name is **Firmware Linker**. It takes as input the executable application file and the Feature binary code into which to be linked. It outputs a new executable application file, including the Installed Feature. This tool can be used to append multiple Features, by setting as the input file the output file of the previous pass.

8.3.1 Category: Firmware Linker



8.3.1.1 Group: Inputs

8.3.1.1.1 Option(browse): Executable File

Default value: (empty)

8.3.1.1.2 Option(browse): Feature File

Default value: (empty)

8.3.1.2 Group: Output

8.3.1.2.1 Option(text): Firmware Name

Default value: firmware.out

8.4 Memory Considerations

Multi applications memory overhead of MicroEJ core engine runtime elements are described in Table 8.1, “Multi Applications Memory Overhead”.

Runtime element	Memory	Description
Object	RW	4 bytes
Thread	RW	24 bytes
Stack Frame	RW	8 bytes
Class Type	RO	4 bytes
Interface Type	RO	8 bytes

Table 8.1. Multi Applications Memory Overhead

8.5 Dependencies

- LLKERNEL_impl.h implementation (see “LLKERNEL: Multi Applications”).

8.6 Installation

Multi Applications is an additional module, disabled by default.

To enable multi applications of the MicroEJ core engine, in the platform configuration file, check Multi Applications.

8.7 Use

A classpath variable named KF-1.4 is available.

This library provides a set of options. Refer to the chapter “Appendix E: Application Launch Options” which lists all available options.

9 Tiny Application

9.1 Principle

The Tiny Application capability of the MicroEJ core engine allows to build a main application optimized for size. This capability is suitable for environments requiring a small memory footprint.

9.2 Installation

Tiny Application is an option disabled by default. To enable Tiny application of the MicroEJ core engine, set the property mjvm.standalone.configuration in configuration.xml file as follows:

```
<property name="mjvm.standalone.configuration" value="tiny"/>
```

See section “Platform Customization” for more info on the configuration.xml file.

9.3 Limitations

In addition to general “Limitations”:

- The maximum application code size (classes and methods) cannot exceed 256KB. This does not include application resources, immutable objects and internal strings which are not limited.
- The option SOAR > Debug > Embed all type names has no effect. Only the fully qualified names of types marked as required types are embedded.

10 Native Interface Mechanisms

The MicroEJ Core Engine provides two ways to link MicroEJ application code with native C code. The two ways are fully complementary, and can be used at the same time.

10.1 Simple Native Interface (SNI)

10.1.1 Principle

SNI provides a simple mechanism for implementing native Java methods in the C language.

SNI allows you to:

- Call a C function from a Java method.
- Access an Immortal array in a C function (see the [B-ON] specification to learn about immortal objects).

SNI does not allow you to:

- Access or create a Java object in a C function.
- Access Java static variables in a C function.
- Call Java methods from a C function.

SNI provides some Java APIs to manipulate some data arrays between Java and the native (C) world.

10.1.2 Functional Description

SNI defines how to cross the barrier between the Java world and the native world:

- Call a C function from Java.
- Pass parameters to the C function.
- Return a value from the C world to the Java world.
- Manipulate (read & write) shared memory both in Java and C : the immortal space.

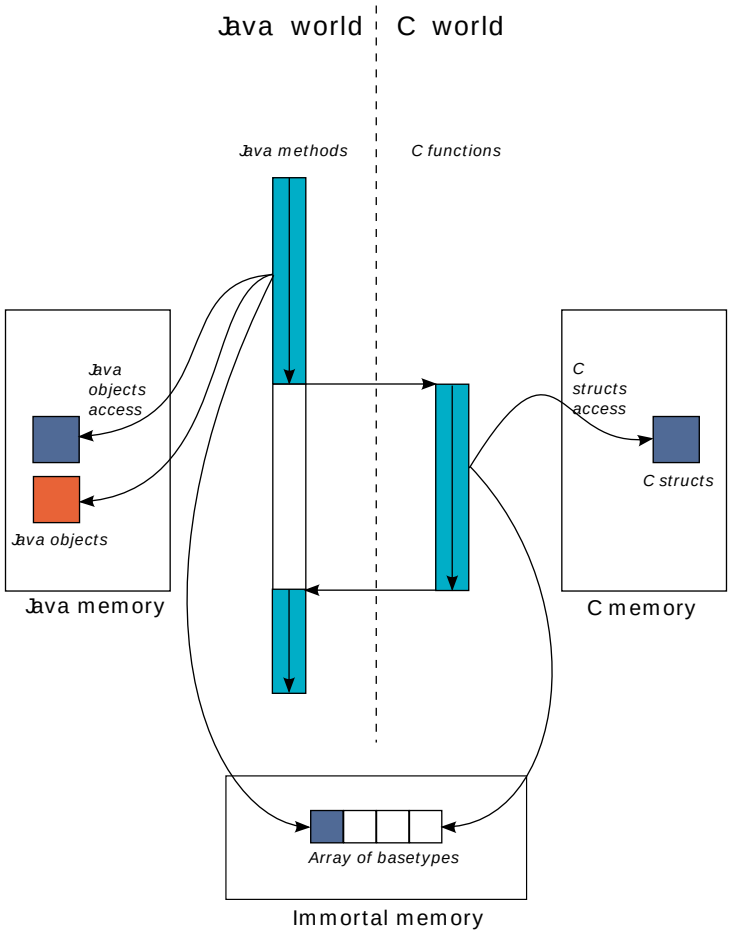


Figure 10.1. SNI Processing

Figure 10.1 illustration shows both Java and C code accesses to shared objects in the immortal space, while also accessing their respective memory.

10.1.3 Example

```
package example;

import java.io.IOException;

/**
 * Abstract class providing a native method to access sensor value.
 * This method will be executed out of virtual machine.
 */
public abstract class Sensor {

 public static final int ERROR = -1;

 public int getValue() throws IOException {
  int sensorID = getSensorID();
  int value = getSensorValue(sensorID);
  if (value == ERROR) {
   throw new IOException("Unsupported sensor");
  }
  return value;
 }

 protected abstract int getSensorID();

 public static native int getSensorValue(int sensorID);
}

class Potentiometer extends Sensor {

 protected int getSensorID() {
  return Constants.POTENTIOMETER_ID; // POTENTIOMETER_ID is a static final
 }
}
```

```
  // File providing an implementation of native method using a C function
  #include <sni.h>
  #include <potentiometer.h>

  #define SENSOR_ERROR (-1)
  #define POTENTIOMETER_ID (3)

  jint Java_example_Sensor_getSensorValue(jint sensor_id){

   if (sensor_id == POTENTIOMETER_ID)
   {
    return get_potentiometer_value();
   }
   return SENSOR_ERROR;
  }
```

10.1.4 Synchronization

A call to a native function uses the same RTOS task as the RTOS task used to run all Java green threads. So during this call, the MicroEJ Core Engine cannot schedule other Java threads.

SNI defines C functions that provide controls for the green threads' activities:

- int32_t SNI_suspendCurrentJavaThread(int64_t timeout): Suspends the execution of the Java thread that initiated the current C call. This function does not block the C execution. The suspension is effective only at the end of the native method call (when the C call returns). The green thread is suspended until either an RTOS task calls SNI_resumeJavaThread, or the specified number of milliseconds has elapsed.

- int32_t SNI_getCurrentJavaThreadID(void): Permits retrieval of the ID of the current Java thread within the C function (assuming it is a "native Java to C call"). This ID must be given to the SNI_resumeJavaThread function in order to resume execution of the green thread.
- int32_t SNI_resumeJavaThread(int32_t id): Resumes the green thread with the given ID. If the thread is not suspended, the resume stays pending.

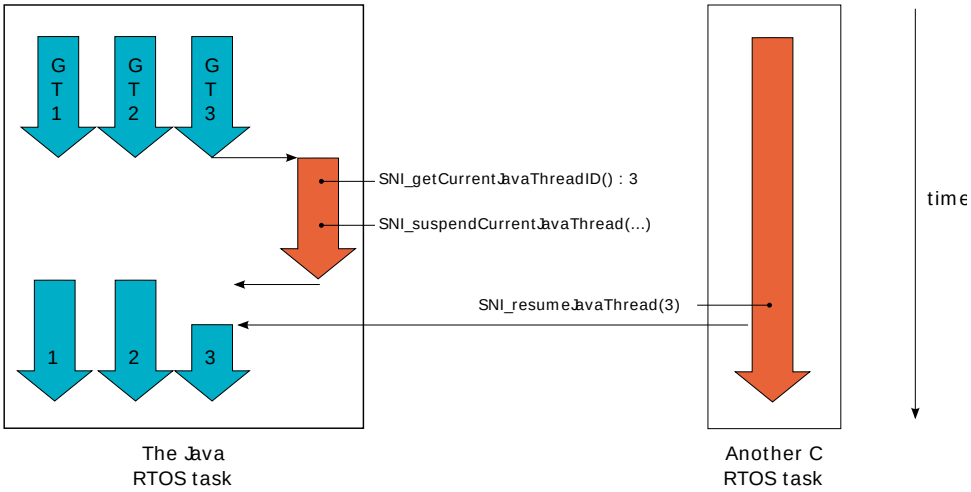


Figure 10.2. Green Threads and RTOS Task Synchronization

Figure 10.2 shows a green thread (GT3) which has called a native method that executes in C. The C code suspends the thread after having provisioned its ID (e.g. 3). Another RTOS task may later resume the Java green thread.

10.1.5 Dependencies

No dependency.

10.1.6 Installation

The SNI library is a built-in feature of the platform, so there is no additional dependency to call native code from Java. In the platform configuration file, check Java to C Interface > SNI API to install the additional Java APIs in order to manipulate the data arrays.

10.1.7 Use

A classpath variable named SNI-1.2 is available, which must be added to the build path of the MicroEJ application project, in order to allow access to the SNI library.

10.2 Shielded Plug (SP)

10.2.1 Principle

The Shielded Plug [SP] provides data segregation with a clear publish-subscribe API. The data-sharing between modules uses the concept of shared memory blocks, with introspection. The database is made of blocks: chunks of RAM.

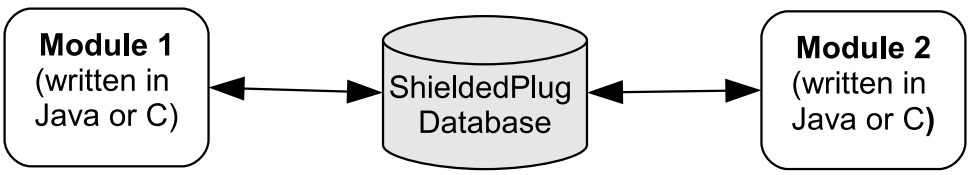


Figure 10.3. A Shielded Plug Between Two Application (Java/C) Modules.

10.2.2 Functional Description

The usage of the Shielded Plug (SP) starts with the definition of a database. The implementation of the SP for the MicroEJ platform uses an XML file description to describe the database; the syntax follows the one proposed by the SP specification [SP].

Once this database is defined, it can be accessed within the MicroEJ application or the C application. The SP foundation library is accessible from the classpath variable SP-2.0. This library contains the classes and methods to read and write data in the database. See also the Java documentation from the MicroEJ workbench resources center ("Javadoc" menu). The C header file sp.h available in the MicroEJ platform source/MICROJVM/include folder contains the C functions for accessing the database.

To embed the SP database in your binary file, the XML file description must be processed by the SP compiler. This compiler generates a binary file (.o) that will be linked to the overall application by the linker. It also generates two descriptions of the block ID constants, one in Java and one in C. These constants can be used by either the Java or the C application modules.

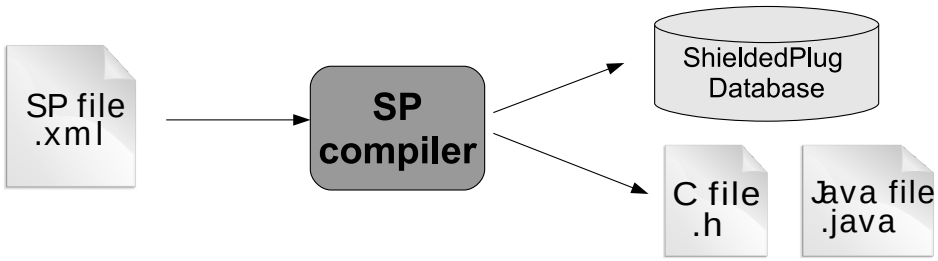


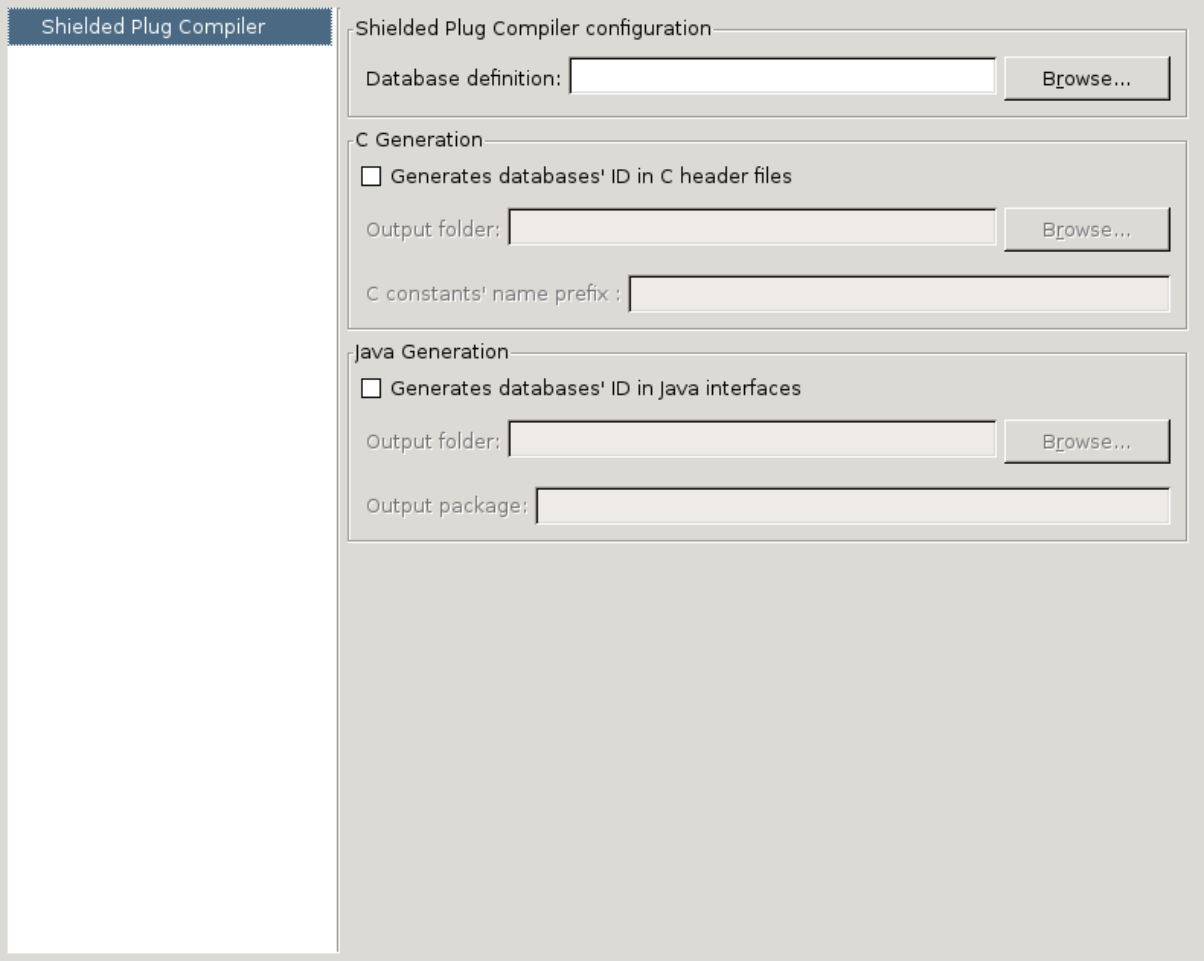
Figure 10.4. Shielded Plug Compiler Flow.

10.2.3 Shielded Plug Compiler

A MicroEJ tool is available to launch the SP compiler tool. The tool name is **Shielded Plug Compiler**. It outputs:

- A description of the requested resources of the database as a binary file (.o) that will be linked to the overall application by the linker. It is an ELF format description that reserves both the necessary RAM and the necessary Flash memory for the database of the Shielded Plug.
- Two descriptions, one in Java and one in C, of the block ID constants to be used by either Java or C application modules.

10.2.3.1 Category: Shielded Plug Compiler



10.2.3.1.1 Group: Shielded Plug Compiler configuration

10.2.3.1.1.1 Option(browse): Database definition

Default value: (empty)

Description:

Choose the database XML definition.

10.2.3.1.2 Group: C Generation

10.2.3.1.2.1 Option(checkbox): Generates databases' ID in C header files

Default value: unchecked

Description:

When checked, databases' ID are generated into C header files.

10.2.3.1.2.2 Option(browse): Output folder

Default value: (empty)

Description:

Folder where C header files are generated.

10.2.3.1.2.3 Option(text): C constants' name prefix

Default value: (empty)

10.2.3.1.3 Group: Java Generation

10.2.3.1.3.1 Option(checkbox): Generates databases' ID in Java interfaces

Default value: unchecked

Description:

When checked, databases' ID are generated into Java interfaces.

10.2.3.1.3.2 Option(browse): Output folder

Default value: (empty)

Description:

Folder where Java interfaces are generated.

10.2.3.1.3.3 Option(text): Output package

Default value: (empty)

10.2.4 Example

Below is an example of using a database SP. The code that publishes the data is written in C, and the code that receives the data is written in Java. The data is transferred using two memory blocks. One is a scalar value, the other is a more complex object representing a two-dimensional vector.

10.2.4.1 Database Description

The database is described as follows:

```
<shieldedPlug>
 <database name="Forecast" id="0" immutable="true" version="1.0.0">
  <block id="1" name="TEMP" length="4" maxTasks="1"/>
  <block id="2" name="THERMOSTAT" length="4" maxTasks="1"/>
 </database>
</shieldedPlug>
```

10.2.4.2 Java Code

From the database description we can create an interface.

```
 public interface Forecast {
  public static final int ID = 0;
  public static final int TEMP = 1;
  public static final int THERMOSTAT = 2;
 }
```

Below is the task that reads the published temperature and controls the thermostat.

```
public void run(){
 ShieldedPlug database = ShieldedPlug.getDatabase(Forecast.ID);
 while (isRunning){
  //reading the temperature every 30 seconds
  //and update thermostat status
  try {
   int temp = database.readInt(Forecast.TEMP);
   print(temp);
   //update the thermostat status
   database.writeInt(Forecast.THERMOSTAT,temp>tempLimit ? 0 : 1);
  }
  catch(EmptyBlockException e){
   print("Temperature not available");
  }
  sleep(30000);
 }
}
```

10.2.4.3 C Code

Here is a C header that declares the constants defined in the XML description of the database.

```
#define Forecast_ID 0
#define Forecast_TEMP 1
#define Forecast_THERMOSTAT 2
```

Below, the code shows the publication of the temperature and thermostat controller task.

```
void temperaturePublication(){
 ShieldedPlug database = SP_getDatabase(Forecast_ID);
 int32_t temp = temperature();
 SP_write(database, Forecast_TEMP, &temp);
}

void thermostatTask(){
 int32_t thermostatOrder;
 ShieldedPlug database = SP_getDatabase(Forecast_ID);
 while(1){
  SP_waitFor(database, Forecast_THERMOSTAT);
  SP_read(database, Forecast_THERMOSTAT, &thermostatOrder);
  if(thermostatOrder == 0) {
   thermostatOFF();
  }
  else {
   thermostatON();
  }
 }
}
```

10.2.5 Dependencies

- LLSP_impl.h implmentation (see “LLSP: Shielded Plug”).

10.2.6 Installation

The SP library and its relative tools are an optional feature of the platform. In the platform configuration file, check Java to C Interface > Shielded Plug to install the library and its relative tools.

10.2.7 Use

A classpath variable named SP-2.0 is available, which must be added to the build path of the MicroEJ application project in order to access the SP library.

This library provides a set of options. Refer to the chapter “Appendix E: Application Launch Options” which lists all available options.

10.3 MicroEJ Java H

10.3.1 Principle

This MicroEJ tool is useful for creating the skeleton of a C file, to which some Java native implementation functions will later be written. This tool helps prevent misses of some #include files, and helps ensure that function signatures are correct.

10.3.2 Functional Description

MicroEJ Java H tool takes as input one or several Java class files (*.class) from directories and / or JAR files. It looks for Java native methods declared in these class files, and generates a skeleton(s) of the C file(s).

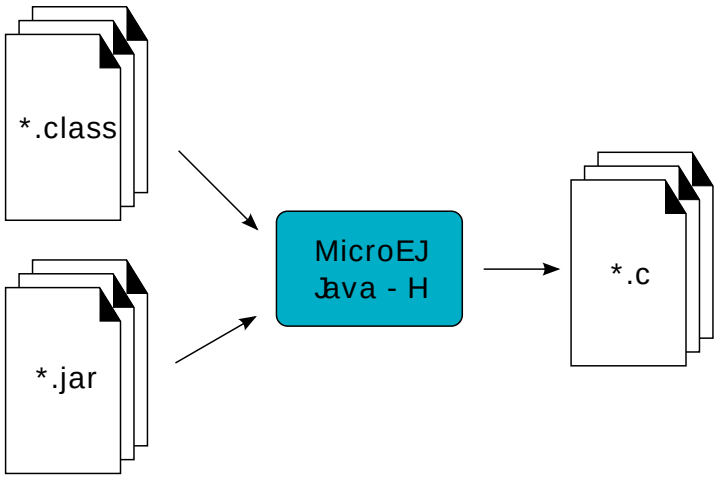


Figure 10.5. MicroEJ Java H Process

10.3.3 Dependencies

No dependency.

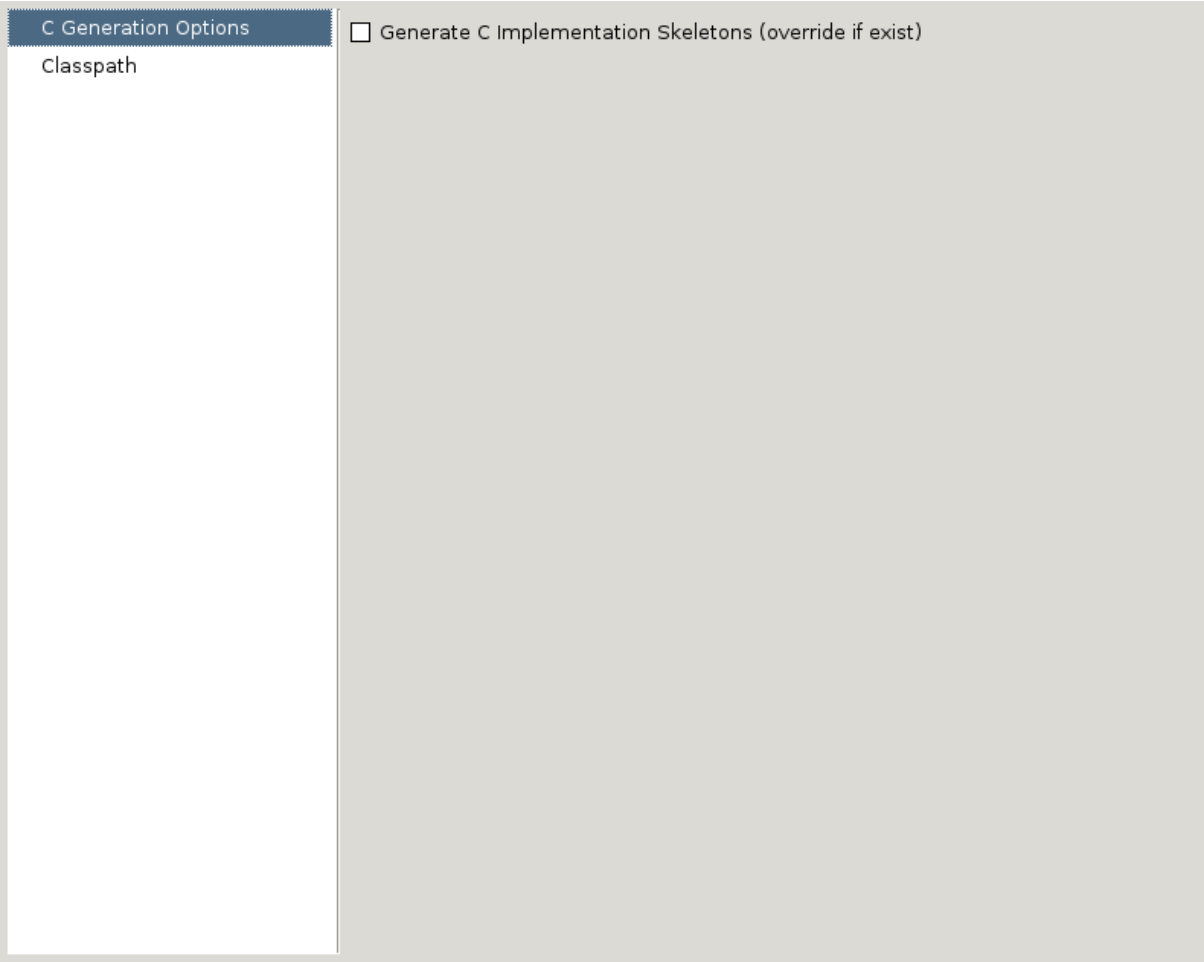
10.3.4 Installation

This is an additional tool. In the platform configuration file, check Java to C Interface > MicroEJ Java H to install the tool.

10.3.5 Use

This chapter explains the MicroEJ tool options.

10.3.5.1 Category: C Generation Options

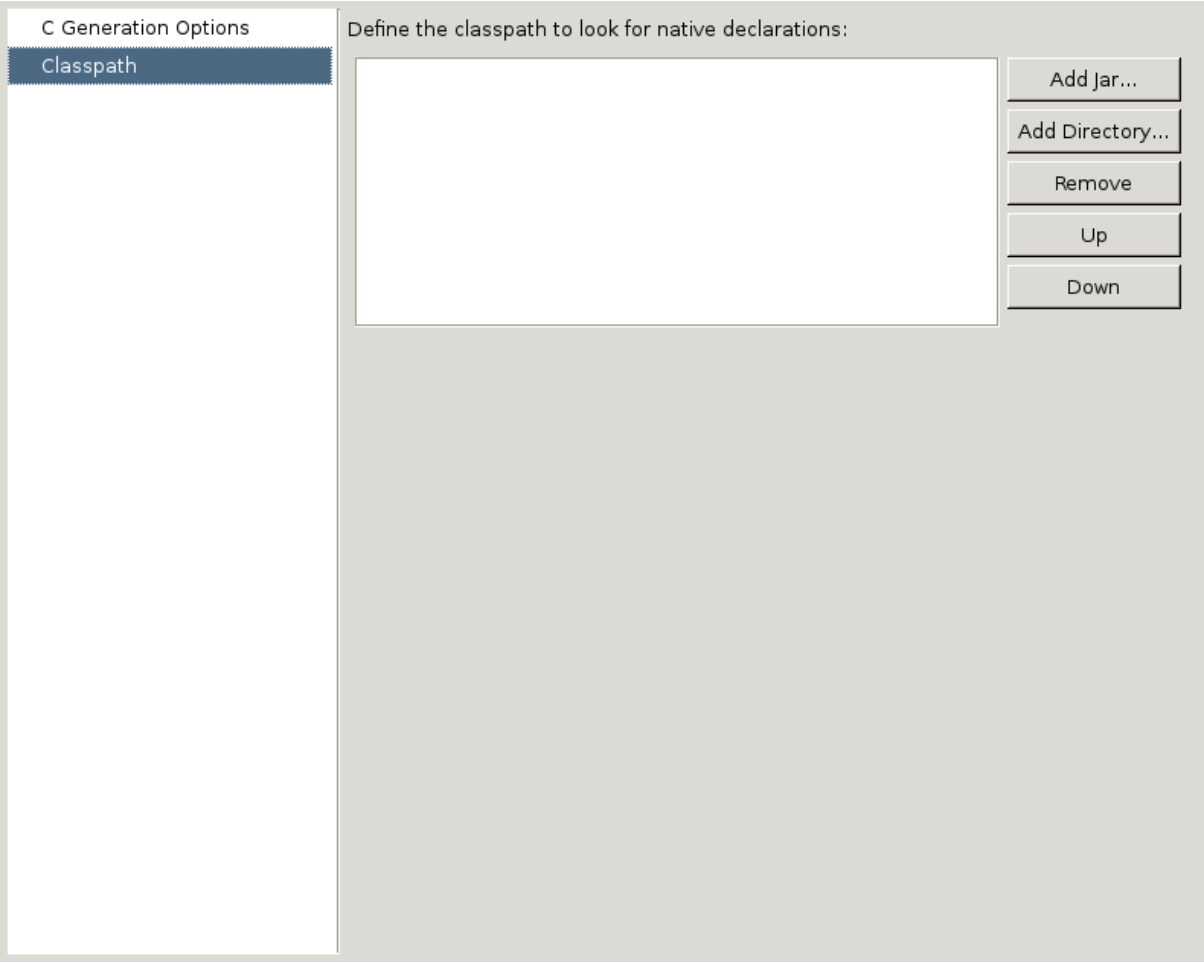


Description: Define the C Generation options

10.3.5.1.1 Option(checkbox): Generate C Implementation Skeletons (override if exist)

Default value: unchecked

10.3.5.2 Category: Classpath



Description: Define the classpath to look for native declarations

10.3.5.2.1 Option(list): Define the classpath to look for native declarations

Default value: (empty)

11 External Resources Loader

11.1 Principle

A *resource* is, for a MicroEJ application, the contents of a file. This file is known by its path (its relative path from the MicroEJ application classpath) and its name. The file may be stored in RAM, flash, or external flash; and it is the responsibility of the MicroEJ core engine and/or the BSP to retrieve and load it.

MicroEJ platform makes the distinction between two kinds of resources:

- Internal resource: The resource is taken into consideration during the MicroEJ application build. The SOAR step loads the resource and copies it into the same C library as the MicroEJ application. Like the MicroEJ application, the resource is linked into the CPU address space range (internal device memories, external parallel memories, etc.).

  The available list of internal resources to embed must be specified in the MicroEJ application launcher (MicroEJ launch). Under the tab “Resources”, select all internal resources to embed in the final binary file.

- External resource: The resource is not taken into consideration by MicroEJ. It is the responsibility of the BSP project to manage this kind of resource. The resource is often programmed outside the CPU address space range (storage media like SD card, serial NOR flash, EEPROM, etc.).

  The BSP must implement some specific Low Level API (LLAPI) C functions: LLEXT_RES_impl.h. These functions allow the MicroEJ application to load some external resources.

11.2 Functional Description

The External Resources Loader is an optional module. When not installed, only internal resources are available for the MicroEJ application. When the External Resources Loader is installed, the MicroEJ core engine tries first to retrieve the expected resource from its available list of internal resources, before asking the BSP to load it (using LLEXT_RES_impl.h functions).

11.3 Implementations

External Resources Loader module provides some Low Level API (LLEXT_RES) to let the BSP manage the external resources.

11.3.1 Open a Resource

The LLAPI to implement in the BSP are listed in the header file LLEXT_RES_impl.h. First, the framework tries to open an external resource using the open function. This function receives the resources path as a parameter. This path is the absolute path of the resource from the MicroEJ application classpath (the MicroEJ application source base directory). For example, when the resource is located here: com.mycompany.myapplication.resource.MyResource.txt , the given path is: com/mycompany/myapplication/resource/MyResource.txt.

11.3.2 Resource Identifier

This open function has to return a unique ID (positive value) for the external resource, or returns an error code (negative value). This ID will be used by the framework to manipulate the resource (read, seek, close, etc.).

Several resources can be opened at the same time. The BSP does not have to return the same identifier for two resources living at the same time. However, it can return this ID for a new resource as soon as the old resource is closed.

11.3.3 Resource Offset

The BSP must hold an offset for each opened resource. This offset must be updated after each call to read and seek.

11.3.4 Resource Inside the CPU Address Space Range

An external resource can be programmed inside the CPU address space range. This memory (or a part of memory) is not managed by the SOAR and so the resources inside are considered as external.

Most of time the content of an external resource must be copied in a memory inside the CPU address space range in order to be accessible by the MicroEJ algorithms (draw an image etc.). However, when the resource is already inside the CPU address space range, this copy is useless. The function LLEXT_RES_getBaseAddress must return a valid CPU memory address in order to avoid this copy. The MicroEJ algorithms are able to target the external resource bytes without using the other LLEXT_RES APIs such as read, mark etc.

11.4 External Resources Folder

The External Resource Loader module provides an option (MicroEJ launcher option) to specify a folder for the external resources. This folder has two roles:

- It is the output folder used by some extra generators during the MicroEJ application build. All output files generated by these tools will be copied into this folder. This makes it easier to retrieve the exhaustive list of resources to program on the board.
- This folder is taken into consideration by the simulator in order to simulate the availability of these resources. When the resources are located in another computer folder, the simulator is not able to load them.

If not specified, this folder is created (if it does not already exist) in the MicroEJ project specified in the MicroEJ launcher. Its name is externalResources.

11.5 Dependencies

- LLEXT_RES_impl.h implementation (see “LLEXT_RES: External Resources Loader”).

11.6 Installation

The External Resources Loader is an additional module. In the platform configuration file, check External Resources Loader to install this module.

11.7 Use

The External Resources Loader is automatically used when the MicroEJ application tries to open an external resource.

12 Serial Communications

MicroEJ provides some foundation libraries to instantiate some communications with external devices. Each communication method has its own library. A global library called ECOM provides support for abstract communication streams (communication framework only), and a generic devices manager.

12.1 ECOM

12.1.1 Principle

The Embedded COMmunication foundation library (ECOM) is a generic communication library with abstract communication stream support (a communication framework only). It allows you to open and use streams on communication devices such as a COMM port.

This library also provides a device manager, including a generic device registry and a notification mechanism, which allows plug&play-based applications.

This library does not provide APIs to manipulate some specific options for each communication method, but it does provide some generic APIs which abstract the communication method. After the opening step, the MicroEJ application can use every communications method (COMM, USB etc.) as generic communication in order to easily change the communication method if needed.

12.1.2 Functional Description

Figure 12.1 shows the overall process to open a connection on a hardware device.

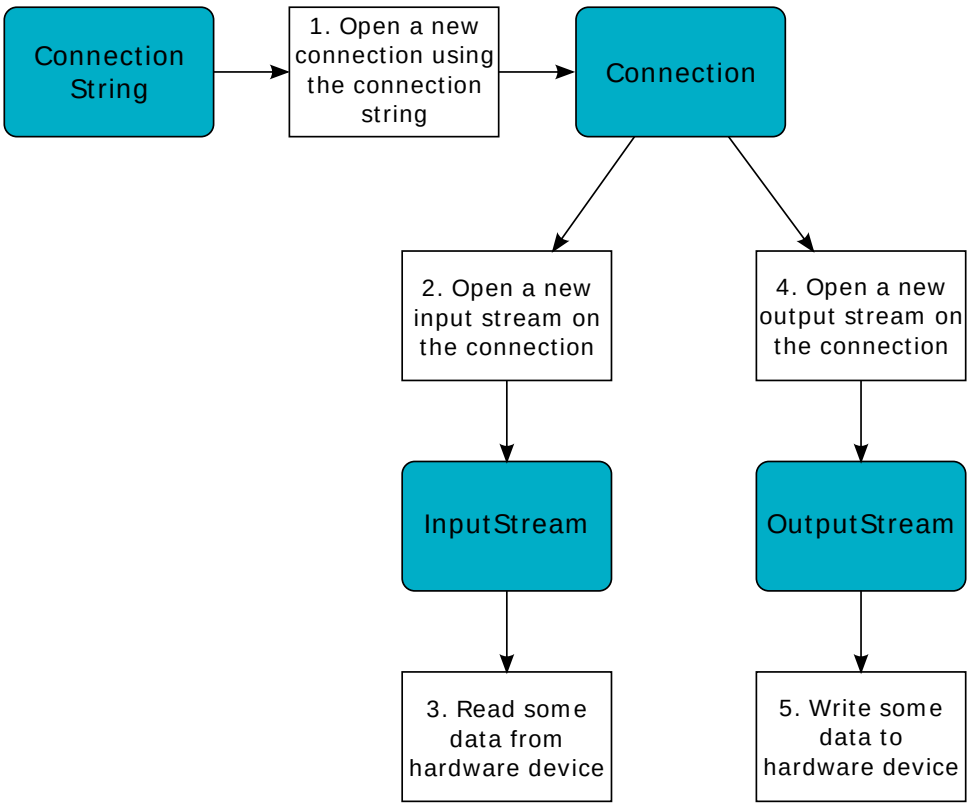


Figure 12.1. ECOM Flow

1. Step 1 consists of opening a connection on a hardware device. The connection kind and its configuration are fixed by the parameter `String connectionString` of the method `Connection.open`.

2. Step 2 consists of opening an `InputStream` on the connection. This stream allows the MicroEJ application to access the "RX" feature of the hardware device.

3. Step 3 consists of using the InputStream APIs to receive in the MicroEJ application all hardware device data.
4. Step 4 consists of opening an OutputStream on the connection. This stream allows the MicroEJ application to access the "TX" feature of the hardware device.
5. Step 5 consists of using the OutputStream APIs to transmit some data from the MicroEJ application to the hardware device.

Note that steps 2 and 4 may be performed in parallel, and do not depend on each other.

12.1.3 Device Management API

A device is defined by implementing ej.ecom.Device. It is identified by a name and a descriptor (ej.ecom.HardwareDescriptor), which is composed of a set of MicroEJ properties. A device can be registered/unregistered in the ej.ecom.DeviceManager.

A device registration listener is defined by implementing ej.ecom.RegistrationListener. When a device is registered to or unregistered from the device manager, listeners registered for the device type are notified. The notification mechanism is done in a dedicated MicroEJ thread. The mechanism can be enabled or disabled (see “Appendix E: Application Launch Options”).

12.1.4 Dependencies

No dependency.

12.1.5 Installation

ECOM foundation library is an additional libray. In the platform configuration file, check Serial Communication > ECOM to install the library.

12.1.6 Use

A classpath variable named ECOM-1.1 is available. This foundation library is always required when developing a MicroEJ application which communicates with some external devices. It is automatically embedded as soon as a sub communication library is added in the classpath.

12.2 ECOM Comm

12.2.1 Principle

The ECOM Comm Java library provides support for serial communication. ECOM Comm extends ECOM to allow stream communication via serial communication ports (typically UARTs). In the MicroEJ application, the connection is established using the Connector.open() method. The returned connection is a ej.ecom.io.CommConnection , and the input and output streams can be used for full duplex communication.

The use of ECOM Comm in a custom platform requires the implementation of an UART driver. There are two different modes of communication:

- In Buffered mode, ECOM Comm manages software FIFO buffers for transmission and reception of data. The driver copies data between the buffers and the UART device.
- In Custom mode, the buffering of characters is not managed by ECOM Comm. The driver has to manage its own buffers to make sure no data is lost in serial communications because of buffer overruns.

This ECOM Comm implementation also allows dynamic add or remove of a connection to the pool of available connections (typically hot-plug of a USB Comm port).

12.2.2 Functional Description

The ECOM Comm process respects the ECOM process. Please refer to the illustration “ ECOM Flow ”.

12.2.3 Component architecture

The ECOM Comm C module relies on a native driver to perform actual communication on the serial ports. Each port can be bound to a different driver implementation, but most of the time, it is possible to use the same implementation (i.e. same code) for multiple ports. Exceptions are the use of different hardware UART types, or the need for different behaviors.

Five C header files are provided:

- LLCOMM_impl.h

  Defines the set of functions that the driver must implement for the global ECOM comm stack, such as synchronization of accesses to the connections pool.

- LLCOMM_BUFFERED_CONNECTION_impl.h

  Defines the set of functions that the driver must implement to provide a Buffered connection

- LLCOMM_BUFFERED_CONNECTION.h

  Defines the set of functions provided by ECOM Comm that can be called by the driver (or other C code) when using a Buffered connection

- LLCOMM_CUSTOM_CONNECTION_impl.h

  Defines the set of functions that the driver must implement to provide a Custom connection

- LLCOMM_CUSTOM_CONNECTION.h

  Defines the set of functions provided by ECOM Comm that can be called by the driver (or other C code) when using a Custom connection

The ECOM Comm drivers are implemented using standard LLAPI features. The diagram below shows an example of the objects (both Java and C) that exist to support a Buffered connection.

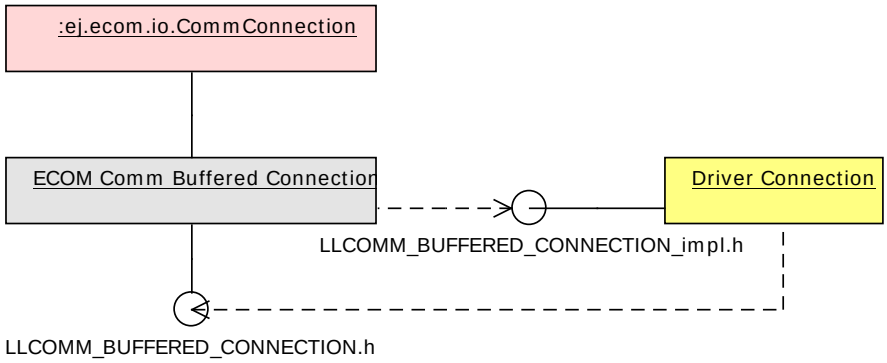


Figure 12.2. ECOM Comm components

The connection is implemented with three objects [3] :

- The Java object used by the application; an instance of ej.ecom.io.CommConnection
- The connection object within the ECOM Comm C module
- The connection object within the driver

Each driver implementation provides one or more connections. Each connection typically corresponds to a physical UART.

[3] This is a conceptual description to aid understanding - the reality is somewhat different, although that is largely invisible to the implementor of the driver.

12.2.4 Comm Port Identifier

Each serial port available for use in ECOM Comm can be identified in three ways:

- An application port number. This identifier is specific to the application, and should be used to identify the data stream that the port will carry (for example, "debug traces" or "GPS data").
- A platform port number. This is specific to the platform, and may directly identify an hardware device [4].
- A platform port name. This is mostly used for dynamic connections or on platforms having a file-system based device mapping.

When the Comm Port is identified by a number, its string identifier is the concatenation of "com" and the number (e.g. com11).

12.2.4.1 Application port mapping

The mapping from application port numbers to platform ports is done in the application launch configuration. This way, the application can refer only to the application port number, and the data stream can be directed to the matching I/O port on different versions of the hardware.

Ultimately, the application port number is only visible to the application. The platform identifier will be sent to the driver.

12.2.4.2 Opening Sequence

The following flow chart explains Comm Port opening sequence according to the given Comm Port identifier.

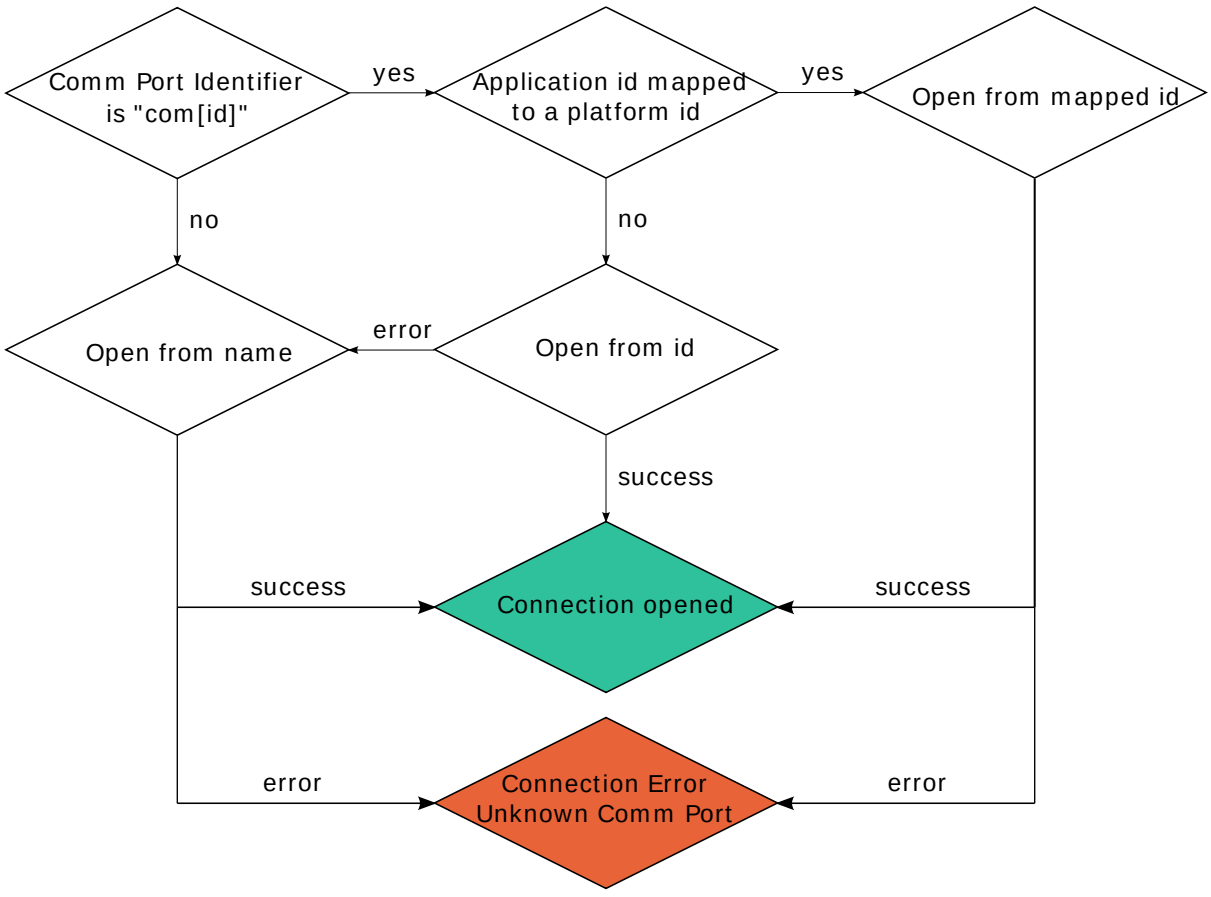


Figure 12.3. Comm Port Open Sequence

[4] Some drivers may reuse the same UART device for different ECOM ports with a hardware multiplexer. Drivers can even treat the platform port number as a logical id and map the ids to various I/O channels.

12.2.5 Dynamic Connections

The ECOM Comm stack allows to dynamically add and remove connections from the “Driver API”. When a connection is added, it can be immediately open by the application. When a connection is removed, the connection cannot be open anymore and java.io.IOException is thrown in threads that are using it.

In addition, a dynamic connection can be registered and unregistered in ECOM device manager (see “Device Management API”). The registration mechanism is done in dedicated thread. It can be enabled or disabled, see “Appendix E: Application Launch Options”.

A removed connection is alive until it is closed by the application and, if enabled, unregistered from ECOM device manager. A connection is effectively uninstalled (and thus eligible to be reused) only when it is released by the stack.

The following sequence diagram shows the lifecycle of a dynamic connection with ECOM registration mechanism enabled.

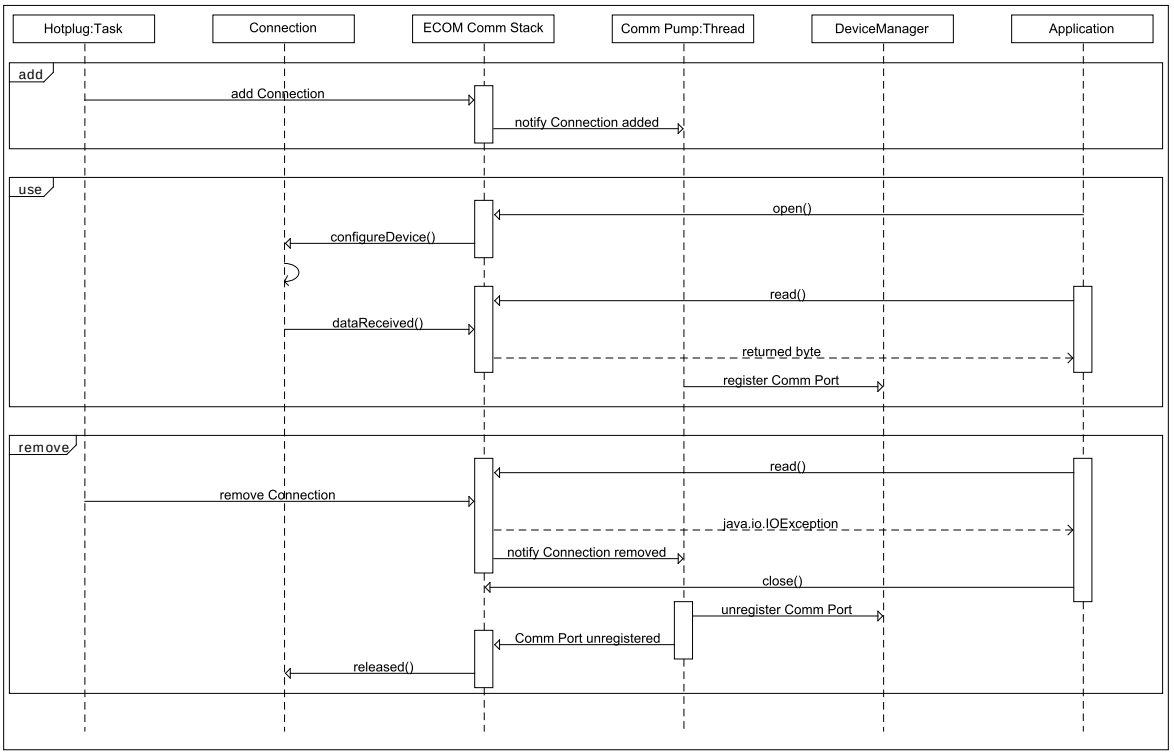


Figure 12.4. Dynamic Connection Lifecycle

12.2.6 Java API

Opening a connection is done using ej.ecom.io.Connector.open(String name) . The connection string (the name parameter) must start with "comm:", followed by the Comm port identifier, and a semicolon-separated list of options. Options are the baudrate, the parity, the number of bits per character, and the number of stop bits:

- baudrate=n (9600 by default)
- bitsperchar=n where n is in the range 5 to 9 (8 by default)
- stopbits=n where n is 1, 2, or 1.5 (1 by default)
- parity=x where x is odd, even or none (none by default)

All of these are optional. Illegal or unrecognized parameters cause an IllegalArgumentException .

12.2.7 Driver API

The ECOM Comm Low Level API is designed to allow multiple implementations (e.g. drivers that support different UART hardware) and connection instances (see Low Level API Pattern chapter). Each ECOM Comm driver defines a data structure that holds information about a connection, and functions take an instance of this data structure as the first parameter.

The name of the implementation must be set at the top of the driver C file, for example[5]:

```
#define LLCOMM_BUFFERED_CONNECTION MY_LLCOMM
```

This defines the name of this implementation of the LLCOMM_BUFFERED_CONNECTION interface to be MY_LLCOMM.

The data structure managed by the implementation must look like this:

```
typedef struct MY_LLCOMM{
   struct LLCOMM_BUFFERED_CONNECTION header;
   // extra data goes here
} MY_LLCOMM;

void MY_LLCOMM_new(MY_LLCOMM* env);
```

In this example the structure contains only the default data, in the header field. Note that the header must be the first field in the structure. The name of this structure must be the same as the implementation name (MY_LLCOMM in this example).

The driver must also declare the "new" function used to initialize connection instances. The name of this function must be the implementation name with _new appended, and it takes as its sole argument a pointer to an instance of the connection data structure, as shown above.

The driver needs to implement the functions specified in the LLCOMM_impl.h file and for each kind of connection, the LLCOMM_BUFFERED_CONNECTION_impl.h (or LLCOMM_CUSTOM_CONNECTION_impl.h) file.

The driver defines the connections it provides by adding connection objects using LLCOMM_addConnection. Connections can be added to the stack as soon as the LLCOMM_initialize function is called. Connections added during the call of the LLCOMM_impl_initialize function are static connections. A static connection is registered to the ECOM registry and cannot be removed. When a connection is dynamically added outside the MicroJVM task context, a suitable reentrant synchronization mechanism must be implemented (see LLCOMM_IMPL_syncConnectionsEnter and LLCOMM_IMPL_syncConnectionsExit).

When opening a port from the MicroEJ application, each connection declared in the connections pool will be asked about its platform port number (using the getPlatformId method) or its name (using the getName method) depending on the requested port identifier. The first matching connection is used.

The life of a connection starts with the call to getPlatformId() or getName() method. If the the connection matches the port identifier, the connection will be initialized, configured and enabled. Notifications and interrupts are then used to keep the stream of data going. When the connection is closed by the application, interrupts are disabled and the driver will not receive any more notifications. It is important to remember that the transmit and receive sides of the connection are separate Java stream objects, thus, they may have a different life cycle and one side may be closed long before the other.

12.2.7.1 The Buffered Comm stream

In Buffered mode, two buffers are allocated by the driver for sending and receiving data. The ECOM Comm C module will fill the transmit buffer, and get bytes from the receive buffer. There is no flow control.

[5]The following examples use Buffered connections, but Custom connections follow the same pattern.

When the transmit buffer is full, an attempt to write more bytes from the MicroEJ application will block the Java thread trying to write, until some characters are sent on the serial line and space in the buffer is available again.

When the receive buffer is full, characters coming from the serial line will be discarded. The driver must allocate a buffer big enough to avoid this, according to the UART baudrate, the expected amount of data to receive, and the speed at which the application can handle it.

The Buffered C module manages the characters sent by the application and stores them in the transmit buffer. On notification of available space in the hardware transmit buffer, it handles removing characters from this buffer and putting them in the hardware buffer. On the other side, the driver notifies the C module of data availability, and the C module will get the incoming character. This character is added to the receive buffer and stays there until the application reads it.

The driver should take care of the following:

- Setting up interrupt handlers on reception of a character, and availability of space in the transmit buffer. The C module may mask these interrupts when it needs exclusive access to the buffers. If no interrupt is available from the hardware or underlying software layers, it may be faked using a polling thread that will notify the C module.
- Initialization of the I/O pins, clocks, and other things needed to get the UART working.
- Configuration of the UART baudrate, character size, flow control and stop bits according to the settings given by the C module.
- Allocation of memory for the transmit and receive buffers.
- Getting the state of the hardware: is it running, is there space left in the TX and RX hardware buffers, is it busy sending or receiving bytes?

The driver is notified on the following events:

- Opening and closing a connection: the driver must activate the UART and enable interrupts for it.
- A new byte is waiting in the transmit buffer and should be copied immediately to the hardware transmit unit. The C module makes sure the transmit unit is not busy before sending the notification, so it is not needed to check for that again.

The driver must notify the C module on the following events:

- Data has arrived that should be added to the receive buffer (using the LLCOMM_BUFFERED_CONNECTION_dataReceived function)
- Space available in the transmit buffer (using the LLCOMM_BUFFERED_CONNECTION_transmitBufferReady function)

12.2.7.2 The Custom Comm stream

In custom mode, the ECOM Comm C module will not do any buffering. Read and write requests from the application are immediately forwarded to the driver.

Since there is no buffer on the C module side when using this mode, the driver has to define a strategy to store received bytes that were not handed to the C module yet. This could be a fixed or variable side FIFO, the older received but unread bytes may be dropped, or a more complex priority arbitration could be set up. On the transmit side, if the driver does not do any buffering, the Java thread waiting to send something will be blocked and wait for the UART to send all the data.

In Custom mode flow control (eg. RTS/CTS or XON/XOFF) can be used to notify the device connected to the serial line and so avoid losing characters.

12.2.8 BSP File

The ECOM Comm C module needs to know, when the MicroEJ application is built, the name of the implementation. This mapping is defined in a BSP definition file. The name of this file must be bsp.xml and must be written in the ECOM comm module configuration folder (near the ecom-comm.xml file). In previous example the bsp.xml file would contain:

```
<bsp>
  <nativeImplementation
    name="MY_LLCOMM"
    nativeName="LLCOMM_BUFFERED_CONNECTION"
  />
</bsp>
```

Figure 12.5. ECOM Comm Driver Declaration (bsp.xml)

where nativeName is the name of the interface, and name is the name of the implementation.

12.2.9 XML File

The Java platform has to know the maximum number of Comm ports that can be managed by the ECOM Comm stack. It also has to know each Comm port that can be mapped from an application port number. Such Comm port is identified by its platform port number and by an optional nickname (The port and its nickname will be visible in the MicroEJ launcher options, see “Appendix E: Application Launch Options”).

A XML file is so required to configure the Java platform. The name of this file must be ecom-comm.xml. It has to be stored in the module configuration folder (see “Installation”).

This file must start with the node <ecom> and the sub node <comms>. It can contain several time this kind of line: <comm platformId="A_COMM_PORT_NUMBER" nickname="A_NICKNAME"/> where:

- A_COMM_PORT_NUMBER refers the Comm port the Java platform user will be able to use (see “Application port mapping”).
- A_NICKNAME is optional. It allows to fix a printable name of the Comm port.

The maxConnections attribute indicates the maximum number of connections allowed, including static and dynamic connections. This attribute is optional. By default, it is the number of declared Comm Ports.

Example:

```
<ecom>
  <comms maxConnections="20">
    <comm platformId="2"/>
    <comm platformId="3" nickname="DB9"/>
    <comm platformId="5"/>
  </comms>
</ecom>
```

Figure 12.6. ECOM Comm Module Configuration (ecom-comm.xml)

First Comm port holds the port 2, second "3" and last "5". Only the second Comm port holds a nickname "DB9".

12.2.10 ECOM Comm Mock

In the simulation environment, no driver is required. The ECOM Comm mock handles communication for all the serial ports and can redirect each port to one of the following:

- An actual serial port on the host computer: any serial port identified by your operating system can be used. The baudrate and flow control settings are forwarded to the actual port.

- A TCP socket. You can connect to a socket on the local machine and use netcat or telnet to see the output, or you can forward the data to a remote device.
- Files. You can redirect the input and output each to a different file. This is useful for sending pre-computed data and looking at the output later on for offline analysis.

When using the socket and file modes, there is no simulation of an UART baudrate or flow control. On a file, data will always be available for reading and will be written without any delay. On a socket, you can reach the maximal speed allowed by the network interface.

12.2.11 Dependencies

- ECOM (see “ECOM”).
- LLCOMM_impl.h and LLCOMM_xxx_CONNECTION_impl.h implmentations (see “LLCOMM: Serial Communications”).

12.2.12 Installation

ECOM-Comm Java library is an additional library. In the platform configuration file, check Serial Communication > ECOM-COMM to install it. When checked, the xml file ecom-comm > ecom-comm.xml is required during platform creation to configure the module (see “XML File”).

12.2.13 Use

A classpath variable named ECOM-COMM-1.1 is available. This foundation library is always required when developing a MicroEJ application which communicates with some external devices using the serial communication mode.

This library provides a set of options. Refer to the chapter “Appendix E: Application Launch Options” which lists all available options.

13 Native Language Support

13.1 Principle

The NLS library facilitates internationalization. It provides support to manipulate messages and translate them into different languages.

Each message for which there will be an alternative translation is given a logical name (the *message name*), and the set of messages is itself identified by a name, called the *header*.

Each language for which message translations exist is identified by a string called the *locale*. The format of the locale string is not restricted, but by convention it is the concatenation of a language code and a country code:

- The language code is a lowercase, two-letter code as defined by ISO-639.
- The country code is an uppercase, two-letter code as defined by ISO-3166.

Therefore, the required message string is obtained by specifying the *header*, the *locale* and the *message name*.

The NLS data is defined using a combination of interfaces and text files. The message strings are pre-processed into immutable objects, which are available to the NLS library at runtime.

13.2 Functional Description

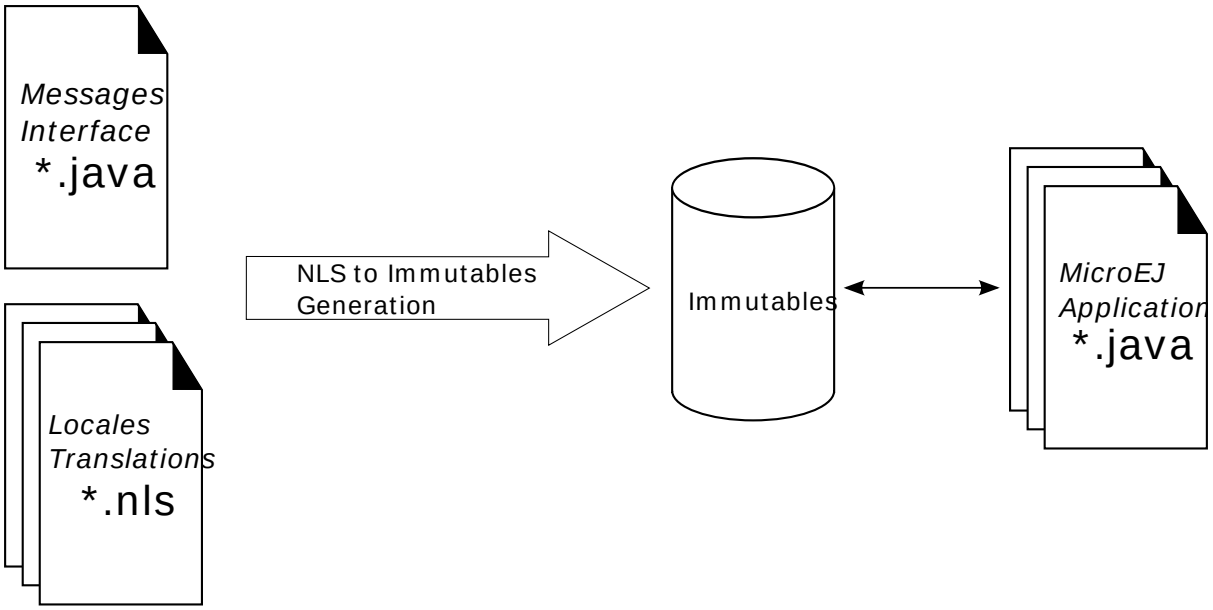


Figure 13.1. Native Language Support Process

The header and message names are specified by an interface. The name of the interface is the *header*. It defines a constant (public static final int) for each message. The name of the field is the *message name*. The values of the fields must form a contiguous range of integers starting at 1. Here is an example:

```
package com.is2t.appnotes.nls;

public interface HelloWorld {

 public static final int HELLO_WORLD = 1;

}
```

The application can define multiple headers, each specified by a separate interface.

For each locale, a properties file is defined that will translate all messages and define the language-printable name (DISPLAY_NAME). Make sure that:

- The file name matches [header]_[locale].nls.
- The message keys match (case sensitive) the constants defined in the interface.

An example of English NLS file, helloworld_en_US.nls:

```
DISPLAY_NAME=English
HELLO_WORLD=Hello world!
```

To be available at runtime, the list of messages must be defined in a file that contains the list of the fully-qualified names of the interfaces for the messages set. For example:

```
com.is2t.appnotes.nls.HelloWorld
```

This file must then be referenced in the launcher. The messages will be pre-processed into immutable files.

The use of these messages (converted into immutables) is allowed by creating a BasicImmutablesNLS instance that passes the lowercased header name as an argument:

```
NLS nls = new BasicImmutablesNLS("helloworld");
```

The messages can then be referenced by using the NLS.getMessage(int) method passing a message constant as an argument:

```
String message = nls.getMessage(HelloWorld.HELLO_WORLD);
```

The current locale can be changed using the NLS.setCurrentLocale(String) method passing the string representing the locale as an argument:

```
nls.setCurrentLocale("en_US");
```

The available locales list can be retrieved with the NLS.getAvailableLocales() method:

```
String[] locales = nls.getAvailableLocales();
```

13.3 Dependencies

No dependency.

13.4 Installation

The NLS foundation library is a built-in libray.

13.5 Use

A classpath variable named NLS-2.0 is available.

This library provides a set of options. Refer to the chapter “Appendix E: Application Launch Options” which lists all available options.

14 Graphics User Interface

14.1 Principle

The User Interface Extension features one of the fastest graphical engines, associated with a unique int-based event management system. It provides [MUI] library implementation. The following diagram depicts the components involved in its design, along with the provided tools:

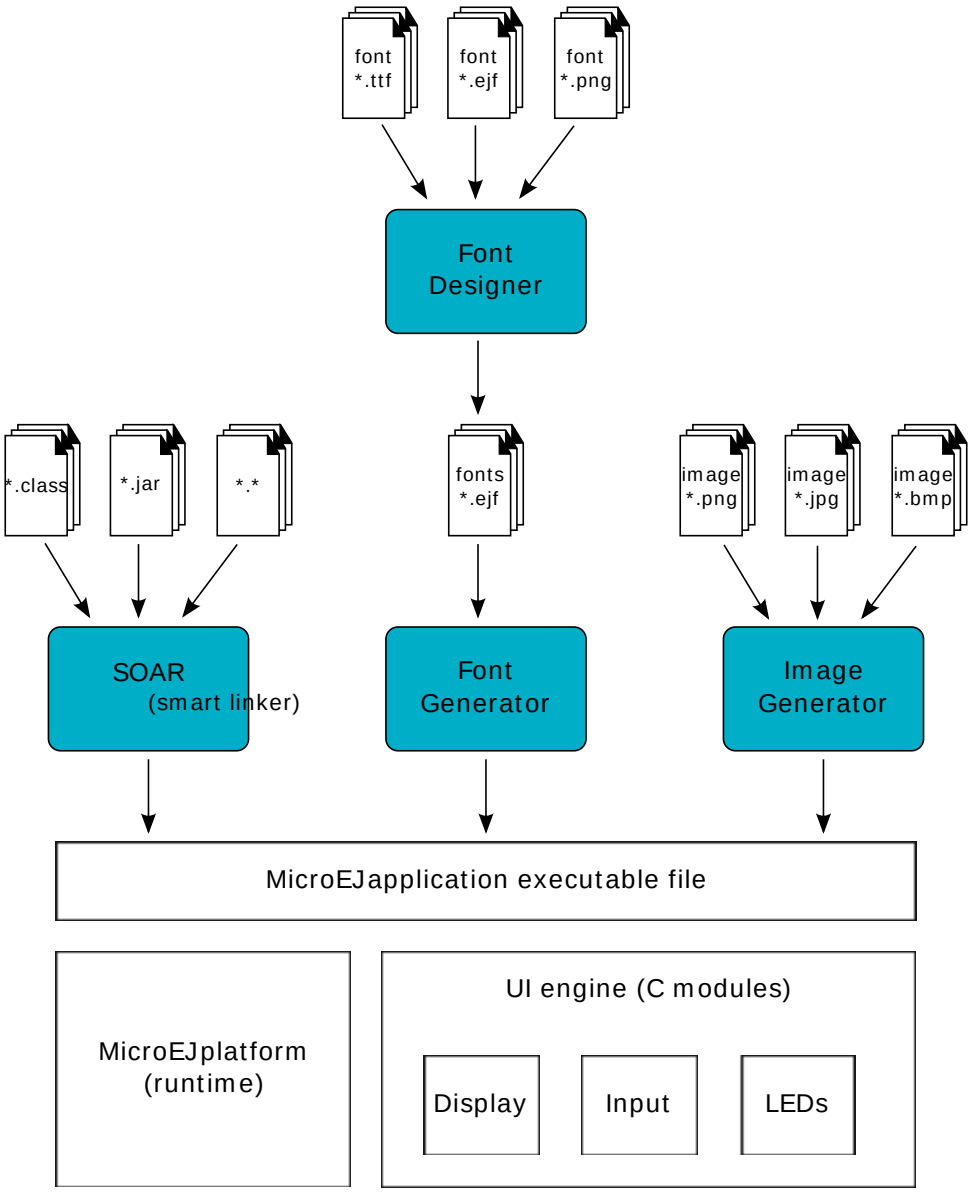


Figure 14.1. The User Interface Extension Components along with a Platform

The diagram below shows a simplified view of the components involved in the provisioning of a Java user interface.

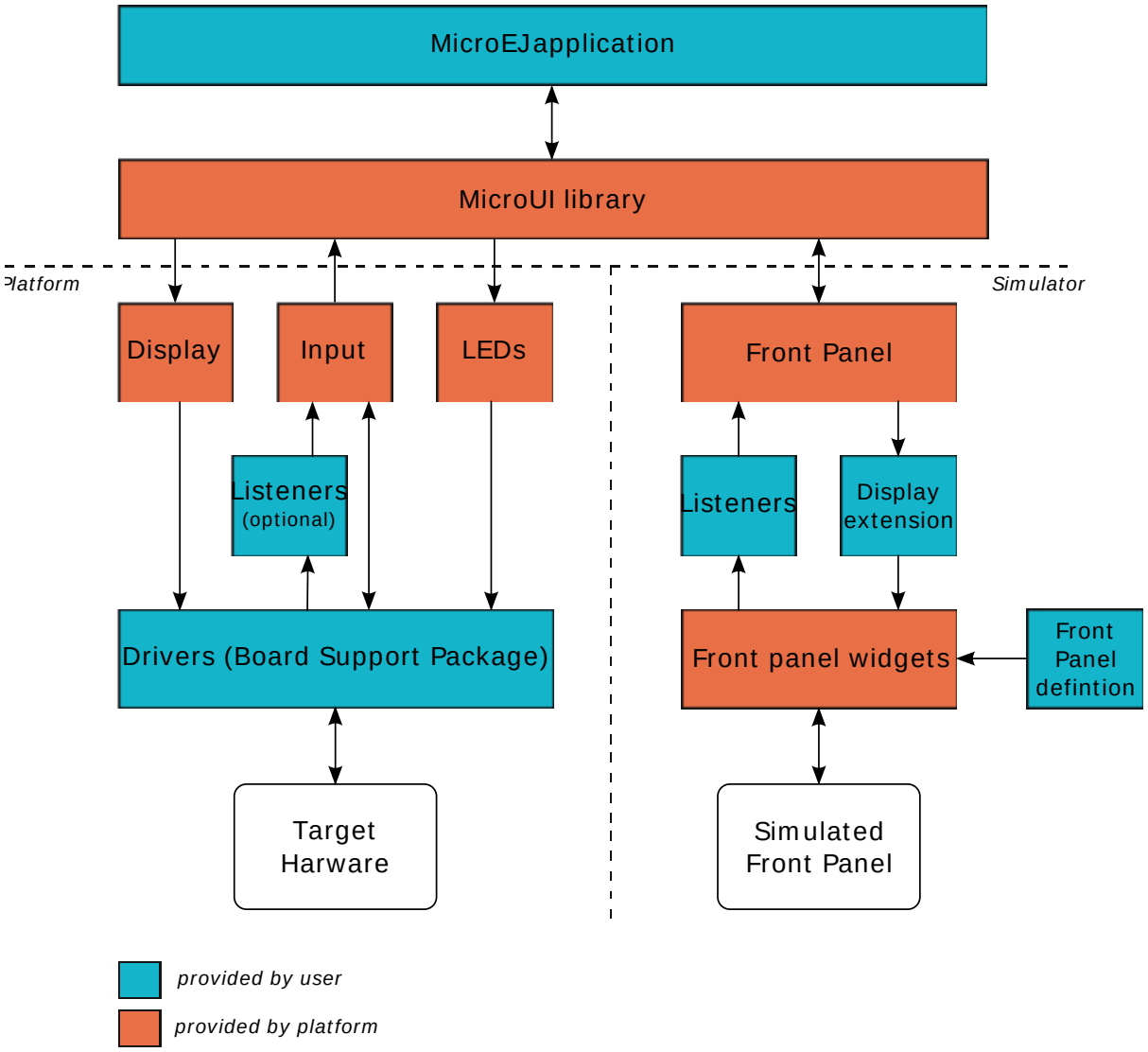


Figure 14.2. Overview

Stacks are the native parts of MicroUI. They connect the MicroUI library to the user-supplied drivers code (coded in C).

Drivers for input devices must generate events that are sent, via a MicroUI *Event Generator*, to the MicroEJ application. An event generator accepts notifications from devices, and generates an event in a standard format that can be handled by the application. Depending on the MicroUI configuration, there can be several different types of event generator in the system, and one or more instances of each type. Each instance has an unique id.

Drivers may either interface directly with event generators, or they can send their notifications to a *Listener*, also written in C, and the listener passes the notifications to the event generator. This decoupling has two major benefits:

- The drivers are isolated from the MicroEJ libraries – they can even be existing code.
- The listener can translate the notification; so, for example, a joystick could generate pointer events.

For the MicroEJ simulator, the platform is supplied with a set of software widgets that generically support a range of input devices, such as buttons, joysticks and touchscreens, and output devices such as pixelated displays and LEDs. With the help of the Front Panel Designer tool that forms part of the MicroEJ workbench the user must define a front panel mock-up using these widgets. The

user must provide a set of listeners that connects the input widgets to event generators. The user may choose to simulate events that will ultimately come from a special-purpose input device using one of the standard input widgets; the listener will do the necessary translation. The user must also supply, in Java, a display extension that adapts the supplied display widget to the specifics of the hardware being simulated.

14.2 MicroUI

14.2.1 Principle

The MicroUI module defines a low-level UI framework for embedded devices. This module allows the creation of basic Human-Machine-Interfaces (HMI), with output on a pixelated screen. For more information, please consult the MUI Specification [MUI].

14.2.2 Architecture

MicroUI is not a standalone library. It requires a configuration step and several extensions to drive I/O devices (display, inputs, LEDs, etc.).

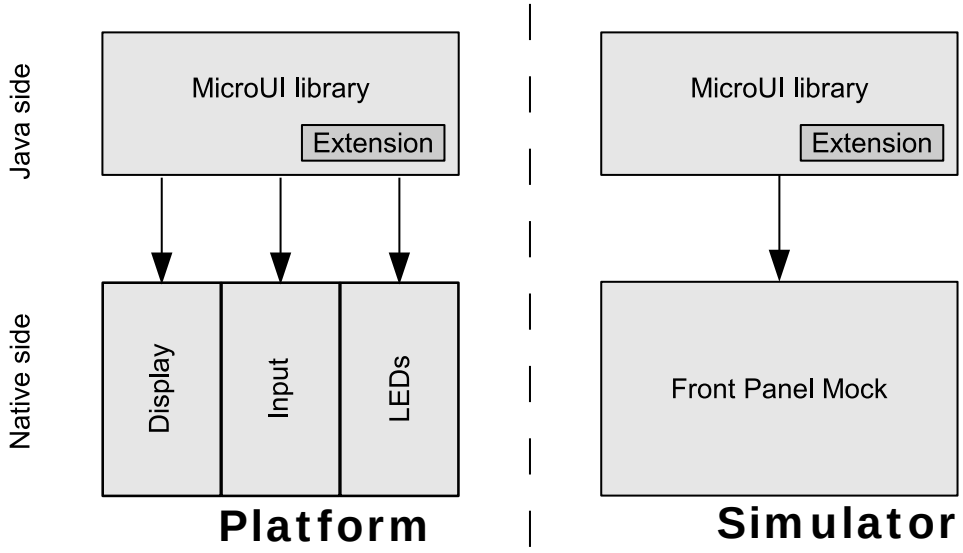


Figure 14.3. MicroUI Elements

At MicroEJ application startup all MicroUI objects relative to the I/O devices are created and accessible. The following MicroUI methods allow you to access these internal objects:

- Display.getDefaultDisplay(): returns the instance of the default display which drives the main LCD screen.
- Leds.getNumberOfLeds(): returns the numbers of available LEDs.

First, MicroUI requires a configuration step in order to create these internal objects before the call to the main() method. The chapter “Static Initialization” explains how to perform the configuration step.

Note

This configuration step is the same for both embedded and simulation platforms.

The embedded platform requires some additional C libraries to drive the I/O devices. Each C library is dedicated to a specific kind of I/O device. A specific chapter is available to explain each kind of I/O device.

I/O devices	Extension Name	Chapter
Graphical / pixelated display (LCD screen)	Display	Section 14.6
Inputs (buttons, joystick, touch, pointers etc.)	Input	Section 14.5
LEDs	LEDs	Section 14.4

Table 14.1. MicroUI C libraries

The simulation platform uses a mock which simulates all I/O devices. Refer to the chapter “Simulation”

14.2.3 Threads

14.2.3.1 Principle

The MicroUI implementation for MicroEJ uses internal threads. These threads are created during the MicroUI initialization step, and are started by a call to MicroUI.start(). Refer the the MicroUI specification [MUI] for more information about internal threads.

14.2.3.2 List

- DisplayPump: This thread manages all display events (repaint, show(), etc. There is one thread per display.
- InputPump: This thread reads the I/O devices inputs and dispatches them into the display pump(s).

14.2.3.3 Memory

The threads are always running. The user has to count them to determine the number of concurrent threads the MicroEJ core engine can run (see Memory options in Section 27).

14.2.3.4 Exceptions

The threads cannot be stopped with a Java exception: The exceptions are always checked by the framework.

When an exception occurs in a user method called by an internal thread (for instance paint()), the current UncaughtExceptionHandler receives the exception. The behavior of the default handler is to print the stack trace.

14.2.4 Transparency

MicroUI provides several policies to use the transparency. These policies depend on several factors, including the kind of drawing and the LCD pixel rendering format. The main concept is that MicroUI does not allow you to draw something with a transparency level different from 255 (fully opaque). There are two exceptions: the images and the fonts.

14.2.4.1 Images

Drawing an image (a pre-generated image or an image decoded at runtime) which contains some transparency levels does not depend on the LCD pixel rendering format. During the image drawing, each pixel is converted into 32 bits by pixel format.

This pixel format contains 8 bits to store the transparency level (alpha). This byte is used to merge the foreground pixel (image transparent pixel) with the background pixel (LCD buffer opaque pixel). The formula to obtain the pixel is:

```
#Mult = (#FG * #BG) / 255
#Out = #FG + #BG - #Mult
COut = (CFG * #FG + CBG * #BG - CBG * #Mult) / #Out
```

where:

- αFG is the alpha level of the foreground pixel (layer pixel)
- αBG is the alpha level of the background pixel (working buffer pixel)
- C*xx* is a color component of a pixel (Red, Green or Blue).
- αOut is the alpha level of the final pixel

14.2.4.2 Fonts

A font holds only a transparency level (alpha). This fixed alpha level is defined during the pre-generation of a font (see “Fonts”).

- 1 means 2 levels are managed: fully opaque and fully transparent.
- 2 means 4 levels are managed: fully opaque, fully transparent and 2 intermediate levels.
- 4 means 16 levels are managed: fully opaque, fully transparent and 14 intermediate levels.
- 8 means 256 levels are managed: fully opaque, fully transparent and 254 intermediate levels.

14.2.5 Dependencies

- MicroUI initialization step (see “Static Initialization”).
- MicroUI C libraries (see “Architecture”).

14.2.6 Installation

The MicroUI library is an additional module. In the platform configuration file, check UI > MicroUI to install the library. When checked, the XML file microui > microui.xml is required during platform creation in order to configure the module. This configuration step is used to extend the MicroUI library. Refer to the chapter “Static Initialization” for more information about the MicroUI Initialization step.

14.2.7 Use

The classpath variable named MICROUI-2.0 is available.

This library provides a set of options. Refer to the chapter “Appendix E: Application Launch Options” which lists all available options.

14.3 Static Initialization

14.3.1 Principle

MicroUI requires a configuration step (also called extension step) to customize itself before MicroEJ application startup (see “Architecture”). This configuration step uses an XML file. In order to save both runtime execution time and flash memory, the file is processed by the Static MicroUI Initializer tool, avoiding the need to process the XML configuration file at runtime. The tool generates appropriate initialized objects directly within the MicroUI library, as well as Java and C constants files for sharing MicroUI event generator IDs.

This XML file (also called the initialization file) defines:

- The MicroUI event generators that will exist in the application in relation to low level drivers that provide data to these event generators (see “Inputs”).
- Whether the application has a display; and if so, it provides its logical name.
- Which fonts will be provided to the application.

14.3.2 Functional Description

The Static MicroUI Initializer tool takes as entry point the initialization file which describes the MicroUI library extension. This tool is automatically launched during the MicroUI module installation (see “Installation”).

The Static MicroUI Initializer tool is able to out until three files:

- A Java library which extends MicroUI library. This library is automatically added to the MicroEJ application classpath when MicroUI library is set as a classpath variable. This library is used at MicroUI startup to create all instances of I/O devices (Display, EventGenerator etc.) and contains the fonts described into the configuration file (these fonts are also called "system fonts").

  This MicroUI extension library is always generated and MicroUI library cannot run without this extension.

- A C header file (*.h) file. This H file contains some IDs which are used to make a link between an input device (buttons, touch) and its MicroUI event generator (see “Inputs”).

  This file is useless if the BSP does not provide any input device and the Static MicroUI Initializer tool is able to not generate this file. Otherwise the MicroUI configuration file has to specify where put this file, typically in a BSP include directory.

- A Java interface file. This Java file contains the same IDs which are used to make a link between an input device (buttons, touch) and its MicroUI event generator (see “Inputs”).

  This Java file is used to configure the simulator with the same characteristics as the BSP.

  This file is useless if the BSP does not provide any input device and the Static MicroUI Initializer tool is able to not generate this file. Otherwise the MicroUI configuration file has to specify where put this file, typically in the simulator project (also called front panel project, see “Simulation”).

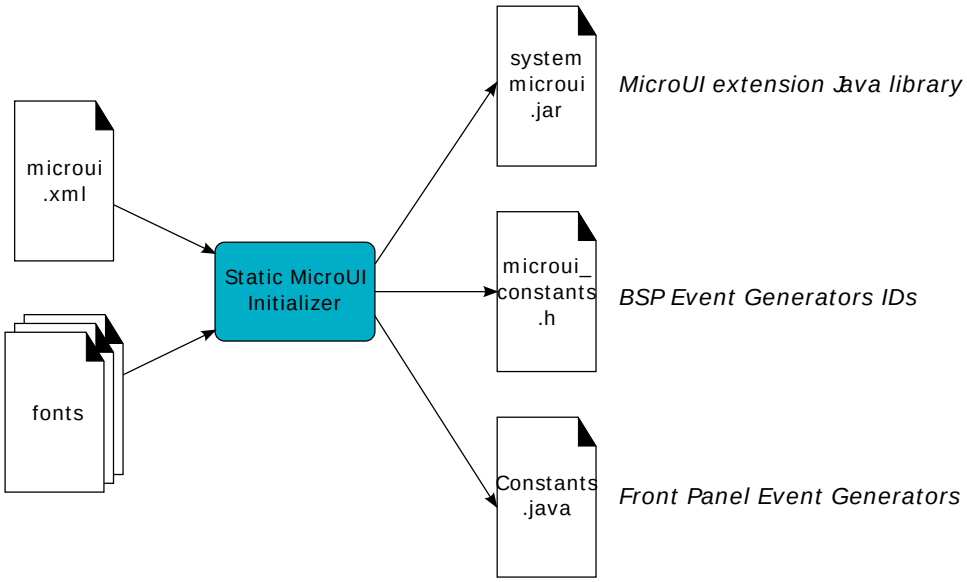


Figure 14.4. MicroUI Process

14.3.3 Root Element

The initialization file root element is <microui> and contains component-specific elements.

```
<microui>
   [ component specific elements ]
</microui>
```

Figure 14.5. Root Element

14.3.4 Display Element

The display component augments the initialization file with:

- The configuration of the display.

- Fonts that are implicitly embedded within the application (also called system fonts). Applications can also embed their own fonts.

```
<display name="DISPLAY"/>

<fonts>
  <font file="resources\fonts\myfont.ejf">
    <range name="LATIN" sections="0-2"/>
    <customrange start="0x21" end="0x3f"/>
  </font>
  <font file="C:\data\myfont.ejf"/>
</fonts>
```

Figure 14.6. Display Element

14.3.5 Event Generators Element

The event generators component augments the initialization file with:

- the configuration of the predefined MicroUI Event Generator: Command, Buttons, States, Pointer, Touch
- the configuration of the generic MicroUI Event Generator

```
<eventgenerators>
 <!-- Generic Event Generators -->
  <eventgenerator name="GENERIC" class="foo.bar.Zork">
    <property name="PROP1" value="3"/>
    <property name="PROP2" value="aaa"/>
  </eventgenerator>

  <!-- Predefined Event Generators -->
  <command name="COMMANDS"/>
  <buttons name="BUTTONS" extended="3"/>
  <buttons name="JOYSTICK" extended="5"/>
  <pointer name="POINTER" width="1200" height="1200"/>
  <touch name="TOUCH" display="DISPLAY"/>
  <states name="STATES" numbers="NUMBERS" values="VALUES"/>

</eventgenerators>

<array name="NUMBERS">
  <elem value="3"/>
  <elem value="2"/>
  <elem value="5"/>
</array>

<array name="VALUES">
  <elem value="2"/>
  <elem value="0"/>
  <elem value="1"/>
</array>
```

Figure 14.7. Event Generator Element

14.3.6 Example

This common MicroUI initialization file initializes MicroUI with:

- a display
- a Command event generator
- a Buttons event generator which targets *n* buttons (3 first buttons having extended features)
- a Buttons event generator which targets the buttons of a joystick
- a Pointer event generator which targets a touch panel
- a DisplayFont whose path is relative to this file

```
<microui>

 <display name="DISPLAY"/>

 <eventgenerators>
    <command name="COMMANDS"/>
    <buttons name="BUTTONS" extended="3"/>
    <buttons name="JOYSTICK" extended="5"/>
    <touch name="TOUCH" display="DISPLAY"/>
 </eventgenerators>

 <fonts>
    <font file="resources\fonts\myfont.ejf"/>
 </fonts>

</microui>
```

Figure 14.8. MicroUI Initialization File Example

14.3.7 Dependencies

No dependency.

14.3.8 Installation

The Static Initialization tool is part of the MicroUI module (see “MicroUI”). Install the MicroUI module to install the Static Initialization tool and fill all properties in MicroUI module configuration file (which must specify the name of the initialization file).

14.3.9 Use

The Static MicroUI Initializer tool is automatically launched during the MicroUI module installation.

14.4 LEDs

14.4.1 Principle

The LEDs module contains the C part of the MicroUI implementation which manages LED devices. This module is composed of two elements:

- the C part of the MicroUI LEDs API (a built-in C archive),
- an implementation of a low level API for the LEDs (LLLEDS) which must be provided by the BSP (see “LLLEDS: LEDs”).

14.4.2 Implementations

The LEDs module provides only one implementation which exposes some low level API (LLLEDS) that allow the BSP to manage the LEDs. This implementation of the MicroUI Leds API provides some low level API. The BSP has to implement these LLAPI, making the link between the MicroUI C library leds and the BSP LEDs drivers.

The LLAPI to implement are listed in the header file LLLEDS_impl.h. First, in the initialization function, the BSP must return the available number of LEDs the board provides. The others functions are used to turn the LEDs on and off.

The LLAPI are the same for the LED which is connected to a GPIO (0 or 1) or via a PWM. The BSP has the responsibility of interpreting the MicroEJ application parameter intensity.

Typically, when the LED is connected to a GPIO, the intensity "0" means "OFF," and all others values "ON." When the LED is connected via a PWM, the intensity "0" means "OFF," and all others values must configure the PWM signal.

The BSP should be able to return the state of an LED. If it is not able to do so (for example GPIO is not accessible in read mode), the returned value may be wrong. The MicroEJ application may not be able to know the LEDs states.

When there is no LED on the board, a *stub* implementation of C library is available. This C library must be linked by the third-party C IDE when the MicroUI module is installed in the MicroEJ platform.

14.4.3 Dependencies

- MicroUI module (see “MicroUI”)
- LLLEDS_impl.h implementation if standard implementation is chosen (see “Implementations” and “LLLEDS: LEDs”).

14.4.4 Installation

LEDs is a sub-part of MicroUI library. When the MicroUI module is installed, the LEDs module must be installed in order to be able to connect physical LEDs with MicroEJ platform. If not installed, the *stub* module will be used.

In the platform configuration file, check UI > LEDs to install LEDs.

14.4.5 Use

The MicroUI LEDs APIs are available in the class ej.microui.led.Leds.

14.5 Inputs

14.5.1 Principle

The Inputs module contains the C part of the MicroUI implementation which manages input devices. This module is composed of two elements:

- the C part of MicroUI input API (a built-in C archive)
- an implementation of a low level API for the input devices (LLINPUT) that must be provided by the BSP (see “LLINPUT: Inputs”)

14.5.2 Functional Description

The Inputs module implements the MicroUI int-based event generators' framework. LLINPUT specifies the low level API that send events to the Java world.

Each MicroUI Event Generator represents one side of a pair of collaborative components that communicate using a shared buffer:

- The producer: the C driver connected to the hardware. As a producer, it sends its data into the communication buffer.
- The consumer: the MicroUI Event Generator. As a consumer, it reads (and removes) the data from the communication buffer.

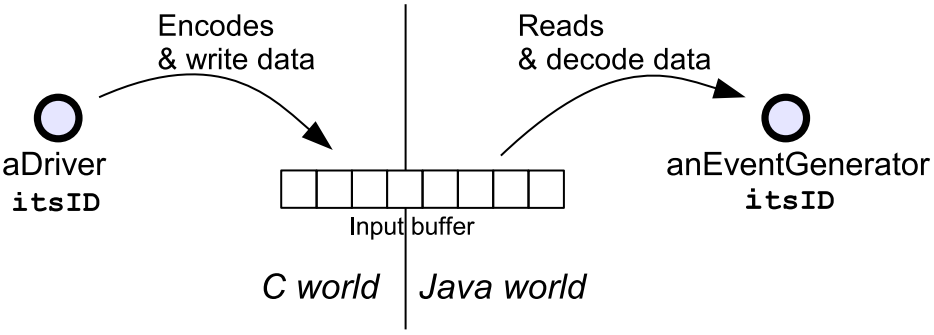


Figure 14.9. Drivers and MicroUI Event Generators Communication

The LLINPUT API allows multiple pairs of <driver - event generator> to use the same buffer, and associates drivers and event generators using an int ID. The ID used is the event generator ID held within the MicroUI global registry [MUI]. Apart from sharing the ID used to "connect" one driver's data to its respective event generator, both entities are completely decoupled.

A Java green thread, called the InputPump thread, waits for data to be published by drivers into the "input buffer," and dispatches to the correct (according to the ID) event generator to read the received data. This "driver-specific-data" is then transformed into MicroUI events by event generators and sent to objects that listen for input activity.

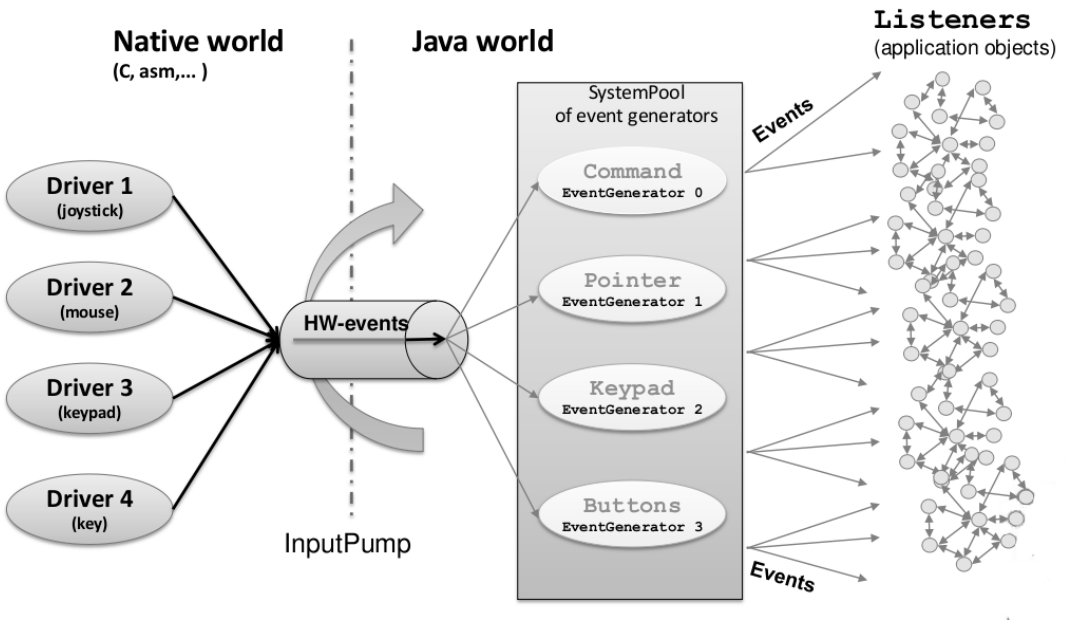


Figure 14.10. MicroUI Events Framework

14.5.3 Implementation

The implementation of the MicroUI Event Generator APIs provides some low level APIs. The BSP has to implement these LLAPI, making the link between the MicroUI C library inputs and the BSP input devices drivers.

The LLAPI to implement are listed in the header file LLINPUT_impl.h. It allows events to be sent to the MicroUI implementation. The input drivers are allowed to add events directly using the event generator's unique ID (see “Static Initialization”). The drivers are fully dependent on the MicroEJ framework (a driver cannot be developed without MicroEJ because it uses the header file generated during the MicroUI initialization step).

When there is no input device on the board, a *stub* implementation of C library is available. This C library must be linked by the third-party C IDE when the MicroUI module is installed in the MicroEJ platform.

14.5.4 Generic Event Generators

On the application side, the UI extension provides an abstract class GenericEventGenerator (package ej.microui.event) that must be implemented by clients who want to define their own event generators. Two abstract methods must be implemented by subclasses:

- eventReceived: The event generator received an event from a C driver through the low level API sendEvent function.
- eventsReceived: The event generator received an event made of several ints.

- setProperty: Handle a generic property (key/value pair) set from the static initialization file (see Section 25.6)

The event generator is responsible for converting incoming data into a MicroUI event and sending the event to its listener.

14.5.5 Dependencies

- MicroUI module (see “MicroUI”)
- Static MicroUI initialization step (see “Static Initialization”). This step generates a header file which contains some unique event generator IDs. These IDs must be used in the BSP to make the link between the input devices drivers and the MicroUI Event Generators.
- LLINPUT_impl.h implmentation (see “LLINPUT: Inputs”).

14.5.6 Installation

Inputs is a sub-part of the MicroUI library. When the MicroUI module is installed, the Inputs module must be installed in order to be able to connect physical input devices with MicroEJ platform. If not installed, the *stub* module will be used. In the platform configuration file, check UI > Inputs to install Inputs.

14.5.7 Use

The MicroUI Input APIs are available in the class ej.microui.EventGenerator.

14.6 Display

14.6.1 Principle

The Display module contains the C part of the MicroUI implementation which manages graphical displays. This module is composed of two elements:

- the C part of MicroUI Display API (a built-in C archive)
- an implementation of a low level API for the displays (LLDISPLAY) that the BSP must provide (see “LLDISPLAY: Display”)

14.6.2 Display Configurations

The Display modules provides a number of different configurations. The appropriate configuration should be selected depending on the capabilities of the screen and other related hardware, such as LCD controllers.

The modes can vary in three ways:

- the buffer mode: double-buffer, simple buffer (also known as "direct")
- the memory layout of the pixels
- pixel format or depth

The supplied configurations offer a limited range of combinations of the options.

14.6.3 Buffer Modes

14.6.3.1 Overview

When using the double buffering technique, the memory into which the application draws (called graphics buffer or back buffer) is not the memory used by the screen to refresh it (called frame buffer or display buffer). When everything has been drawn consistently from the application point of view,

the back buffer contents are synchronized with the display buffer. Double buffering avoids flickering and inconsistent rendering: it is well suited to high quality animations.

For more static display-based applications, and/or to save memory, an alternative configuration is to use only one buffer, shared by both the application and the screen.

Displays addressed by one of the standard configurations are called *generic displays*. For these generic displays, there are three buffer modes: switch, copy and direct. The following flow chart provides a handy guide to selecting the appropriate buffer mode according to the hardware configuration.

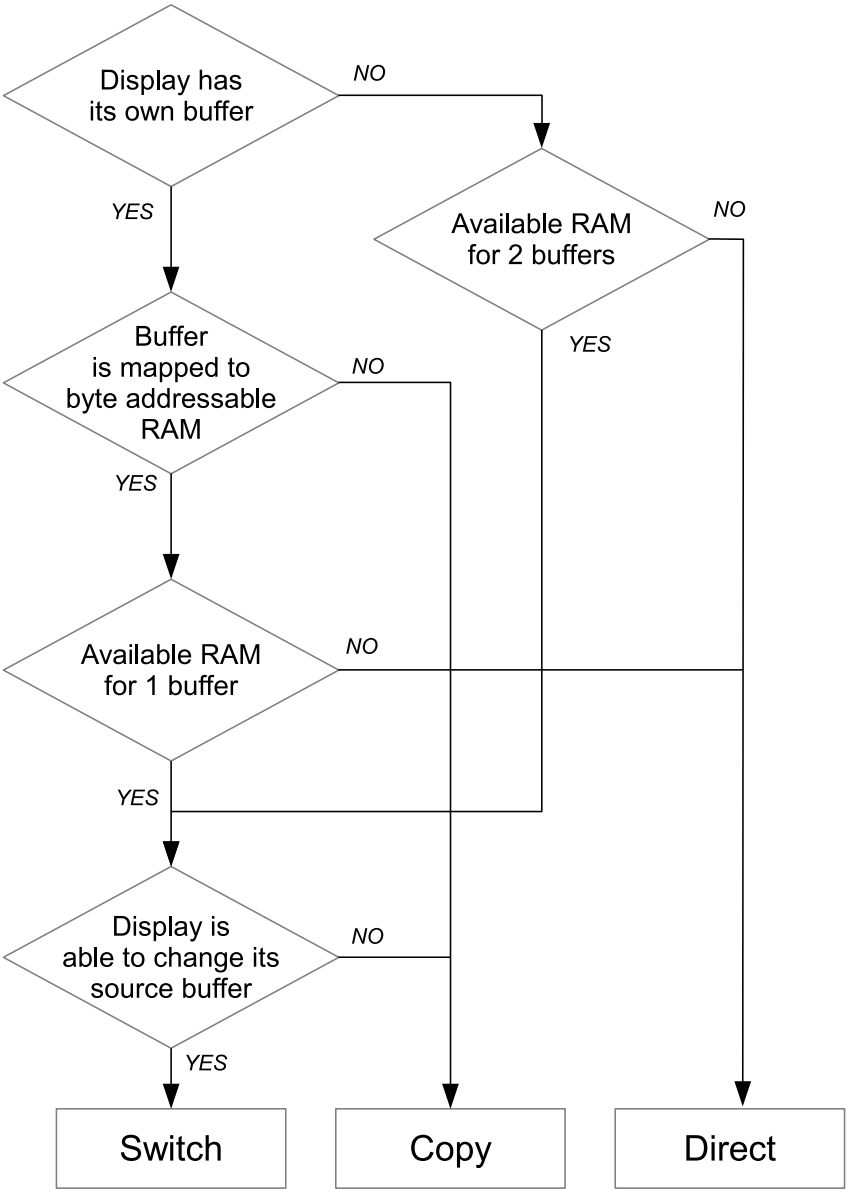


Figure 14.11. Buffer Modes

14.6.3.2 Implementation

The display module (or stack) does not depend on type of buffer mode. At the end of a drawing, the display stack calls the LLAPI LLDISPLAY_IMPL_flush to let the implementation to update the LCD data. This function should be atomic and the implementation has to return the new graphics buffer address (back buffer address). In direct and copy modes, this address never changes and the implementation has always to return the back buffer address. In switch mode, the implementation has to return the old LCD frame buffer address.

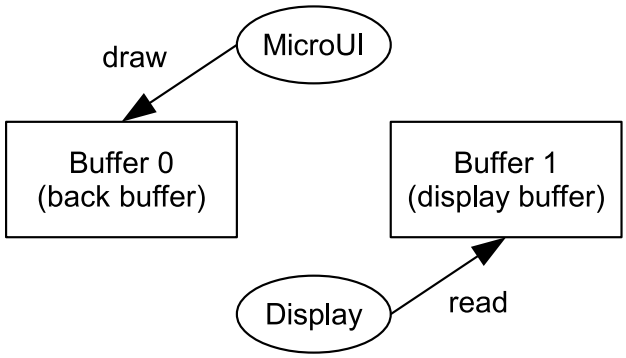
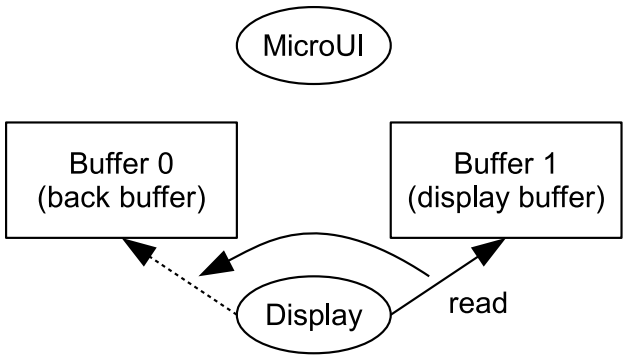
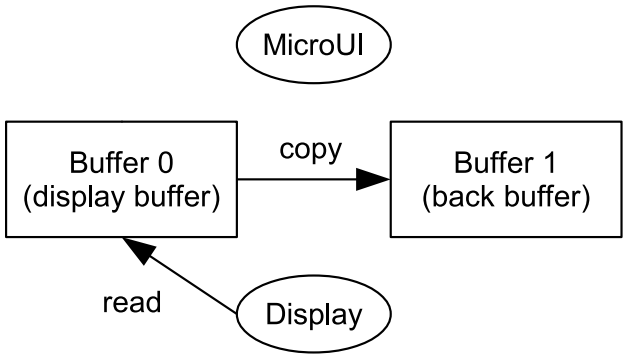
The next sections describe the work to do for each mode.

14.6.3.3 Switch

The switch mode is a double-buffered mode where two buffers in RAM alternately play the role of the back buffer and the display buffer. The display source is alternatively changed from one buffer to the other.

Switching the source address may be done asynchronously. The synchronize function is called before starting the next set of draw operations, and must wait until the driver has switched to the new buffer.

Synchronization steps are described in Table 14.2.

Step 1: Drawing MicroUI is drawing in buffer 0 (back buffer) and the display is reading its contents from buffer 1 (display buffer).	
Step 2: Switch The drawing is done. Set that the next read will be done from buffer 0. Note that the display "hardware component" asynchronously continues to read data from buffer 1.	
Step 3: Copy A copy from the buffer 0 (new display buffer) to the buffer 1 (new back buffer) must be done to keep the contents of the current drawing. The copy routine must wait until the display has finished the switch, and start asynchronously by comparison with the MicroUI drawing routine (see next step). This copy routine can be done in a dedicated RTOS task or in an interrupt routine. The copy should start after the display "hardware component" has finished a full buffer read to avoid flickering. Usually a tearing signal from the LCD at the end of the read of the previous buffer (buffer 1) or at the beginning of the read of the new buffer (buffer 0)	

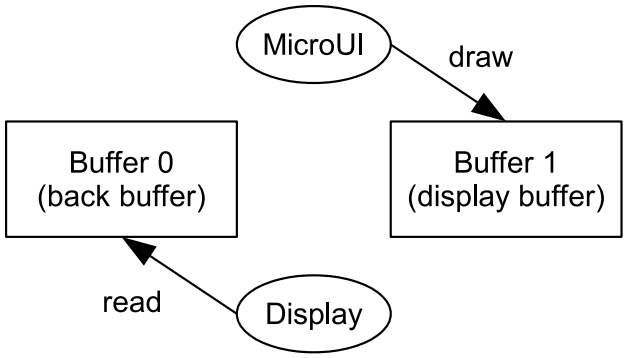
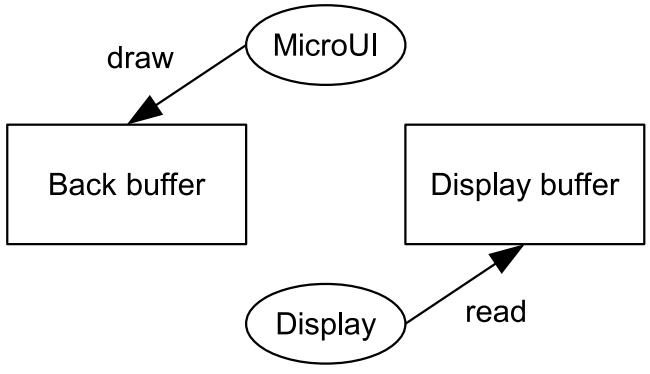
throws an interrupt. The interrupt routine starts the copy using a DMA. If it is not possible to start an asynchronous copy, the copy must be performed in the MicroUI drawing routine, at the beginning of the next step. Note that the copy is partial: only the parts that have changed need to be copied, lowering the CPU load.	
Step 4: Synchronization Waits until the copy routine has finished the full copy. If the copy has not been done asynchronously, the copy must start after the display has finished the switch. It is a blocking copy because the next drawing operation has to wait until this copy is done.	
Step 4: Next draw operation Same behavior as step 1 with buffers reversed.	

Table 14.2. Switch Mode Synchronization Steps

14.6.3.4 Copy

The copy mode is a double-buffered mode where the back buffer is in RAM and has a fixed address. To update the display, data is sent to the display buffer. This can be done either by a memory copy or by sending bytes using a bus, such as SPI or I2C.

Synchronization steps are described in Table 14.3.

Step 1: Drawing MicroUI is drawing in the back buffer and the display is reading its content from the display buffer.	

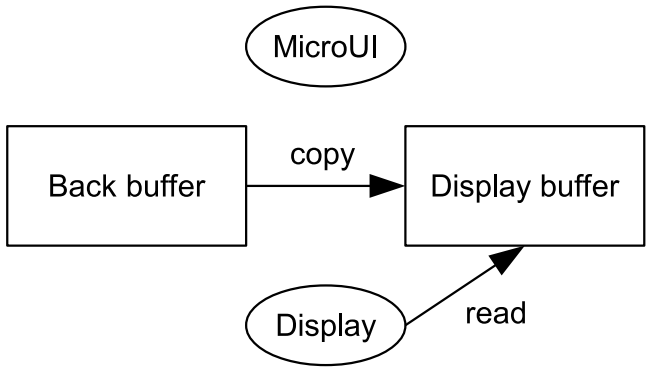
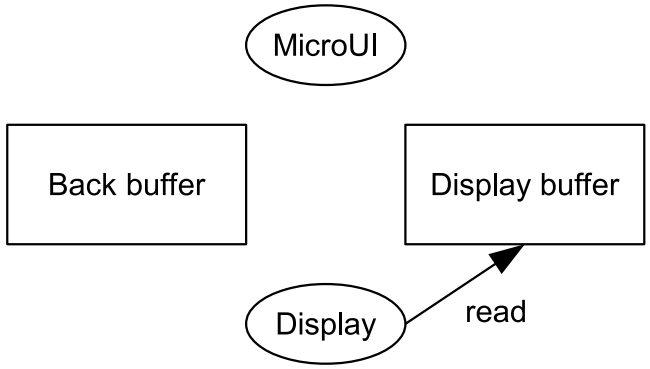
Step 2: Copy The drawing is done. A copy from the back buffer to the display buffer is triggered. Note that the implementation of the copy operation may be done asynchronously – it is recommended to wait until the display "hardware component" has finished a full buffer read to avoid flickering. At the implementation level, the copy may be done by a DMA, a dedicated RTOS task, interrupt, etc.	
Step 3: Synchronization The next drawing operation waits until the copy is complete.	

Table 14.3. Display Copy Mode

14.6.3.5 Direct

The direct mode is a single-buffered mode where the same memory area is used for the back buffer and the display buffer (Figure 14.12). Use of the direct mode is likely to result in "noisy" rendering and flickering, but saves one buffer in runtime memory.

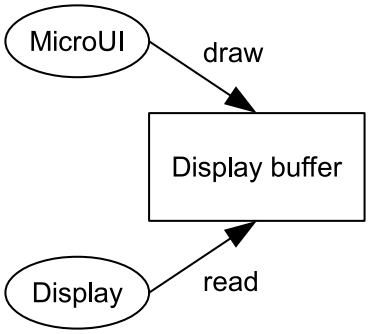


Figure 14.12. Display Direct Mode

14.6.4 Byte Layout

This chapter concerns only LCD with a number of bits-per-pixel (BPP) smaller than 8. For this kind of LCD, a byte contains several pixels and the display module allows to customize how to organize the pixels in a byte.

Two layouts are available:

- line: The byte contains several consecutive pixels on same line. When the end of line is reatched, a padding is added in order to start a new line with a new byte.

- column: The byte contains several consecutive pixels on same column. When the end of column is reatched, a padding is added in order to start a new column with a new byte.

When installing the display module, a property byteLayout is required to specify the kind of pixels representation (see “Installation”).

BPP	MSB							LSB
4	pixel 1				pixel 0			
2	pixel 3		pixel 2		pixel 1		pixel 0	
1	pixel 7	pixel 6	pixel 5	pixel 4	pixel 3	pixel 2	pixel 1	pixel 0

Table 14.4. Byte Layout: line

BPP	4	2	1
MSB	pixel 1	pixel 3	pixel 7
			pixel 6
		pixel 2	pixel 5
			pixel 4
	pixel 0	pixel 1	pixel 3
			pixel 2
		pixel 0	pixel 1
LSB			pixel 0

Table 14.5. Byte Layout: column

14.6.5 Memory Layout

For the LCD with a number of bits-per-pixel (BPP) higher or equal to 8, the display module supports the line-by-line memory organization: pixels are laid out from left to right within a line, starting with the top line. For a display with 16 bits-per-pixel, the pixel at (0,0) is stored at memory address 0, the pixel at (1,0) is stored at address 2, the pixel at (2,0) is stored at address 4, and so on.

BPP	@ + 0	@ + 1	@ + 2	@ + 3	@ + 4
32	pixel 0 [7:0]	pixel 0 [15:8]	pixel 0 [23:16]	pixel 0 [31:24]	pixel 1 [7:0]
24	pixel 0 [7:0]	pixel 0 [15:8]	pixel 0 [23:16]	pixel 1 [7:0]	pixel 1 [15:8]
16	pixel 0 [7:0]	pixel 0 [15:8]	pixel 1 [7:0]	pixel 1 [15:8]	pixel 2 [7:0]
8	pixel 0 [7:0]	pixel 1 [7:0]	pixel 2 [7:0]	pixel 3 [7:0]	pixel 4 [7:0]

Table 14.6. Memory Layout for BPP >= 8

For the LCD with a number of bits-per-pixel (BPP) lower than 8, the display module supports the both memory organizations: line by line (pixels are laid out from left to right within a line, starting with the top line) and column by column (pixels are laid out from top to bottom within a line, starting with the left line). These byte organizations concern until 8 consecutives pixels (see “Byte Layout”). When installing the display module, a property memoryLayout is required to specify the kind of pixels representation (see “Installation”).

BPP	@ + 0	@ + 1	@ + 2	@ + 3	@ + 4
4	(0,0) to (1,0)	(2,0) to (3,0)	(4,0) to (5,0)	(6,0) to (7,0)	(8,0) to (9,0)
2	(0,0) to (3,0)	(4,0) to (7,0)	(8,0) to (11,0)	(12,0) to (15,0)	(16,0) to (19,0)
1	(0,0) to (7,0)	(8,0) to (15,0)	(16,0) to (23,0)	(24,0) to (31,0)	(32,0) to (39,0)

Table 14.7. Memory Layout 'line' for BPP < 8 and byte layout 'line'

BPP	@ + 0	@ + 1	@ + 2	@ + 3	@ + 4
4	(0,0) to (0,1)	(1,0) to (1,1)	(2,0) to (2,1)	(3,0) to (3,1)	(4,0) to (4,1)

BPP	@ + 0	@ + 1	@ + 2	@ + 3	@ + 4
2	(0,0) to (0,3)	(1,0) to (1,3)	(2,0) to (2,3)	(3,0) to (3,3)	(4,0) to (4,3)
1	(0,0) to (0,7)	(1,0) to (15,7)	(2,0) to (23,7)	(3,0) to (31,7)	(4,0) to (39,7)

Table 14.8. Memory Layout 'line' for BPP < 8 and byte layout 'column'

BPP	@ + 0	@ + 1	@ + 2	@ + 3	@ + 4
4	(0,0) to (1,0)	(0,1) to (1,1)	(0,2) to (1,2)	(0,3) to (1,3)	(0,4) to (1,4)
2	(0,0) to (3,0)	(0,1) to (3,1)	(0,2) to (3,2)	(0,3) to (3,3)	(0,4) to (3,4)
1	(0,0) to (7,0)	(0,1) to (7,1)	(0,2) to (7,2)	(0,3) to (7,3)	(0,4) to (7,4)

Table 14.9. Memory Layout 'column' for BPP < 8 and byte layout 'line'

BPP	@ + 0	@ + 1	@ + 2	@ + 3	@ + 4
4	(0,0) to (0,1)	(0,2) to (0,3)	(0,4) to (0,5)	(0,6) to (0,7)	(0,8) to (0,9)
2	(0,0) to (0,3)	(0,4) to (0,7)	(0,8) to (0,11)	(0,12) to (0,15)	(0,16) to (0,19)
1	(0,0) to (0,7)	(0,8) to (0,15)	(0,16) to (0,23)	(0,24) to (0,31)	(0,32) to (0,39)

Table 14.10. Memory Layout 'column' for BPP < 8 and byte layout 'column'

14.6.6 Pixel Structure

The Display module provides pre-built display configurations with standard pixel memory layout. The layout of the bits within the pixel may be standard (see MicroUI GraphicsContext pixel formats) or driver-specific. When installing the display module, a property `bpp` is required to specify the kind of pixel representation (see “Installation”).

When the value is one among this list: `ARGB8888 | RGB888 | RGB565 | ARGB1555 | ARGB4444 | C4 | C2 | C1`, the display module considers the LCD pixels representation as standard. According to the chosen format, some color data can be lost or cropped.

- ARGB8888: the pixel uses 32 bits-per-pixel (alpha[8], red[8], green[8] and blue[8]).

```
u32 convertARGB8888toLCDPixel(u32 c){
 return c;
}

u32 convertLCDPixeltoARGB8888(u32 c){
 return c;
}
```

- RGB888: the pixel uses 24 bits-per-pixel (alpha[0], red[8], green[8] and blue[8]).

```
u32 convertARGB8888toLCDPixel(u32 c){
 return c & 0xffffff;
}

u32 convertLCDPixeltoARGB8888(u32 c){
 return 0
   | 0xff000000
   | c
   ;
}
```

- RGB565: the pixel uses 16 bits-per-pixel (alpha[0], red[5], green[6] and blue[5]).

```
u32 convertARGB8888toLCDPixel(u32 c){
 return 0
   | ((c & 0xf80000) >> 8)
   | ((c & 0x00fc00) >> 5)
   | ((c & 0x0000f8) >> 3)
   ;
}

u32 convertLCDPixeltoARGB8888(u32 c){
 return 0
   | 0xff000000
   | ((c & 0xf800) << 8)
   | ((c & 0x07e0) << 5)
   | ((c & 0x001f) << 3)
   ;
}
```

- ARGB1555: the pixel uses 16 bits-per-pixel (alpha[1], red[5], green[5] and blue[5]).

```
u32 convertARGB8888toLCDPixel(u32 c){
 return 0
   | (((c & 0xff000000) == 0xff000000) ? 0x8000 : 0)
   | ((c & 0xf80000) >> 9)
   | ((c & 0x00f800) >> 6)
   | ((c & 0x0000f8) >> 3)
   ;
}

u32 convertLCDPixeltoARGB8888(u32 c){
 return 0
   | ((c & 0x8000) == 0x8000 ? 0xff000000 : 0x00000000)
   | ((c & 0x7c00) << 9)
   | ((c & 0x03e0) << 6)
   | ((c & 0x001f) << 3)
   ;
}
```

- ARGB4444: the pixel uses 16 bits-per-pixel (alpha[4], red[4], green[4] and blue[4]).

```
u32 convertARGB8888toLCDPixel(u32 c){
 return 0
   | ((c & 0xf0000000) >> 16)
   | ((c & 0x00f00000) >> 12)
   | ((c & 0x0000f000) >> 8)
   | ((c & 0x000000f0) >> 4)
   ;
}

u32 convertLCDPixeltoARGB8888(u32 c){
 return 0
   | ((c & 0xf000) << 16)
   | ((c & 0xf000) << 12)
   | ((c & 0x0f00) << 12)
   | ((c & 0x0f00) << 8)
   | ((c & 0x00f0) << 8)
   | ((c & 0x00f0) << 4)
   | ((c & 0x000f) << 4)
   | ((c & 0x000f) << 0)
   ;
}
```

- C4: the pixel uses 4 bits-per-pixel (grayscale[4]).

```
u32 convertARGB8888toLCDPixel(u32 c){
 return (toGrayscale(c) & 0xff) / 0x11;
}

u32 convertLCDPixeltoARGB8888(u32 c){
 return 0xff000000 | (c * 0x111111);
}
```

- C2: the pixel uses 2 bits-per-pixel (grayscale[2]).

```
u32 convertARGB8888toLCDPixel(u32 c){
 return (toGrayscale(c) & 0xff) / 0x55;
}

u32 convertLCDPixeltoARGB8888(u32 c){
 return 0xff000000 | (c * 0x555555);
}
```

- C1: the pixel uses 1 bit-per-pixel (grayscale[1]).

```
u32 convertARGB8888toLCDPixel(u32 c){
 return (toGrayscale(c) & 0xff) / 0xff;
}

u32 convertLCDPixeltoARGB8888(u32 c){
 return 0xff000000 | (c * 0xffffff);
}
```

When the value is one among this list: 1 | 2 | 4 | 8 | 16 | 24 | 32, the display module considers the LCD pixel representation as generic but not standard. In this case, the driver must implement functions that convert MicroUI's standard 32 bits ARGB colors to LCD color representation (see “LLDISPLAY: Display”). This mode is often used when the pixel representation is not ARGB or RGB but BGRA or BGR instead. This mode can also be used when the number of bits for a color component (alpha, red, green or blue) is not standard or when the value does not represent a color but an index in an LUT.

14.6.7 Antialiasing

14.6.7.1 Fonts

The antialiasing mode for the fonts concerns only the fonts with more than 1 bit per pixel (see “Font Generator”).

14.6.7.2 Background Color

For each pixel to draw, the antialiasing process blends the foreground color with a background color. This background color is static or dynamic:

- static: The background color is fixed by the MicroEJ application (GraphicsContext.setBackgroundColor()).
- dynamic: The background color is the original color of the destination pixel (a "read pixel" operation is performed for each pixel).

Note that the dynamic mode is slower than the static mode.

14.6.8 LUT

The display module allows to target LCD which uses a pixel indirection table (LUT). This kind of LCD are considered as generic but not standard (see “Pixel Structure”). By consequence, the driver must implement functions that convert MicroUI's standard 32 bits ARGB colors (see “LLDISPLAY: Display”) to LCD color representation. For each application ARGB8888 color, the diplay driver has to find the corresponding color in the table. The display module will store the index of the color in the table instead of using the color itself.

When an application color is not available in the display driver table (LUT), the display driver can try to find the nearest color or return a default color. First solution is often quite difficult to write and can

cost a lot of time at runtime. That's why the second solution is prefered. However, a consequence is that the application has only to use a range of colors provided by the display driver.

MicroUI and the display module uses blending when drawing some texts or anti-aliased shapes. For each pixel to draw, the display stack blends the current application foreground color with the targeted pixel current color or with the current application background color (when enabled). This blending *creates* some intermediate colors which are managed by the display driver. Most of time the default color will be returned and so the rendering will be wrong. To prevent this use case, the display module offers a specific LLAPI LLDISPLAY_EXTRA_IMPL_prepareBlendingOfIndexedColors(void* foreground, void* background). This API is only used when a blending is required and when the background color is enabled. Display module calls the API just before the blending and gives as parameter the pointers on the both ARGB colors. The display driver should replace the ARGB colors by the LUT indexes. Then the display module will only use the indexes between the both indexes. For instance, when the returned indexes are 20 and 27, the display stack will use the indexes 20 to 27, where all indexes between 20 and 27 target some intermediate colors between the both original ARGB colors.

This solution requires several conditions:

- Background color is enabled and it is an available color in the LUT.
- Application can only use foreground colors provided by the LUT. The platform designer should give to the application developer the available list of colors the LUT manages.
- The LUT must provide a set blending ranges the application can use. Each range can have its own size (different number of colors between two colors). Each range is independant. For instance if the foreground color RED (0xFFFF0000) can be blent with two background colors WHITE (0xFFFFFFFF) and BLACK (0xFF000000), two ranges must be provided. The both ranges have to contain the same index for the color RED.
- Application can only use blending ranges provided by the LUT. Otherwise the display driver is not able to find the range and the default color will be used to perform the blending.
- Rendering of dynamic images (images decoded at runtime) may be wrong because the ARGB colors may be out of LUT range.

14.6.9 Hardware Accelerator

14.6.9.1 Overview

The display module allows to use an hardware accelerator to perform some drawings: fill a rectangle, draw an image, rotate an image etc. Some optional functions are available in LLDISPLAY_EXTRA.h file (see “LLDISPLAY_EXTRA: Display Extra Features”). These functions are not automatically call by the display module. The display module must be configured during the MicroEJ platform construction specifying which hardware accelerator to use. It uses the property hardwareAccelerator in display/display.properties file to select a hardware accelerator (see “Installation”).

The following table lists the available hardware accelerators supported by MicroEJ, their full names, short names (used in the next tables) and the hardwareAccelerator property value (see “Installation”).

	Short name	Property
Renesas Graphics Library RGA [a]	RGA	rga
Renesas TES Dave/2d	Dave2D	dave2d
STMicroelectronics Chrom-ART Graphics Accelerator	DMA2D	dma2d
Custom Hardware Accelerator	Custom	custom [b]

[a] hardware or software implementation

[b] see next note

Table 14.11. Hardware Accelerators

Note

It is possible to target an hardware accelerator which is not supported by MicroEJ yet. Set the property hardwareAccelerator to custom to force display module to call all drawing functions which can be accelerated. The LLDISPLAY implementation is able or not to implement a function. If not, the software algorithm will be used.

The available list of supported hardware accelerators is MicroEJ architecture dependent. For instance, the STMicroelectronics Chrom-ART Graphics Accelerator is only available for the MicroEJ architecture for Cortex-M4 and Cortex-M7. The Renesas Graphics Library RGA is only available for the MicroEJ architecture for Cortex-A9. The following table shows in which MicroEJ architecture an hardware accelerator is available.

	RGA	Dave2D	DMA2D	Custom
ARM Cortex-M0+ IAR				•
ARM Cortex-M4 ARMCC			•	•
ARM Cortex-M4 GCC		•	•	•
ARM Cortex-M4 IAR			•	•
ARM Cortex-M7 ARMCC			•	•

Table 14.12. Hardware Accelerators according MicroEJ Architectures

Note

Some hardware accelerators may not be available in off-the-self architectures . However they are available on some specific architectures. Please consult the engineering services page on MicroEJ website.

All hardware accelerators are not available for each number of bits-per-pixel configuration. The following table illustrates in which display stack according bpp, an hardware accelerator can be used.

	RGA	Dave2D	DMA2D	Custom
1 BPP				
C1				
2 BPP				
C2				
4 BPP				
C4				
8 BPP				
16 BPP				•
RGB565	•	•	•	•
ARGB1555	•	•	•	•
ARGB4444	•	•	•	•
24 BPP				•
RGB888			•	•
32 BPP				•

	RGA	Dave2D	DMA2D	Custom
ARGB8888	•	•	•	•

Table 14.13. Hardware Accelerators according BPP

14.6.9.2 Features and Limits

Each hardware accelerator has a list of features (list of drawings the hardware accelerator can perform) and some constraints. When the display module is configured to use an hardware accelerator, it takes in consideration these features and limits. If a drawing is detected by the display module as a drawing to be hardware accelerated, the LLDISPLAY implementation *must* configure and use the hardware accelerator to perform the full drawing (not just a part of drawing).

Note

The *custom* hardware generator does not have any limit by default. This is the LLDISPLAY implementation which fixes the limits.

The following table lists the algorithms accelerated by each hardware accelerator.

	RGA	Dave2D	DMA2D
Fill a rectangle	•	•	•
Draw an image	•	•	•
Scale an image	•		
Rotate an image	•		

Table 14.14. Hardware Accelerators Algorithms

14.6.9.3 Images

The available list of supported image formats is not the same for all hardware accelerators. Furthermore some hardware accelerators require a custom header before the RAW pixel data, require a padding between each line etc.. MicroEJ manages these contraints for supported hardware accelerators. For *custom* hardware accelerator, no image header can be added and no padding can be set.

The following table illustratres the RAW image formats supported by each hardware accelerator.

	RGA	Dave2D	DMA2D
A1	• [a]		
A2			
A4	• [b]		•
A8	• [c]		•
C1			
C2			
C4			
AC11			
AC22			
AC44			
RGB565	•	•	•
ARGB1555	•	•	•
ARGB4444	•	•	•

	RGA	Dave2D	DMA2D
RGB888			•
ARGB8888	•	•	•

[a]maximum size <= display width
[b]maximum size <= display width
[c]maximum size <= display width

Table 14.15. Hardware Accelerators RAW Image Formats

The RAW image given as parameter (in input and/or in output) respects the hardware accelerator specification. For instance a RAW image with 4BPP must be often aligned on 8 bits, even if its size is odd. The RAW image size given as parameter is the *software* size. That means it is the size of the original image.

Example for a A4 image with required alignment on 8 bits:

- Original image width in pixels (== width in MicroEJ application): 47
- Hardware image width in pixels (== line width in pixels in RAW image data): 48
- Width in pixels available in LLDISPLAY (((LLDISPLAY_SImage*)src)->width): 48
- Hardware width in bytes (== line width in bytes in RAW image data): 48 / 2 = 24

The hardware size may be higher than the software size (like in the example). However the number of pixels to draw (((LLDISPLAY_SDrawImage*)drawing)->src_width) is *always* smaller or equal to the software area size. That means the display module never asks to draw the pixels which are outside the software area. The hardware size is only useful to be compatible with the hardware accelerator restrictions about memory alignment.

14.6.10 Implementations

The implementation of the MicroUI Display API targets a generic display (see “Display Configurations”): Switch, Copy and Direct. It provides some low level API. The BSP has to implement these LLAPI, making the link between the MicroUI C library display and the BSP display driver. The LLAPI to implement are listed in the header file LLDISPLAY_impl.h.

When there is no display on the board, a *stub* implementation of C library is available. This C library must be linked by the third-party C IDE when MicroUI module is installed in the MicroEJ platform.

14.6.11 Dependencies

- MicroUI module (see “MicroUI”)
- LLDISPLAY_impl.h implementation if standard or custom implementation is chosen (see “Implementations” and “LLDISPLAY: Display”).

14.6.12 Installation

Display is a sub-part of the MicroUI library. When the MicroUI module is installed, the Display module must be installed in order to be able to connect the physical display with the MicroEJ platform. If not installed, the *stub* module will be used.

In the platform configuration file, check UI > Display to install the Display module. When checked, the properties file display > display .properties is required during platform creation to configure the module. This configuration step is used to choose the kind of implementation (see “Implementations”).

The properties file must / can contain the following properties:

- bpp [mandatory]: Defines the number of bits per pixels the display device is using to render a pixel. Expected value is one among these both list:

  Standard formats:

- ARGB8888: Alpha 8 bits; Red 8 bits; Green 8 bits; Blue 8 bits
- RGB888: Alpha 0 bit; Red 8 bits; Green 8 bits; Blue 8 bits (fully opaque)
- RGB565: Alpha 0 bit; Red 5 bits; Green 6 bits; Blue 5 bits (fully opaque)
- ARGB1555: Alpha 1 bit; Red 5 bits; Green 5 bits; Blue 5 bits (fully opaque or fully transparent)
- ARGB4444: Alpha 4 bits; Red 4 bits; Green 4 bits; Blue 4 bits
- C4: 4 bits to encode linear grayscale colors between 0xff000000 and 0xffffffff (fully opaque)
- C2: 2 bits to encode linear grayscale colors between 0xff000000 and 0xffffffff (fully opaque)
- C1: 1 bit to encode grayscale colors 0xff000000 and 0xffffffff (fully opaque)

Custom formats:

- 32: until 32 bits to encode Alpha, Red, Green and/or Blue
- 24: until 24 bits to encode Alpha, Red, Green and/or Blue
- 16: until 16 bits to encode Alpha, Red, Green and/or Blue
- 8: until 8 bits to encode Alpha, Red, Green and/or Blue
- 4: until 4 bits to encode Alpha, Red, Green and/or Blue
- 2: until 2 bits to encode Alpha, Red, Green and/or Blue
- 1: 1 bit to encode Alpha, Red, Green or Blue

All others values are forbidden (throw a generation error).

- byteLayout [optional, default value is "line"]: Defines the pixels data order in a byte the display device is using. A byte can contain several pixels when the number of bits-per-pixels (see 'bpp' property) is lower than 8. Otherwise this property is useless. Two modes are available: the next bit(s) on same byte can target the next pixel on same line or on same column. In first case, when the end of line is reatched, the next byte contains the first pixels of next line. In second case, when the end of column is reatched, the next byte contains the first pixels of next column. In both cases, a new line or a new column restarts with a new byte, even if it remains some free bits in previous byte.
  - line: the next bit(s) on current byte contains the next pixel on same line (x increment)
  - column: the next bit(s) on current byte contains the next pixel on same column (y increment)

Note

- Default value is 'line'.
- All others modes are forbidden (throw a generation error).
- When the number of bits-per-pixels (see 'bpp' property) is higher or equal than 8, this property is useless and ignored.

- memoryLayout [optional, default value is "line"]: Defines the pixels data order in memory the display device is using. This option concerns only the LCD with a bpp lower than 8 (see 'bpp' property).

Two modes are available: when the byte memory address is incremented, the next targeted group of pixels is the next group on the same line or the next group on same column. In first case, when the end of line is reatched, the next group of pixels is the first group of next line. In second case, when the end of column is reatched, the next group of pixels is the first group of next column.

- line: the next memory address targets the next group of pixels on same line (x increment)
- column: the next memory address targets the next group of pixels on same column (y increment)

Note

- Default value is 'line'.
- All others modes are forbidden (throw a generation error).
- When the number of bits-per-pixels (see 'bpp' property) is higher or equal than 8, this property is useless and ignored.

14.6.13 Use

The MicroUI Display APIs are available in the class ej.microui.display.Display.

14.7 Images

The Image Engine is composed of:

- The "Image Engine Core" module which is able to load and drawing simultaneously some pre-generated images and some dynamic images.
- An "Image Generator" module, for converting standard image formats into the display image format before runtime (pre-generated images).
- A set of "Image Decoder" modules, for converting standard image formats into the display image format at runtime. Each Image Decoder is an additional module of the main module "Image Engine".

14.7.1 Image Engine Core

14.7.1.1 Principle

The Image Engine Core module is a built-in module of the MicroUI module (see “MicroUI”) for the application side, and a built-in module of the Display module (see “Display”) for the C side.

14.7.1.2 Functional Description

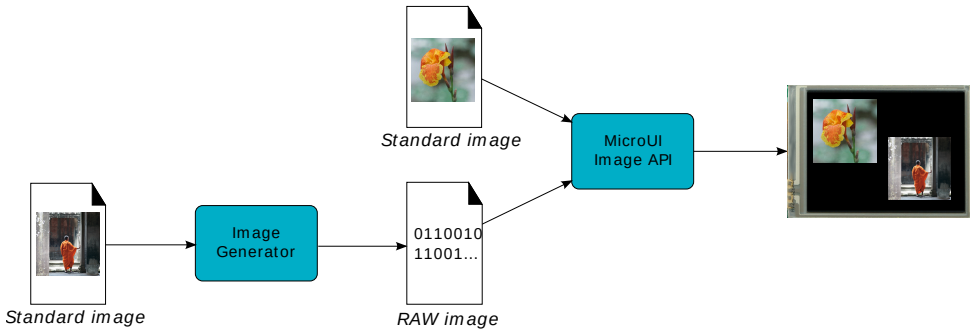


Figure 14.13. Image Engine Core Principle

Process overview:

1. The user specifies the pre-generated images to embed (see “Image Generator”) and / or the images to embed as regular resources (see “Image Decoder”)

2. The files are embedded as resources with the MicroEJ application. The files' data are linked into the FLASH memory.

3. When the MicroEJ application creates a MicroUI Image object, the Image Engine Core loads the image, calling the right sub Image Engine module (see “Image Generator” and “Image Decoder”) to decode the specified image.

4. When the MicroEJ application draws this MicroUI Image on the display (or on another image), the decoded image data is used, and no more decoding is required, so the decoding is done only once.

5. When the MicroUI Image is no longer needed, it is garbage-collected by the platform; and the Image Engine Core asks the right sub Image Engine module (see “Image Generator” and “Image Decoder”) to free the image working area.

14.7.1.3 Image Identifier

Before loading an image calling the right sub module, the Image Engine Core module tries first to attribute a unique identifier to the future decoded image. This identifier will be used to retrieve the image after the decoding step, in order to draw it and free it.

This identifier also targets some metadata for the image (same size for all images, specific to the Display module). An identifier is reserved for an image as long as the image is used by the MicroEJ application. When the MicroUI Image is no longer needed, it is garbage collected by the platform. The identifier (and its meta data memory space) is freed. Thus, a new image can use this identifier.

To prevent some C allocation at runtime, the number of identifiers and the memory space useful to store the image metadata are allocated at compile time. By consequence the available number of identifiers is limited. The MicroEJ launcher of the MicroEJ application has to specify the number of identifiers.

When the limit of identifiers is reached, the MicroUI library throws an OutOfMemoryError, error code -5. In this case try to augment the number of concurrent images in the MicroEJ launcher or try to remove the links on useless MicroUI Image objects.

14.7.1.4 External Resources

The Image Engine Core is able to load some images located outside the CPU addresses' space range. It uses the External Resource Loader.

When an image is located in such memory, the Image Engine Core copies it into RAM (into the CPU address space range). Then it calls the right sub Image Engine module (see “Image Generator” and “Image Decoder”) to decode the specified image.

The RAM section used to load the external image is automatically freed when the Image Engine Core and its modules do not need it again.

14.7.1.5 Dependencies

- MicroUI module (see “MicroUI”)

- Display module (see “Display”)

14.7.1.6 Installation

Image Engine Core modules are part of the MicroUI module and Display module. Install them in order to be able to use some images.

14.7.1.7 Use

The MicroUI image APIs are available in the class ej.microui.display.Image.

14.7.2 Image Generator

14.7.2.1 Principle

The Image Generator module is an off-board tool that generates image data that is ready to be displayed without needing additional runtime memory. The two main advantages of this module are:

- A pre-generated image is already encoded in the format known by the display stack. The image loading is very fast and does not require any RAM.
- No extra support is needed (no runtime decoder).

14.7.2.2 Functional Description

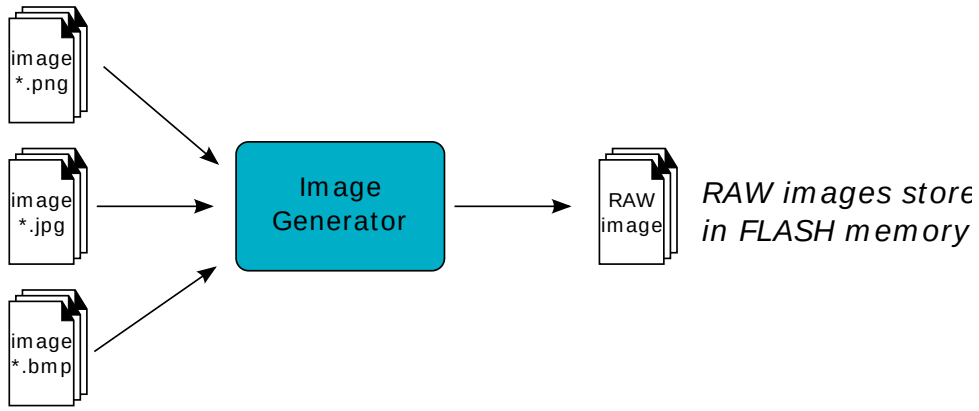


Figure 14.14. Image Generator Principle

Process overview (see too “Functional Description”)

1. The user defines, in a text file, the images to load.
2. The Image Generator outputs a raw file for each image to convert (the raw format is display device-dependent).
3. The raw files are embedded as (hidden) resources within the MicroEJ application. The raw files' data are linked into the FLASH memory.
4. When the MicroEJ application creates a MicroUI Image object which targets a pre-generated image, the Image Engine Core has only to create a link from the MicroUI image object to the data in the FLASH memory. Therefore, the loading is very fast; only the image data from the FLASH memory is used: no copy of the image data is sent to the RAM first.
5. When the MicroUI Image is no longer needed, it is garbage-collected by the platform, which just deletes the useless link to the FLASH memory.

14.7.2.3 Extensions Purpose

The output representation of the images in the same format as the LCD (same pixel representation, see “Display Output Format”) is dependent on the drivers that run the underlying screen. Indeed, the output raw format is specific to each display device. The Image Generator tool provided is expandable by extensions, each extension implementing a dedicated display device layout.

14.7.2.3.1 Standard Extension

When the LCD pixels representation is standard (ARGB8888 or RGB565 etc., see “Pixel Structure”) the image generator does not need an extension. The formulas of conversions ARGB8888 to RAW formats are the same as described in the chapter “Pixel Structure”.

14.7.2.3.2 Generic Extension

When the LCD pixel representation is generic (1 | 2 | 4 | 8 | 16 | 24 | 32, see “Pixel Structure”) the image generator requires an extension in order to understand how to convert ARGB pixels into LCD pixel representations.

The Display module provides generic display implementation according the number of bits-per-pixels (1, 2, 4, 8, 16, 24 and 32). The Image Generator tool provides a simple extension to implement in order to target these kinds of displays: GenericDisplayExtension. [6]

A method must be implemented in relation to the way the driver has built the layout of the display buffers in memory: The convertARGBColorToDisplayColor method is used to convert a 32-bits ARGB color into the display pixel memory representation.

Note

The Image Generator automatically uses the right number of bits to represent a pixel (BPP) and respect the memory buffer layout using the result of the installation of the Display module.

14.7.2.3.3 Create an Extension

Follow the steps below to create an Image Generator extension:

1. First, create a new J2SE project, called (for example) imageGeneratorExtension.
2. In the project's Java build path (project's property window, select **Java Build Path > Libraries tab**), add the variable IMAGE-GENERATOR-x.y.
3. Create the package com.is2t.microui.generators.extension.
4. Create a class in the package whose name must be: MicroUIGeneratorExtension.
5. The Java class must implement the extension interface available in the library IMAGE-GENERATOR-x.y (see previous chapters). Fill the required methods.

The Java project should now look like this:

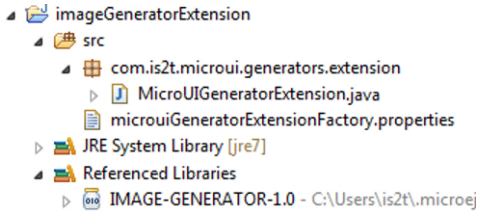


Figure 14.15. Image Generator Extension Project

With a Java class like this:

[6] Package com.is2t.microej.microui.image

```
package com.is2t.microui.generators.extension;

import com.is2t.microej.microui.image.GenericDisplayExtension;

public class MicroUIGeneratorExtensionMyLCD implements GenericDisplayExtension{

   public int convertARGBColorToDisplayColor(int color) {
      return (char)
         ((color & 0xf80000) >>> 8) |
         ((color & 0x00fc00) >>> 5) |
         ((color & 0x0000f8) >>> 3);
   }

}
```

Figure 14.16. Image Generator Extension Implementation Example

14.7.2.4 Configuration File

The Image Generator uses a configuration file (also called the "list file") for describing images that need to be processed. The list file is a text file in which each line describes an image to convert. The image is described as a resource path, and should be available from the application classpath.

Note

The list file must be specified in the MicroEJ application launcher (see “Appendix E: Application Launch Options”). However, all files in application classpath with suffix `.images.list` are automatically parsed by the Image Generator tool.

Each line can add optional parameters (separated by a ':') which define and/or describe the output file format (raw format). When no option is specified, the image is converted into the default format.

Note

See “Image Generator” to understand the list file grammar.

Below is an example of a list file for the Image Generator:

```
image1
image2:RGB565
```

Figure 14.17. Image Generator Configuration File Example

The next chapters describe the available output formats.

14.7.2.5 Generic Output Formats

Several generic output formats are available. Some formats may be directly managed by the display driver. Refers to the platform specification to retrieve the list of better formats.

Advantages:

- The pixels layout and bits format are standard, so it is easy to manipulate these images on the C-side.
- Drawing an image is very fast when the display driver recognizes the format (with or without transparency).
- Supports or not the alpha encoding: select the better format according to the image to encode.

Disadvantages:

- No compression: the image size in bytes is proportional to the number of pixels, the transparency, and the bits-per-pixel.

Select one the following format to use a generic format:

- ARGB8888: 32 bits format, 8 bits for transparency, 8 per color.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return c;
}
```

- RGB888: 24 bits format, 8 per color. Image is always fully opaque.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return c & 0xffffff;
}
```

- ARGB4444: 16 bits format, 4 bits for transparency, 4 per color.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return 0
   | ((c & 0xf0000000) >> 16)
   | ((c & 0x00f00000) >> 12)
   | ((c & 0x0000f000) >> 8)
   | ((c & 0x000000f0) >> 4)
   ;
}
```

- ARGB1555: 16 bits format, 1 bit for transparency, 5 per color.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return 0
   | (((c & 0xff000000) == 0xff000000) ? 0x8000 : 0)
   | ((c & 0xf80000) >> 9)
   | ((c & 0x00f800) >> 6)
   | ((c & 0x0000f8) >> 3)
   ;
}
```

- RGB565: 16 bits format, 5 or 6 per color. Image is always fully opaque.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return 0
   | ((c & 0xf80000) >> 8)
   | ((c & 0x00fc00) >> 5)
   | ((c & 0x0000f8) >> 3)
   ;
}
```

- A8: 8 bits format, only transparency is encoded. The color to apply when drawing the image, is the current GraphicsContext color.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return 0xff - (toGrayscale(c) & 0xff);
}
```

- A4: 4 bits format, only transparency is encoded. The color to apply when drawing the image, is the current GraphicsContext color.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return (0xff - (toGrayscale(c) & 0xff)) / 0x11;
}
```

- A2: 2 bits format, only transparency is encoded. The color to apply when drawing the image, is the current GraphicsContext color.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return (0xff - (toGrayscale(c) & 0xff)) / 0x55;
}
```

- A1: 1 bit format, only transparency is encoded. The color to apply when drawing the image, is the current GraphicsContext color.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return (0xff - (toGrayscale(c) & 0xff)) / 0xff;
}
```

- C4: 4 bits format with grayscale conversion. Image is always fully opaque.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return (toGrayscale(c) & 0xff) / 0x11;
}
```

- C2: 2 bits format with grayscale conversion. Image is always fully opaque.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return (toGrayscale(c) & 0xff) / 0x55;
}
```

- C1: 1 bit format with grayscale conversion. Image is always fully opaque.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return (toGrayscale(c) & 0xff) / 0xff;
}
```

- AC44: 4 bits for transparency, 4 bits with grayscale conversion.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return 0
  | ((color >> 24) & 0xf0)
  | ((toGrayscale(color) & 0xff) / 0x11)
  ;
}
```

- AC22: 2 bits for transparency, 2 bits with grayscale conversion.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return 0
  | ((color >> 28) & 0xc0)
  | ((toGrayscale(color) & 0xff) / 0x55)
  ;
}
```

- AC11: 1 bit for transparency, 1 bit with grayscale conversion.

```
u32 convertARGB8888toRAWFormat(u32 c){
 return 0
  | ((c & 0xff000000) == 0xff000000 ? 0x2 : 0x0)
  | ((toGrayscale(color) & 0xff) / 0xff)
  ;
}
```

```
image1:ARGB8888
image2:RGB565
image3:A4
```

Figure 14.18. Generic Output Format Examples

14.7.2.6 Display Output Format

The default embedded image data format provided by the Image Generator tool when using a generic extension is to encode the image into the exact display memory representation. If the image to encode contains some transparent pixels, the output file will embed the transparency according to the display's implementation capacity. When all pixels are fully opaque, no extra information will be stored in the output file in order to free up some memory space.

Advantages:

- Drawing an image is very fast.
- Supports alpha encoding.

Disadvantages:

- No compression: the image size in bytes is proportional to the number of pixels.

```
image1:display
```

Figure 14.19. Display Output Format Example

14.7.2.7 RLE1 Output Format

The image engine can display embedded images that are encoded into a compressed format which encodes several consecutive pixels into one or more 16-bits words. This encoding manages a maximum alpha level of 2 (alpha level is always assumed to be 2, even if the image is not transparent).

- Several consecutive pixels have the same color (2 words).
  - First 16-bit word specifies how many consecutive pixels have the same color.
  - Second 16-bit word is the pixels' color.
- Several consecutive pixels have their own color (1 + n words).
  - First 16-bit word specifies how many consecutive pixels have their own color.
  - Next 16-bit word is the next pixel color.
- Several consecutive pixels are transparent (1 word).
  - 16-bit word specifies how many consecutive pixels are transparent.

Advantages:

- Supports 0 & 2 alpha encoding.
- Good compression when several consecutive pixels respect one of the three previous rules.

Disadvantages:

- Drawing an image is slightly slower than when using Display format.

```
image1:RLE1
```

Figure 14.20. RLE1 Output Format Example

14.7.2.8 No compression

When no output format is set in the images list file, the image is embedded without any conversion / compression. This allows you to embed the resource as well, in order to keep the source image char-

acteristics (compression, bpp etc.). This option produces the same result as specifiying an image as a resource in the MicroEJ launcher.

Advantages:

- Conserves the image characteristics.

Disadvantages:

- Requires an image runtime decoder.
- Requires some RAM in which to store the decoded image

```
image1
```

Figure 14.21. Unchanged Image Example

14.7.2.9 External Resources

The Image Generator manages two configuration files when the External Resources Loader is enabled. The first configuration file lists the images which will be stored as internal resources with the MicroEJ application. The second file lists the images the Image Generator must convert and store in the External Resource Loader output directory. It is the BSP's responsibility to load the converted images into an external memory.

14.7.2.10 Dependencies

- Image Engine Core module (see “Image Engine Core”).
- Display module (see “Display”): This module gives the characteristics of the graphical display that are useful in configuring the Image Generator.

14.7.2.11 Installation

The Image Generator is an additional module for the MicroUI library. When the MicroUI module is installed, also install this module in order to be able to target pre-generated images.

In the platform configuration file, check UI > Image Generator to install the Image Generator module. When checked, the properties file imageGenerator > imageGenerator.properties is required during platform creation to configure the module, only when the LCD pixel representation is not standard (see “Pixel Structure”). This configuration step is used to identify the extension class name (see “Create an Extension”).

14.7.2.12 Use

The MicroUI Image APIs are available in the class ej.microui.display.Image. There are no specific APIs that use a pre-generated image. When an image has been pre-processed, the MicroUI Image APIs createImage* will load the image.

Refer to the chapter “Appendix E: Application Launch Options” (Libraries > MicroUI > Image) for more information about specifying the image configuration file.

14.7.3 Image Decoder

14.7.3.1 Principle

The Image Engine provides runtime decoders which allow the dynamic loading of images without using the Image Generator (see “Image Generator”). The two main advantages are:

- The original image is embedded as a resource with the MicroEJ application.

- The original image size in bytes is often smaller than a pre-generated image (especially in PNG mode).

14.7.3.2 Functional Description

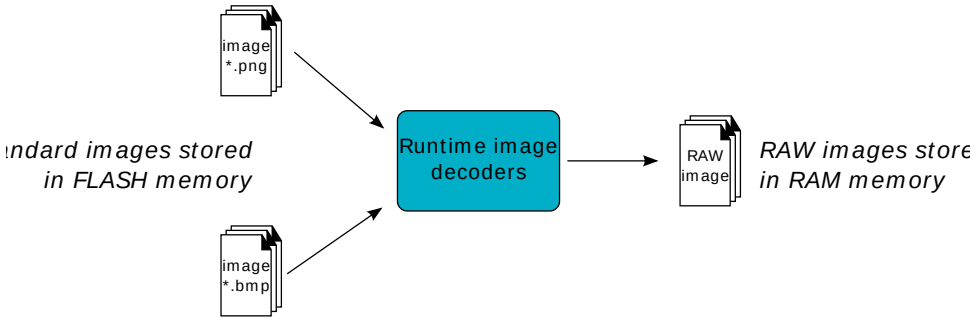


Figure 14.22. Image Decoder Principle

Process overview (see too “Functional Description”)

1. The user specifies the images to embed as regular resources.

2. The original files are embedded as resources with the MicroEJ application. The original files' data are linked into the FLASH memory.

3. When the Image Engine Core calls the decoder to load an image, it transforms the image into a raw format that is compatible with the display format. It may need some additional RAM to store some working buffers. At the end of the decoding step, the working buffers are freed: Only the decoded image memory needs to be retained.

4. When the Image Engine Core calls the decoder to free the image resources, the decoder frees the decoded image buffer area.

14.7.3.3 Internal Decoders

The UI extension provides two internal Image Decoders modules:

- PNG Decoder: a full PNG decoder that implements the PNG format (www.w3.org/Graphics/PNG [http://www.w3.org/Graphics/PNG]). Regular, interlaced, indexed (palette) compressions are handled. The RAM used by the decoder is allocated outside the Java heap.

- BMP Monochrome Decoder: .bmp format files that embed only 1 bit per pixel can be decoded by this decoder. The RAM used by the decoder to store the decoded image is outside the Java heap.

14.7.3.4 External Decoders

Some additional decoders can be added. Implement the function LLDISPLAY_EXTRA_IMPL_decodeImage to add a new decoder (see “LLDISPLAY_EXTRA: Display Extra Features”).

The implementation must respect the following rules:

- Fills the LLDISPLAY_SImage structure with the image characteristics: width, height and format.

Note

The output image format might be different than the expected format (given as argument). In this way, the display module will perform a conversion after the decoding

step. During this conversion, an out of memory error can occur because the final RAW image cannot be allocated.

- Allocates the RAW image data calling the function LLDISPLAY_UTILS_allocateRawImage. This function will allocates the RAW image data space in the display working buffer according the RAW image format and size.
- Decodes the image in the allocated buffer.
- Waiting the end of decoding step before returning.

14.7.3.5 Dependencies

- Image Engine Core module (see “Image Engine Core”)

14.7.3.6 Installation

The Image Decoders modules are some additional modules to the Display module. The decoders belong to distinct modules, and either or several may be installed.

In the platform configuration file, check UI > Image PNG Decoder to install the runtime PNG decoder. Check UI > Image BMP Monochrome Decoder to install the runtime BMP monochrom decoder.

14.7.3.7 Use

The MicroUI Image APIs are available in the class ej.microui.display.Image. There is no specific API that uses a runtime image. When an image has not been pre-processed (see “Image Generator”), the MicroUI Image APIs createImage* will load this image.

14.8 Fonts

The Font Engine is composed of:

- The "Font Engine Core" module which decodes and prints at application runtime the platform-dependent fonts files generated by the "Font Generator."
- A "Font Designer" module: a graphical tool which runs within the MicroEJ workbench used to build and edit MicroUI fonts; it stores fonts in a platform-independent format.
- A "Font Generator" module, for converting fonts from the platform-independent format into a platform-dependent format.

The three modules are complementary: a MicroUI font must be created and edited with the Font Designer before being integrated as a resource by the Font Generator. Finally the Font Engine Core uses the generated fonts at runtime.

The Font Designer module and Font Generator module options are the direct consequence of the Font Engine Core capacities. You must understand the Font Engine Core capacities in order to correctly use the modules.

14.8.1 Font Engine Core

14.8.1.1 Principle

The Font Engine Core module is a built-in module of the MicroUI module (see “MicroUI”) for the application side; and is a built=in module of the Display module (see “Display”) for the C side.

14.8.1.2 Functional Description

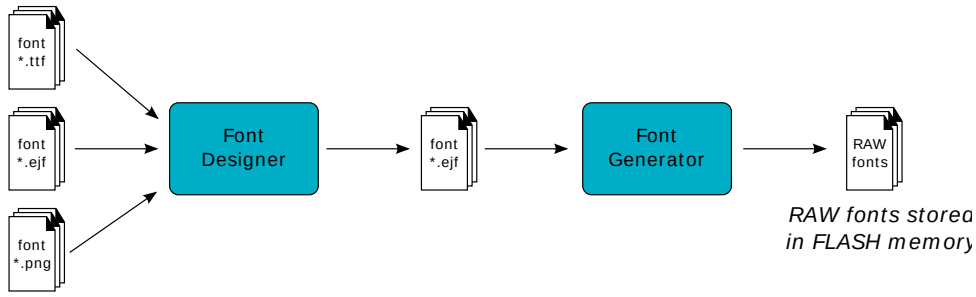


Figure 14.23. Font Generation

Process overview:

1. User uses the Font Designer module to create a new font, and imports characters from system fonts (*.ttf files) and / or user images (*.png, *.jpg, *.bmp, etc.).
2. Font Designer module saves the font as a MicroEJ Font (*.ejf file).
3. The user defines, in a text file, the fonts to load.
4. The Font Generator outputs a raw file for each font to convert (the raw format is display device-dependent).
5. The raw files are embedded as (hidden) resources within the MicroEJ application. The raw files' data are linked into the FLASH memory.
6. When the MicroEJ application creates a MicroUI DisplayFont object which targets a pre-generated image, the Font Engine Core only has to link from the MicroUI DisplayFont object to the data in the FLASH memory. Therefore, the loading is very fast; only the font data from the FLASH memory is used: no copy of the image data is sent to RAM memory first.
7. When the MicroUI DisplayFont is no longer needed, it is garbage-collected by the platform, which just deletes the useless link to the FLASH memory.

14.8.1.3 Font Format

The font engine module provides fonts that conform to the Unicode Standard [U61]. The .ejf files hold font properties:

- Identifiers: Fonts hold at least one identifier that can be one of the predefined Unicode scripts [U61] or a user-specified identifier. The intention is that an identifier indicates that the font contains a specific set of character codes, but this is not enforced.
- Font height and width, in pixels. A font has a fixed height. This height includes the white pixels at the top and bottom of each character, simulating line spacing in paragraphs. A monospace font is a font where all characters have the same width; for example, a '!' representation has the same width as a 'w'. In a proportional font, 'w' will be wider than a '!'. No width is specified for a proportional font.

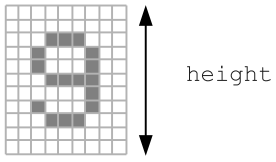


Figure 14.24. Font Height

- Baseline, in pixels. All characters have the same baseline, which is an imaginary line on top of which the characters seem to stand. Characters can be partly under the line, for example 'g' or '}'. The number of pixels specified is the number of pixels above the baseline.

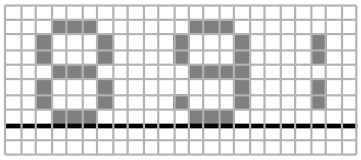


Figure 14.25. Font baseline

- Space character size, in pixels. For proportional fonts, the Space character (0x20) is a specific character because it has no filled pixels, and so its width must be specified. For monospace, the space size is equal to the font width (and hence the same as all other characters).
- Styles: A font holds either a combination of these styles: BOLD, ITALIC, UNDERLINED, or is said to be PLAIN.
- Runtime filters: Some fonts may allow the font engine to apply a transformation (in other words, a filter) on characters before they are displayed in order to provide some visual effect on characters (BOLD, ITALIC, UNDERLINED). Unless specified, a font allows the font engine to apply any of its filters.
- When the selected font does not have a graphical representation of the required character, a rectangle is displayed instead. For proportional fonts, the width is one third of the height of the font.

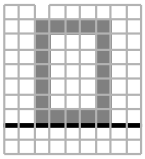


Figure 14.26. Default Character

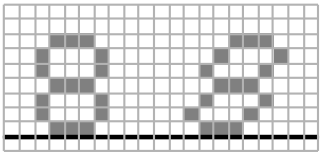
14.8.1.4 Font Selection

The font engine implements the [MUI] selection semantics, and also tries to select fonts for which styles are built in, instead of applying a runtime filter. The font is selected based on the following process:

1. Select fonts that define the specified identifier.
2. Select within the step1 fonts, those whose height is the closest to the specified height.
3. Select within the step2 fonts, those with built-in styles that match the specified styles.
4. If more than one font is selected by the steps above, select those fonts that have the most built-in styles. If there is still more than one font, one is selected arbitrarily.

14.8.1.5 Runtime Transformation: Filters

The user interface extension font engine provides three runtime filters that may apply if the (currently selected) font allows it. The filters are:

Name	Description	Rendering sample
ITALIC	Pixels on upper rows are shifted right. The higher a pixel is relative to the base line, the more it is right-shifted.	

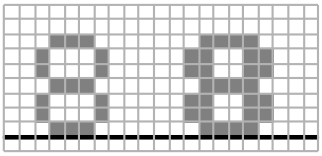
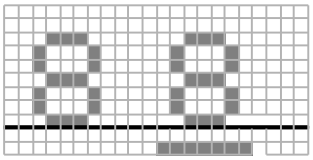
Name	Description	Rendering sample
BOLD	1 pixel is added to the right of each original pixel.	
UNDERLINED	A line is displayed two pixels below the baseline position.	

Table 14.16. The Three Font Runtime Style Transformations (filters).

Multiple filters may apply at the same time, combining their transformations on the displayed characters.

14.8.1.6 Pixel Transparency

The font engine renders the font according the the value stored for each pixel. If the value is 0, the pixel is not rendered. If the value is the maximum value (for example the value 3 for 2 bits-per-pixel), the pixel is rendered using the current foreground color, completely overwriting the current value of the destination pixel. For other values, the pixel is rendered by blending the selected foreground color with the current color of the destination.

If n is the number of bits-per-pixel, then the maximum value of a pixel (pmax) is 2^n – 1. The value of each color component of the final pixel is equal to:

foreground * pixelValue / pmax + background * (pmax - pixelValue) / pmax + adjustment

where adjustment is an adjustment factor specified in the board support package of the platform.

14.8.1.7 Font Identifier

All fonts are loaded at MicroUI startup. Before loading a font, the Image Engine Core module first tries to attribute a unique identifier to the future loaded font. This identifier will be used to retrieve the font after the loading step, in order to draw it and to free it.

An identifier targets a font file (an ejf raw file), which can contain until eight DisplayFont inside. To prevent some C allocation at runtime, the number of identifiers is allocated at compile-time. By consequence, the available number of identifiers is limited. The MicroEJ launcher of the MicroEJ application has to specify the number of identifiers (refer to the chapter “Appendix E: Application Launch Options” (Target > Memory) to have more information where specify this number of identifiers.)

Note

This number has to include the number of system fonts. A system font is a font file specified during the MicroUI static initialization step (see “Static Initialization”).

When the limit of identifiers is reached, the MicroUI library throws an error, and the non-loaded fonts are unusable.

14.8.1.8 Arabic Support

The font engine manages the ARABIC font specificities: the diacritics and contextual letters. Contrary to the LATIN fonts, some ARABIC characters can overlap another character. When a character must

overlap the previous character in the text, the font engine repositions the X coordinate before rendering the new character (instead of placing the next character just after the previous one).

To render an Arabic text, the font engine requires several points:

- To determinate if a character has to overlap the previous character, the font engine uses a specific range of ARABIC characters: from 0xfe70 to 0xfefc. All others characters (ARABIC or not) outside this range are considered *classic* and no overlap is performed. Note that several ARABIC characters are available outside this range, but the same characters (same representation) are available inside this range.
- The application strings must use the UTF-8 encoding. Furthermore, in order to force the use of characters in the range 0xfe70 to 0xfefc, the string must be filled with the following syntax: '\ufee2\ufedc\ufe91\u0020\ufe8e\ufe92\ufea3\ufeae\ufee3'; where \uxxxx is the UTF-8 character encoding.
- The application string and its rendering are always performed from left to right. However the string contents are managed by the application itself, and so can be filled from right to left. To write the text:

  the string characters must be : '\ufee2\ufedc\ufe91\u0020\ufe8e\ufe92\ufea3\ufeae\ufee3'. The font engine will first render the character '\ufee2', then '\ufedc,' and so on.
- Each character in the font (in the ejf file) must have a rendering compatible with the character position. The character will be rendered by the font engine as-is. No support is performed by the font engine to obtain a *linear* text.

14.8.1.9 External Resources

The Font Engine Core is able to load some fonts located outside the CPU addresses' space range. It uses the External Resource Loader.

When a font is located in such memory, the Font Engine Core copies a very short part of the resource (the font file) into a RAM memory (into CPU addresses space range): the font header. This header stays located in RAM during the full MicroEJ application time. Then, on MicroEJ application demand, the Font Engine Core loads some extra information from the font into the RAM memory (the font meta data, the font pixels, etc.). This extra information is automatically unloaded from RAM when the Font Engine Core no longer needs them.

14.8.1.10 Dependencies

- MicroUI module (see “MicroUI”)
- Display module (see “Display”)

14.8.1.11 Installation

The Font Engine Core modules are part of the MicroUI module and Display module. You must install them in order to be able to use some fonts.

14.8.1.12 Use

The MicroUI font APIs are available in the class ej.microui.display.Font.

14.8.2 Font Designer

14.8.2.1 Principle

The Font Designer module is a graphical tool (Eclipse plugin) that runs within the MicroEJ workbench used to build and edit MicroUI fonts. It stores fonts in a platform-independent format.

14.8.2.2 Functional Description

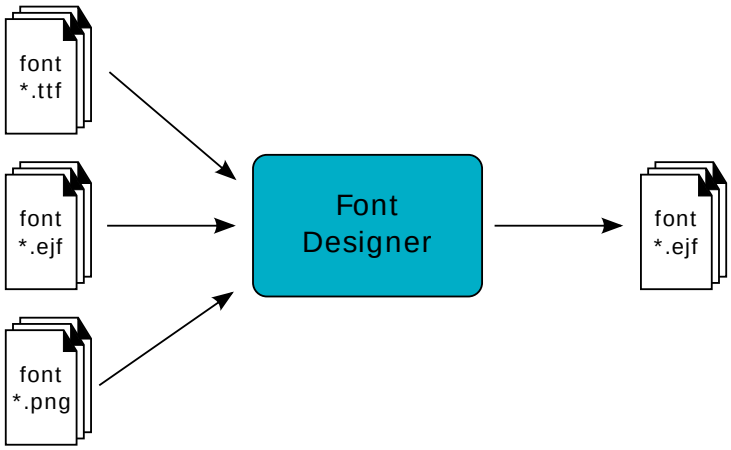


Figure 14.27. Font Generation

14.8.2.3 Create a MicroEJ Font

To create a MicroEJ font, follow the steps below:

1. Open the Eclipse wizard: **File > New > Other > MicroEJ > MicroEJ Font.**
2. Select a directory and a name.
3. Click **Finish.**

Once the font is created, a new editor is opened: the MicroEJ Font Designer Editor.

14.8.2.4 Edit a MicroEJ Font

You can edit your font with the MicroEJ Font Designer Editor (by double-clicking on a *.ejf file or after running the new MicroEJ Font wizard).

This editor is divided into three main parts:

- The top left part manages the main font properties.
- The top right part manages the character to embed in your font.
- The bottom part allows you to edit a set of characters or an individual character.

14.8.2.4.1 Main Properties

The main font properties are:

- font size: height and width (in pixels).
- baseline (in pixels).
- space character size (in pixels).
- styles and filters.
- identifiers.

Refer to the following sections for more information about these properties.

14.8.2.4.1.1 Font Height

A font has a fixed height. This height includes the white pixels at the top and at the bottom of each character simulating line spacing in paragraphs.

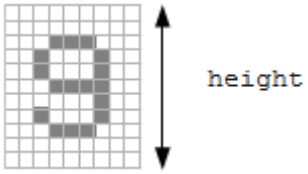


Figure 14.28. Font Height

14.8.2.4.1.2 Font Width: Proportional and Monospace Fonts

A monospace font is a font in which all characters have the same width. For example a '!' representation will be the same width as a 'w' (they will be in the same size rectangle of pixels). In a proportional font, a 'w' will be wider than a '!'.

A monospace font usually offers a smaller memory footprint than a proportional font because the Font Designer does not need to store the size of each character. As a result, this option can be useful if the difference between the size of the smallest character and the biggest one is small.

14.8.2.4.1.3 Baseline

Characters have a baseline: an imaginary line on top of which the characters seem to stand. Note that characters can be partly under the line, for example, 'g' or '}'.

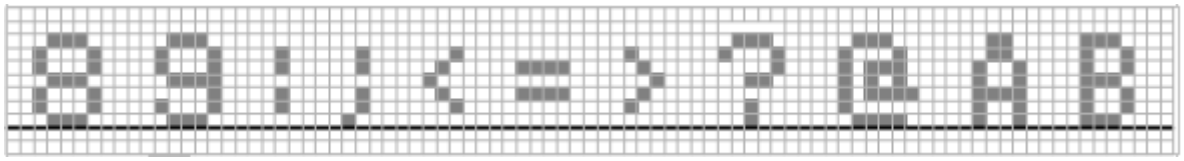


Figure 14.29. The Baseline

14.8.2.4.1.4 Space Character

The Space character (0x20) is a specific character because it has no filled pixels. From the Main Properties Menu you can fix the space character size in pixels.

Note

When the font is monospace, the space size is equal to the font width.

14.8.2.4.1.5 Styles and Filters

A MicroUI font holds a style: PLAIN, BOLD, ITALIC, UNDERLINED, and the combinations between BOLD, ITALIC and UNDERLINED. Font Designer can use one file to describe several MicroUI fonts.

For example, a font file that describes a PLAIN font can also describe an UNDERLINED font because the MicroUI implementation just has to draw a line under the characters. In this way, from a developer's point of view, there are two fonts: a PLAIN font and an UNDERLINED font. From the Font Designer point of view, there are also two fonts, but they use the same data file. Font Designer adds a tag to describe the UNDERLINED font in the generated font file.

This tag is a *filter*. When a file contains one or more filters, MicroUI implementation knows that it has to perform post processing to obtain a specific MicroUI font from the encoded font.

Alternatively, the user can create two distinct files to describe the two fonts. From the MicroUI application point of view, there are always two fonts: a PLAIN font and an UNDERLINED font, but no post-processing step is required (no filter tag).

Examples:

1. A font file contains the styles PLAIN and UNDERLINED and the filters PLAIN and UNDERLINED. The MicroUI implementation detects two MicroUI fonts. To draw each font, the PLAIN filter or the UNDERLINED filter is used accordingly.

2. A font file contains the styles PLAIN and UNDERLINED and the filter PLAIN. The MicroUI implementation detects two MicroUI fonts. To draw the underlined font, it will not apply the underlining process (the filter UNDERLINED is absent). So the MicroUI underlined font will have the same rendering as the MicroUI plain font.

Font Designer features three drop-downs, one for each of BOLD, ITALIC and UNDERLINED. Each drop-down has three options:

- None – Font Designer will not set this style, nor include a filter for it.
- Built-in – Font Designer will set this style, but not include a filter for it.
- Dynamic – Font Designer will set this style, and include a filter for it.

If all three drop-downs are set to None, only a plain font is generated.

The number of fonts that will result is shown below the drop-downs.

14.8.2.4.1.6 Identifiers

A number of identifiers can be attached to a MicroUI font. At least one identifier is required to specify the font. Identifiers are a mechanism for specifying the contents of the font – the set or sets of characters it contains. The identifier may be a standard identifier (for example, LATIN) or a user-defined identifier. Identifiers are numbers, but standard identifiers, which are in the range 0 to 80, are typically associated with a handy name. A user-defined identifier is an identifier with a value of 81 or higher.

14.8.2.4.2 Character List

The list of characters can be populated through the **import** button, which allows you to import characters from system fonts, images or another MicroEJ font.

14.8.2.4.2.1 Import from System Font

This page allows you to select the system font to use (left part) and the range of characters. There are predefined ranges of characters below the font selection, as well as a custom selection picker (for example 0x21 to 0xfe for Latin characters).

The right part displays the selected characters with the selected font. If the background color of a displayed character is red, it means that the character is too large for the defined height, or in the case of a monospace font, it means the character is too high or too wide. You can then adjust the font properties (font size and style) to ensure that characters will not be truncated.

When your selection is done, click the **Finish** button to import this selection into your font.

14.8.2.4.2.2 Import from Images

This page allows the loading of images from a directory. The images must be named as follows: 0x[UTF-8].[extension].

When your selection is done, click the **Finish** button to import the images into your font.

14.8.2.4.3 Character Editor

When a single character is selected in the list, the character editor is opened.

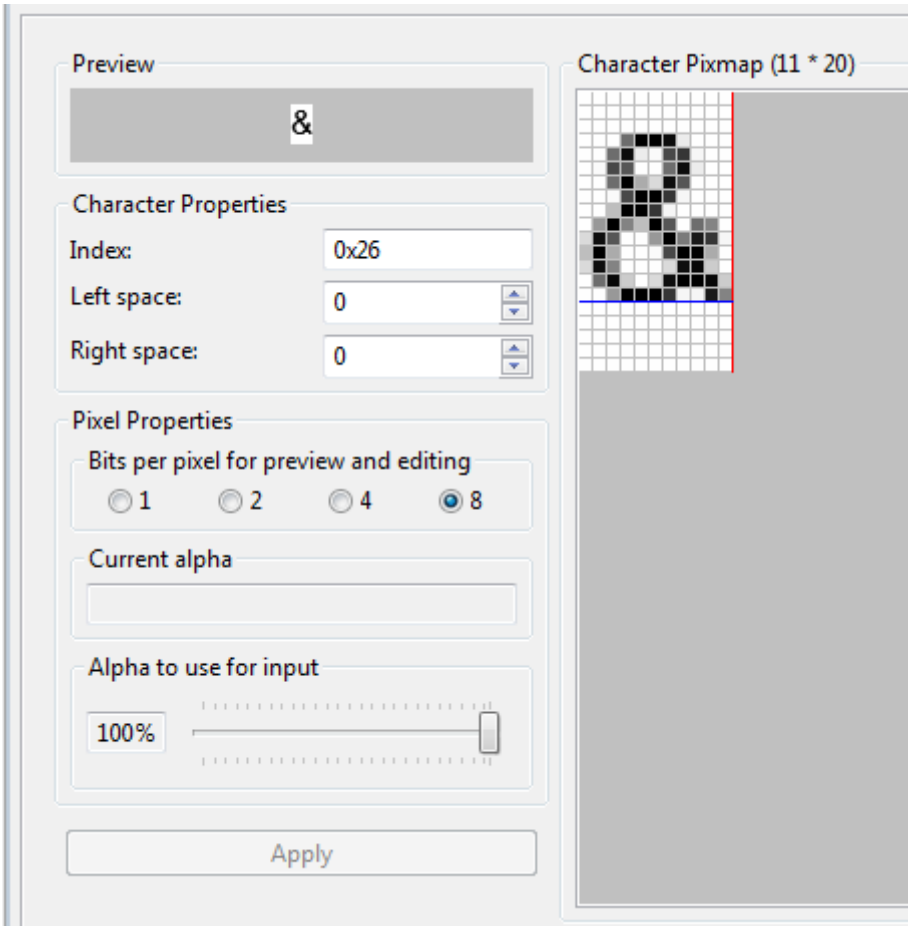


Figure 14.30. Character Editor

You can define specific properties, such as left and right space, or index. You can also draw the character pixel by pixel - a left-click in the grid draws the pixel, a right-click erases it.

The changes are not saved until you click the **Apply** button. When changes are applied to a character, the editor shows that the font has changed, so you can now save it.

The same part of the editor is also used to edit a set of characters selected in the top right list. You can then edit the common editable properties (left and right space) for all those characters at the same time.

14.8.2.4.3.1 Working With Anti-Aliased Fonts

By default, when characters are imported from a system font, each pixel is either fully opaque or fully transparent. Fully opaque pixels show as black squares in the character grid in the right-hand part of the character editor; fully transparent pixels show as white squares.

However, the pixels stored in an ejf file can take one of 256 grayscale values. A fully-transparent pixel has the value 255 (the RGB value for white), and a fully-opaque pixel has the value 0 (the RGB value for black). These grayscale values are shown in parentheses at the end of the text in the **Current alpha** field when the mouse cursor hovers over a pixel in the grid. That field also shows the transparency level of the pixel, as a percentage, where 100% means fully opaque.

It is possible to achieve better-looking characters by using a combination of fully-opaque and partially-transparent pixels. This technique is called *anti-aliasing*. Anti-aliased characters can be imported from system fonts by checking the **anti aliasing** box in the import dialog. The '&' character shown in the screenshot above was imported using anti aliasing, and you can see the various gray levels of the pixels.

When the Font Generator converts an ejf file into the raw format used at runtime, it can create fonts with characters that have 1, 2, 4 or 8 bits-per-pixel (bpp). If the raw font has 8 bpp, then no conversion is necessary and the characters will render with the same quality as seen in the character editor. However, if the raw font has less than 8 bpp (the default is 1 bpp) any gray pixels in the input file are compressed to fit, and the final rendering will be of lower quality (but less memory will be required to hold the font).

It is useful to be able to see the effects of this compression, so the character editor provides radio buttons that allow the user to preview the character at 1, 2, 4, or 8 bpp. Furthermore, when 2, 4 or 8 bpp is selected, a slider allows the user to select the transparency level of the pixels drawn when the left mouse button is clicked in the grid.

14.8.2.4.4 Previewing a Font

You can preview your font by pressing the **Preview...** button, which opens the Preview wizard. In the Preview wizard, press the **Select File** button, and select a text file which contains text that you want to see rendered using your font. Characters that are in the selected text file but not available in the font will be shown as red rectangles.

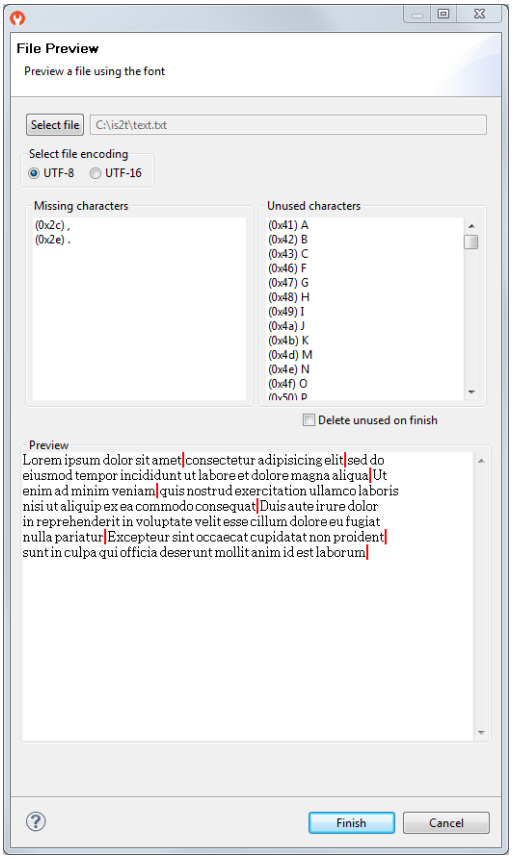


Figure 14.31. Font Preview

14.8.2.4.5 Removing unused characters

In order to reduce the size of a font file, you can reduce the number of characters in your font to be only those characters used by your application. To do this, create a file which contains all the characters used by your application (for example, concatenating all your NLS files is a good starting

point). Then open the Preview wizard as described above, selecting that file. If you select the check box **Delete unused on finish**, then those characters that are in the font but not in the text file will be deleted from the font when you press the **Finish** button, leaving your font containing the minimum number of characters. As this font will contain only characters used by a specific application, it is best to prepare a "complete" font, and then apply this technique to a copy of that font to produce an application specific cut-down version of the font.

14.8.2.5 Use a MicroEJ Font

A MicroEJ Font must be converted to a format which is specific to the targeted platform. The Font Generator tool performs this operation for all fonts specified in the list of fonts configured in the application launch.

14.8.2.6 Dependencies

No dependency.

14.8.2.7 Installation

The Font Designer module is already installed in the MicroEJ environment. The module is optional for the platform, and allows the platform user to create new fonts.

Note

When the platform user already has a MicroEJ environment which provides the Font Designer module, he/she will able to create a new font even if the platform does not provide the Font Designer module.

In the platform configuration file, check `UI > Font Designer` to install the Font Designer module.

14.8.2.8 Use

Create a new `ejf` font file or open an existing one in order to open the Font Designer plugin.

14.8.3 Font Generator

14.8.3.1 Principle

The Font Generator module is an off-board tool that generates fonts ready to be displayed without the need for additional runtime memory. It outputs a raw file for each converted font.

14.8.3.2 Functional Description

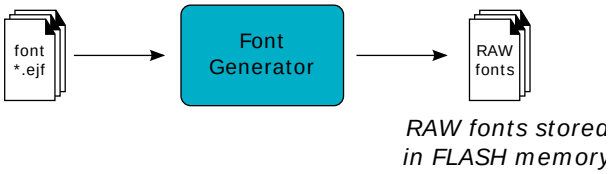


Figure 14.32. Font Generator Principle

Process overview:

1. The user defines, in a text file, the fonts to load.
2. The Font Generator outputs a raw file for each font to convert.

3. The raw files are embedded as (hidden) resources within the MicroEJ application. The raw file's data is linked into the FLASH memory.

4. When the MicroEJ application draws text on the display (or on an image), the font data comes directly from the FLASH memory (the font data is not copied to the RAM memory first).

14.8.3.3 Pixel Transparency

As mentioned above, each pixel of each character in an .ejf file has one of 256 different gray-scale values. However RAW files can have 1, 2, 4 or 8 bits-per-pixel (respectively 2, 4, 16 or 256 gray-scale values). The required pixel depth is defined in the configuration file (see next chapter). The Font Generator compresses the input pixels to the required depth.

The following tables illustrates the conversion "grayscale to transparency level". The grayscale value '0x00' is black whereas value '0xff' is white. The transparency level '0x0' is fully transparent whereas level '0x1' (bpp == 1), '0x3' (bpp == 2) or '0xf' (bpp == 4) is fully opaque.

Grayscale Ranges	Transparency Levels
0x00 to 0x7f	0x1
0x80 to 0xff	0x0

Table 14.17. Font 1-BPP RAW Conversion

Grayscale Ranges	Transparency Levels
0x00 to 0x1f	0x3
0x20 to 0x7f	0x2
0x80 to 0xdf	0x1
0xe0 to 0xff	0x0

Table 14.18. Font 2-BPP RAW Conversion

Grayscale Ranges	Transparency Levels
0x00 to 0x07	0xf
0x08 to 0x18	0xe
0x19 to 0x29	0xd
0x2a to 0x3a	0xc
0x3b to 0x4b	0xb
0x4c to 0x5c	0xa
0x5d to 0x6d	0x9
0x6e to 0x7e	0x8
0x7f to 0x8f	0x7
0x90 to 0xa0	0x6
0xa1 to 0xb1	0x5
0xb2 to 0xc2	0x4
0xc3 to 0xd3	0x3
0xd4 to 0xe4	0x2
0xe5 to 0xf5	0x1
0xf6 to 0xff	0x0

Table 14.19. Font 4-BPP RAW Conversion

For 8-BPP RAW font, a transparency level is equal to 255 - grayscale value.

14.8.3.4 Configuration File

The Font Generator uses a configuration file (called the "list file") for describing fonts that must be processed. The list file is a basic text file where each line describes a font to convert. The font file is described as a resource path, and should be available from the application classpath.

Note

The list file must be specified in the MicroEJ application launcher (see “Appendix E: Application Launch Options”). However, all files in application classpath with suffix .fonts.list are automatically parsed by the Font Generator tool.

Each line can have optional parameters (separated by a ':') which define some ranges of characters to embed in the final raw file, and the required pixel depth. By default, all characters available in the input font file are embedded, and the pixel depth is 1 (i.e 1 bit-per-pixel).

Note

See “Font Generator” to understand the list file grammar.

Selecting only a specific set of characters to embed reduces the memory footprint. There are two ways to specify a character range: the custom range and the known range. Several ranges can be specified, separated by ";" .

Below is an example of a list file for the Font Generator:

```
myfont
myfont1:latin
myfont2:latin:8
myfont3::4
```

Figure 14.33. Fonts Configuration File Example

14.8.3.5 External Resources

The Font Generator manages two configuration files when the External Resources Loader is enabled. The first configuration file lists the fonts which will be stored as internal resources with the MicroEJ application. The second file lists the fonts the Font Generator must convert and store in the External Resource Loader output directory. It is the BSP's responsibility to load the converted fonts into an external memory.

14.8.3.6 Dependencies

- Font Engine Core module (see “Font Engine Core”)

14.8.3.7 Installation

The Font Generator module is an additional tool for MicroUI library. When the MicroUI module is installed, install this module in order to be able to embed some additional fonts with the MicroEJ application.

If the module is not installed, the platform user will not be able to embed a new font with his/her MicroEJ application. He/she will be only able to use the system fonts specified during the MicroUI initialization step (see “Static Initialization”).

In the platform configuration file, check UI > Font Generator to install the Font Generator module.

14.8.3.8 Use

In order to be able to embed ready-to-be-displayed fonts, you must activate the fonts convertion feature and specify the fonts configuration file.

Refer to the chapter “Appendix E: Application Launch Options” (Libraries > MicroUI > Font) for more information about specifying the fonts configuration file.

14.9 Simulation

14.9.1 Principle

A major strength of the MicroEJ environment is that it allows applications to be developed and tested in a simulator rather than on the target device, which might not yet be built. To make this possible for devices that have a display or controls operated by the user (such as a touch screen or buttons), the simulator must connect to a "mock" of the control panel (the "Front Panel") of the device. This mock is called the *mockFP*. The mockFP generates a graphical representation of the required front panel, and is displayed in a window on the user's development machine when the application is executed in the simulator. The mockFP is the equivalent of the three embedded modules (Display, Inputs and LED) of the MicroEJ platform (see “MicroUI”).

The Front Panel mock enhances the development environment by allowing User Interface applications to be designed and tested on the computer rather than on the target device (which may not yet be built). The mock interacts with the user's computer in two ways:

- output: LEDs, graphical displays
- input: buttons, joystick, touch, haptic sensors

14.9.2 Functional Description

1. Creates a new Front Panel project.
2. Creates an image of the required front panel. This could be a photograph or a drawing.
3. Defines the contents and layout of the front panel by editing an XML file (called an fp file). Full details about the structure and contents of fp files can be found in chapter “Front Panel”.
4. Creates images to animate the operation of the controls (for example button down image).
5. Creates *Listeners* that generate the same MicroUI input events as the hardware.
6. Creates a *Display Extension* that configures the simulated display to match the real display.
7. Previews the front panel to check the layout of controls and the events they create, etc.
8. Exports the Front Panel project into a MicroEJ platform project.

14.9.3 The Front Panel Project

14.9.3.1 Creating a Front Panel Project

A Front Panel project is created using the New Front Panel Project wizard. Select:

New > Project... > MicroEJ > Front Panel Project

The wizard will appear:

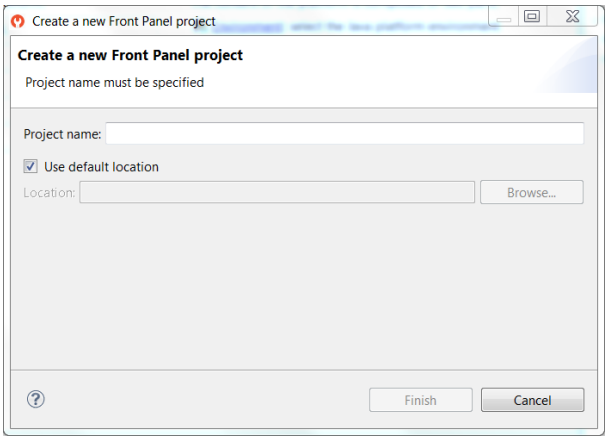


Figure 14.34. New Front Panel Project Wizard

Enter the name for the new project.

14.9.3.2 Project Contents

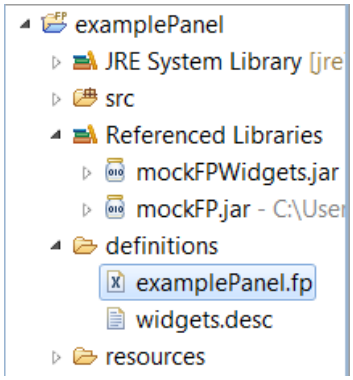


Figure 14.35. Project Contents

A Front Panel project has the following structure and contents:

- The src folder is provided for the definition of Listeners and DisplayExtensions. It is initially empty. The creation of Listeners and DisplayExtensions will be explained later.
- The JRE System Library is referenced, because a Front Panel project needs to support the writing of Java for the Listeners and DisplayExtensions.
- The mockFPWidgets.jar contains the code for the front panel simulation, the widgets it supports and the types needed to implement Listeners and DisplayExtensions.
- The definitions folder holds the file or files that define the contents and layout of the front panel, with a .fp extension (the fp file or files), plus some supporting files. A newly created project will have a single fp file with the same name as the project, as shown above. The contents of fp files are detailed later in this document.
- The widgets.desc file contains descriptions of the widgets supplied with the Front Panel Designer. It is used by the Front Panel Designer tool and must not be edited.
- The resources folder holds images used to create the mockFP. It is initially empty.

14.9.4 FP File

14.9.4.1 File Contents

The mock engine takes an XML file (the fp file) as input. It describes the panel using mock-widgets: They simulate the drivers, sensors and actuators of the real device. The mock engine generates the

graphical representation of the real device, and is displayed in a window on the user's development machine when the application is executed in the simulator.

The following example file describes a typical board with one LCD, a touch panel, three buttons, a joystick and four LEDs:

```
<?xml version="1.0"?>
<frontpanel
 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 xmlns="http://xml.is2t.com/ns/1.0/frontpanel"
 xsi:schemaLocation="http://xml.is2t.com/ns/1.0/frontpanel .fp1.0.xsd">

 <description file="widgets.desc"/>

 <device name="MyBoard" skin="myboard.png">
  <body>
   <pixelatedDisplay id="0" x="162" y="114" width="320" height="240" initialColor="0x000000"/>
   <pointer id="0" x="162" y="114" width="320" height="240" touch="true"
listenerClass="com.is2t.microej.fp.PointerListenerImpl"/>

   <led2states id="0" x="277" y="374" ledOff="led0_0.png" ledOn="led0_1.png" overlay="false"/>
   <led2states id="1" x="265" y="374" ledOff="led1_0.png" ledOn="led1_1.png" overlay="false"/>
   <led2states id="2" x="254" y="374" ledOff="led2_0.png" ledOn="led2_1.png" overlay="false"/>
   <led2states id="3" x="242" y="372" ledOff="led3_0.png" ledOn="led3_1.png" overlay="false"/>

   <repeatPush id="0" x="250" y="395" skin="Button1_0.png" pushedSkin="Button1_1.png" repeatPeriod="250"
listenerClass="com.is2t.microej.fp.ButtonListener"/>
   <repeatPush id="1" x="322" y="395" skin="Button1_0.png" pushedSkin="Button1_1.png" repeatPeriod="250"
listenerClass="com.is2t.microej.fp.ButtonListener"/>
   <repeatPush id="2" x="456" y="395" skin="Button1_0.png" pushedSkin="Button1_1.png" repeatPeriod="250"
listenerClass="com.is2t.microej.fp.ButtonListener"/>
   <joystick id="0" x="368" y="375" skin="Joy0.png" mask="JoyMask.png" enterSkin="Joy1.png"
upSkin="Joy_UP.png" downSkin="Joy_DOWN.png" leftSkin="Joy_LEFT.png" rightSkin="Joy_RIGHT.png"
listenerClass="com.is2t.microej.fp.JoystickListenerImpl"/>
  </body>
 </device>
</frontpanel>
```

The description element must appear exactly as shown. It refers to the widgets.desc file mentioned above.

The device skin must refer to a png file in the resources folder. This image is used to render the background of the front panel. The widgets are drawn on top of this background.

The body element contains the elements that define the widgets that make up the front panel. The name of the widget element defines the type of widget. The set of valid types is determined by the Front Panel Designer. Every widget element defines an id, which must be unique for widgets of this type, and the x and y coordinates of the position of the widget within the front panel (0,0 is top left). There may be other attributes depending on the type of the widget.

The file and tags specifications are available in chapter “Front Panel”.

14.9.4.2 Working with fp Files

To edit an fp file, open it using the Eclipse XML editor (right-click on the fp file, select **Open With > XML Editor**). This editor features syntax highlighting and checking, and content-assist based on the schema (XSD file) referenced in the fp file. This schema is a hidden file within the project's definitions folder. An incremental builder checks the contents of the fp file each time it is saved and highlights problems in the **Eclipse Problems** view, and with markers on the fp file itself.

A preview of the front panel can be obtained by opening the Front Panel Preview (**Window > Show View > Other... > MicroEJ > Front Panel Preview**).

The preview updates each time the fp file is saved.

A typical working layout is shown below.

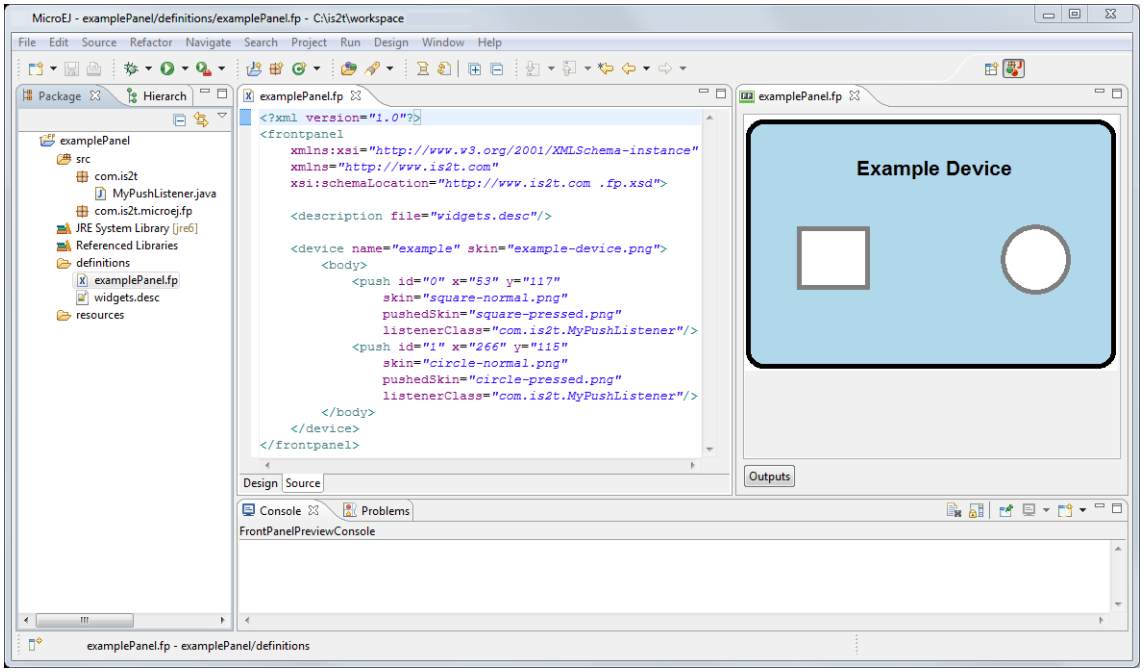


Figure 14.36. Working Layout Example

Within the XML editor, content-assist is obtained by pressing **ctrl+space**. The editor will list all the elements valid at the cursor position, and insert a template for the selected element.

14.9.4.3 Skins and Filters

The widgets which simulate the input devices use images (or "skins") to show their current states (pressed and released). The user can change the state of the widget by clicking anywhere on the skin: it is the active area. This active area is, by default, rectangular.

These skins can be associated with an additional image called a filter or mask. This image defines the widget's active area. It is useful when the widget is not rectangular.

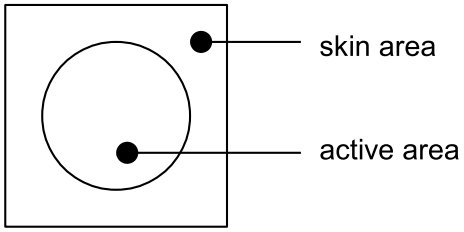


Figure 14.37. Active Area

The filter image must have the same size as the skin image. The active area is delimited by the color 0xFF00FF (pink). Every pixel in the filter image which is not this color is considered not part of the active area.

14.9.4.4 Display Mask

By default, a display area is rectangular. Some displays can have another appearance (for instance: circular). The front panel is able to simulate that using a mask. This mask defines the pixels inside and outside the real display area. The mask image must have the same size than display rectangular area. A display pixel at a given position will be not rendered if the pixel at the same position in mask is fully transparent.

14.9.5 Inputs Extensions

The mock engine also requires several extensions to know how to react to input events. The extension names (package and classname) are specified in the fp file.

14.9.5.1 Widgets and Listeners

For widgets that generate events, a Listener class must be specified within the .fp file.

As an example, consider this snippet of an .fp file for defining a push button:

```
<push id="0" x="54" y="117"
  skin="square-normal.png"
  pushedSkin="square-pressed.png"
  listenerClass="com.is2t.MyPushListener" />
```

Figure 14.38. .fp File - Push Example

The value of the listenerClass attribute is the fully qualified name of a class which has to implement the com.is2t.microej.frontpanel.input.listener.PushButtonListener interface. This class, com.is2t.MyPushListener, is written by the developer, and implements the PushButtonListener interface.

The package com.is2t.microej.frontpanel.input.listener provides Listeners required by other widgets too:

- push requires PushButtonListener
- repeatPush requires RepeatButtonListener
- joystick requires JoystickListener
- pointer requires PointerListener

A listener implementation can target several widgets. Each action method receives the ID of the widget that has changed as a parameter.

14.9.5.2 Event Generator

The Listener needs to be written to generate the same events that the hardware will. In order to send an event, the implementation of a Listener needs to use the EventGenerator class provided. For example, a PushButtonListener can generate button events by calling static methods sendButtons[...]Event.

Note

A Listener can generate events using any methods of the provided EventGenerator. In some cases, this may provide useful functionality.

Each EventGenerator method requires a unique ID of the MicroUI event generator it targets. This unique ID is available in the interface com.is2t.microej.microui.Constants which has been generated by the Static MicroUI Initializer tool.

The EventGenerator class targets six MicroUI event generators:

- EventGenerator: sendEvent, sendEvents
- CommandEventGenerator: sendCommandEvent
- ButtonsEventGenerator: sendButtons[...]Event
- PointerEventGenerator: sendPointer[...]Event
- TouchEventGenerator: sendTouch[...]Event

- StatesEventGenerator: sendState[...]Event

14.9.6 Image Decoders

Front Panel uses its own internal image decoders when the internal image decoders related modules have been selected (see “Internal Decoders”).

Front Panel can add some additional decoders like the C-side for the embedded platform (see “External Decoders”). However, the exhaustive list of additional decoders is limited (Front Panel is using the Java AWT ImageIO API). To add an additional decoder, specify the property hardwareImageDecoders.list in front panel configuration properties file (see “Installation”) with one or several property values:

Type	Property value
Graphics Interchange Format (GIF)	gif
Joint Photographic Experts Group (JPEG)	jpeg | jpg
Portable Network Graphics (PNG)	png
Windows bitmap (BMP)	bmp

Table 14.20. Front Panel Additional Image Decoders

The decoders list is comma (,) separated. Example:

```
hardwareImageDecoders.list=jpg,bmp
```

14.9.7 Dependencies

- MicroUI module (see “MicroUI”).
- Display module (see “Display”): This module gives the characteristics of the graphical display that are useful for configuring the Front Panel.

14.9.8 Installation

Front Panel is an additional module for MicroUI library. When the MicroUI module is installed, install this module in order to be able to simulate UI drawings on the simulator.

In the platform configuration file, check UI > Front Panel to install the Front Panel module. When checked, the properties file frontpanel > frontpanel .properties is required during platform creation to configure the module. This configuration step is used to identify and configure the front panel.

The properties file must / can contain the following properties:

- project.name [mandatory]: Defines the name of the front panel project (same workspace as the platform configuration project). If the project name does not exist, a new project will be created.
- fpFile.name [optional, default value is "" (*empty*)]: Defines the front panel file (*.fp) to export (in case "project.name" contains several fp files). If empty or unspecified, the first ".fp" file found will be exported.
- hardwareImageDecoders.list [optional, default value is "" (*empty*)]: Defines the available list of additional image decoders provided by the hardware. Use comma (',') to specify several decoders among this list: bmp, jpg, jpeg, gif, png. If empty or unspecified, no image decoder is added.

14.9.9 Use

Launch a MicroUI application on the simulator to run the Front Panel.

15 Networking

15.1 Principle

MicroEJ provides some foundation libraries to initiate raw TCP/IP protocol-oriented communications and secure this communication by using Secure Socket Layer (SSL) or Transport Layer Security (TLS) cryptographic protocols.

The diagram below shows a simplified view of the components involved in the provisioning of a Java network interface.

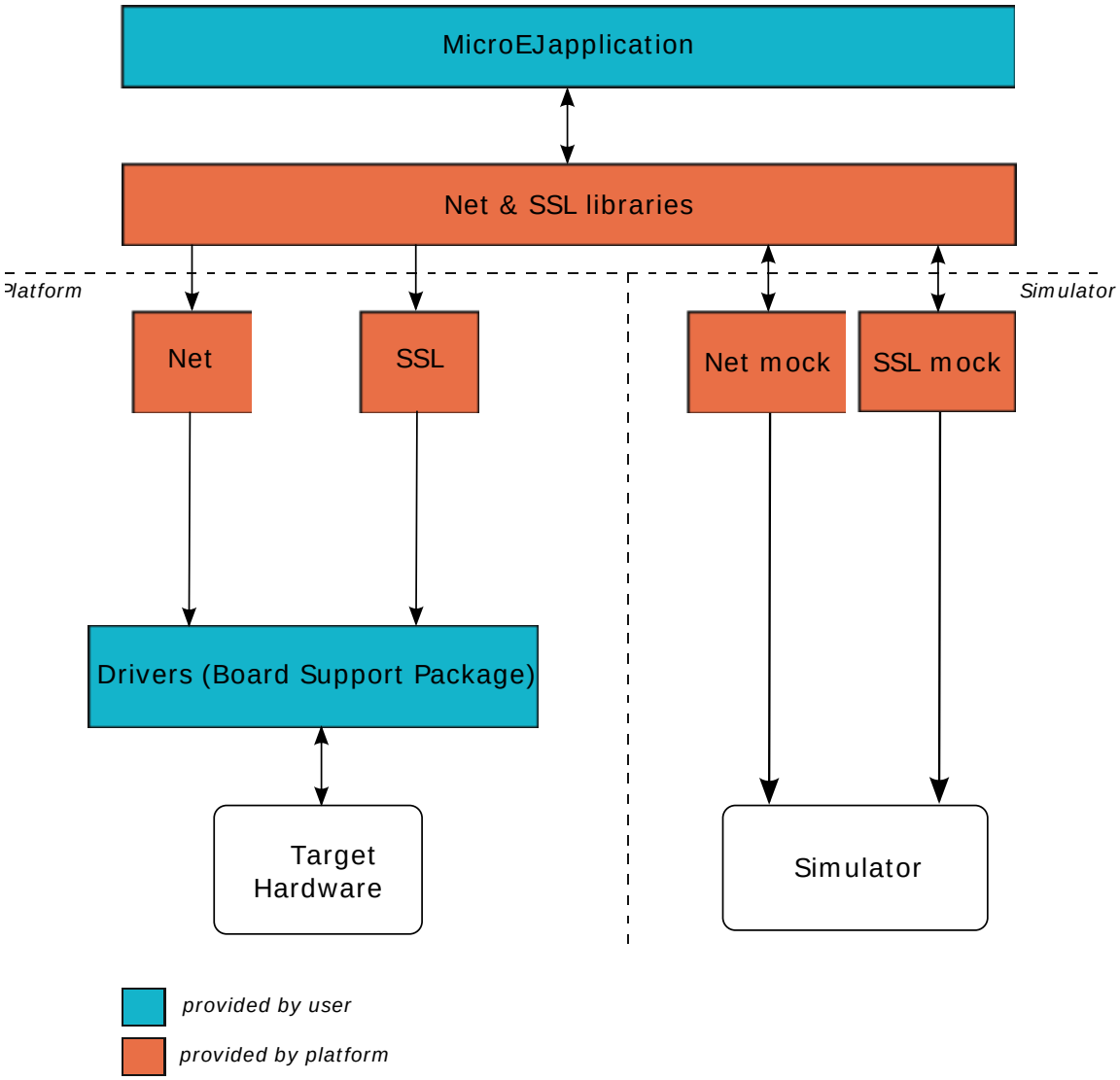


Figure 15.1. Overview

Net and SSL low level parts connects the Net and SSL libraries to the user-supplied drivers code (coded in C).

The MicroEJ simulator provides all features of Net and SSL libraries. This one takes part of the network settings stored in the operating system on which the simulator will be launched.

15.2 Network Core Engine

15.2.1 Principle

The Net module defines a low-level network framework for embedded devices. This module allows you to manage connection (TCP)- or connectionless (UDP)-oriented protocols for client/server networking applications.

15.2.2 Functional Description

15.2.2 Functional Description

The Net library includes two sub-protocols:

- UDP: a connectionless-oriented protocol that allows communication with the server or client side in a non-reliable way. No handshake mechanisms, no guarantee on delivery, and no order in packet sending.
- TCP: a connection-oriented protocol that allows communication with the server or client side in a reliable way. Handshakes mechanism used, bytes ordered, and error checking performed upon delivery.

15.2.3 Dependencies

- LLNET_CHANNEL_impl.h, LLNET_SOCKETCHANNEL_impl.h, LLNET_STREAMSOCKETCHANNEL_impl.h, LLNET_DATAGRAMSOCKETCHANNEL_impl.h, LLNET_DNS_impl.h, LLNET_NETWORKADDRESS_impl.h, LLNET_NETWORKINTERFACE_impl.h (see “LLNET: Network”).

15.2.4 Installation

Network is an additional module. In the platform configuration file, check NET to install this module. When checked, the properties file net > net.properties is required during platform creation to configure the module. This configuration step is used to customize the kind of TCP/IP native stack used and the Domain Name System (DNS) implementation.

The properties file must / can contain the following properties:

- stack [optional, default value is "custom"]: Defines the kind of TCP/IP interface used in the C project.
  - custom: Select this configuration to make a "from scratch" implementation glue between the C Network Core Engine and the C project TCP/IP interface.
  - bsd: Select this configuration to use a BSD-like library helper to implement the glue between the C Network Core Engine and the C project TCP/IP interface. This property requires that the C project provides a TCP/IP native stack with a Berkeley Sockets API and a select mechanism.
- dns [optional, default value is "native"]: Defines the kind of Domain Name System implementation used.
  - native: Select this configuration to implement the glue between the C Network Core Engine DNS part and the C project TCP/IP interface.
  - soft: Select this configuration if you want a software implementation of the DNS part. Only the IPs list of the DNS server must be provided by the C Network Core Engine glue.

15.2.5 Use

A classpath variable named NET-1.1 is available.

This library provides a set of options. Refer to the chapter “Appendix E: Application Launch Options” which lists all available options.

15.3 SSL

15.3.1 Principle

SSL (Secure Sockets Layer) library provides APIs to create and establish an encrypted connection between a server and a client. It implements the standard SSL/TLS (Transport Layer Security) protocol that manages client or server authentication and encrypted communication.

15.3.2 Functional Description

The SSL/TLS process includes two sub-protocols :

- Handshake protocol : consists that a server presents its digital certificate to the client to authenticate the server's identity. The authentication process uses public-key encryption to validate the digital certificate and confirm that a server is in fact the server it claims to be.
- Record protocol : after the server authentication, the client and the server establish cipher settings to encrypt the information they exchange. This provides data confidentiality and integrity.

15.3.3 Dependencies

- Network core module (see “Network Core Engine”).
- LLNET_SSL_CONTEXT_impl.h, LLNET_SSL_SOCKET_impl.h and LLNET_SSL_X509_CERT_impl.h implementations (see “LLNET_SSL: SSL”).

15.3.4 Installation

SSL is an additional module. In the platform configuration file, check SSL to install the module.

15.3.5 Use

A classpath variable named SSL-2.0 is available.

16 File System

16.1 Principle

The FS module defines a low-level File System framework for embedded devices. It allows you to manage abstract files and directories without worrying about the native underlying File System kind.

16.2 Functional Description

The MicroEJ application manages File System elements using File/Directory abstraction. The FS implementation made for each MicroEJ platform is responsible for surfacing the native File System specific behavior.

16.3 Dependencies

- LLFS_impl.h and LLFS_File_impl.h implementations (see “LLFS: File System”).

16.4 Installation

FS is an additional module. In the platform configuration file, check FS to install it. When checked, the properties file fs > fs.properties are required during platform creation in order to configure the module.

The properties file must / can contain the following properties:

- fs [optional, default value is "Custom"]: Defines the kind of File System native stack used in the C project.
  - Custom: select this configuration to make a specific File System portage.
  - FatFS: select this configuration to use FatFS native File System-compliant settings.
- root.dir [optional, for a FatFS File System. Mandatory, for a Custom File System.]: Defines the native File System root volume (default value is "/" for FatFS).
- user.dir [optional, for a FatFS File System. Mandatory, for a Custom File System.]: Defines the native File System user directory (default value is "/usr" for FatFS).
- tmp.dir [optional, for a FatFS File System. Mandatory, for a Custom File System.]: Defines the native File System temporary directory (default value is "/tmp" for FatFS).
- file.separator [optional, for a FatFS File System. Mandatory, for a Custom File System.]: Defines the native File System file separator (default value is "/" for FatFS).
- path.separator [optional, for a FatFS File System. Mandatory, for a Custom File System.]: Defines the native File System path separator (default value is ":" for FatFS).

16.5 Use

A classpath variable named FS-2.0 is available.

17 Hardware Abstraction Layer

17.1 Principle

The Hardware Abstraction Layer (HAL) library features API that target IO devices, such as GPIOs, analog to/from digital converters (ADC / DAC), etc. The API are very basic in order to be as similar as possible to the BSP drivers.

17.2 Functional Description

The MicroEJ application configures and uses some physical GPIOs, using one unique identifier per GPIO. The HAL implementation made for each MicroEJ platform has the responsability of verifying the veracity of the GPIO identifier and the valid GPIO configuration.

Theoretically, a GPIO can be reconfigured at any time. For example a GPIO is configured in OUTPUT first, and later in ADC entry. However the HAL implementation can forbid the MicroEJ application from performing this kind of operation.

17.3 Identifier

17.3.1 Basic Rule

MicroEJ application manipulates anonymous identifiers used to identify a specific GPIO (port and pin). The identifiers are fixed by the HAL implementation made for each MicroEJ platform, and so this implementation is able to make the link between the MicroEJ application identifiers and the physical GPIOs.

- A port is a value between 0 and n - 1, where n is the available number of ports.
- A pin is a value between 0 and m - 1, where m is the maximum number of pins per port.

17.3.2 Generic Rules

Most of time the basic implementation makes the link between the port / pin and the physical GPIO following these rules:

- The port 0 targets all MCU pins. The first pin of the first MCU port has the ID 0, the second pin has 1; the first pin of the next MCU port has the ID m (where m is the maximum number of pins per port), etc. Examples:

```
/* m = 16 (16 pins max per MCU port) */
mcu_pin = application_pin & 0xf;
mcu_port = (application_pin >> 4) + 1;
```

```
/* m = 32 (32 pins max per MCU port) */
mcu_pin = application_pin & 0x1f;
mcu_port = (application_pin >> 5) + 1;
```

- The port from 1 to n (where n is the available number of MCU ports) targets the MCU ports. The first MCU port has the ID 1, the second has the ID 2, and the last port has the ID n.
- The pin from 0 to m - 1 (where m is the maximum number of pins per port) targets the port pins. The first port pin has the ID 0, the second has the ID 1, and the last pin has the ID m - 1.

The implementation can also normalize virtual and physical board connectors. A physical connector is a connector available on the board, and which groups several GPIOs. The physical connector is usually called JPn or CNn, where n is the connector ID. A virtual connector represents one or several physical connectors, and has a *name*; for example ARDUINO_DIGITAL.

Using a unique ID to target a virtual connector allows you to make an abstraction between the MicroEJ application and the HAL implementation. For exmaple, on a board A, the pin D5 of ARDUINO_DIGITAL port will be connected to the MCU portA, pin12 (GPIO ID = 1, 12). And on board B, it will be connected to the MCU port5, pin0 (GPIO ID = 5, 0). From the MicroEJ application point of view, this GPIO has the ID 30, 5.

Standard virtual connector IDs are:

```
ARDUINO_DIGITAL = 30;
ARDUINO_ANALOG = 31;
```

Finally, the available physical connectors can have a number from 64 to 64 + i - 1, where i is the available number of connectors on the board. This allows the application to easily target a GPIO that is available on a physical connector, without knowing the corresponding MCU port and pin.

```
JP3 = 64;
JP6 = 65;
JP11 = 66;
```

17.4 Configuration

A GPIO can be configured in any of five modes:

- Digital input: The MicroEJ application can read the GPIO state (for example a button state).
- Digital input pull-up: The MicroEJ application can read the GPIO state (for example a button state); the default GPIO state is driven by a pull-up resistor.
- Digital output: The MicroEJ application can set the GPIO state (for example to drive an LED).
- Analog input: The MicroEJ application can convert some incoming analog data into digital data (ADC). The returned values are values between 0 and n - 1, where n is the ADC precision.
- Analog output: The MicroEJ application can convert some outgoing digital data into analog data (DAC). The digital value is a percentage (0 to 100%) of the duty cycle generated on selected GPIO.

17.5 Dependencies

- LLHAL_impl.h implementation (see “LLHAL: Hardware Abstraction Layer”).

17.6 Installation

HAL is an additional module. In the platform configuration file, check HAL to install the module.

17.7 Use

A classpath variable named HAL-1.0 is available.

18 Device Information

18.1 Principle

The Device library provides access to the device information. This includes the architecture name and a unique identifier of the device for this architecture.

18.2 Dependencies

- LLDEVICE_impl.h implementation (see “LLDEVICE: Device Information”).

18.3 Installation

Device Information is an additional module. In the platform configuration file, check Device Information to install it. When checked, the property file device > device.properties may be defined during platform creation to customize the module.

The properties file must / can contain the following properties:

- architecture [optional, default value is "Virtual Device"]: Defines the value returned by the ej.util.Device.getArchitecture() method on the simulator.
- id.length [optional]: Defines the size of the ID returned by the ej.util.Device.getId() method on the simulator.

18.4 Use

A classpath variable named DEVICE-1.0 is available.

19 Development Tools

MicroEJ provides several development tools to help to develop and debug the MicroEJ application. Some tools are common for the Embedded platform and for the Simulator, some others are only for one of both.

19.1 Memory Map Analyzer

19.1.1 Principle

When a MicroEJ application is linked with the MicroEJ workbench, a Memory MAP file is generated. The Memory Map Analyzer (MMA) is an Eclipse plug-in made for exploring the map file. It displays the memory consumption of different features in the RAM and ROM.

19.1.2 Functional Description

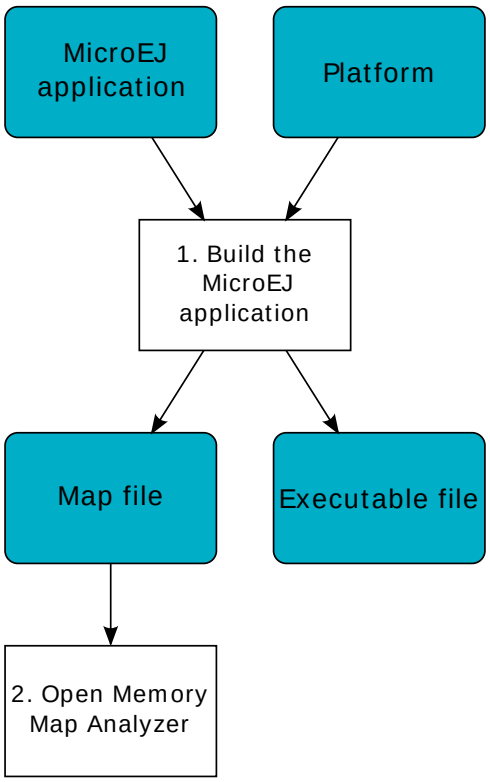


Figure 19.1. Memory Map Analyzer Process

In addition to the executable file, the MicroEJ platform generates a map file. Double click on this file to open the Memory Map Analyzer.

19.1.3 Dependencies

No dependency.

19.1.4 Installation

This tool is a built-in platform tool.

19.1.5 Use

The map file is available in the MicroEJ application project output directory.

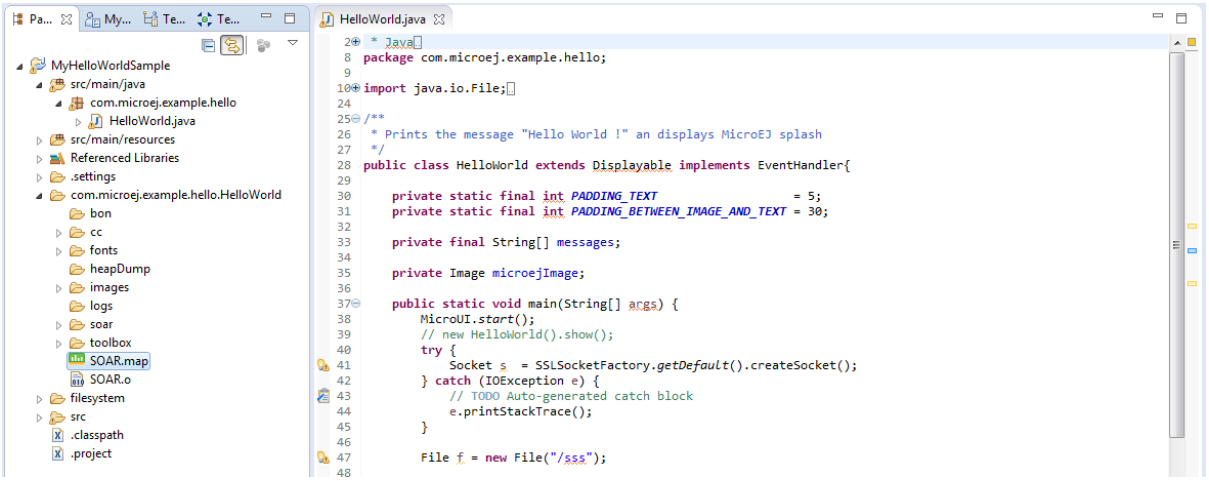


Figure 19.2. Retrieve Map File

Select an item (or several) to show the memory used by this item(s) on the right. Select "All" to show the memory used by all items. This special item performs the same action as selecting all items in the list.

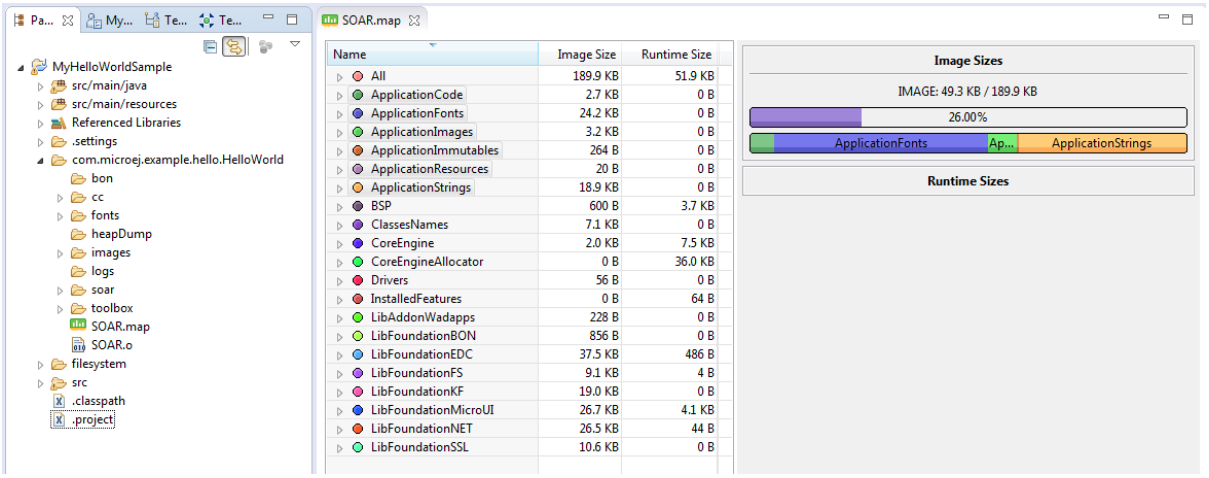


Figure 19.3. Consult Full Memory

Select an item in the list, and expand it to see all symbols used by the item. This view is useful in understanding why a symbol is embedded.

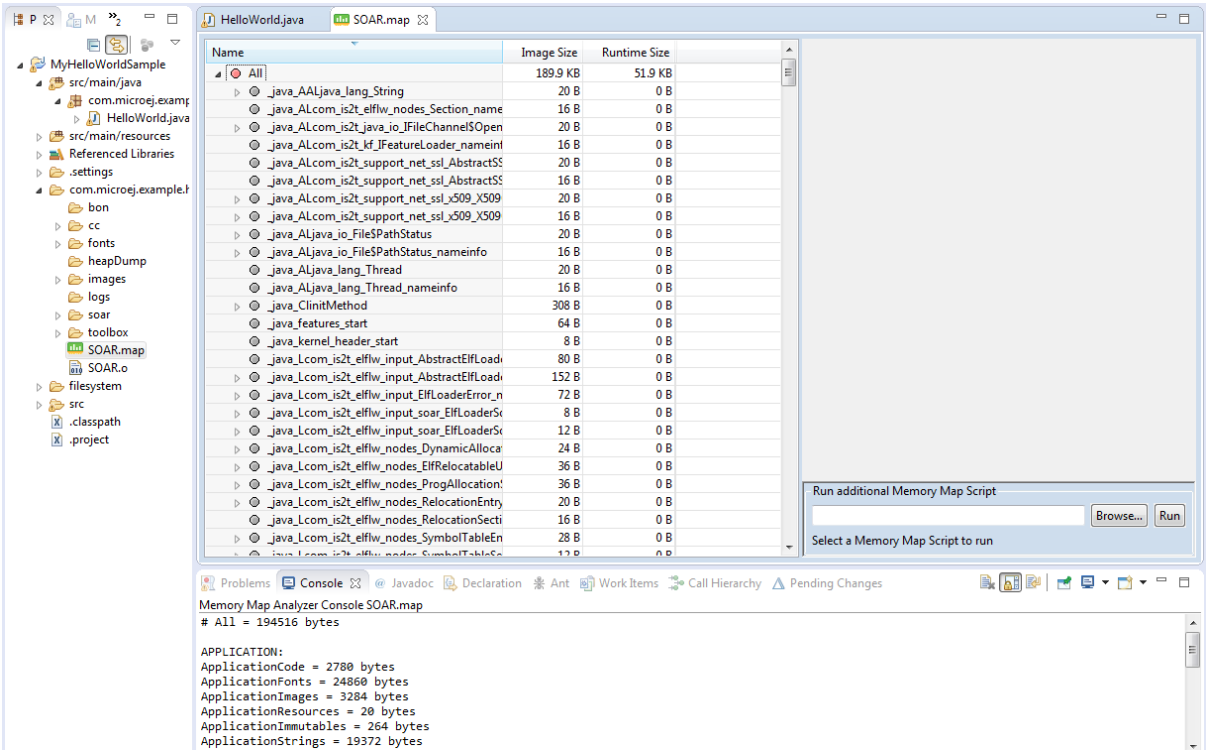


Figure 19.4. Detailed View

19.2 Stack Trace Reader

19.2.1 Principle

Stack Trace Reader is a MicroEJ tool which reads and decodes the MicroEJ stack traces. When an exception occurs, the MicroEJ Core Engine prints the stack trace on the standard output System.out. The class names and method names obtained are encoded with a MicroEJ internal format. This internal format prevents the embedding of all class names and method names in the flash, in order to save some memory space. The Stack Trace Reader tool allows you to decode the stack traces by replacing the internal class names and method names with their real names. It also retrieves the line number in the MicroEJ application.

19.2.2 Functional Description

The Stack Trace Reader reads the debug info from the fully linked ELF file (the ELF file that contains the MicroEJ Core Engine, the other libraries, the BSP, the OS, and the compiled MicroEJ application). It prints the decoded stack trace.

19.2.3 Dependencies

No dependency.

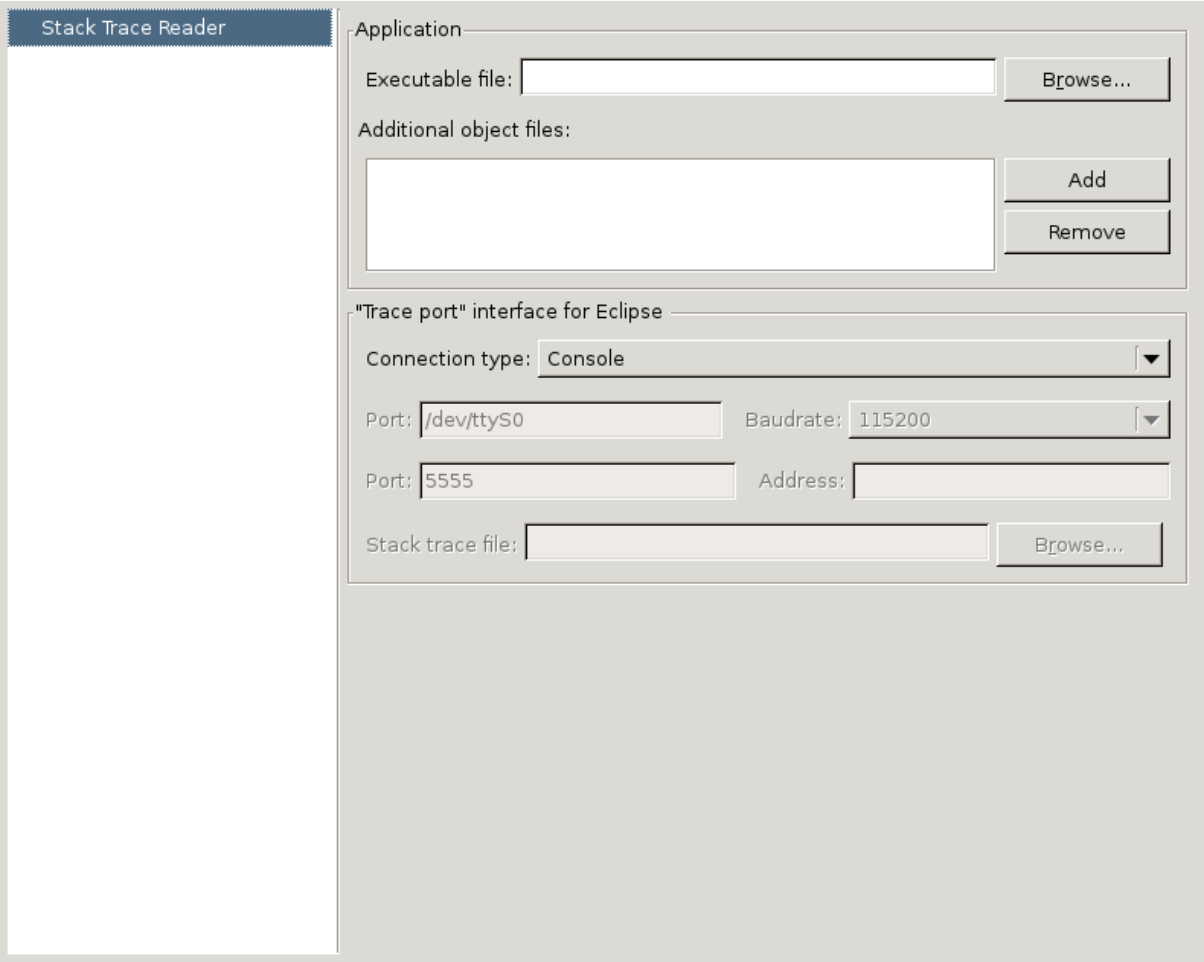
19.2.4 Installation

This tool is a built-in platform tool.

19.2.5 Use

This chapter explains MicroEJ tool options.

19.2.5.1 Category: Stack Trace Reader



19.2.5.1.1 Group: Application

19.2.5.1.1.1 Option(browse): Executable file

Default value: (empty)

Description:

Specify the full path of a full linked elf file.

19.2.5.1.1.2 Option(list): Additional object files

Default value: (empty)

19.2.5.1.2 Group: "Trace port" interface for Eclipse

Description:

This group describes the hardware link between the device and the PC.

19.2.5.1.2.1 Option(combo): Connection type

Default value: Console

Available values:

Uart (COM)

Socket

File

Console

Description:

Specify the connection type between the device and PC.

19.2.5.1.2.2 Option(text): Port

Default value: /dev/ttyS0

Description:

Format: port name

Specifies the PC COM port:

Windows - COM1, COM2, ..., COM*n*

Linux - /dev/ttyS0, /dev/ttyS1, ..., /dev/ttyS*n*

19.2.5.1.2.3 Option(combo): Baudrate

Default value: 115200

Available values:

9600

38400

57600

115200

Description:

Defines the COM baudrate for PC-Device communication.

19.2.5.1.2.4 Option(text): Port

Default value: 5555

Description:

IP port.

19.2.5.1.2.5 Option(text): Address

Default value: (empty)

Description:

IP address, on the form A.B.C.D.

19.2.5.1.2.6 Option(browse): Stack trace file

Default value: (empty)

19.3 Code Coverage Analyzer

19.3.1 Principle

The MicroEJ simulator features an option to output .cc (Code Coverage) files that represent the use rate of functions of an application. It traces how the opcodes are really executed.

19.3.2 Functional Description

The Code Coverage Analyzer scans the output .cc files, and outputs an HTML report to ease the analysis of methods coverage. The HTML report is available in a folder named htmlReport in the same folder as the .cc files.

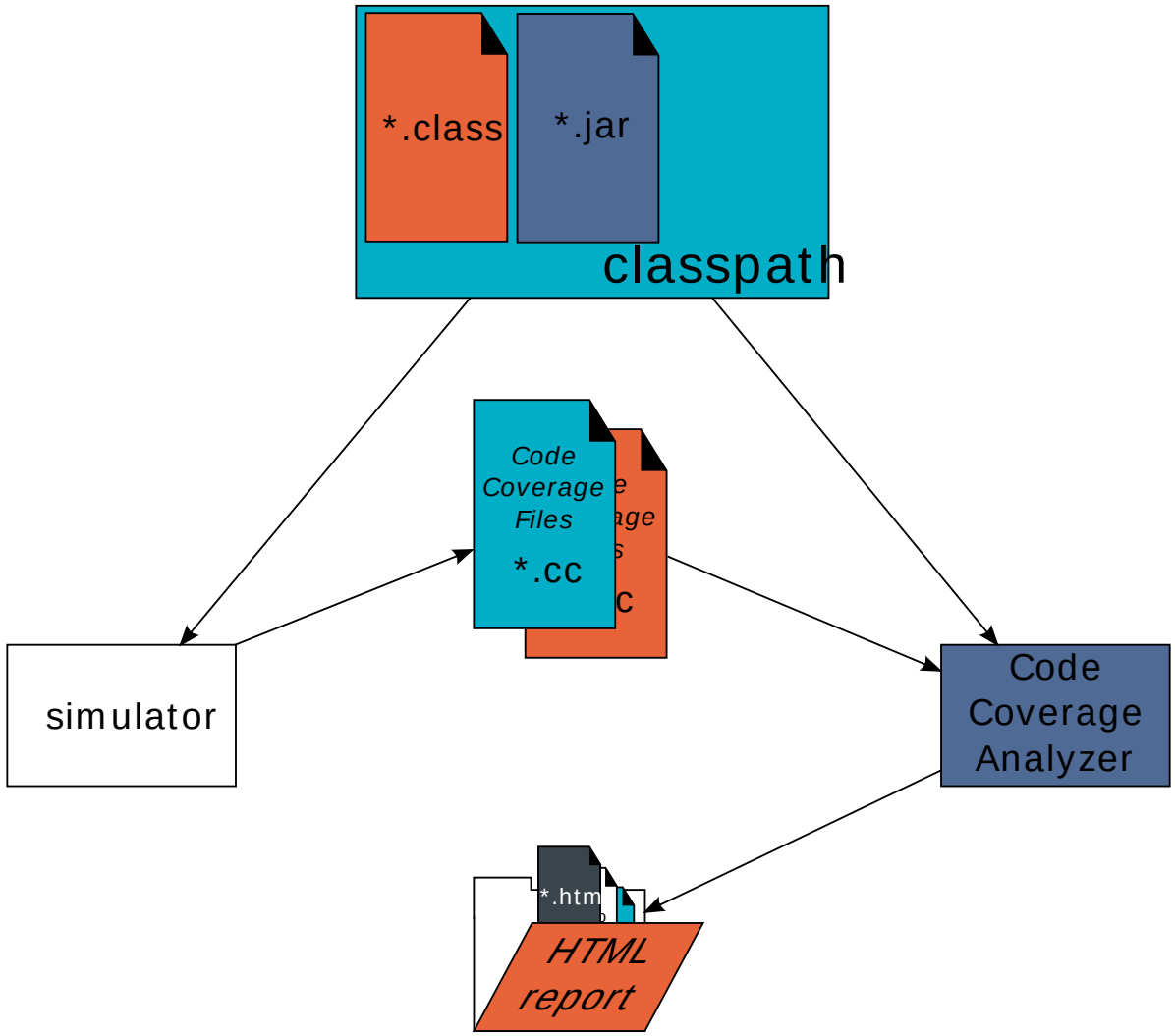


Figure 19.5. Code Coverage Analyzer Process

19.3.3 Dependencies

In order to work properly, the Code Coverage Analyzer should input the .cc files. The .cc files relay the classpath used during the execution of the simulator to the Code Coverage Analyzer. Therefore the classpath is considered to be a dependency of the Code Coverage Analyzer.

19.3.4 Installation

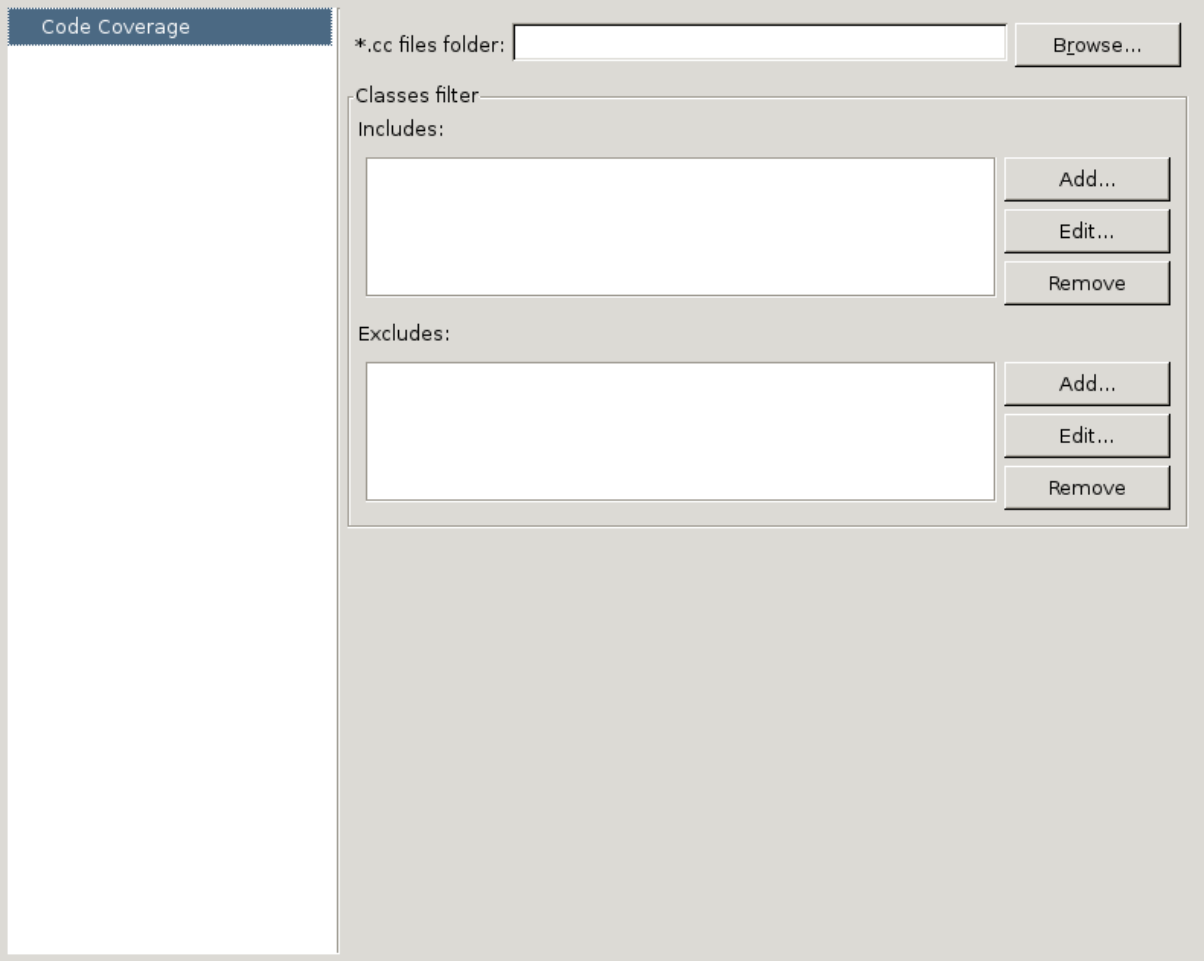
This tool is a built-in platform tool.

19.3.5 Use

A MicroEJ tool is available to launch the Code Coverage Analyzer tool. The tool name is **Code Coverage Analyzer**.

Two levels of code analysis are provided, the Java level and the bytecode level. Also provided is a view of the fully or partially covered classes and methods. From the HTML report index, just use hyperlinks to navigate into the report and source / bytecode level code.

19.3.5.1 Category: Code Coverage



19.3.5.1.1 Option(browse): *.cc files folder

Default value: (empty)

Description:

Specify a folder which contains the cc files to process (*.cc).

19.3.5.1.2 Group: Classes filter

19.3.5.1.2.1 Option(list): Includes

Default value: (empty)

Description:

List packages and classes to include to code coverage report. If no package/class is specified, all classes found in the project classpath will be analyzed.

Examples:

packageA.packageB.*: includes all classes which are in package packageA.packageB

packageA.packageB.className: includes the class packageA.packageB.className

19.3.5.1.2.2 Option(list): Excludes

Default value: (empty)

Description:

List packages and classes to exclude to code coverage report. If no package/class is specified, all classes found in the project classpath will be analyzed.

Examples:

packageA.packageB.*: excludes all classes which are in package packageA.packageB

packageA.packageB.className: excludes the class packageA.packageB.className

19.4 Heap Dumper & Heap Analyzer

19.4.1 Principle

The heap is a memory area used to hold Java objects created at runtime. Objects persist in the heap until they are garbage-collected. An object becomes eligible for garbage collection when there are no longer any references to it from other objects.

Heap Dumper is a tool that takes a snapshot of the heap. Generated files (with the .heap extension) are available on the application output folder. Note that it works only on simulations.

For its part, the Heap Analyzer plug-in is able to open dump files. It helps you analyze their contents thanks to the following features:

- memory leaks detection
- objects instances browse
- heap usage optimization (using immortal or immutable objects)

19.4.2 Dependencies

No dependency.

19.4.3 Installation

This tool is a built-in platform tool.

19.4.4 Use

When the Heap Dumper option is activated, the garbage collector process ends by performing a dump file that represent a snapshot of the heap at this moment. Thus, to generate such dump files, you must explicitly call the System.gc() method in your code, or wait long enough for garbage collector activation.

The heap dump file contains the list of all instances of both class and array types that exist in the heap. For each instance it records:

- the time at which the instance was created
- the thread that created it
- the method that created it

For instances of class types, it also records:

- the class
- the values in the instance's non-static fields

For instances of array types, it also records:

- the type of the contents of the array
- the contents of the array

For each referenced class type, it records the values in the static fields of the class.

For more information about using the Heap Analyzer plug-in, please refer to the menu **Help > Help Contents > Heap Analyzer User Guide.**

19.5 Test Suite Engine

19.5.1 Definition

The MicroEJ Test-Suite is an engine made for validating any development project using automatic testing. The MicroEJ Test-Suite engine allows the user to test any kind of projects within the configuration of a generic ant file.

19.5.2 Using the MicroEJ Test-Suite Ant tasks

Multiple Ant tasks are available in the testsuite-engine provided jar:

- testsuite allows the user to run a given test suite and to retrieve an XML report document in a JUnit format.
- javaTestsuite is a subtask of the testsuite task, used to run a specialized test suite for Java (will only run Java classes).
- htmlReport is a task which will generate an HTML report from a list of JUnit report files.

19.5.2.1 The test suite task

This task have some mandatory attributes to fill:

- outputDir: the output folder of the test-suite. The final report will be generated at [outputDir]/[label]/[reportName].xml, see the testsuiteReportFileProperty and testsuiteReportDirProperty attributes.
- harnessScript: the harness script must be an Ant script and it is the script which will be called for each test by the test-suite engine. It is called with a basedir located at output location of the current test. The test-suite engine will provide to it some properties giving all the informations to start the test:
  - testsuite.test.name: The output name of the current test in the report. Default value is the relative path of the test. It can be manually set by the user. More details on the output name are available in the section Specific custom properties.
  - testsuite.test.path: The current test absolute path in the filesystem.
  - testsuite.test.properties: The absolute path to the custom properties of the current test (see the property customPropertiesExtension)
  - testsuite.common.properties: The absolute path to the common properties of all the tests (see the property commonProperties)
  - testsuite.report.dir: The absolute path to the directory of the final report.

Some attributes are optional, and if not set by the user, a default value will be attributed.

- timeOut: the time in seconds before any test is considerated as unknown. Set it to 0 to disable the time-out. Will be defaulted as 60.
- verboseLevel: the required level to output messages from the test-suite. Can be one of those values: error, warning, info, verbose, debug. Will be defaulted as info.
- reportName: the final report name (without extension). Default value is testsuite-report.
- customPropertiesExtension: the extension of the custom properties for each test. For instance, if it is set to .options, a test named xxx/Test1.class will be associated with xxx/Test1.options. If a file exists for a test, the property testsuite.test.properties is set with its absolute path and given to the harnessScript. If the test path references a directory, then the custom properties path is the concatenation of the test path and the customPropertiesExtension value. By default, custom properties extension is .properties.
- commonProperties: the properties to apply to every test of the test-suite. Those options might be overridden by the custom properties of each test. If this option is set and the file exists, the property testsuite.common.properties is set to the absolute path of the harnessScript file. By default, there is not any common properties.
- label: the build label. Will be generated as a timestamp by the test-suite if not set.
- productName: the name of the current tested product. Default value is TestSuite.
- jvm: the location of your Java VM to start the test suite (the harnessScript is called as is: [jvm] [...] -buildfile [harnessScript]). Will be defaulted as your java.home location if the property is set, or to java.
- jvmargs: the arguments to pass to the Java VM started for each test.
- testsuiteReportFileProperty: the name of the Ant property in which is stored the path of the final report. Default value is testsuite.report.file and path is [outputDir]/[label]/[reportName].xml
- testsuiteReportDirProperty: the name of the Ant property in which is store the path of the directory of the final report. Default value is testsuite.report.dir and path is [outputDir]/[label]
- testsuiteResultProperty: the name of the Ant property in which you want to have the result of the test-suite (true or false), depending if every tests successfully passed the test-suite or not. Ignored tests do not affect this result.

Finally, you have to give as nested element the path containing the tests.

- testPath: containing all the file of the tests which will be launched by the test-suite.
- testIgnoredPath (optional): Any test in the intersection between testIgnoredPath and testPath will be executed by the test-suite, but will not appear in the JUnit final report. It will still generate a JUnit report for each test, which will allow the HTML report to let them appears as "ignored" if it is generated. Mostly used for known bugs which are not considered as failure but still relevant enough to appears on the HTML report.

19.5.2.2 The javaTestsuite task

This task extends the testsuite task, specializing the test-suite to only start real Java class. This task will retrieve the classname of the tests from the classfile and will provide new properties to the harness script:

- testsuite.test.class: The classname of the current test. The value of the property testsuite.test.name is also set to the classname of the current test.
- testsuite.test.classpath: The classpath of the current test.

19.5.2.3 The htmlReport task

This task allow the user to transform a given path containing a sample of JUnit reports to an HTML detailled report. Here is the attributes to fill:

- A nested fileset containing all the JUnit reports of each test. Take care to exclude the final JUnit report generated by the test suite.
- A nested element report
  - format: The format of the generated HTML report. Must be noframes or frames. When noframes format is choosen, a standalone HTML file is generated.
  - todir: The output folder of your HTML report.
  - The report tag accepts the nested tag param with name and expression attributes. These tags can pass XSL parameters to the stylesheet. The built-in stylesheets support the following parameters:
    - PRODUCT: the product name that is displayed in the title of the HTML report.
    - TITLE: the comment that is displayed in the title of the HTML report.

Tip: It is advised to set the format to noframes if your test suite is not a Java test suite. If the format is set to frames, with a non-Java MicroEJ Test-Suite, the name of the links will not be relevant because of the non-existency of packages.

19.5.3 Using the trace analyzer

This section will shortly explains how to use the Trace Analyzer. The MicroEJ Test-Suite comes with an archive containing the Trace Analyzer which can be used to analyze the output trace of an application. It can be used from different forms;

- The FileTraceAnalyzer will analyze a file and research for the given tags, failing if the success tag is not found.
- The SerialTraceAnalyzer will analyze the data from a serial connection.

19.5.3.1 The TraceAnalyzer tasks options

Here is the common options to all TraceAnalyzer tasks:

- successTag: the regular expression which is synonym of success when found (by default .*PASSED.*).
- failureTag: the regular expression which is synonym of failure when found (by default .*FAILED.*).
- verboseLevel: int value between 0 and 9 to define the verbose level.
- waitingTimeAfterSuccess: waiting time (in s) after success before closing the stream (by default 5).
- noActivityTimeout: timeout (in s) with no activity on the stream before closing the stream. Set it to 0 to disable timeout (default value is 0).
- stopEOFReached: boolean value. Set to true to stop analyzing when input stream EOF is reached. If false, continue until timeout is reached (by default false).
- onlyPrintableCharacters: boolean value. Set to true to only dump ASCII printable characters (by default false).

19.5.3.2 The FileTraceAnalyzer task options

Here is the specific options of the FileTraceAnalyzer task:

- traceFile: path to the file to analyze.

19.5.3.3 The SerialTraceAnalyzer task options

Here is the specific options of the SerialTraceAnalyzer task:

- port: the comm port to open.
- baudrate: serial baudrate (by default 9600).
- databits: databits (5|6|7|8) (by default 8).
- stopBits: stopbits (0|1|3 for (1_5)) (by default 1).
- parity: none | odd | event (by default none).

19.5.4 Appendix

The goal of this section is to explain some tips and tricks that might be useful in your usage of the test-suite engine.

19.5.4.1 Specific custom properties

Some custom properties are specifics and retrieved from the test-suite engine in the custom properties file of a test.

- The testsuite.test.name property is the output name of the current test. Here are the steps to compute the output name of a test:
  - If the custom properties are enabled and a property named testsuite.test.name is find on the corresponding file, then the output name of the current test will be set to it.
  - Otherwise, if the running MicroEJ Test-Suite is a Java testsuite, the output name is set to the class name of the test.
  - Otherwise, from the path containing all the tests, a common prefix will be retrieved. The output name will be set to the relative path of the current test from this common prefix. If the common prefix equals the name of the test, then the output name will be set to the name of the test.
  - Finally, if multiples tests have the same output name, then the current name will be followed by _XXX, an underscore and an integer.
- The testsuite.test.timeout property allow the user to redefine the time out for each test. If it is negative or not an integer, then global timeout defined for the MicroEJ Test-Suite is used.

19.5.5 Dependencies

No dependency.

19.5.6 Installation

This tool is a built-in platform tool.

19.6 ELF to Map File Generator

19.6.1 Principle

The ELF to Map generator takes an ELF executable file and generates a MicroEJ compliant .map file. Thus, any ELF executable file produced by third party linkers can be analyzed and interpreted using the “Memory Map Analyzer”.

19.6.2 Functional Description

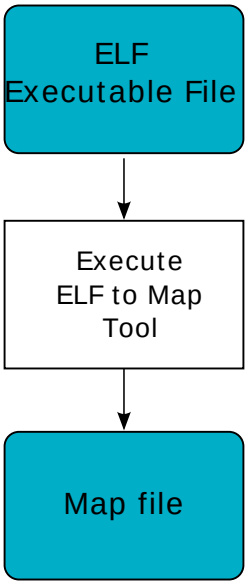


Figure 19.6. ELF To Map Process

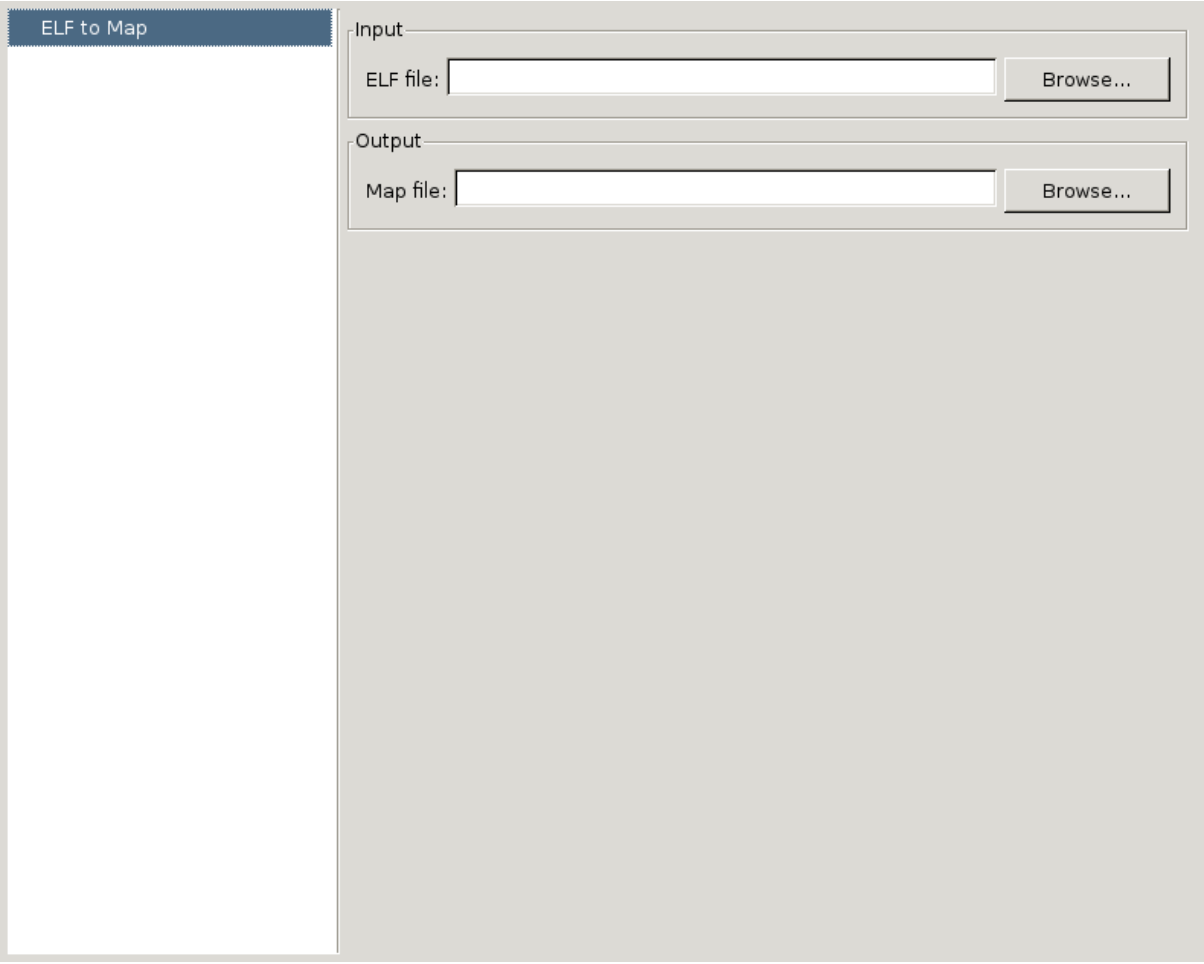
19.6.3 Installation

This tool is a built-in platform tool.

19.6.4 Use

This chapter explains MicroEJ tool options.

19.6.4.1 Category: ELF to Map



19.6.4.1.1 Group: Input

19.6.4.1.1.1 Option(browse): ELF file

Default value: (empty)

19.6.4.1.2 Group: Output

19.6.4.1.2.1 Option(browse): Map file

Default value: (empty)

19.7 Serial to Socket Transmitter

19.7.1 Principle

The MicroEJ serialToSocketTransmitter is a piece of software which transfers all bytes from a serial port to a tcp client or tcp server.

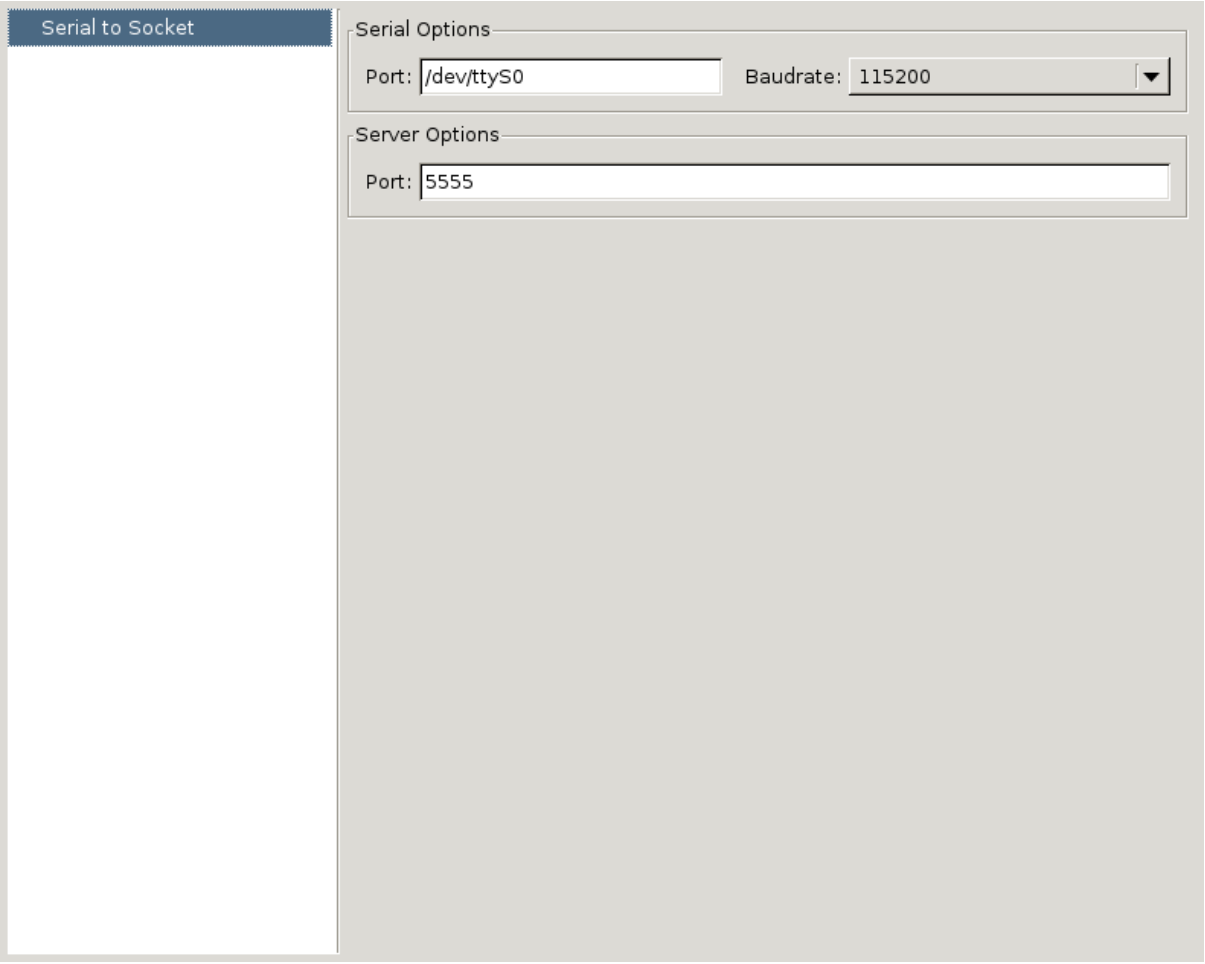
19.7.2 Installation

This tool is a built-in platform tool.

19.7.3 Use

This chapter explains MicroEJ tool options.

19.7.3.1 Category: Serial to Socket



19.7.3.1.1 Group: Serial Options

19.7.3.1.1.1 Option(text): Port

Default value: /dev/ttyS0

Description: Defines the COM port:

Windows - COM1, COM2, ..., COM*n*

Linux - /dev/ttyS0, /dev/ttyUSB0, ..., /dev/ttyS*n*, /dev/ttyUSB*n*

19.7.3.1.1.2 Option(combo): Baudrate

Default value: 115200

Available values:

9600

38400

57600

115200

Description: Defines the COM baudrate.

19.7.3.1.2 Group: Server Options

19.7.3.1.2.1 Option(text): Port

Default value: 5555

Description: Defines the server IP port.

20 Simulation

20.1 Principle

The MicroEJ platform provides an accurate MicroEJ simulator that runs on workstations. Applications execute in an almost identical manner on both the workstation and on target devices. The MicroEJ simulator features IO simulation, JDWP debug coupled with Eclipse, accurate Java heap dump, and an accurate Java scheduling policy (the same as the embedded one). [7]

20.2 Functional Description

In order to simulate external stimuli that come from the native world (that is, "the C world"), the MicroEJ simulator has a Hardware In the Loop interface, HIL, which performs the simulation of Java-to-C calls. All Java-to-C calls are rerouted to an HIL engine. Indeed HIL is a replacement for the [SNI] interface.

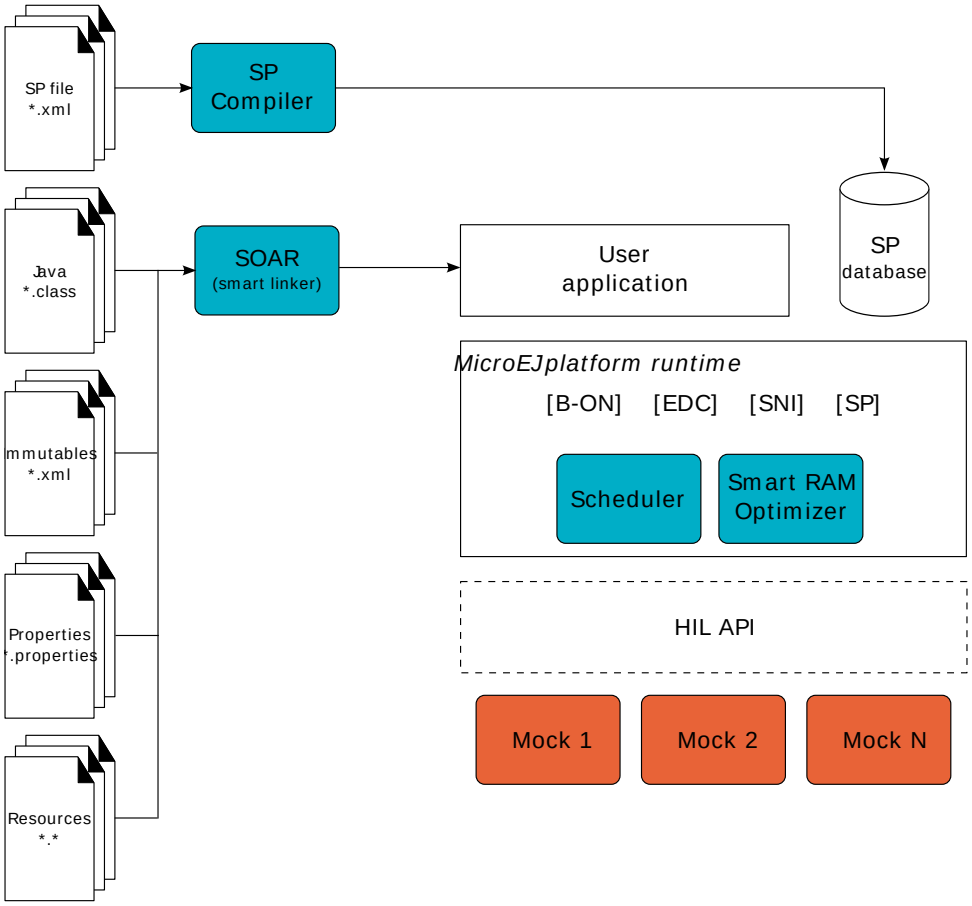


Figure 20.1. The HIL Connects the MicroEJ simulator to the Workstation.

The "simulated C world" is made of mocks that simulate native code (such as drivers and any other kind of C libraries), so that the MicroEJ application can behave the same as the device using the MicroEJ platform.

The MicroEJ simulator and the HIL are two processes that run in parallel: the communication between them is through a socket connection. Mocks run inside the process that runs the HIL engine.

[7] Only the execution speed is not accurate. The simulator speed can be set to match the average MicroEJ platform speed in order to adapt the simulator speed to the desktop speed.

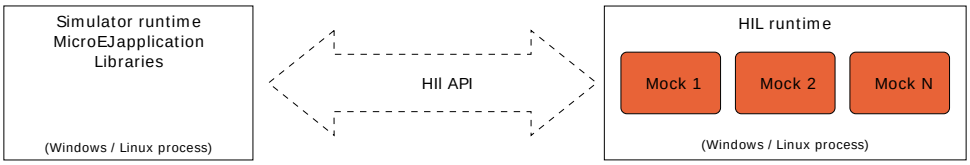


Figure 20.2. A MicroEJ simulator connected to its HIL Engine via a socket.

20.3 Mock

20.3.1 Principle

The HIL engine is a Java standard-based engine that runs mocks. A mock is a jar file containing some Java classes that simulate natives for the simulator. Mocks allow applications to be run unchanged in the simulator while still (apparently) interacting with native code.

20.3.2 Functional Description

As with [SNI], HIL is responsible for finding the method to execute as a replacement for the native Java method that the MicroEJ simulator tries to run. Following the [SNI] philosophy, the matching algorithm uses a naming convention. When a native method is called in the MicroEJ simulator, it requests that the HIL engine execute it. The corresponding mock executes the method and provides the result back to the MicroEJ simulator.

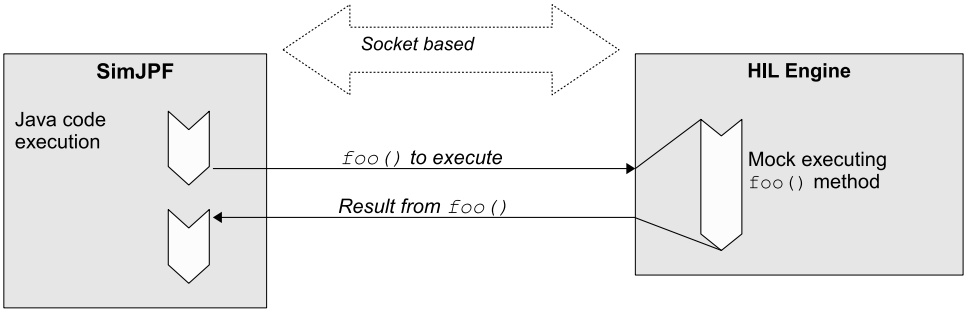


Figure 20.3. The MicroEJ simulator Executes a Native Java Method foo().

20.3.3 Example

```
package example;

import java.io.IOException;

/**
 * Abstract class providing a native method to access sensor value.
 * This method will be executed out of virtual machine.
 */
public abstract class Sensor {

 public static final int ERROR = -1;

 public int getValue() throws IOException {
  int sensorID = getSensorID();
  int value = getSensorValue(sensorID);
  if (value == ERROR) {
   throw new IOException("Unsupported sensor");
  }
  return value;
 }

 protected abstract int getSensorID();

 public static native int getSensorValue(int sensorID);
}

class Potentiometer extends Sensor {

 protected int getSensorID() {
  return Constants.POTENTIOMETER_ID; // POTENTIOMETER_ID is a static final
 }
}
```

To implement the native method getSensorValue(int sensorID), you need to create a MicroEJ standard project containing the same Sensor class on the same example package. To do so, open the Eclipse menu **File > New > Project... > Java > Java Project** in order to create a MicroEJ standard project.

The following code is the required Sensor class of the created mock project :

```
package example;

import java.util.Random;

/**
 * Java standard class included in a mock jar file.
 * It implements the native method using a Java method.
 */
public class Sensor {

 /**
  * Constants
  */
 private static final int SENSOR_ERROR = -1;
 private static final int POTENTIOMETER_ID = 3;

 private static final Random RANDOM = new Random();

 /**
  * Implementation of native method "getSensorValue()"
  *
  * @param sensorID Sensor ID
  * @return Simulated sensor value
  */
 public static int getSensorValue(int sensorID) {
  if( sensorID == POTENTIOMETER_ID ) {
   // For the simulation, mock returns a random value
   return RANDOM.nextInt();
  }
  return SENSOR_ERROR;
 }

}
```

20.3.4 Mocks Design Support

20.3.4.1 Interface

The MicroEJ simulator interface is defined by static methods on the Java class com.is2t.hil.NativeInterface.

20.3.4.2 Array Type Arguments

Both [SNI] and HIL allow arguments that are arrays of base types. By default the contents of an array are NOT sent over to the mock. An "empty copy" is sent by the HIL engine, and the contents of the array must be explicitly fetched by the mock. The array within the mock can be modified using a regular assignment. Then to apply these changes in the MicroEJ simulator, the modifications must be flushed back. There are two methods provided to support fetch and flush between the MicroEJ simulator and the HIL:

- refreshContent: initializes the array argument from the contents of its MicroEJ simulator counterpart.
- flushContent: propagates (to the MicroEJ simulator) the contents of the array that is used within the HIL engine.

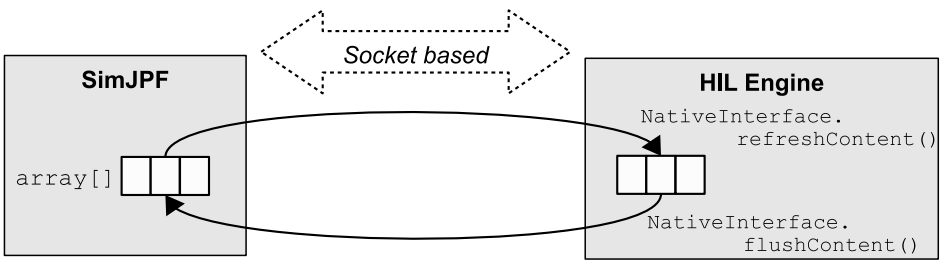


Figure 20.4. An Array and Its Counterpart in the HIL Engine.

Below is a typical usage.

```
public static void foo(char[] chars, int offset, int length){
      NativeInterface ni = HIL.getInstance();
      //inside the mock
      ni.refreshContent(chars, offset, length);
      chars[offset] = 'A';
      ni.flushContent(chars, offset, 1);
}
```

Figure 20.5. Typical Usage of HIL Engine.

20.3.4.3 Blocking Native Methods

Some native methods block until an event has arrived [SNI]. Such behavior is implemented in a mock using the following three methods:

- suspendCurrentJavaThread(long timeout): Tells the MicroEJ simulator that the green thread should block after returning from the current native. This method does not block the mock execution. The green thread is suspended until either a mock thread calls resumeJavaThread or the specified amount of milliseconds has elapsed.
- resumeJavaThread(int id): Resumes the green thread with the given ID. If the thread is not suspended, the resume stays pending, and the next call to suspendCurrentJavaThread will not block the thread.
- getCurrentJavaThreadID(): Retrieves the ID of the current Java thread. This ID must be given to the resumeJavaThread method in order to resume execution of the green thread.

```
public static byte[] Data = new byte[BUFFER_SIZE];
public static int DataLength = 0;

//Mock native method
public static void waitForData(){
    NativeInterface ni = HIL.getInstance();
    //inside the mock
    //wait until the data is received
    setWaitingThread(ni.getCurrentJavaThreadID());
    if(DataLength == 0){
        ni.suspendCurrentJavaThread(0);
    }
}

//Mock data reader thread
public static void notifyDataReception()
    NativeInterface ni = HIL.getInstance();
  DataLength = readFromInputStream(Data);
  ni.resumeJavaThread(getWaitingThread());
}
```

Figure 20.6. Suspend/Resume Java Threads Example

20.3.4.4 Resource Management

In Java, every class can play the role of a small read-only file system root: The stored files are called "Java resources" and are accessible using a path as a String.

The MicroEJ simulator interface allows the retrieval of any resource from the original Java world, using the getResourceContent method.

```
public static void bar(byte[] path, int offset, int length) {
    NativeInterface ni = HIL.getInstance();
    ni.refreshContent(path, offset, length);
    String pathStr = new String(path, offset, length);
    byte[] data = ni.getResourceContent(pathStr);
    ...
}
```

Figure 20.7. GetResourceContent Example

20.3.4.5 Synchronous Terminations

To terminate the whole simulation (MicroEJ simulator and HIL), use the stop() method.

```
public static void windowClosed() {
    HIL.getInstance().stop();
}
```

Figure 20.8. MicroEJ Simulator Stop Example

20.3.5 Dependencies

The MicroEJ platform architecture provides some APIs (HIL APIs) to develop a mock that will be ready to be used against the simulator. The classpath variable that allows you to access to the HIL Engine API is HILENGINE-2.0.1. MicroEJ projects that build mocks should put that library on their build path.

20.3.6 Installation

The mock creator is responsible for building the mock jar file using his/her own method (Eclipse build, javac, etc.).

Once built, the jar file must be put in this specific platform configuration project folder in order to be included during the platform creation : dropins/mocks/dropins/.

20.3.7 Use

Once installed, a mock is used automatically by the simulator when the MicroEJ application calls a native method which is implemented into the mock.

20.4 Shielded Plug Mock

20.4.1 General Architecture

The Shielded Plug Mock simulates a Shielded Plug [SP] on desktop computer. This mock can be accessed from the MicroEJ simulator, the hardware platform or a Java J2SE application.

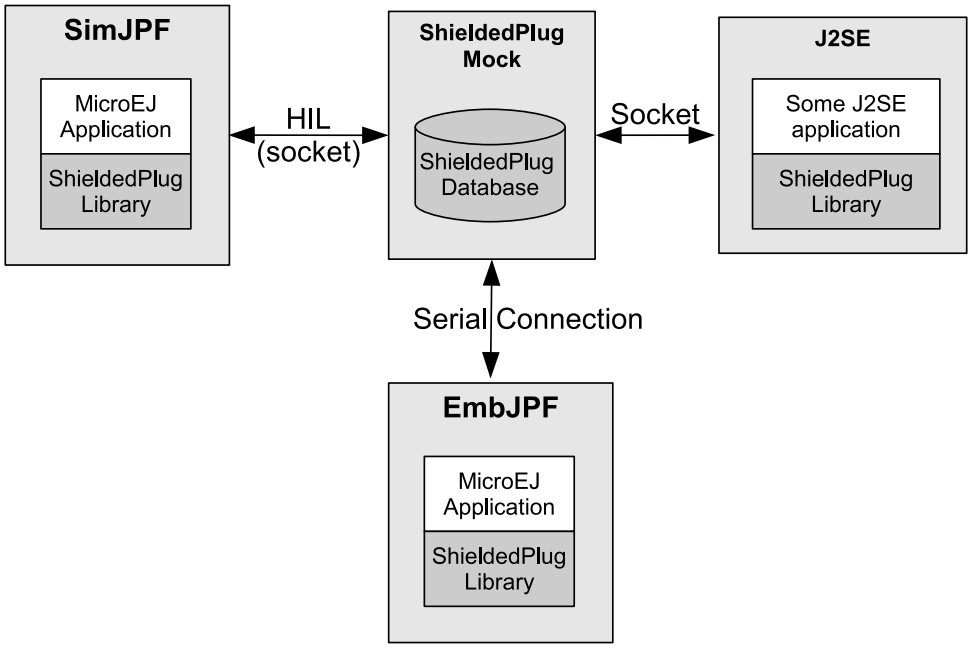


Figure 20.9. Shielded Plug Mock General Architecture

20.4.2 Configuration

The mock socket port can be customized for J2SE clients, even though several Shielded Plug mocks with the same socket port cannot run at the same time. The default socket port is 10082.

The Shielded Plug mock is a standard MicroEJ application. It can be configured using Java properties:

- sp.connection.address
- sp.connection.port

20.5 Dependencies

No dependency.

20.6 Installation

The simulator is a built-in feature of MicroEJ platform architecture.

20.7 Use

To run an application in the simulator, create a MicroEJ launch configuration by right-clicking on the main class of the application, and selecting **Run As > MicroEJ Application.**

This will create a launch configuration configured for the simulator, and will run it.

21 MicroEJ Linker

21.1 Overview

MicroEJ linker is a standard linker that is compliant with the Executable and Linkable File format (ELF).

MicroEJ linker takes one or several relocatable binary files and generates an image representation using a description file. The process of extracting binary code, positioning blocks and resolving symbols is called linking.

Relocatable object files are generated by SOAR and third-party compilers. An archive file is a container of Relocatable object files.

The description file is called a Linker Specific Configuration file (lsc). It describes what shall be embedded, and how those things shall be organized in the program image. The linker outputs :

- An ELF executable file that contains the image and potential debug sections. This file can be directly used by debuggers or programming tools. It may also be converted into a another format (Intel* hex, Motorola* s19, rawBinary, etc.) using external tools, such as standard GNU binutils toolchain (objcopy, objdump, etc.).
- A map file, in XML format, which can be viewed as a database of what has been embedded and resolved by the linker. It can be easily processed to get a sort of all sizes, call graphs, statistics, etc.

21.2 ELF Overview

An ELF relocatable file is split into several sections:

- allocation sections representing a part of the program
- control sections describing the binary sections (relocation sections, symbol tables, debug sections, etc.)

An allocation section can hold some image binary bytes (assembler instructions and raw data) or can refer to an interval of memory which makes sense only at runtime (statics, main stack, heap, etc.). An allocation section is an atomic block and cannot be split. A section has a name that by convention, represents the kind of data it holds. For example, .text sections hold binary instructions, .bss sections hold read-write static data, .rodata hold read-only data, and .data holds read-write data (initialized static data). The name is used in the .lsc file to organize sections.

A symbol is an entity made of a name and a value. A symbol may be absolute (link-time constant) or relative to a section: Its value is unknown until MicroEJ linker has assigned a definitive position to the target section. A symbol can be local to the relocatable file or global to the system. All global symbol names should be unique in the system (the name is the key that connects an unresolved symbol reference to a symbol definition). A section may need the value of symbols to be fully resolved: the address of a function called, address of a static variable, etc.

21.3 Linking Process

The linking process can be divided into three main steps:

1. Symbols and sections resolution. Starting from root symbols and root sections, the linker embeds all sections targeted by symbols and all symbols referred by sections. This process is transitive while new symbols and/or sections are found. At the end of this step, the linker may stop and output errors (unresolved symbols, duplicate symbols, unknown or bad input libraries, etc.)
2. Memory positioning. Sections are laid out in memory ranges according to memory layout constraints described by the lsc file. Relocations are performed (in other words, symbol values are

resolved and section contents are modified). At the end of this step, the linker may stop and output errors (it could not resolve constraints, such as not enough memory, etc.)

3. An output ELF executable file and map file are generated.

A partial map file may be generated at the end of step 2. It provides useful information to understand why the link phase failed. Symbol resolution is the process of connecting a global symbol name to its definition, found in one of the linker input units. The order the units are passed to the linker may have an impact on symbol resolution. The rules are :

- Relocatable object files are loaded without order. Two global symbols defined with the same name result in an unrecoverable linker error.
- Archive files are loaded on demand. When a global symbol must be resolved, the linker inspects each archive unit in the order it was passed to the linker. When an archive contains a relocatable object file that declares the symbol, the object file is extracted and loaded. Then the first rule is applied. It is recommended that you group object files in archives as much as possible, in order to improve load performances. Moreover, archive files are the only way to tie with relocatable object files that share the same symbols definitions.
- A symbol name is resolved to a weak symbol if - and only if - no global symbol is found with the same name.

21.4 Linker Specific Configuration File Specification

21.4.1 Description

A Linker Specific Configuration (Lsc) file contains directives to link input library units. An lsc file is written in an XML dialect, and its contents can be divided into two principal categories:

- Symbols and sections definitions.
- Memory layout definitions.

```
<?xml version="1.0" encoding="UTF-8"?>
<!--
   An example of linker specific configuration file
-->
<lsc name="MyAppInFlash">
   <include name="subfile.lscf"/>
   <!--
     Define symbols with arithmetical and logical expressions
   -->
   <defSymbol name="FlashStart" value="0"/>
   <defSymbol name="FlashSize"  value="0x10000"/>
   <defSymbol name="FlashEnd"   value="FlashStart+FlashSize-1"/>
   <!--
      Define FLASH memory interval
   -->
   <defSection name="FLASH" start="FlashStart" size="FlashSize"/>

   <!--
      Some memory layout directives
   -->
   <memoryLayout ranges ="FLASH">
      <sectionRef name ="*.text"/>
      <sectionRef name ="*.data"/>
   </memoryLayout>
</lsc>
```

Figure 21.1. MicroEJ Linker Flow

21.4.2 File Fragments

An lsc file can be physically divided into multiple lsc files, which are called lsc fragments. Lsc fragments may be loaded directly from the linker path option, or indirectly using the include tag in an lsc file.

Lsc fragments start with the root tag lscFragment. By convention the lsc fragments file extension is .lscf. From here to the end of the document, the expression "the lsc file" denotes the result of the union of all loaded (directly and indirectly loaded) lsc fragments files.

21.4.3 Symbols and Sections

A new symbol is defined using defSymbol tag. A symbol has a name and an expression value. All symbols defined in the lsc file are global symbols.

A new section is defined using the defSection tag. A section may be used to define a memory interval, or define a chunk of the final image with the description of the contents of the section.

21.4.4 Memory Layout

A memory layout contains an ordered set of statements describing what shall be embedded. Memory positioning can be viewed as moving a cursor into intervals, appending referenced sections in the order they appear. A symbol can be defined as a "floating" item: Its value is the value of the cursor when the symbol definition is encountered. In Figure 21.2, the memory layout sets the FLASH section. First, all sections named .text are embedded. The matching sections are appended in a undefined order. To reference a specific section, the section shall have a unique name (for example a reset vector is commonly called .reset or .vector, etc.). Then, the floating symbol dataStart is set to the absolute address of the virtual cursor right after embedded .text sections. Finally all sections named .data are embedded.

A memory layout can be relocated to a memory interval. The positioning works in parallel with the layout ranges, as if there were two cursors. The address of the section (used to resolve symbols) is the address in the relocated interval. Floating symbols can refer either to the layout cursor (by default), or to the relocated cursor, using the relocation attribute. A relocation layout is typically used to embed data in a program image that will be used at runtime in a read-write memory. Assuming the program image is programmed in a read only memory, one of the first jobs at runtime, before starting the main program, is to copy the data from read-only memory to RAM, because the symbols targeting the data have been resolved with the address of the sections in the relocated space. To perform the copy, the program needs both the start address in FLASH where the data has been put, and the start address in RAM where the data shall be copied.

```
<memoryLayout ranges="FLASH" relocation="RAM" image="true">
  <defSymbol name="DataFlashStart" value="."/>
  <defSymbol name="DataRamStart" value=" ." relocation="true"/>
  <sectionRef name=".data"/>
  <defSymbol name="DataFlashLimit" value="."/>
</memoryLayout>
```

Figure 21.2. Example of Relocation of Runtime Data from FLASH to RAM

Note: the symbol DataRamStart is defined to the start address where .data sections will be inserted in RAM memory.

21.4.5 Tags Specification

Here is the complete syntactical and semantical description of all available tags of the .lsc file.

Tags	Attributes	Description
defSection		Defines a new section. A floating section only holds a declared size attribute. A fixed section declares at least one of the start / end attributes. When this tag is empty, the section is a runtime sec-

Tags	Attributes	Description
		tion, and must define at least one of the start, end or size attributes. When this tag is not empty (when it holds a binary description), the section is an image section.
	name	Name of the section. The section name may not be unique. However, it is recommended that you define a unique name if the section must be referred separately for memory positioning.
	start	Optional. Expression defining the absolute start address of the section. Must be resolved to a constant after the full load of the lsc file.
	end	Optional. Expression defining the absolute end address of the section. Must be resolved to a constant after the full load of the lsc file.
	size	Optional. Expression defining the size in bytes of the section. Invariant: (end-start)+1=size. Must be resolved to a constant after the full load of the lsc file.
	align	Optional. Expression defining the alignment in bytes of the section.
	rootSection	Optional. Boolean value. Sets this section as a root section to be embedded even if it is not targeted by any embedded symbol. See also rootSection tag.
	symbolPrefix	Optional. Used in collaboration with symbolTags. Prefix of symbols embedded in the auto-generated section. See Section 21.5.
	symbolTags	Optional. Used in collaboration with symbolPrefix. Comma separated list of tags of symbols embedded in the auto-generated section. See Section 21.5.
defSymbol		Defines a new global symbol. Symbol name must be unique in the linker context.
	name	Name of the symbol.
	type	Optional. Type of symbol usage. This may be necessary to set the type of a symbol when using third party ELF tools. There are three types: • none: default. No special type of use. • function: symbol describes a function. • data: symbol describes some data.
	value	The value "." defines a floating symbol that holds the current cursor position in a memory layout. (This is the only form of this tag that can be used as a memoryLayout directive) Otherwise value is an expression. A symbol expression must be resolved to a constant after memory positioning.
	relocation	Optional. The only allowed value is true. Indicates that the value of the symbol takes the address of the current cursor in the memory layout relocation space. Only allowed on floating symbols.
	rootSymbol	Optional. Boolean value. Sets this symbol as a root symbol that must be resolved. See also rootSymbol tag.
	weak	Optional. Boolean value. Sets this symbol as a weak symbol.

Tags	Attributes	Description
group		memoryLayout directive. Defines a named group of sections. Group name may be used in expression macros START, END, SIZE. All memoryLayout directives are allowed within this tag (recursively).
	name	The name of the group.
include		Includes an lsc fragment file, semantically the same as if the fragment contents were defined in place of the include tag.
	name	Name of the file to include. When the name is relative, the file separator is /, and the file is relative to the directory where the current lsc file or fragment is loaded. When absolute, the name describes a platform-dependent filename.
lsc		Root tag for an .lsc file.
	name	Name of the lsc file. The ELF executable output will be {name}.out, and the map file will be {name}.map
lscFragment		Root tag for an lsc file fragment. Lsc fragments are loaded from the linker path option, or included from a master file using athe include tag.
memoryLayout		Describes the organization of a set of memory intervals. The memory layouts are processed in the order in which they are declared in the file. The same interval may be organized in several layouts. Each layout starts at the value of the cursor the previous layout ended. The following tags are allowed within a memoryLayout directive: defSymbol (under certain conditions), group, memoryLayoutRef, padding, and sectionRef.
	ranges	Exclusive with default. Comma-separated ordered list of fixed sections to which the layout is applied. Sections represent memory segments.
	image	Optional. Boolean value. false if not set. If true, the layout describes a part of the binary image: Only image sections can be embedded. If false, only runtime sections can be embedded.
	relocation	Optional. Name of the section to which this layout is relocated.
	name	Exclusive with ranges. Defines a named memoryLayout directive instead of specifying a concrete memory location. May be included in a parent memoryLayout using memoryLayoutRef.
memoryLayoutRef		memoryLayout directive. Provides an extension-point mechanism to include memoryLayout directives defined outside the current one.
	name	All directives of memoryLayout defined with the same name are included in an undefined order.
padding		memoryLayout directive. Append padding bytes to the current cursor. Either size or align attributes should be provided.
	size	Optional. Expression must be resolved to a constant after the full load of the lsc file. Increment the cursor position with the given size.
	align	Optional. Expression must be resolved to a constant after the full load of the lsc file. Move the current cursor position to the next address that matches the given alignment. Warning: when used with relocation, the relocation cursor is also aligned. Keep

Tags	Attributes	Description
		in mind this may increase the cursor position with a different amount of bytes.
	address	Optional. Expression must be resolved to a constant after the full load of the lsc file. Move the current cursor position to the given absolute address.
	fill	Optional. Expression must be resolved to a constant after the full load of the lsc file. Fill padding with the given value (32 bits).
rootSection		References a section name that must be embedded. This tag is not a definition. It forces the linker to embed all loaded sections matching the given name.
	name	Name of the section to be embedded.
rootSymbol		References a symbol that must be resolved. This tag is not a definition. It forces the linker to resolve the value of the symbol.
	name	Name of the symbol to be resolved.
sectionRef		Memory layout statement. Embeds all sections matching the given name starting at the current cursor address.
	file	Select only sections defined in a linker unit matching the given file name. The file name is the simple name without any file separator, e.g. bsp.o or mylink.lsc. Link units may be object files within archive units.
	name	Name of the sections to embed. When the name ends with *, all sections starting with the given name are embedded (name completion), except sections that are embedded in another sectionRef using the exact name (without completion).
	symbol	Optional. Only embeds the section targeted by the given symbol. This is the only way at link level to embed a specific section whose name is not unique.
	force	Optional. Deprecated. Replaced by the rootSection tag. The only allowed value is true. By default, for compaction, the linker embeds only what is needed. Setting this attribute will force the linker to embed all sections that appear in all loaded relocatable files, even sections that are not targeted by a symbol.
	sort	Optional. Specifies that the sections must be sorted in memory. The value can be: • order: the sections will be in the same order as the input files • name: the sections are sorted by their file names • unit: the sections declared in an object file are grouped and sorted in the order they are declared in the object file
u4		Binary section statement. Describes the four next raw bytes of the section. Bytes are organized in the endianness of the target ELF executable.
	value	Expression must be resolved to a constant after the full load of the lsc file (32 bits value).
fill		Binary section statement. Fills the section with the given expression. Bytes are organized in the endianness of the target ELF executable.
	size	Expression defining the number of bytes to be filled.

Tags	Attributes	Description
	value	Expression must be resolved to a constant after the full load of the lsc file (32 bits value).

Table 21.1. Linker Specific Configuration Tags

21.4.6 Expressions

An attribute expression is a value resulting from the computation of an arithmetical and logical expression. Supported operators are the same operators supported in the Java language, and follow Java semantics:

- Unary operators: + , - , ~ , !
- Binary operators: + , - , * , / , % , << , >>> , >> , < , > , <= , >= , == , != , &, | , ^ , && , ||
- Ternary operator: cond ? ifTrue : ifFalse
- Built-in macros:
  - START(name): Get the start address of a section or a group of sections
  - END(name): Get the end address of a section or a group of sections
  - SIZE(name): Get the size of a section or a group of sections. Equivalent to END(name)-START(name)
  - TSTAMPH(), TSTAMPL(): Get 32 bits linker time stamp (high/low part of system time in milliseconds)
  - SUM(name,tag): Get the sum of an auto-generated section (Section 21.5) column. The column is specified by its tag name.

An operand is either a sub expression, a constant, or a symbol name. Constants may be written in decimal (127) or hexadecimal form (0x7F). There are no boolean constants. Constant value 0 means false, and other constants' values mean true. Examples of use:

```
value=”symbol+3”
value=”((symbol1*4)-(symbol2*3)”
```

Note: Ternary expressions can be used to define selective linking because they are the only expressions that may remain partially unresolved without generating an error. Example:

```
<defSymbol name=“myFunction” value=”condition ? symb1 : symb2”/>
```

No error will be thrown if the condition is true and symb1 is defined, or the condition is false and symb2 is defined, even if the other symbol is undefined.

21.5 Auto-generated Sections

The MicroEJ linker allows you to define sections that are automatically generated with symbol values. This is commonly used to generate tables whose contents depends on the linked symbols. Symbols eligible to be embedded in an auto-generated section are of the form: prefix_tag_suffix. An auto-generated section is viewed as a table composed of lines and columns that organize symbols sharing the same prefix. On the same column appear symbols that share the same tag. On the same line appear symbols that share the same suffix. Lines are sorted in the lexical order of the symbol name. The next line defines a section which will embed symbols starting with zeroinit. The first column refers to symbols starting with zeroinit_start_; the second column refers to symbols starting with zeroinit_end_.

```
<defSection
   name=".zeroinit"
   symbolPrefix="zeroInit"
   symbolTags="start,end"
/>
```

Consider there are four defined symbols named zeroinit_start_xxx, zeroinit_end_xxx, zeroinit_start_yyy and zeroinit_end_yyy. The generated section is of the form:

```
0x00: zeroinit_start_xxx
0x04: zeroinit_end_xxx
0x08: zeroinit_start_yyy
0x0C: zeroinit_end_yyy
```

If there are missing symbols to fill a line of an auto-generated section, an error is thrown.

21.6 Execution

MicroEJ linker can be invoked through an ANT task. The task is installed by inserting the following code in an ANT script

```
<taskdef
   name="linker"
   classname="com.is2t.linker.GenericLinkerTask"
   classpath="[LINKER_CLASSPATH]"
/>
```

[LINKER_CLASSPATH] is a list of path-separated jar files, including the linker and all architecture-specific library loaders.

The following code shows a linker ANT task invocation and available options.

```
<linker
   doNotLoadAlreadyDefinedSymbol="[true|false]"
   endianness="[little|big|none]"
   generateMapFile="[true|false]"
   ignoreWrongPositioningForEmptySection="[true|false]"
   lsc="[filename]"
   linkPath="[path1:...pathN]"
   mergeSegmentSections="[true|false]"
   noWarning="[true|false]"
   outputArchitecture="[tag]"
   outputName="[name]"
   stripDebug="[true|false]"
   toDir="[outputDir]"
   verboseLevel="[0...9]"
>
      <!-- ELF object & archives files using ANT paths / filesets -->
      <fileset dir="xxx" includes="*.o">
      <fileset file="xxx.a">
      <fileset file="xxx.a">

      <!-- Properties that will be reported into .map file -->
      <property name="myProp" value="myValue"/>
</linker>
```

Option	Description
doNotLoadAlreadyDefinedSymbol	Silently skip the load of a global symbol if it has already been loaded before. (false by default. Only the first loaded symbol is taken into account (in the order input files are declared). This option only affects the load semantic for global symbols, and does not modify the semantic for loading weak symbols and local symbols.

Option	Description
endianness	Explicitly declare linker endianness [little, big] or [none] for auto-detection. All input files must declare the same endianness or an error is thrown.
generateMapFile	Generate the .map file (true by default).
ignoreWrongPositioningFor EmptySection	Silently ignore wrong section positioning for zero size sections. (false by default).
lsc	Provide a master lsc file. This option is mandatory unless the linkPath option is set.
linkPath	Provide a set of directories into which to load link file fragments. Directories are separated with a platform-path separator. This option is mandatory unless the lsc option is set.
noWarning	Silently skip the output of warning messages.
mergeSegmentSections	(*experimental*). Generate a single section per segment. This may speed up the load of the output executable file into debuggers or flasher tools. (false by default).
outputArchitecture	Set the architecture tag for the output ELF file (ELF machine id).
outputName	Specify the output name of the generated files. By default, take the name provided in the lsc tag. The output ELF executable filename will be name.out. The map filename will be name.map.
stripDebug	Remove all debug information from the output ELF file. A stripped output ELF executable holds only the binary image (no remaining symbols, debug sections, etc.).
toDir	Specify the output directory in which to store generated files. Output filenames are in the form: od + separator + value of the lsc name attribute + suffix. By default, without this option, files are generated in the directory from which the linker was launched.
verboseLevel	Print additional messages on the standard output about linking process.

Table 21.2. Linker Options Details

21.7 Error Messages

This section lists MicroEJ linker error messages.

Message ID	Description
0	The linker has encountered an unexpected internal error. Please contact the support hotline.
1	A library cannot be loaded with this linker. Try verbose to check installed loaders.
2	No lsc file provided to the linker.
3	A file could not be loaded. Check the existence of the file and file access rights.
4	Conflicting input libraries. A global symbol definition with the same name has already been loaded from a previous object file.
5	Completion (*) could not be used in association with the force attribute. Must be an exact name.

6	A required section refers to an unknown global symbol. Maybe input libraries are missing.
7	A library loader has encountered an unexpected internal error. Check input library file integrity.
8	Floating symbols can only be declared inside memoryLayout tags.
9	Invalid value format. For example, the attribute relocation in defSymbol must be a boolean value.
10	Missing one of the following attributes: address, size, align.
11	Too many attributes that cannot be used in association.
13	Negative padding. Memory layout cursor cannot decrease.
15	Not enough space in the memory layout intervals to append all sections that need to be embedded. Check the output map file to get more information about what is required as memory space.
16	A block is referenced but has already been embedded. Most likely a block has been especially embedded using the force attribute and the symbol attribute.
17	A block that must be embedded has no matching sectionRef statement.
19	An IO error occurred when trying to dump one of the output files. Check the output directory option and file access rights.
20	size attribute expected.
21	The computed size does not match the declared size.
22	Sections defined in the lsc file must be unique.
23	One of the memory layout intervals refers to an unknown lsc section.
24	Relocation must be done in one and only one contiguous interval.
25	force and symbol attributes are not allowed together.
26	XML char data not allowed at this position in the lsc file.
27	A section which is a part of the program image must be embedded in an image memory layout.
28	A section which is not a part of the program image must be embedded in a non-image memory layout.
29	Expression could not be resolved to a link-time constant. Some symbols are unresolved.
30	Sections used in memory layout ranges must be sections defined in the lsc file.
31	Invalid character encountered when scanning the lsc expression.
32	A recursive include cycle was detected.
33	An alignment inconsistency was detected in a relocation memory layout. Most likely one of the start addresses of the memory layout is not aligned on the current alignment.
34	An error occurs in a relocation resolution. In general, the relocation has a value that is out of range.
35	symbol and sort attributes are not allowed together.
36	Invalid sort attribute value is not one of order, name, or no.
37	Attribute start or end in defSection tag is not allowed when defining a floating section.
38	Autogenerated section can build tables according to symbol names (see Section 21.5). A symbol is needed to build this section but has not been loaded.

39	Deprecated feature warning. Remains for backward compatibility. It is recommended that you use the new indicated feature, because this feature may be removed in future linker releases.
40	Unknown output architecture. Either the architecture ID is invalid, or the library loader has not been loaded by the linker. Check loaded library loaders using verbose option.
41...43	Reserved.
44	Duplicate group definition. A group name is unique and cannot be defined twice.
45	Invalid endianness. The endianness mnemonic is not one of the expected mnemonics (little,big,none).
46	Multiple endiannesses detected within loaded input libraries.
47	Reserved.
48	Invalid type mnemonic passed to a defSymbol tag. Must be one of none, function, or data.
49	Warning. A directory of link path is invalid (skipped).
50	No linker-specific description file could be loaded from the link path. Check that the link path directories are valid, and that they contain .lsc or .lscf files.
51	Exclusive options (these options cannot be used simultaneously). For example, -linkFilename and -linkPath are exclusive; either select a master lsc file or a path from which to load .lscf files.
52	Name given to a memoryLayoutRef or a memoryLayout is invalid. It must not be empty.
53	A memoryLayoutRef with the same name has already been processed.
54	A memoryLayout must define ranges or the name attribute.
55	No memory layout found matching the name of the current memoryLayoutRef.
56	A named memoryLayout is declared with a relocation directive, but the relocation interval is incompatible with the relocation interval of the memoryLayout that referenced it.
57	A named memoryLayout has not been referenced. Every declared memoryLayout must be processed. A named memoryLayout must be referenced by a memoryLayoutRef statement.
58	SUM operator expects an auto-generated section.
59	SUM operator tag is unknown for the targetted auto-generated section.
60	SUM operator auto-generated section name is unknown.
61	An option is set for an unknown extension. Most likely the extension has not been set to the linker classpath.
62	Reserved.
63	ELF unit flags are inconsistent with flags set using the -forceFlags option.
64	Reserved.
65	Reserved.
66	Found an executable object file as input (expected a relocatable object file).
67	Reserved.
68	Reserved.
69	Reserved.

70	Not enough memory to achieve the linking process. Try to increase JVM heap that is running the linker (e.g. by adding option -Xmx1024M to the JRE command line).

Table 21.3. Linker-Specific Configuration Tags

21.8 Map File Interpretor

The map file interpretor is a tool that allows you to read, classify and display memory information dumped by the linker map file. The map file interpretor is a graph-oriented tool. It supports graphs of symbols and allows standard operations on them (union, intersection, subtract, etc.). It can also dump graphs, compute graph total sizes, list graph paths, etc.

The map file interpretor uses the standard Java regular expression syntax.

It is used internally by the graphical “Memory Map Analyzer” tool.

Commands:

- `createGraph graphName symbolRegExp ... section=regexp`

  `createGraph all section=.*`

  Recursively create a graph of symbols from root symbols and sections described as regular expressions. For example, to extract the complete graph of the application:

- `createGraphNoRec symbolRegExp ... section=regexp`

  The above line is similar to the previous statement, but embeds only declared symbols and sections (without recursive connections).

- `removeGraph graphName`

  Removes the graph for memory.

- `listGraphs`

  Lists all the created graphs in memory.

- `listSymbols graphName`

  Lists all graph symbols.

- `listPadding`

  Lists the padding of the application.

- `listSections graphName`

  Lists all sections targeted by all symbols of the graph.

- `inter graphResult g1 ... gn`

  Creates a graph which is the intersection of g1/\ ... /\ gn.

- `union graphResult g1 ... gn`

  Creates a graph which is the union of g1\/ ...\/ gn.

- `substract graphResult g1 ... gn`

Creates a graph which is the substract of `g1\ ... \ gn`.

- `reportConnections graphName`

  Prints the graph connections.

- `totalImageSize graphName`

  Prints the image size of the graph.

- `totalDynamicSize graphName`

  Prints the dynamic size of the graph.

- `accessPath symbolName`

  The above line prints one of the paths from a root symbol to this symbol. This is very useful in helping you understand why a symbol is embedded.

- `echo arguments`

  Prints raw text.

- `exec commandFile`

  Execute the given commandFile. The path may be absolute or relative from the current command file.

22 Limitations

Item		EVAL	DEV
Number of classes		4000	4000
Number of methods per class		3000	65000
Total number of methods		4000	unlimited
Class / Interface hierarchy depth		127 max	127 max
Number of monitors[a] per thread		8 max	8 max
Numbers of exception handlers per method		63 max	63 max
Number of fields	Base type	65000	65000
	References	65000	65000
Number of statics	boolean + byte	limited	65000
	short + char	limited	65000
	int + float	limited	65000
	long + double	limited	65000
	References	limited	65000
Method size		65000	65000
Time limit		60 minutes	unlimited
Number of threads		62	62

[a]No more than n different monitors can be held by one thread at any time.

Table 22.1. Platform Limitations

23 Appendix A: Low Level API

This chapter describes succinctly the available Low Level API, module by module. The exhaustive documentation of each LLAPI function is available in the LLAPI header files themselves. The required header files to implement are automatically copied in the folder include of MicroEJ platform at platform build time.

23.1 LLMJVM: MicroEJ core engine

23.1.1 Naming Convention

The Low Level MicroEJ core engine API, the LLMJVM API, relies on functions that need to be implemented. The naming convention for such functions is that their names match the LLMJVM_IMPL_* pattern.

23.1.2 Header Files

Three C header files are provided:

- LLMJVM_impl.h

  Defines the set of functions that the BSP must implement to launch and schedule the virtual machine

- LLMJVM.h

  Defines the set of functions provided by virtual machine that can be called by the BSP when using the virtual machine

- LLBSP_impl.h

  Defines the set of extra functions that the BSP must implement.

23.2 LLKERNEL: Multi Applications

23.2.1 Naming Convention

The Low Level Kernel API, the LLKERNEL API, relies on functions that need to be implemented. The naming convention for such functions is that their names match the LLKERNEL_IMPL_* pattern.

23.2.2 Header Files

One C header file is provided:

- LLKERNEL_impl.h

  Defines the set of functions that the BSP must implement to manage memory allocation of dynamically installed applications.

23.3 LLSP: Shielded Plug

23.3.1 Naming Convention

The Low Level Shielded Plug API, the LLSP API, relies on functions that need to be implemented. The naming convention for such functions is that their names match the LLSP_IMPL_* pattern.

23.3.2 Header Files

The implementation of the SP for the MicroEJ platform assumes some support from the underlying RTOS. It is mainly related to provide some synchronization when reading / writing into Shielded Plug blocks.

- LLSP_IMPL_syncWriteBlockEnter and LLSP_IMPL_syncWriteBlockExit are used as a semaphore by RTOS tasks. When a task wants to write to a block, it "locks" this block until it has finished to write in it.

- LLSP_IMPL_syncReadBlockEnter and LLSP_IMPL_syncReadBlockExit are used as a semaphore by RTOS tasks. When a task wants to read a block, it "locks" this block until it is ready to release it.

The [SP] specification provides a mechanism to force a task to wait until new data has been provided to a block. The implementation relies on functions LLSP_IMPL_wait and LLSP_IMPL_wakeup to block the current task and to reschedule it.

23.4 LLEXT_RES: External Resources Loader

23.4.1 Principle

This LLAPI allows to use the External Resource Loader. When installed, the External Resource Loader is notified when the MicroEJ core engine is not able to find a resource (an image, a file etc.) in the resources area linked with the MicroEJ core engine.

When a resource is not available, the MicroEJ core engine invokes the External Resource Loader in order to load an unknown resource. The External Resource Loader uses the LLAPI EXT_RES to let the BSP loads or not the expected resource. The implementation has to be able to load several files in parallel.

23.4.2 Naming Convention

The Low Level API, the LLEXT_RES API, relies on functions that need to be implemented. The naming convention for such functions is that their names match the LLEXT_RES_IMPL_* pattern.

23.4.3 Header Files

One header file is provided:

- LLEXT_RES_impl.h
  Defines the set of functions that the BSP must implement to load some external resources.

23.5 LLCOMM: Serial Communications

23.5.1 Naming Convention

The Low Level Comm API (LLCOMM), relies on functions that need to be implemented by engineers in a driver. The names of these functions match the LLCOM_BUFFERED_CONNECTION_IMPL_* or the LLCOM_CUSTOM_CONNECTION_IMPL_*pattern.

23.5.2 Header Files

Four C header files are provided:

- LLCOMM_BUFFERED_CONNECTION_impl.h
  Defines the set of functions that the driver must implement to provide a Buffered connection
- LLCOMM_BUFFERED_CONNECTION.h
  Defines the set of functions provided by ECOM Comm that can be called by the driver (or other C code) when using a Buffered connection
- LLCOMM_CUSTOM_CONNECTION_impl.h
  Defines the set of functions that the driver must implement to provide a Custom connection
- LLCOMM_CUSTOM_CONNECTION.h
  Defines the set of functions provided by ECOM Comm that can be called by the driver (or other C code) when using a Custom connection

23.6 LLINPUT: Inputs

LLINPUT API is composed of the following files:

- the file LLINPUT_impl.h that defines the functions to be implemented
- the file LLINPUT.h that provides the functions for sending events

23.6.1 Implementation

LLINPUT_IMPL_initialize is the first function called by the input stack, and it may be used to initialize the underlying devices and bind them to event generator IDs.

LLINPUT_IMPL_enterCriticalSection and LLINPUT_IMPL_exitCriticalSection need to provide the stack with a critical section mechanism for synchronizing devices when sending events to the internal event queue. The mechanism used to implement the synchronization will depend on the platform configuration (with or without RTOS), and whether or not events are sent from an interrupt context.

LLINPUT_IMPL_getInitialStateValue allows the input stack to get the current state for devices connected to the MicroUI States event generator, such as switch selector, coding wheels, etc.

23.6.2 Sending Events

The LLINPUT API provides two generic functions for a C driver to send data to its associated event generator:

- LLINPUT_sendEvent: Sends a 32-bit encoded event to a specific event generator, specified by its ID. If the input buffer is full, the event is not added, and the function returns 0; otherwise it returns 1.
- LLINPUT_sendEvents: Sends event data to a specific event generator, specified by its ID. If the input buffer cannot receive the whole data, the event is not added, and the function returns 0; otherwise it returns 1.

Events will be dispatched to the associated event generator that will be responsible for decoding them (see Section 14.5.4).

The UI extension provides an implementation for each of MicroUI's built-in event generators. Each one has dedicated functions that allows a driver to send them structured data without needing to understand the underlying protocol to encode/decode the data. Table 23.1 shows the functions provided to send structured events to the predefined event generators:

Function name	Default event generator kind[a]	Comments
LLINPUT_sendCommandEvent	Command	Constants are provided that define all standard MicroUI commands [MUI].
LLINPUT_sendButtonPressedEvent LLINPUT_sendButtonReleasedEvent LLINPUT_sendButtonRepeatedEvent	Buttons	In the case of chronological sequences (for example, a RELEASE that may occur only after a PRESSED), it is the responsibility of the driver to ensure the integrity of such sequences.
LLINPUT_sendPointerPressedEvent LLINPUT_sendPointerReleasedEvent LLINPUT_sendPointerMovedEvent	Pointer	In the case of chronological sequences (for example, a RELEASE that may occur only after a PRESSED), it is the responsibility of the driver to ensure the integrity of such sequences. Depending on whether a button of the pointer is pressed while moving, a DRAG and/or a MOVE MicroUI event is generated.
LLINPUT_sendStateEvent	States	The initial value of each state machine (of a States) is retrieved by a call to LLINPUT_IMPL_getInitialStateValue that must

Function name	Default event generator kind[a]	Comments
		be implemented by the device. Alternatively, the initial value can be specified in the XML static configuration.
LLINPUT_sendTouchPressedEvent LLINPUT_sendTouchReleasedEvent LLINPUT_sendTouchMovedEvent	Pointer	In the case of chronological sequences (for example, a RELEASE that may only occur after a PRESSED), it is the responsibility of the driver to ensure the integrity of such sequences. These APIs will generate a DRAG MicroUI event instead of a MOVE while they represent a touch pad over a display.

[a]The implementation class is a subclass of the MicroUI class of the column.

Table 23.1. LLINPUT API for predefined event generators

23.6.3 Event Buffer

The maximum usage of the internal event buffer may be retrieved at runtime using the LLINPUT_getMaxEventsBufferUsage function. This is useful for tuning the size of the buffer.

23.7 LLDISPLAY: Display

23.7.1 Principle & Naming Convention

Each display stack provides a low level API in order to connect a display driver. The file LLDISPLAY_impl.h defines the API headers to be implemented. For the APIs themselves, the naming convention is that their names match the *_IMPL_* pattern when the functions need to be implemented.

23.7.2 Initialization

Each display stack gets initialized the same way:

- First, the function LLDISPLAY_IMPL_initialize is called: It asks its display driver to initialize itself.
- Second, the functions LLDISPLAY_IMPL_getWidth and LLDISPLAY_IMPL_getHeight are called to retrieve the size of the physical screen.

23.7.3 Working buffer

The display driver must allocate a runtime memory buffer for creating dynamic images when using MicroUI Image.createImage() methods that explicitly create mutable images.

The display driver may choose to return an empty buffer. Thus, calling MicroUI Image.createImage() methods will result in a java.lang.OutOfMemoryError exception.

LLDISPLAY_getWorkingBufferStartAddress returns the buffer start address. LLDISPLAY_getWorkingBufferEndAddress returns the next address after the buffer (end-start is the buffer length).

23.7.4 Flush and Synchronization

Function LLDISPLAY_getGraphicsBufferAddress returns the address of the graphics buffer (back buffer) for the very first drawing. The content of this buffer is flushed to the external display memory by the function LLDISPLAY_flush. The parameters define the rectangular area of the content which has changed during the last drawing action, and which must be flushed to the display buffer (dirty area).

LLDISPLAY_synchronize is called before the next drawing after a call to the flush function, in order to avoid flickering on the display device.

23.8 LLDISPLAY_EXTRA: Display Extra Features

23.8.1 Principle

An additional low level API allows you to connect display extra features. The files LLDISPLAY_EXTRA_impl.h define the API headers to be implemented. For the APIs themselves, the naming convention is that their names match the *_IMPL_* pattern when the functions must be implemented. These LLAPIs are not required. When they are not implemented, a default implementation is used (weak function).

23.8.2 Display characteristics

Function LLDISPLAY_EXTRA_IMPL_isColor directly implements the method from the MicroUI Display class of the same name. The default implementation always returns LLDISPLAY_EXTRA_OK.

Function LLDISPLAY_EXTRA_IMPL_getNumberOfColors directly implements the method from the MicroUI Display class of the same name. The default implementation returns a value according to the number of bits by pixels, without taking into consideration the alpha bit(s).

Function LLDISPLAY_EXTRA_IMPL_isDoubleBuffered directly implements the method from the MicroUI Display class of the same name. The default implementation returns LLDISPLAY_EXTRA_OK. When LLAPI implementation targets a LCD in direct mode, this function must be implemented and return LLDISPLAY_EXTRA_NOT_SUPPORTED.

23.8.3 Contrast

LLDISPLAY_EXTRA_IMPL_setContrast and DISPLAY_EXTRA_IMPL_getContrast are called to set/get the current display contrast intensity. The default implementations don't manage the contrast.

23.8.4 BackLight

LLDISPLAY_EXTRA_IMPL_hasBackLight indicates whether the display has backlight capabilities.

LLDISPLAY_EXTRA_IMPL_setBackLight and DISPLAY_EXTRA_IIMPL_getBackLight are called to set/get the current display backlight intensity.

LLDISPLAY_EXTRA_IMPL_backlightOn and LLDISPLAY_EXTRA_IMPL_backlightOff enable/disable the backlight. The default implementations don't manage the backlight.

23.8.5 Color conversions

LLDISPLAY_EXTRA_IMPL_convertARGBColorToDisplayColor is called to convert a 32-bit ARGB MicroUI color in 0xAARRGGBB format into the "driver" display color.

LLDISPLAY_EXTRA_IMPL_convertDisplayColorToARGBColor is called to convert a display color to a 32-bit ARGB MicroUI color.

23.8.6 Drawings

23.8.6.1 Synchronization

The display stack calls the functions LLDISPLAY_EXTRA_IMPL_enterDrawingMode and LLDISPLAY_EXTRA_IMPL_exitDrawingMode to enter / leave a critical section. This is useful when some drawings are performed in C-side using the LLDISPLAY_UTILS API. This function implementation can stay empty when there is no call from C-side, or when the calls from C-side are performed in the same OS task, rather than in the MicroEJ core engine task. By default these functions do nothing.

23.8.6.2 LUT

The function LLDISPLAY_EXTRA_IMPL_prepareBlendingOfIndexedColors is called when drawing an image with indexed color. See “LUT” to have more information about indexed images.

23.8.6.3 Hardware Accelerator

Some functions allow you to use an hardware accelerator to perform some drawings: LLDISPLAY_EXTRA_IMPL_fillRect, LLDISPLAY_EXTRA_IMPL_drawImage, LLDISPLAY_EXTRA_IMPL_scaleImage and LLDISPLAY_EXTRA_IMPL_rotateImage. When called, the LLDISPLAY *must* perform the drawing (see "Hardware Accelerator"). Otherwise a call to LLDISPLAY_EXTRA_IMPL_error will be performed with an error code as parameter (see "LLDISPLAY_EXTRA"). Furthermore, the drawing will be not performed by software.

A drawing may be executed directly during the call of the relative function (synchronous execution), may be executed by a hardware peripheral like a DMA (asynchronous execution), or may be executed by a dedicated OS task (asynchronous execution). When the drawing is synchronous, the function must return LLDISPLAY_EXTRA_DRAWING_COMPLETE, which indicates the drawing is complete. When the drawing is asynchronous, the function must return LLDISPLAY_EXTRA_DRAWING_RUNNING, which indicates that the drawing is running. In this case, the very next drawing (with or without hardware acceleration) will be preceded by a specific call in order to synchronize the display stack work with the end of hardware drawing. The function used to wait for the end of drawing is LLDISPLAY_EXTRA_IMPL_waitPreviousDrawing.

The default implementations call the error function.

23.8.7 Structures

The drawing functions are using some struct to specify the drawing to perform. These structures are listed in LLDISPLAY_EXTRA_drawing.h. Refer to this h file have the exhaustive list of structures and structures elements.

- int32_t LLDISPLAY_EXTRA_IMPL_fillRect(LLDISPLAY_SImage* dest, int32_t destAddr, LLDISPLAY_SRectangle* rect, int32_t color)
- int32_t LLDISPLAY_EXTRA_IMPL_drawImage(LLDISPLAY_SImage* src, int32_t srcAddr, LLDISPLAY_SImage* dest, int32_t destAddr, LLDISPLAY_SDrawImage* drawing)
- int32_t LLDISPLAY_EXTRA_IMPL_scaleImage(LLDISPLAY_SImage* src, int32_t srcAddr, LLDISPLAY_SImage* dest, int32_t destAddr, LLDISPLAY_SScaleImage* drawing)
- int32_t LLDISPLAY_EXTRA_IMPL_rotateImage(LLDISPLAY_SImage* src, int32_t srcAddr, LLDISPLAY_SImage* dest, int32_t destAddr, LLDISPLAY_SRotateImage* drawing)

23.8.8 Image Decoders

The API LLDISPLAY_EXTRA_IMPL_decodeImage allows to add some additional image decoders (see "External Decoders"). This LLAPI uses some structures as parameter:

int32_t LLDISPLAY_EXTRA_IMPL_decodeImage(int32_t address, int32_t length, int32_t expected_format, LLDISPLAY_SImage* image, LLDISPLAY_SRawImageData* image_data)

23.9 LLDISPLAY_UTILS: Display Utils

23.9.1 Principle

This header file lets some APIs in C-side perform some drawings in the same buffers used by the display stack. This is very useful for reusing legacy code, performing a specific drawing, etc.

23.9.2 Synchronization

Every drawing performed in C-side must be synchronized with the display stack drawings. The idea is to force the display stack to wait the end of previous asynchronous drawings before drawing anything else. Use the functions enterDrawingMode and exitDrawingMode to enter / leave a critical section.

23.9.3 Buffer Characteristics

A set of functions allow retrieval of several characterics of an image (or the display buffer itself). These functions use a parameter to identify the image: the image Java object hash code (myImage.hashCode() or myGraphicsContext.hashCode()).

The function getBufferAddress returns the address of the image data buffer. This buffer can be located in runtime memory (RAM, SRAM, SDRAM, etc.) or in read-only memory (internal flash, NOR, etc.).

The functions getWidth and getHeight return the size of the image / graphics context.

The function getFormat returns the format of the image / graphics context. The formats list is available in MicroUI GraphicsContext class.

The functions getClipX1, getClipX2, getClipY1 and getClipY2 return the current clip of the image / graphics context. The C-side drawing can use the clip limits (this is optional).

23.9.4 Drawings

A set of functions allows you to use internal display stack functions to draw something on an image (or in the display buffer itself). These functions use a parameter to identify the image: the image Java object hash code (myImage.hashCode() or myGraphicsContext.hashCode()).

The basic functions drawPixel and readPixel are useful for drawing or reading a pixel. The function blend allows you to blend two colors and a global alpha.

The C-side can change the current clip of an image / graphics context only in the display stack. The clip is not updated in MicroUI. Use the function setClip to do this.

A C-side drawing has to update the drawing limits (before or after the drawing itself), using the function setDrawingLimits when the drawing is made in the display back buffer. This allows you to update the size of the dirty area the display stack has to flush. If it is not updated, the C-side drawing (available in back buffer) may never be flushed to the display graphical memory.

23.9.5 Allocation

When decoding an image with an external image decoder (see “External Decoders”), the C-side has to allocate a RAW image in the working buffer. The function LLDISPLAY_UTILS_allocateRawImage takes as parameter a strucutre which describes the image (size and format) and an output structure where it stores the image allocation data:

```
int32_t LLDISPLAY_UTILS_allocateRawImage(LLDISPLAY_SImage* image, LLDISPLAY_SRawImageData* image_data)
```

This function can also be used by C-side to allocate a RAW image in the working buffer. This image will not be known by MicroUI but this image can be used in C-side.

23.10 LLLEDS: LEDs

23.10.1 Principle

The LEDs stack provides a Low Level API for connecting LED drivers. The file LLLEDS_impl.h, which comes with the LEDs stack, defines the API headers to be implemented.

23.10.2 Naming convention

The Low Level API relies on functions that must be implemented. The naming convention for such functions is that their names match the *_IMPL_* pattern.

23.10.3 Initialization

The first function called is LLLEDS_IMPL_initialize, which allows the driver to initialize all LED devices. This method must return the number of LEDs available.

Each LED has a unique identifier. The first LED has the ID 0, and the last has the ID NbLEDs – 1.

This UI extension provides support to efficiently implement the set of methods that interact with the LEDs provided by a device. Below are the relevant C functions:

- LLLEDS_IMPL_getIntensity: Get the intensity of a specific LED using its ID.
- LLLEDS_IMPL_setIntensity: Set the intensity of an LED using its ID.

23.11 LLNET: Network

23.11.1 Naming Convention

The Low Level API, the LLNET API, relies on functions that need to be implemented. The naming convention for such functions is that their names match the LLNET_IMPL_* pattern.

23.11.2 Header Files

Several header files are provided:

- LLNET_CHANNEL_impl.h

  Defines a set of functions that the BSP must implement to initialize the Net native component. It also defines some configuration operations to setup a network connection.

- LLNET_SOCKETCHANNEL_impl.h

  Defines a set of functions that the BSP must implement to create, connect and retrieve information on a network connection.

- LLNET_STREAMSOCKETCHANNEL_impl.h

  Defines a set of functions that the BSP must implement to do some I/O operations on connection oriented socket (TCP). It also defines function to put a server connection in accepting mode (waiting for a new client connection).

- LLNET_DATAGRAMSOCKETCHANNEL_impl.h

  Defines a set of functions that the BSP must implement to do some I/O operations on connectionless oriented socket (UDP).

- LLNET_DNS_impl.h

  Defines a set of functions that the BSP must implement to request host IP address associated to a host name or to request Domain Name Service (DNS) host IP addresses setup in the underlying system.

- LLNET_NETWORKADDRESS_impl.h

  Defines a set of functions that the BSP must implement to convert string IP address or retrieve specific IP addresses (lookup, localhost or loopback IP address).

- LLNET_NETWORKINTERFACE_impl.h

  Defines a set of functions that the BSP must implement to retrieve information on a network interface (MAC address, interface link status, etc.).

23.12 LLNET_SSL: SSL

23.12.1 Naming Convention

The Low Level API, the LLNET_SSL API, relies on functions that need to be implemented. The naming convention for such functions is that their names match the LLNET_SSL_* pattern.

23.12.2 Header Files

Three header files are provided:

- LLNET_SSL_CONTEXT_impl.h

  Defines a set of functions that the BSP must implement to create a SSL Context and to load CA (Certificate Authority) certificates as trusted certificates.

- LLNET_SSL_SOCKET_impl.h

  Defines a set of functions that the BSP must implement to initialize the SSL native components, to create an underlying SSL Socket and to initiate a SSL session handshake. It also defines some I/O operations such as LLNET_SSL_SOCKET_IMPL_write or LLNET_SSL_SOCKET_IMPL_read used for encrypted data exchange between the client and the server.

- LLNET_SSL_X509_CERT_impl.h

  Defines a function named LLNET_SSL_X509_CERT_IMPL_parse for certificate parsing. This function checks if a given certificate is an X.509 digital certificate and returns its encoded format type : Distinguished Encoding Rules (DER) or Privacy-Enchanced Mail (PEM).

23.13 LLFS: File System

23.13.1 Naming Convention

The Low Level File System API (LLFS), relies on functions that need to be implemented by engineers in a driver. The names of these functions match the LLFS_IMPL_* and the LLFS_File_IMPL_* pattern.

23.13.2 Header Files

Two C header files are provided:

- LLFS_impl.h

  Defines a set of functions that the BSP must implement to initialize the FS native component. It also defines some functions to manage files, directories and retrieve information about the underlying File System (free space, total space, etc.).

- LLFS_File_impl.h

  Defines a set of functions that the BSP must implement to do some I/O operations on files (open, read, write, close, etc.).

23.14 LLHAL: Hardware Abstraction Layer

23.14.1 Naming Convention

The Low Level API, the LLHAL API, relies on functions that need to be implemented. The naming convention for such functions is that their names match the LLHAL_IMPL_* pattern.

23.14.2 Header Files

One header file is provided:

- LLHAL_impl.h

  Defines the set of functions that the BSP must implement to configure and drive some MCU GPIO.

23.15 LLDEVICE: Device Information

23.15.1 Naming Convention

The Low Level Device API (LLDEVICE), relies on functions that need to be implemented by engineers in a driver. The names of these functions match the LLDEVICE_IMPL_* pattern.

23.15.2 Header Files

One C header file is provided:

- LLDEVICE_impl.h

  Defines a set of functions that the BSP must implement to get the platform architecture name and unique device identifier.

24 Appendix B: Foundation Libraries

24.1 EDC

24.1.1 Error Messages

When an exception is thrown by the runtime, the error message

Generic:E=<messageId>

is issued, where **<messageId>** meaning is defined in the next table:

Message ID	Description
1	Negative offset.
2	Negative length.
3	Offset + length > object length.

Table 24.1. Generic Error Messages

When an exception is thrown by the implementation of the EDC API, the error message

EDC-1.2:E=<messageId>

is issued, where **<messageId>** meaning is defined in the next table:

Message ID	Description
-4	No native stack found to execute the Java native method.
-3	Maximum stack size for a thread has been reached. Increase the maximum size of the thread stack parameter.
-2	No Java stack block could be allocated with the given size. Increase the Java stack block size.
-1	The Java stack space is full. Increase the Java stack size or the number of Java stack blocks.
1	A closed stream is being written/read.
2	The operation Reader.mark() is not supported.
3	lock is null in Reader(Object lock).
4	String index is out of range.
5	Argument must be a positive number.
6	Invalid radix used. Must be from Character.MIN_RADIX to Character.MAX_RADIX.

Table 24.2. EDC Error Messages

24.1.2 Exit Codes

The RTOS task that runs the MicroEJ runtime may end, especially when the MicroEJ application calls System.exit method [EDC]. By convention, a negative value indicates abnormal termination.

Message ID	Meaning
0	The MicroEJ application ended normally.
-1	The SOAR and the MicroEJ platform are not compatible.
-2	Incompatible link configuration (lsc file) with either the SOAR or the MicroEJ platform.
-3	Evaluation version limitations reached: termination of the application.
-5	Not enough resources to start the very first MicroEJ thread that executes main method.

Message ID	Meaning
-12	Maximum number of threads reached.
-13	Fail to start the MicroEJ platform because the specified MicroEJ heap is too large.
-14	Invalid stack space due to a link placement error.
-15	The application has too many static (the requested static head is too large).
-16	The MicroEJ core engine cannot be restarted.

Table 24.3. MicroEJ platform exit codes

24.2 SNI

24.2.1 Error Messages

The following error messages are issued at runtime.

Message ID	Description
-1	Not enough blocks.
-2	Reserved.
-3	Max stack blocks per thread reached.

Table 24.4. SNI Run Time Error Messages.

24.3 KF

24.3.1 Feature Definition Files

A Feature is a group of types, resources and [B-ON] immutables objects defined using two files that shall be in application classpath:

- [featureName].kf, a Java properties file. Keys are described in Table 24.5, “Feature definition file properties”.
- [featureName].cert, an X509 certificate file that uniquely identifies the Feature

Key	Usage	Description
entryPoint	Mandatory	The fully qualified name of the class that implements ej.kf.FeatureEntryPoint
immutables	Optional	Semicolon separated list of paths to [B-ON] immutable files owned by the Feature. [B-ON] immutable file is defined by a / separated path relative to application classpath
resources	Optional	Semicolon separated list of resource names owned by the Feature. Resource name is defined by Class.getResourceAsStream(String)
requiredTypes	Optional	Comma separated list of fully qualified names of required types. (Types that may be dynamically loaded using Class.forName()).
types	Optional	Comma separated list of fully qualified names of types owned by the Feature. A wildcard is allowed as terminal character to embed all types starting with the given qualified name (a.b.C,x.y.*)
version	Mandatory	String version, that can retrieved using ej.kf.Module.getVersion()

Table 24.5. Feature definition file properties

24.3.2 Kernel Definition Files

Kernel definition files are mandatory if one or more Feature definition file is loaded and are named kernel.kf and kernel.cert. kernel.kf must only define the version key. All types, resources and immutables are automatically owned by the Kernel if not explicitly set to be owned by a Feature.

24.3.2.1 Kernel API Definition

Kernel types, methods and static fields allowed to be accessed by Features must be declared in kernel.api file. Kernel API file is an XML file (see Figure 24.1, “Kernel API XML Schema” and Table 24.6, “XML elements specification”).

```
<xs:schema xmlns:xs='http://www.w3.org/2001/XMLSchema'>
 <xs:element name='require'>
  <xs:complexType>
   <xs:choice minOccurs='0' maxOccurs='unbounded'>
    <xs:element ref='type'/>
    <xs:element ref='field'/>
     <xs:element ref='method'/>
     </xs:choice>
   </xs:complexType>
 </xs:element>

  <xs:element name='type'>
   <xs:complexType>
     <xs:attribute name='name' type='xs:string' use='required'/>
   </xs:complexType>
  </xs:element>

  <xs:element name='field'>
   <xs:complexType>
     <xs:attribute name='name' type='xs:string' use='required'/>
   </xs:complexType>
  </xs:element>

  <xs:element name='method'>
   <xs:complexType>
     <xs:attribute name='name' type='xs:string' use='required'/>
   </xs:complexType>
  </xs:element>
</xs:schema>
```

Figure 24.1. Kernel API XML Schema

Tag	Attributes	Description
require		The root element
field		Static field declaration. Declaring a field as a Kernel API automatically sets the declaring type as a Kernel API
	name	Fully qualified name on the form [type].[fieldName]
method		Method or constructor declaration. Declaring a method or a constructor as a Kernel API automatically sets the declaring type as a Kernel API
	name	Fully qualified name on the form [type].[methodName]([typeArg1,...,typeArgN)typeReturned. Types are fully qualified names or one of a base type as described by the Java language (boolean, byte, char, short, int, long, float, double) When declaring a constructor, methodName is the single type name. When declaring a void method or a constructor, typeReturned is void
type		Type declaration, allowed to be loaded from a Feature using Class.forName()
	name	Fully qualified name on the form [package].[package].[typeName]

Table 24.6. XML elements specification

24.3.3 Access Error Codes

When an instruction is executed that will break a [KF] insulation semantic rule, a java.lang.IllegalAccessError is thrown, with an error code composed of two parts: [source][errorKind].

- source: a single character indicating the kind of Java element on which the access error occurred (Table 24.7, “Error codes: source”)

- errorKind: an error number indicating the action on which the access error occurred (Table 24.8, “Error codes: kind”)

Character	Description
A	Error thrown when accessing an array
I	Error thrown when calling a method
F	Error thrown when accessing an instance field
M	Error thrown when entering a synchronized block or method
P	Error thrown when passing a parameter to a method call
R	Error thrown when returning from a method call
S	Error thrown when accessing a static field

Table 24.7. Error codes: source

Id	Description
1	An object owned by a Feature is being assigned to an object owned by the Kernel, but the current context is not owned by the Kernel
2	An object owned by a Feature is being assigned to an object owned by another Feature
3	An object owned by a Feature is being accessed from a context owned by another Feature
4	A synchronize on an object owned by the Kernel is executed in a method owned by a Feature
5	A call to a feature code occurs while owning a Kernel monitor

Table 24.8. Error codes: kind

24.3.4 Loading Features Dynamically

Features may be statically embedded with the Kernel or dynamically built against a Kernel. To build a Feature binary file, select Build Dynamic FeatureMicroEJ platformExecution tab. The generated file can be dynamically loaded by the Kernel runtime using ej.kf.Kernel.load(InputStream).

24.4 ECOM

24.4.1 Error Messages

When an exception is thrown by the implementation of the ECOM API, the error message

ECOM-1.1:E=<messageId>

is issued, where **<messageId>** meaning is defined in the next table:

Message ID	Description
1	The connection has been closed. No more action can be done on this connection.
2	The connection has already been closed.
3	The connection description is invalid. The connection cannot be opened.
4	The connection stream has already been opened. Only one stream per kind of stream (input or output stream) can be opened at the same time.
5	Too many connections have been opened at the same time. The platform is not able to open a new one. Try to close useless connections before trying to open the new connection.

Table 24.9. ECOM Error Messages

24.5 ECOM Comm

24.5.1 Error Messages

When an exception is thrown by the implementation of the ECOM-COMM API, the error message

ECOM-COMM:E=<messageId>

is issued, where **<messageId>** meaning is defined in the next table:

Message ID	Description
1	The connection descriptor must start with "comm:"
2	Reserved.
3	The Comm port is unknown.
4	The connection descriptor is invalid.
5	The Comm port is already open.
6	The baudrate is unsupported.
7	The number of bits per character is unsupported.
8	The number of stop bits is unsupported.
9	The parity is unsupported.
10	The input stream cannot be opened because native driver is not able to create a RX buffer to store the incoming data.
11	The output stream cannot be opened because native driver is not able to create a TX buffer to store the outgoing data.
12	The given connection descriptor option cannot be parsed.

Table 24.10. ECOM-COMM error messages

24.6 MicroUI

24.6.1 Error Messages

When an exception is thrown by the implementation of the MicroUI API, the exception MicroUIException with the error message

MicroUI:E=<messageId>

is issued, where the meaning of **<messageId>** is defined in Table 24.11.

Message ID	Description
1	Deadlock. Cannot wait for an event in the same thread that runs events. Display.waitForEvent() must not be called in the display pump thread (for example in paint methods).
2	Out of memory. The image limit has been reached because too many images are opened at the same time. Try to remove references on useless images, and retry opening the new image, or increase the number of concurrent images in the MicroEJ launcher.
3	Out of memory. Not enough memory to allocate the Image's buffer. Try to remove references on useless images and retry opening the new image, or increase the size of the MicroUI working buffer.
4	A polygon cannot have more than 16 sides.
5	The platform cannot allocate memory to create a dynamic image.
6	Image's path is limited to 100 characters.

Message ID	Description
7	The platform cannot decode this kind of image, because the required runtime image decoder is not available in the platform.
8	Another EventGenerator cannot be added into the system pool (max 254).
9	Font's path is limited to 100 characters.
10	Invalid font path: cannot load this font.
11	MicroUI is not started; call MicroUI.start() before using a MicroUI API.
15	FIFOPump size must be positive
17	Out of memory. There is not enough memory to open a new FlyingImage Try to increase the number of concurrent flying images in the MicroEJ launcher.
18	There is not enough memory to add a new font. Try to increase the number of fonts in the MicroEJ launcher
19	Font's path must be relative to the classpath.
20	Unknown event generator class name.
21	The font data cannot be loaded for an unknown reason (font is stored outside the CPU address space range).
22	Out of memory. There is not enough room to allocate the font data (font is stored outside the CPU address space range).

Table 24.11. MicroUI Error Messages

24.6.2 Exceptions

Some other exceptions can be thrown by the MicroUI framework in addition to the generic MicroUIException (see previous chapter).

Message ID	Description
OutOfEventsException	This exception is thrown when the pump of the internal thread DisplayPump is full. In this case, no more event (such as repaint, input events etc.) can be added into it. Most of time this error occurs when: • There is a user thread which performs too many calls to the method paint without waiting for the end of the previous drawing. • Too many input events are pushed from an input driver to the display pump (for example some touch events).

Table 24.12. MicroUI Exceptions

24.7 FS

24.7.1 Error Messages

When an exception is thrown by the implementation of the FS API, the error message

FS:E=<messageId>

is issued, where **<messageId>** meaning is defined in the next table:

Message ID	Description
-1	End of File (EOF).
-2	An error occurred during a File System operation.

Message ID	Description
-3	File System not initialized.

Table 24.13. File System Error Messages

24.8 Net

24.8.1 Error Messages

When an exception is thrown by the implementation of the Net API, the error message

NET-1.1:E=<messageId>

is issued, where **<messageId>** meaning is defined in the next table:

Message ID	Description
-2	Permission denied.
-3	Bad socket file descriptor.
-4	Host is down.
-5	Network is down.
-6	Network is unreachable.
-7	Address already in use.
-8	Connection abort.
-9	Invalid argument.
-10	Socket option not available.
-11	Socket not connected.
-12	Unsupported network address family.
-13	Connection refused.
-14	Socket already connected.
-15	Connection reset by peer.
-16	Message size to be sent is too long.
-17	Broken pipe.
-18	Connection timed out.
-19	Not enough free memory.
-20	No route to host.
-21	Unknown host.
-23	Native method not implemented.
-24	The blocking request queue is full, and a new request cannot be added now.
-25	Network not initialized.
-255	Unknown error.

Table 24.14. Net Error Messages

24.9 SSL

24.9.1 Error Messages

When an exception is thrown by the implementation of the SSL API, the error message

SSL-2.0:E=<messageId>

is issued, where **<messageId>** meaning is defined in the next table:

Message ID	Description
-2	Connection reset by the peer.
-3	Connection timed out.
-5	Dispatch blocking request queue is full, and a new request cannot be added now.
-6	Certificate parsing error.
-7	The certificate data size bigger than the immortal buffer used to process certificate.
-8	No trusted certificate found.
-9	Basic constraints check failed: Intermediate certificate is not a CA certificate.
-10	Subject/issuer name chaining error.
-21	Wrong block type for RSA function.
-22	RSA buffer error: Output is too small, or input is too large.
-23	Output buffer is too small, or input is too large.
-24	Certificate AlogID setting error.
-25	Certificate public-key setting error.
-26	Certificate date validity setting error.
-27	Certificate subject name setting error.
-28	Certificate issuer name setting error.
-29	CA basic constraint setting error.
-30	Extensions setting error.
-31	Invalid ASN version number.
-32	ASN get int error: invalid data.
-33	ASN key init error: invalid input.
-34	Invalid ASN object id.
-35	Not null ASN tag.
-36	ASN parsing error: zero expected.
-37	ASN bit string error: wrong id.
38	ASN OID error: unknown sum id.
-39	ASN date error: bad size.
-40	ASN date error: current date before.
-41	ASN date error: current date after.
-42	ASN signature error: mismatched OID.
-43	ASN time error: unknown time type.
-44	ASN input error: not enough data.
-45	ASN signature error: confirm failure.
-46	ASN signature error: unsupported hash type.
-47	ASN signature error: unsupported key type.
-48	ASN key init error: invalid input.
-49	ASN NTRU key decode error: invalid input.
-50	X.509 critical extension ignored.

Message ID	Description
-51	ASN no signer to confirm failure (no CA found).
-52	ASN CRL signature-confirm failure.
-53	ASN CRL: no signer to confirm failure.
-54	ASN OCSP signature-confirm failure.
-60	ECC input argument is wrong type.
-61	ECC ASN1 bad key data: invalid input.
-62	ECC curve sum OID unsupported: invalid input.
-63	Bad function argument provided.
-64	Feature not compiled in.
-65	Unicode password too big.
-66	No password provided by user.
-67	AltNames extensions too big.
-70	AES-GCM Authentication check fail.
-71	AES-CCM Authentication check fail.
-80	Cavium Init type error.
-81	Bad alignment error, no alloc help.
-82	Bad ECC encrypt state operation.
-83	Bad padding: message wrong length.
-84	Certificate request attributes setting error.
-85	PKCS#7 error: mismatched OID value.
-86	PKCS#7 error: no matching recipient found.
-87	FIPS mode not allowed error.
-88	Name constraint error.
-89	Random Number Generator failed.
-90	FIPS Mode HMAC minimum key length error.
-91	RSA Padding error.
-92	Export public ECC key in ANSI format error: Output length only set.
-93	In Core Integrity check FIPS error.
-94	AES Known Answer Test check FIPS error.
-95	DES3 Known Answer Test check FIPS error.
-96	HMAC Known Answer Test check FIPS error.
-97	RSA Known Answer Test check FIPS error.
-98	DRBG Known Answer Test check FIPS error.
-99	DRBG Continuous Test FIPS error.
-100	AESGCM Known Answer Test check FIPS error.
-101	Process input state error.
-102	Bad index to key rounds.
-103	Out of memory.
-104	Verify problem found on completion.
-105	Verify mac problem.
-106	Parse error on header.

Message ID	Description
-107	Weird handshake type.
-108	Error state on socket.
-109	Expected data, not there.
-110	Not enough data to complete task.
-111	Unknown type in record header.
-112	Error during decryption.
-113	Received alert: fatal error.
-114	Error during encryption.
-116	Need peer's key.
-117	Need the private key.
-118	Error during RSA private operation.
-119	Server missing DH parameters.
-120	Build message failure.
-121	Client hello not formed correctly.
-122	The peer subject name mismatch.
-123	Non-blocking socket wants data to be read.
-124	Handshake layer not ready yet; complete first.
-125	Premaster secret version mismatch error.
-126	Record layer version error.
-127	Non-blocking socket write buffer full.
-128	Malformed buffer input error.
-129	Verify problem on certificate.
-130	Verify problem based on signature.
-131	PSK client identity error.
-132	PSK server hint error.
-133	PSK key callback error.
-134	Record layer length error.
-135	Can't decode peer key.
-136	The peer sent close notify alert.
-137	Wrong client/server type.
-138	The peer didn't send the certificate.
-140	NTRU key error.
-141	NTRU DRBG error.
-142	NTRU encrypt error.
-143	NTRU decrypt error.
-150	Bad ECC Curve Type or unsupported.
-151	Bad ECC Curve or unsupported.
-152	Bad ECC Peer Key.
-153	ECC Make Key failure.
-154	ECC Export Key failure.
-155	ECC DHE shared failure.

Message ID	Description
-157	Not a CA by basic constraint.
-159	Bad Certificate Manager error.
-160	OCSP Certificate revoked.
-161	CRL Certificate revoked.
-162	CRL missing, not loaded.
-165	OCSP needs a URL for lookup.
-166	OCSP Certificate unknown.
-167	OCSP responder lookup fail.
-168	Maximum chain depth exceeded.
-171	Suites pointer error.
-172	No PEM header found.
-173	Out of order message: fatal.
-174	Bad KEA type found.
-175	Sanity check on ciphertext failed.
-176	Receive callback returned more than requested.
-178	Need peer certificate for verification.
-181	Unrecognized host name error.
-182	Unrecognized max fragment length.
-183	Key Use digitalSignature not set.
-185	Key Use keyEncipherment not set.
-186	Ext Key Use server/client authentication not set.
-187	Send callback out-of-bounds read error.
-188	Invalid renegotiation.
-189	Peer sent different certificate during SCR.
-190	Finished message received from peer before receiving the Change Cipher message.
-191	Sanity check on message order.
-192	Duplicate handshake message.
-193	Unsupported cipher suite.
-194	Can't match cipher suite.
-195	Bad certificate type.
-196	Bad file type.
-197	Opening random device error.
-198	Reading random device error.
-199	Windows cryptographic init error.
-200	Windows cryptographic generation error.
-201	No data is waiting to be received from the random device.
-202	Unknown error.

Table 24.15. SSL Error Messages

25 Appendix C: Tools Options and Error Codes

25.1 Smart Linker

When a generic exception is thrown by the Smart linker, the error message

SOAR ERROR [M<messageId>] <message>

is issued, where **<messageId>** and **<message>** meanings are defined in the next table.

Message ID	Description
0	The SOAR process has encountered some internal limits.
1	Unknown option.
2	An option has an invalid value.
3	A mandatory option is not set.
4	A filename given in options does not exist .
5	Failed to write the output file (access permissions required for -toDir and -root options).
6	The given file does not exist.
7	I/O error while reading a file.
8	An option value refers to a directory, instead of a file.
9	An option value refers to a file, instead of a directory or a jar file.
10	Invalid entry point class or no main() method.
11	An information file can not be generated in its entirety.
12	Limitations of the evaluation version have been reached.
13	I/O rrror while reading a jar file.
14	IO Error while writing a file.
15	I/O error while reading a jar file: unknown entry size.
16	Not enough memory to load a jar file.
17	The specified SOAR options are exclusive.
18	XML syntax error for some given files.
19	Unsupported float representation.
23	A clinit cycle has been detected. The clinit cycle can be cut either by simplifying the application clinit code or by explicitly declaring clinit dependencies. Check the generated .clinitmap file for more information.
50	Missing code: Java code refers to a method not found in specified classes.
51	Missing code: Java code refers to a class not found in the specified classpath.
52	Wrong class: Java code refers to a field not found in the specified class.
53	Wrong class: A Java classfile refers to a class as an interface.
54	Wrong class: An abstract method is found in a non-abstract class.
55	Wrong class: illegal access to a method, a field or a type.
56	Wrong class: hierarchy inconsistency; an interface cannot be a superclass of a class.
57	Circularity detected in initializion sequence.
58	Option refers twice to the same resource. The first reference is used.
59	Stack inconsistency detected.

Message ID	Description
60	Constant pool inconsistency detected.
61	Corrupted classfile.
62	Missing native implementation of a native method.
63	Cannot read the specified resource file.
64	The same property name cannot be defined in two different property files.
65	Bad license validity.
66	Classfiles do not contain debug line table information.
67	Same as 51.
150	SOAR limit reached: The specified method uses too many arguments.
151	SOAR limit reached: The specified method uses too many locals.
152	SOAR limit reached: The specified method code is too large.
153	SOAR limit reached: The specified method catches too many exceptions.
154	SOAR limit reached: The specified method defines a stack that is too large.
155	SOAR limit reached: The specified type defines too many methods.
156	SOAR limit reached: Your application defines too many interfaces.
157	SOAR limit reached: The specified type defines too many fields.
158	SOAR limit reached: your application defines too many types.
159	SOAR limit reached: Your application defines too many static fields.
160	SOAR limit reached: The hierarchy depth of the specified type is too high.
161	SOAR limit reached: Your application defines too many bundles.
251	Error in converting an IEE754 float(32) or double(64) to a fixed-point arithmetic number
300	Corrupted class: invalid dup_x1 instruction usage.
301	Corrupted class: invalid dup_x2 instruction usage.
302	Corrupted class:invalid dup_x2 instruction usage.
303	Corrupted class:invalid dup2_x1 instruction usage.
304	Corrupted class:invalid dup2_x1 instruction usage.
305	Corrupted class:invalid dup2_x2 instruction usage.
306	Corrupted class: invalid dup2 instruction usage.
307	Corrupted class:invalid pop2 instruction usage.
308	Corrupted class:invalid swap instruction usage.
309	Corrupted class: Finally blocks must be inlined.
350	SNI incompatibility: Some specified type should be an array.
351	SNI incompatibility: Some type should define some specified field.
352	SNI incompatibility: The specified field is not compatible with SNI.
353	SNI incompatibility: The specified type must be a class.
354	SNI incompatibility: The specified static field must be defined in the specified type.
355	SNI file error: The data must be an integer.
356	SNI file error : unexpected tag

Message ID	Description
357	SNI file error : attributes <name>, <descriptor>, <index> and <size> are expected in the specified tag.
358	SNI file error : invalid SNI tag value.
359	Error parsing the SNI file.
360	XML Error on parsing the SNI file.
361	SNI incompatibility : illegal call to the specified data.
362	No stack found for the specified native group.
363	Invalid SNI method: The argument cannot be an object reference.
364	Invalid SNI method: The array argument must only be a base type array.
365	Invalid SNI method: The return type must be a base type.
366	Invalid SNI method: The method must be static.

Table 25.1. SOAR Error Messages.

25.2 Immutable Files Related Error Messages

The following error messages are issued at SOAR time (link phase) and not at runtime.

Message ID	Description
0	Duplicated ID in immutable files. Each immutable object should have a unique ID in the SOAR image.
1	An immutable file refers to an unknown field of an object.
2	Tried to assign the same object field twice.
3	All immutable object fields should be defined in the immutable file description.
4	The assigned value does not match the expected Java type.
5	An immutable object refers to an unknown ID.
6	The length of the immutable object does not match the length of the assigned object.
7	The type defined in the file doesn't match the Java expected type.
8	Generic error while parsing an immutable file.
9	Cycle detected in an alias definition.
10	An immutable object is an instance of an abstract class or an interface.
11	Unknown XML attribute in an immutable file.
12	A mandatory XML attribute is missing.
13	The value is not a valid Java literal.
14	Alias already exists.

Table 25.2. Errors when parsing immutable files at link time.

25.3 SNI

The following error messages are issued at SOAR time and not at runtime.

Message ID	Description
363	Argument cannot be a reference.
364	Argument can only be from a base type array.
365	Return type must be a base type.

Message ID	Description
366	Method must be a static method.

Table 25.3. SNI Link Time Error Messages.

25.4 SP Compiler

25.4.1 Options

Option name	Description
-verbose[e...e]	Extra messages are printed out to the console according to the number of 'e'.
-descriptionFile file	XML Shielded Plug description file. Multiple files allowed.
-waitingTaskLimit value	Maximum number of task/threads that can wait on a block: a number between 0 and 7. -1 is for no limit; 8 is for unspecified.
-immutable	When specified, only immutable Shielded Plugs can be compiled.
-output dir	Output directory. Default is the current directory.
-outputName name	Output name for the Shielded Plug layout description. Default is "shielded_plug".
-endianness name	Either "little" or "big". Default is "little".
-outputArchitecture value	Output ELF architecture. Only "ELF" architecture is available.
-rwBlockHeaderSize value	Read/Write header file value.
-genIdsC	When specified, generate a C header file with block ID constants.
-cOutputDir dir	Output directory of C header files. Default is the current directory.
-cConstantsPrefix prefix	C constants name prefix for block IDs.
-genIdsJava	When specified, generate Java interfaces file with block ID constants.
-jOutputDir dir	Output directory of Java interfaces files. Default is the current directory.
-jPackage name	The name of the package for Java interfaces.

Table 25.4. Shielded Plug Compiler Options.

25.4.2 Error Messages

Message ID	Description
0	Internal limits reached.
1	Invalid endianness.
2	Invalid output architecture.
3	Error while reading / writing files.
4	Missing a mandatory option.

Table 25.5. Shielded Plug Compiler Error Messages.

25.5 NLS Immutables Creator

ID	Type	Description
1	Error	Error reading the nls list file: invalid path, input/output error, etc.
2	Error	Error reading the nls list file: The file contents are invalid.

ID	Type	Description
3	Error	Specified class is not an interface.
4	Error	Invalid message ID. Must be greater than or equal to 1.
5	Error	Duplicate ID. Both messages use the same message ID.
6	Error	Specified interface does not exist.
7	Error	Specified message constant is not visible (must be public).
8	Error	Specified message constant is not an integer.
9	Error	No locale file is defined for the specified header.
10	Error	IO error: Cannot create the output file.
11	Warning	Missing message value.
12	Warning	There is a gap (or gaps) in messages constants.
13	Warning	Specified property does not denote a message.
14	Warning	Invalid properties header file. File is ignored.
15	Warning	No message is defined for the specified header.
16	Warning	Invalid property.

Table 25.6. NLS Immutables Creator Errors Messages

25.6 MicroUI Static Initializer

25.6.1 Inputs

The XML file used as input by the MicroUI Static Initialization Tool may contain tags related to the Input component as described below.

```
<eventgenerators>
<!-- Generic Event Generators -->
   <eventgenerator name="GENERIC" class="foo.bar.Zork">
      <property name="PROP1" value="3"/>
      <property name="PROP2" value="aaa"/>
   </eventgenerator>

   <!-- Predefined Event Generators -->
   <command name="COMMANDS"/>
   <buttons name="BUTTONS" extended="3"/>
   <buttons name="JOYSTICK" extended="5"/>
   <pointer name="POINTER" width="1200" height="1200"/>
   <touch name="TOUCH" display="DISPLAY"/>
   <states name="STATES" numbers="NUMBERS" values="VALUES"/>

</eventgenerators>

<array name="NUMBERS">
   <elem value="3"/>
   <elem value="2"/>
   <elem value="5"/>
</array>

<array name="VALUES">
   <elem value="2"/>
   <elem value="0"/>
   <elem value="1"/>
</array>
```

Figure 25.1. Event Generators Description

Tag	Attributes	Description
eventgenerators		The list of event generators.

Tag	Attributes	Description
	priority	*Optional.* An integer value. Defines the priority of the MicroUI dispatch thread (also called Input Pump). Default value is 5.
eventgenerator		Describes a generic event generator. See also Section 14.5.4.
	name	The logical name.
	class	The event generator class (must extend the ej.microui.event.generator.GenericEventGenerator class). This class must be available in the MicroEJ application classpath.
	listener	*Optional.* Default listener's logical name. Only a display is a valid listener. If no listener is specified the listener is the default display.
property		A generic event generator property. The generic event generator will receive this property at startup, via the method setProperty.
	name	The property key.
	value	The property value.
command		The default event generator Command.
	name	The logical name.
	listener	*Optional.* Default listener's logical name. Only a display is a valid listener. If no listener is specified, then the listener is the default display.
buttons		The default event generator Buttons.
	name	The logical name.
	extended	*Optional.* An integer value. Defines the number of buttons which support the MicroUI extended features (elapsed time, click and double-click).
	listener	*Optional.* Default listener's logical name. Only a display is a valid listener. If no listener is specified, then the listener is the default display.
pointer		The default event generator Pointer.
	name	The logical name.
	width	An integer value. Defines the pointer area width.
	height	An integer value. Defines the pointer area height.
	extended	*Optional.* An integer value. Defines the number of pointer buttons (right click, left click, etc.) which support the MicroUI extended features (elapsed time, click and double-click).
	listener	*Optional.* Default listener's logical name. Only a display is a valid listener. If no listener is specified, then the listener is the default display.
touch		The default event generator Touch.
	name	The logical name.
	display	Logical name of the Display with which the touch is associated.

Tag	Attributes	Description
	listener	*Optional.* Default listener's logical name. Only a display is a valid listener. If no listener is specified, then the listener is the default display.
states		An event generator that manages a group of state machines. The state of a machine is changed by sending an event using LLINPUT_sendStateEvent.
	name	The logical name.
	numbers	The logical name of the array which defines the number of state machines for this States generator, and their range of state values. The IDs of the state machines start at 0. The number of state machines managed by the States generator is equal to the size of the numbers array, and the value of each entry in the array is the number of different values supported for that state machine. State machine values for state machine i can be in the range 0 to numbers[i]-1.
	values	*Optional.* The logical name of the array which defines the initial state values of the state machines for this States generator. The values array must be the same size as the numbers array. If initial state values are specified using a values array, then the LLINPUT_IMPL_getInitialStateValue function is not called; otherwise that function is used to establish the initial values[a].
	listener	*Optional.* Default listener's logical name. Only a display is a valid listener. If no listener is specified, then the listener is the default display.
array		An array of values.
	name	The logical name.
elem		A value.
	value	An integer value.

[a]Exception: When using MicroEJ platform, where there is no equivalent to the LLINPUT_IMPL_getInitialStateValue function. If no values array is provided, and the MicroEJ platform is being used, all state machines take 0 as their initial state value.

Table 25.7. Event Generators Static Definition

25.6.2 Display

The display component augments the static initialization file with:

- The configuration of each display.
- Fonts that are implicitly embedded within the application (also called system fonts). Applications can also embed their own fonts.

```
<display name="DISPLAY"/>

<fonts>
   <font file="resources\fonts\myfont.ejf">
      <range name="LATIN" sections="0-2"/>
      <customrange start="0x21" end="0x3f"/>
   </font>
   <font file="C:\data\myfont.ejf"/>
</fonts>
```

Tag	Attributes	Description
display		The display element describes one display.
	name	The logical name of the display.
	priority	*Optional.* An integer value. Defines the internal display thread priority. Default value is 5.
	default	*Optional.* true or false. Defines this display to be the default display. By default the very first display described in the XML file is the default display.
fonts		The list of system fonts. The system fonts are available for all displays.
font		A system font.
	file	The font file path. The path may be absolute or relative to the XML file.
range		A font generic range.
	name	The generic range name (LATIN, HAN, etc.)
	sections	*Optional.* Defines one or several sub parts of the generic range. "1": add only part 1 of the range "1-5": add parts 1 to 5 "1,5": add parts 1 and 5 These combinations are allowed: "1,5,6-8" add parts 1, 5, and 6 through 8 By default, all range parts are embedded.
customrange		A font-specific range.
	start	UTF16 value of the very first character to embed.
	end	UTF16 value of the very last character to embed.

Table 25.8. Display Static Initialization XML Tags Definition

25.7 Font Generator

25.7.1 Configuration File

```
ConfigFile        ::= Line [ 'EOL' Line ]*
Line    ::= FontPath [ ':' [ Ranges ] [ ':' BitsPerPixel ] ]
FontPath   ::= Identifier [ '/' Identifier ]*
Ranges     ::= Range [ ';' Range ]*
Range    ::= CustomRangeList | KnownRange
CustomRangeList  ::= CustomRange [ ',' CustomRange ]*
CustomRange   ::= Number | Number '-'  Number
KnownRange   ::= Name [ SubRangeList ]?
SubRangeList  ::= '(' SubRange [ ',' SubRange ]* ')'
SubRange   ::= Number | Number - Number
Identifier   ::= 'a-zA-Z_$' [ 'a-zA-Z_$0-9' ]*
Number    ::= Number16 | Number10
Number16   ::= '0x' [ Digit16 ]+
Number10   ::= [ Digit10 ]+
Digit16    ::= 'a-fA-F0-9'
Digit10    ::= '0-9'
BitsPerPixel  ::= '1' | '2' | '4' | '8'
```

Figure 25.2. Fonts Configuration File Grammar

25.7.2 Custom Range

Allows the selection of raw Unicode character ranges.

Examples:

- myfont:0x21-0x49: Embed all characters from 0x21 to 0x49 (included).
- myfont:0x21-0x49,0x55: Embed all characters from 0x21 to 0x49 and character 0x55
- myfont:0x21-0x49;0x55: Same as previous, but done by declaring two ranges.

25.7.3 Known Range

A known range is a range available in the following table.

Examples:

- myfont:basic_latin: Embed all *Basic Latin* characters.
- myfont:basic_latin;arabic: Embed all *Basic Latin* characters, and all *Arabic* characters.

Table 25.9 describes the available list of ranges and sub-ranges (processed from the "Unicode Character Database" version 9.0.0 available on the official unicode website [http://www.unicode.org/]).

Name	Tag	Start	End
Basic Latin	basic_latin	0x0	0x7f
Latin-1 Supplement	latin-1_supplement	0x80	0xff
Latin Extended-A	latin_extended-a	0x100	0x17f
Latin Extended-B	latin_extended-b	0x180	0x24f
IPA Extensions	ipa_extensions	0x250	0x2af
Spacing Modifier Letters	spacing_modifier_letters	0x2b0	0x2ff
Combining Diacritical Marks	combining_diacritical_marks	0x300	0x36f
Greek and Coptic	greek_and_coptic	0x370	0x3ff
Cyrillic	cyrillic	0x400	0x4ff
Cyrillic Supplement	cyrillic_supplement	0x500	0x52f
Armenian	armenian	0x530	0x58f

Name	Tag	Start	End
Hebrew	hebrew	0x590	0x5ff
Arabic	arabic	0x600	0x6ff
Syriac	syriac	0x700	0x74f
Arabic Supplement	arabic_supplement	0x750	0x77f
Thaana	thaana	0x780	0x7bf
NKo	nko	0x7c0	0x7ff
Samaritan	samaritan	0x800	0x83f
Mandaic	mandaic	0x840	0x85f
Arabic Extended-A	arabic_extended-a	0x8a0	0x8ff
Devanagari	devanagari	0x900	0x97f
Bengali	bengali	0x980	0x9ff
Gurmukhi	gurmukhi	0xa00	0xa7f
Gujarati	gujarati	0xa80	0xaff
Oriya	oriya	0xb00	0xb7f
Tamil	tamil	0xb80	0xbff
Telugu	telugu	0xc00	0xc7f
Kannada	kannada	0xc80	0xcff
Malayalam	malayalam	0xd00	0xd7f
Sinhala	sinhala	0xd80	0xdff
Thai	thai	0xe00	0xe7f
Lao	lao	0xe80	0xeff
Tibetan	tibetan	0xf00	0xfff
Myanmar	myanmar	0x1000	0x109f
Georgian	georgian	0x10a0	0x10ff
Hangul Jamo	hangul_jamo	0x1100	0x11ff
Ethiopic	ethiopic	0x1200	0x137f
Ethiopic Supplement	ethiopic_supplement	0x1380	0x139f
Cherokee	cherokee	0x13a0	0x13ff
Unified Canadian Aboriginal Syllabics	unified_canadian_aboriginal_syllabics	0x1400	0x167f
Ogham	ogham	0x1680	0x169f
Runic	runic	0x16a0	0x16ff
Tagalog	tagalog	0x1700	0x171f
Hanunoo	hanunoo	0x1720	0x173f
Buhid	buhid	0x1740	0x175f
Tagbanwa	tagbanwa	0x1760	0x177f
Khmer	khmer	0x1780	0x17ff
Mongolian	mongolian	0x1800	0x18af
Unified Canadian Aboriginal Syllabics Extended	unified_canadian_aboriginal_syllabics_extended	0x18b0	0x18ff
Limbu	limbu	0x1900	0x194f

Name	Tag	Start	End
Tai Le	tai_le	0x1950	0x197f
New Tai Lue	new_tai_lue	0x1980	0x19df
Khmer Symbols	khmer_symbols	0x19e0	0x19ff
Buginese	buginese	0x1a00	0x1a1f
Tai Tham	tai_tham	0x1a20	0x1aaf
Combining Diacritical Marks Extended	combining_diacritical_marks_extended	0x1ab0	0x1aff
Balinese	balinese	0x1b00	0x1b7f
Sundanese	sundanese	0x1b80	0x1bbf
Batak	batak	0x1bc0	0x1bff
Lepcha	lepcha	0x1c00	0x1c4f
Ol Chiki	ol_chiki	0x1c50	0x1c7f
Cyrillic Extended-C	cyrillic_extended-c	0x1c80	0x1c8f
Sundanese Supplement	sundanese_supplement	0x1cc0	0x1ccf
Vedic Extensions	vedic_extensions	0x1cd0	0x1cff
Phonetic Extensions	phonetic_extensions	0x1d00	0x1d7f
Phonetic Extensions Supplement	phonetic_extensions_supplement	0x1d80	0x1dbf
Combining Diacritical Marks Supplement	combining_diacritical_marks_supplement	0x1dc0	0x1dff
Latin Extended Additional	latin_extended_additional	0x1e00	0x1eff
Greek Extended	greek_extended	0x1f00	0x1fff
General Punctuation	general_punctuation	0x2000	0x206f
Superscripts and Subscripts	superscripts_and_subscripts	0x2070	0x209f
Currency Symbols	currency_symbols	0x20a0	0x20cf
Combining Diacritical Marks for Symbols	combining_diacritical_marks_for_symbols	0x20d0	0x20ff
Letterlike Symbols	letterlike_symbols	0x2100	0x214f
Number Forms	number_forms	0x2150	0x218f
Arrows	arrows	0x2190	0x21ff
Mathematical Operators	mathematical_operators	0x2200	0x22ff
Miscellaneous Technical	miscellaneous_technical	0x2300	0x23ff
Control Pictures	control_pictures	0x2400	0x243f
Optical Character Recognition	optical_character_recognition	0x2440	0x245f
Enclosed Alphanumerics	enclosed_alphanumerics	0x2460	0x24ff
Box Drawing	box_drawing	0x2500	0x257f
Block Elements	block_elements	0x2580	0x259f
Geometric Shapes	geometric_shapes	0x25a0	0x25ff
Miscellaneous Symbols	miscellaneous_symbols	0x2600	0x26ff
Dingbats	dingbats	0x2700	0x27bf
Miscellaneous Mathematical Symbols-A	miscellaneous_mathematical_symbols-a	0x27c0	0x27ef
Supplemental Arrows-A	supplemental_arrows-a	0x27f0	0x27ff

Name	Tag	Start	End
Braille Patterns	braille_patterns	0x2800	0x28ff
Supplemental Arrows-B	supplemental_arrows-b	0x2900	0x297f
Miscellaneous Mathematical Symbols-B	miscellaneous_mathematical_symbols-b	0x2980	0x29ff
Supplemental Mathematical Operators	supplemental_mathematical_operators	0x2a00	0x2aff
Miscellaneous Symbols and Arrows	miscellaneous_symbols_and_arrows	0x2b00	0x2bff
Glagolitic	glagolitic	0x2c00	0x2c5f
Latin Extended-C	latin_extended-c	0x2c60	0x2c7f
Coptic	coptic	0x2c80	0x2cff
Georgian Supplement	georgian_supplement	0x2d00	0x2d2f
Tifinagh	tifinagh	0x2d30	0x2d7f
Ethiopic Extended	ethiopic_extended	0x2d80	0x2ddf
Cyrillic Extended-A	cyrillic_extended-a	0x2de0	0x2dff
Supplemental Punctuation	supplemental_punctuation	0x2e00	0x2e7f
CJK Radicals Supplement	cjk_radicals_supplement	0x2e80	0x2eff
Kangxi Radicals	kangxi_radicals	0x2f00	0x2fdf
Ideographic Description Characters	ideographic_description_characters	0x2ff0	0x2fff
CJK Symbols and Punctuation	cjk_symbols_and_punctuation	0x3000	0x303f
Hiragana	hiragana	0x3040	0x309f
Katakana	katakana	0x30a0	0x30ff
Bopomofo	bopomofo	0x3100	0x312f
Hangul Compatibility Jamo	hangul_compatibility_jamo	0x3130	0x318f
Kanbun	kanbun	0x3190	0x319f
Bopomofo Extended	bopomofo_extended	0x31a0	0x31bf
CJK Strokes	cjk_strokes	0x31c0	0x31ef
Katakana Phonetic Extensions	katakana_phonetic_extensions	0x31f0	0x31ff
Enclosed CJK Letters and Months	enclosed_cjk_letters_and_months	0x3200	0x32ff
CJK Compatibility	cjk_compatibility	0x3300	0x33ff
CJK Unified Ideographs Extension A	cjk_unified_ideographs_extension_a	0x3400	0x4dbf
Yijing Hexagram Symbols	yijing_hexagram_symbols	0x4dc0	0x4dff
CJK Unified Ideographs	cjk_unified_ideographs	0x4e00	0x9fff
Yi Syllables	yi_syllables	0xa000	0xa48f
Yi Radicals	yi_radicals	0xa490	0xa4cf
Lisu	lisu	0xa4d0	0xa4ff
Vai	vai	0xa500	0xa63f
Cyrillic Extended-B	cyrillic_extended-b	0xa640	0xa69f
Bamum	bamum	0xa6a0	0xa6ff
Modifier Tone Letters	modifier_tone_letters	0xa700	0xa71f
Latin Extended-D	latin_extended-d	0xa720	0xa7ff

Name	Tag	Start	End
Syloti Nagri	syloti_nagri	0xa800	0xa82f
Common Indic Number Forms	common_indic_number_forms	0xa830	0xa83f
Phags-pa	phags-pa	0xa840	0xa87f
Saurashtra	saurashtra	0xa880	0xa8df
Devanagari Extended	devanagari_extended	0xa8e0	0xa8ff
Kayah Li	kayah_li	0xa900	0xa92f
Rejang	rejang	0xa930	0xa95f
Hangul Jamo Extended-A	hangul_jamo_extended-a	0xa960	0xa97f
Javanese	javanese	0xa980	0xa9df
Myanmar Extended-B	myanmar_extended-b	0xa9e0	0xa9ff
Cham	cham	0xaa00	0xaa5f
Myanmar Extended-A	myanmar_extended-a	0xaa60	0xaa7f
Tai Viet	tai_viet	0xaa80	0xaadf
Meetei Mayek Extensions	meetei_mayek_extensions	0xaae0	0xaaff
Ethiopic Extended-A	ethiopic_extended-a	0xab00	0xab2f
Latin Extended-E	latin_extended-e	0xab30	0xab6f
Cherokee Supplement	cherokee_supplement	0xab70	0xabbf
Meetei Mayek	meetei_mayek	0xabc0	0xabff
Hangul Syllables	hangul_syllables	0xac00	0xd7af
Hangul Jamo Extended-B	hangul_jamo_extended-b	0xd7b0	0xd7ff
High Surrogates	high_surrogates	0xd800	0xdb7f
High Private Use Surrogates	high_private_use_surrogates	0xdb80	0xdbff
Low Surrogates	low_surrogates	0xdc00	0xdfff
Private Use Area	private_use_area	0xe000	0xf8ff
CJK Compatibility Ideographs	cjk_compatibility_ideographs	0xf900	0xfaff
Alphabetic Presentation Forms	alphabetic_presentation_forms	0xfb00	0xfb4f
Arabic Presentation Forms-A	arabic_presentation_forms-a	0xfb50	0xfdff
Variation Selectors	variation_selectors	0xfe00	0xfe0f
Vertical Forms	vertical_forms	0xfe10	0xfe1f
Combining Half Marks	combining_half_marks	0xfe20	0xfe2f
CJK Compatibility Forms	cjk_compatibility_forms	0xfe30	0xfe4f
Small Form Variants	small_form_variants	0xfe50	0xfe6f
Arabic Presentation Forms-B	arabic_presentation_forms-b	0xfe70	0xfeff
Halfwidth and Fullwidth Forms	halfwidth_and_fullwidth_forms	0xff00	0xffef
Specials	specials	0xfff0	0xffff

Table 25.9. Ranges

25.7.4 Error Messages

ID	Type	Description
0	Error	The static font generator has encountered an unexpected internal error.
1	Error	The Fonts list file has not been specified.

ID	Type	Description
2	Error	The static font generator cannot create the final, raw file.
3	Error	The static font generator cannot read the fonts list file.
4	Warning	The static font generator has found no font to generate.
5	Error	The static font generator cannot load the fonts list file.
6	Warning	The specified font path is invalid: The font will be not converted.
7	Warning	*There are too many arguments on a line: The current entry is ignored.*
8	Error	The static font generator has encountered an unexpected internal error.
9	Error	*The static font generator has encountered an unexpected internal error.*
10	Warning	The specified entry is invalid: The current entry is ignored.
11	Warning	The specified entry does not contain a list of characters: The current entry is ignored.
12	Warning	The specified entry does not contain a list of identifiers: The current entry is ignored.
13	Warning	The specified entry is an invalid width: The current entry is ignored.
14	Warning	The specified entry is an invalid height: the current entry is ignored.
15	Warning	The specified entry does not contain the characters' addresses: The current entry is ignored.
16	Warning	The specified entry does not contain the characters' bitmaps: The current entry is ignored.
17	Warning	The specified entry bits-per-pixel value is invalid: The current entry is ignored.
18	Warning	The specified range is invalid: The current entry is ignored.
19	Error	There are too many identifiers. The output RAW format cannot store all identifiers.
20	Error	The font's name is too long. The output RAW format cannot store all name characters.

Table 25.10. Static Font Generator Error Messages

25.8 Image Generator

25.8.1 Configuration File

```
ConfigFile        ::= Line [ 'EOL' Line ]*
Line              ::= ImagePath [ ':' ImageOption ]*
ImagePath         ::= Identifier [ '/' Identifier ]*
ImageOption       ::= [^:]*
Identifier        ::= Letter [ LetterOrDigit ]*
Letter            ::= 'a-zA-Z_$'
LetterOrDigit     ::= 'a-zA-Z_$0-9'
```

Figure 25.3. Images Static Configuration File Grammar

25.8.2 Error Messages

ID	Type	Description
0	Error	The static image generator has encountered an unexpected internal error.
1	Error	The images list file has not been specified.
2	Error	The static image generator cannot create the final, raw file.

ID	Type	Description
3	Error	The static image generator cannot read the images list file. Make sure the system allows reading of this file.
4	Warning	The static image generator has found no image to generate.
5	Error	The static image generator cannot load the images list file.
6	Warning	The specified image path is invalid: The image will be not converted.
7	Warning	There are too many or too few options for the desired format.
8	Error	A static image generator extension class is unknown.
9	Error	The static image generator has encountered an unexpected internal error.
10	Warning	The specified output format is unknown: The image will be not converted.
11	Warning	The specified format is not managed by the static image generator: The image will be not converted.
12	Warning	The specified alpha level is invalid: The image will be not converted.
13	Warning	The specified alpha level is not compatible with the specified format: The image will be not converted.
14	Warning	A specified attribute is undefined for the specified format.

Table 25.11. Static Image Generator Error Messages

25.9 Front Panel

25.9.1 FP File

25.9.1.1 XML Schema

```
<?xml version="1.0"?>
<frontpanel
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns="http://xml.is2t.com/ns/1.0/frontpanel"
  xsi:schemaLocation="http://xml.is2t.com/ns/1.0/frontpanel .fp1.0.xsd">


  <description file="widgets.desc"/>

  <device name="example" skin="example-device.png">
    <body>
      <init class="[fully-qualified-class-name]"/> (optional)
      <[widget-type] id="0" x="54" y="117" [widget-attributes] />
      <[widget-type] id="1" x="266" y="115" [widget-attributes] />
      ...
    </body>
  </device>
</frontpanel>
```

25.9.1.2 File Specification

Tag	Attributes	Description
fp		The root element.
	xmlns:xsi	Invariant tag[a]
	xmlns	Invariant tag.[b]
	xsi:schemaLocation	Invariant tag.[c]
description		Defines the widgets descriptions file (which is automatically generated).
	file	The widgets descriptions file.[d]

Tag	Attributes	Description
device		The device's root element.
	name	The device's logical name.
	skin	Refers to a PNG file which defines the device background.
body		Defines the device's body. It contains the elements that define the widgets that make up the front panel.
init	class	Optional tag that defines a class to be loaded at startup. The class can contain a static initializer to initiate required behavior. The body tag can contain several init tags; the classes will be loaded in the order of the init tags.
pixelatedDisplay		Defines the widget "display with pixels".
	id	The unique widget ID.
	x	The widget x-coordinate.
	y	The widget y-coordinate.
	width	The display's width in pixels.
	height	The display's height in pixels.
	realWidth	The logical display's width (the width returned to the MicroUI application).
	realHeight	The logical display's height (the height returned to the MicroUI application).
	initialColor	The default display background color.
	mask	The image which defines the visible display area.
extensionClass	The extension class which defines the display's characteristics	
push		Defines the widget "basic push button".
	id	The unique widget ID.
	x	The widget x-coordinate.
	y	The widget y-coordinate.
	skin	The image to show when the button is released.
	pushedSkin	The image to show when the button is pressed.
	filter	The image which defines the button's active area.
	listenerClass	The class which implements the button's listener interface.
repeatPush		Defines the widget "repeat push button".
	id	The unique widget ID.
	x	The widget x-coordinate.
	y	The widget y-coordinate.
	skin	The image to show when the button is released.
	pushedSkin	The image to show when the button is pressed.

Tag	Attributes	Description
	repeatPeriod	The time in milliseconds which defines the period of the repeat action.
	filter	The image which defines the button's active area.
	listenerClass	The class which implements the repeat button's listener interface.
joystick		Defines the widget "joystick".
	id	The unique widget ID.
	x	The widget x-coordinate.
	y	The widget y-coordinate.
	skin	The image to show when the joystick is released.
	mask	The image which defines the joystick's active area.
	upSkin	The image to show when the button UP is pressed.
	downSkin	The image to show when the button DOWN is pressed.
	leftSkin	The image to show when the button LEFT is pressed.
	rightSkin	The image to show when the button RIGHT is pressed.
	enterSkin	The image to show when the button ENTER is pressed (the central button).
	disableEnter	true to disable the ENTER button.
	repeatPeriod	The time in milliseconds which defines the period of the repeat action.
	listenerClass	The class which implements the joystick's listener interface.
pointer		Defines the widget "pointer".
	id	The unique widget ID.
	x	The widget x-coordinate.
	y	The widget y-coordinate.
	width	The pointer area's width.
	height	The pointer area's height.
	touch	true means the pointer simulates a touch.
	listenerClass	The class which implements the pointer's listener interface.
led2states		Defines the widget "2-states LED " (light on or light off).
	id	The unique widget ID.
	x	The widget x-coordinate.
	y	The widget y-coordinate.
	ledOff	The image to show when the LED is off.

Tag	Attributes	Description
	ledOn	The image to show when the LED is on.
	overlay	true means the LED can be overlaid by another LED (transparency management).

[a]Must be "http://www.w3.org/2001/XMLSchema-instance"
[b]Must be "http://xml.is2t.com/ns/1.0/frontpanel"
[c]Must be "http://xml.is2t.com/ns/1.0/frontpanel .fp1.0.xsd"
[d]Must be "widgets.desc"

Table 25.12. FP File Specification

25.10 LLDISPLAY_EXTRA

25.10.1 Error Messages

Display module calls the function LLDISPLAY_EXTRA_IMPL_error when the LLDISPLAY implementation *have to* perform a drawing but do not.

ID	Description
-10	A call to LLDISPLAY_EXTRA_IMPL_fillRect has been performed but the implementation has not performed the drawing.
-11	A call to LLDISPLAY_EXTRA_IMPL_drawImage has been performed but the implementation has not performed the drawing.
-12	A call to LLDISPLAY_EXTRA_IMPL_scaleImage has been performed but the implementation has not performed the drawing.
-13	A call to LLDISPLAY_EXTRA_IMPL_rotateImage has been performed but the implementation has not performed the drawing.

Table 25.13. LLDISPLAY_EXTRA Error Messages

25.11 HIL Engine

Below are the HIL Engine options:

Option name	Description
-verbose[e....e]	Extra messages are printed out to the console (add extra e to get more messages).
-ip <address>	MicroEJ simulator connection IP address (A.B.C.D). By default, set to localhost.
-port <port>	MicroEJ simulator connection port. By default, set to 8001.
-connectTimeout <timeout>	timeout in s for MicroEJ simulator connections. By default, set to 10 seconds.
-excludes <name[sep]name>	Types that will be excluded from the HIL Engine class resolution provided mocks. By default, no types are excluded.
-mocks <name[sep]name>	Mocks are either .jar file or .class files.

Table 25.14. HIL Engine Options

25.12 Heap Dumping

25.12.1 XML Schema

Below is the XML schema for heap dumps.

```
<?xml version='1.0' encoding='UTF-8'?>
<!--
  Schema

  Copyright 2012 IS2T. All rights reserved.
  IS2T PROPRIETARY/CONFIDENTIAL. Use is subject to license terms.
-->

<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
  <!-- root element : heap -->
  <xs:element name="heap">
    <xs:complexType>
      <xs:choice minOccurs="0" maxOccurs="unbounded">
        <xs:element ref="class"/>
        <xs:element ref="object"/>
        <xs:element ref="array"/>
        <xs:element ref="stringLiteral"/>
      </xs:choice>
    </xs:complexType>
  </xs:element>
```

```
  <!-- class element -->
  <xs:element name="class">
    <xs:complexType>
      <xs:choice minOccurs="0" maxOccurs="unbounded">
        <xs:element ref="field"/>
      </xs:choice>
      <xs:attribute name="name" type="xs:string" use = "required"/>
      <xs:attribute name="id" type="xs:string" use = "required"/>
      <xs:attribute name="superclass" type="xs:string"/>
    </xs:complexType>
  </xs:element>
```

```
  <!-- object element-->
  <xs:element name="object">
    <xs:complexType>
      <xs:choice minOccurs="0" maxOccurs="unbounded">
        <xs:element ref="field"/>
      </xs:choice>
      <xs:attribute name="id" type="xs:string" use = "required"/>
      <xs:attribute name="class" type="xs:string" use = "required"/>
      <xs:attribute name="createdAt" type="xs:string" use = "optional"/>
      <xs:attribute name="createdInThread" type="xs:string" use = "optional"/>
      <xs:attribute name="createdInMethod" type="xs:string"/>
        <xs:attribute name="tag" type="xs:string" use = "required"/>
    </xs:complexType>
  </xs:element>
```

```
  <!-- array element-->
  <xs:element name="array" type = "arrayTypeWithAttribute"/>
  <!-- stringLiteral element-->
  <xs:element name="stringLiteral">
    <xs:complexType>
      <xs:sequence>
        <xs:element minOccurs ="4" maxOccurs="4" ref="field "/>
      </xs:sequence>
      <xs:attribute name="id" type="xs:string" use = "required"/>
      <xs:attribute name="class" type="xs:string" use = "required"/>
    </xs:complexType>
  </xs:element>
```

```
  <!-- field element :  child of class, object and stringLiteral-->
  <xs:element name="field">
    <xs:complexType>
      <xs:attribute name="name" type="xs:string" use = "required"/>
      <xs:attribute name="id" type="xs:string" use = "optional"/>
      <xs:attribute name="value" type="xs:string" use = "optional"/>
      <xs:attribute name="type" type="xs:string" use = "optional"/>
    </xs:complexType>
  </xs:element>

  <xs:simpleType name = "arrayType">
    <xs:list itemType="xs:integer"/>
  </xs:simpleType>


  <!-- complex type "arrayTypeWithAttribute". type of array element-->
  <xs:complexType name = "arrayTypeWithAttribute">
    <xs:simpleContent>
      <xs:extension base="arrayType">
        <xs:attribute name="id" type="xs:string" use = "required"/>
        <xs:attribute name="class" type="xs:string" use = "required"/>
        <xs:attribute name="createdAt" type="xs:string" use = "optional"/>
        <xs:attribute name="createdInThread" type="xs:string" use = "optional"/>
        <xs:attribute name="createdInMethod" type="xs:string" use = "optional"/>
        <xs:attribute name="length" type="xs:string" use = "required"/>
        <xs:attribute name="elementsType" type="xs:string" use = "optional"/>
        <xs:attribute name="type" type="xs:string" use = "optional"/>
      </xs:extension>
    </xs:simpleContent>
  </xs:complexType>

</xs:schema>
```

Table 25.15. XML Schema for Heap Dumps

25.12.2 File Specification

Types referenced in heap dumps are represented in the internal classfile format (Figure 25.4). Fully qualified names are names separated by the / separator (For example, a/b/C).

```
Type = <BaseType> | <ClassType> | <ArrayType>
BaseType: B(byte), C(char), D(double), F(float), I(int), J(long), S(short), Z(boolean),
ClassType: L<ClassName>;
ArrayType: [<Type>
```

Figure 25.4. Internal classfile Format for Types

Tags used in the heap dumps are described in the table below.

Tag	Attributes	Description
heap		The root element.
class		Element that references a Java class.
	name	Class type (<ClassType>).
	id	Unique identifier of the class.
	superclass	Identifier of the superclass of this class.
object		Element that references a Java object.
	id	Unique identifier of this object.
	class	Fully qualified name of the class of this object.
array		Element that references a Java array.
	id	Unique identifier of this array.
	class	Fully qualified name of the class of this array.

Tag	Attributes	Description
	elementsType	Type of the elements of this array.
	length	Array length.
stringLiteral		Element that references a java.lang.String literal.
	id	Unique identifier of this object.
	class	Id of java.lang.String class.
field		Element that references the field of an object or a class.
	name	Name of this field.
	id	Object or Array identifier, if it holds a reference.
	type	Type of this field, if it holds a base type.
	value	Value of this field, if it holds a base type.

Table 25.16. Tag Descriptions

26 Appendix D: Architectures MCU / Compiler

26.1 Principle

The MicroEJ C libraries have been built for a specific processor (a specific MCU architecture) with a specific C compiler. The third-party linker must make sure to link C libraries compatible with the MicroEJ C libraries. This chapter details the compiler version, flags and options used to build MicroEJ C libraries for each processor.

Some processors include an optional floating point unit (FPU). This FPU is single precision (32 bits) and is compliant with IEEE 754 standard. It can be disabled when not in use, thus reducing power consumption. There are two steps to use the FPU in an application. The first step is to tell the compiler and the linker that the microcontroller has an FPU available so that they will produce compatible binary code. The second step is to enable the FPU during execution. This is done by writing to CPAR in the SystemInit() function. Even if there is an FPU in the processor, the linker may still need to use runtime library functions to deal with advanced operations. A program may also define calculation functions with floating numbers, either as parameters or return values. There are several Application Binary Interfaces (ABI) to handle floating point calculations. Hence, most compilers provide options to select one of these ABIs. This will affect how parameters are passed between caller functions and callee functions, and whether the FPU is used or not. There are three ABIs:

- Soft ABI without FPU hardware. Values are passed via integer registers.
- Soft ABI with FPU hardware. The FPU is accessed directly for simple operations, but when a function is called, the integer registers are used.
- Hard ABI. The FPU is accessed directly for simple operations, and FPU-specific registers are used when a function is called, for both parameters and the return value.

It is important to note that code compiled with a particular ABI might not be compatible with code compiled with another ABI. MicroEJ modules, including the MicroEJ core engine, use the hard ABI.

26.2 Supported MicroEJ Core Engine Capabilities by Architecture Matrix

The following table lists the supported MicroEJ core engine capabilities by MicroEJ architectures.

MicroEJ core engine Architectures		Capabilities		
MCU	Compiler	Single application	Tiny application	Multi applications
ARM Cortex-M0+	IAR Embedded Workbench for ARM	YES	YES	NO
ARM Cortex-M4	IAR Embedded Workbench for ARM	YES	YES	YES
ARM Cortex-M4	GCC	YES	NO	YES
ARM Cortex-M4	Keil uVision	YES	NO	YES
ARM Cortex-M7	Keil uVision	YES	NO	YES

Table 26.1. Supported MicroEJ Core Engine Capabilities by MicroEJ Architecture Matrix

26.3 ARM Cortex-M0+

Compiler	Version	Flags and Options
IAR C/C++ Compiler for ARM	7.40.3.8902	--cpu Cortex-M0+ --fpu None

Table 26.2. ARM Cortex-M0+ Compilers

26.4 ARM Cortex-M4

Compiler	Version	Flags and Options
Keil uVision	5.18.0.0	--cpu Cortex-M4.fp --apcs=/hardfp --fpmode=ieee_no_fenv

Compiler	Version	Flags and Options
GCC	4.8	-mabi=aapcs -mcpu=cortex-m4 -mlittle-endian -mfpu=fpv4-sp-d16 -mfloat-abi=hard -mthumb
IAR Embedded Workbench for ARM	7.40.3.8938	--cpu Cortex-M4F --fpu VFPv4_sp

Table 26.3. ARM Cortex-M4 Compilers

Note: Since MicroEJ 4.0, Cortex-M4 architectures are compiled using hardfp convention call.

26.5 ARM Cortex-M7

Compiler	Version	Flags and Options
Keil uVision	5.18.0.0	--cpu Cortex-M7.fp.sp --apcs=/hardfp --fpmode=ieee_no_fenv

Table 26.4. ARM Cortex-M7 Compilers

26.6 IAR Linker Specific Options

This section lists options that must be passed to IAR linker for correctly linking the MicroEJ object file (microejapp.o) generated by the smart linker.

26.6.1 --no_range_reservations

MicroEJ smart linker generates ELF absolute symbols to define some link-time options (0 based values). By default, IAR linker allocates a 1 byte section on the fly, which may cause silent sections placement side effects or a section overlap error when multiple symbols are generated with the same absolute value:

```
Error[Lp023]: absolute placement (in [0x00000000-0x000000db]) overlaps with absolute symbol […]
```

The option --no_range_reservations tells IAR linker to manage an absolute symbol as described by the ELF specification.

26.6.2 --diag_suppress=Lp029

MicroEJ smart linker generates internal veneers that may be interpreted as illegal code by IAR linker, causing the following error:

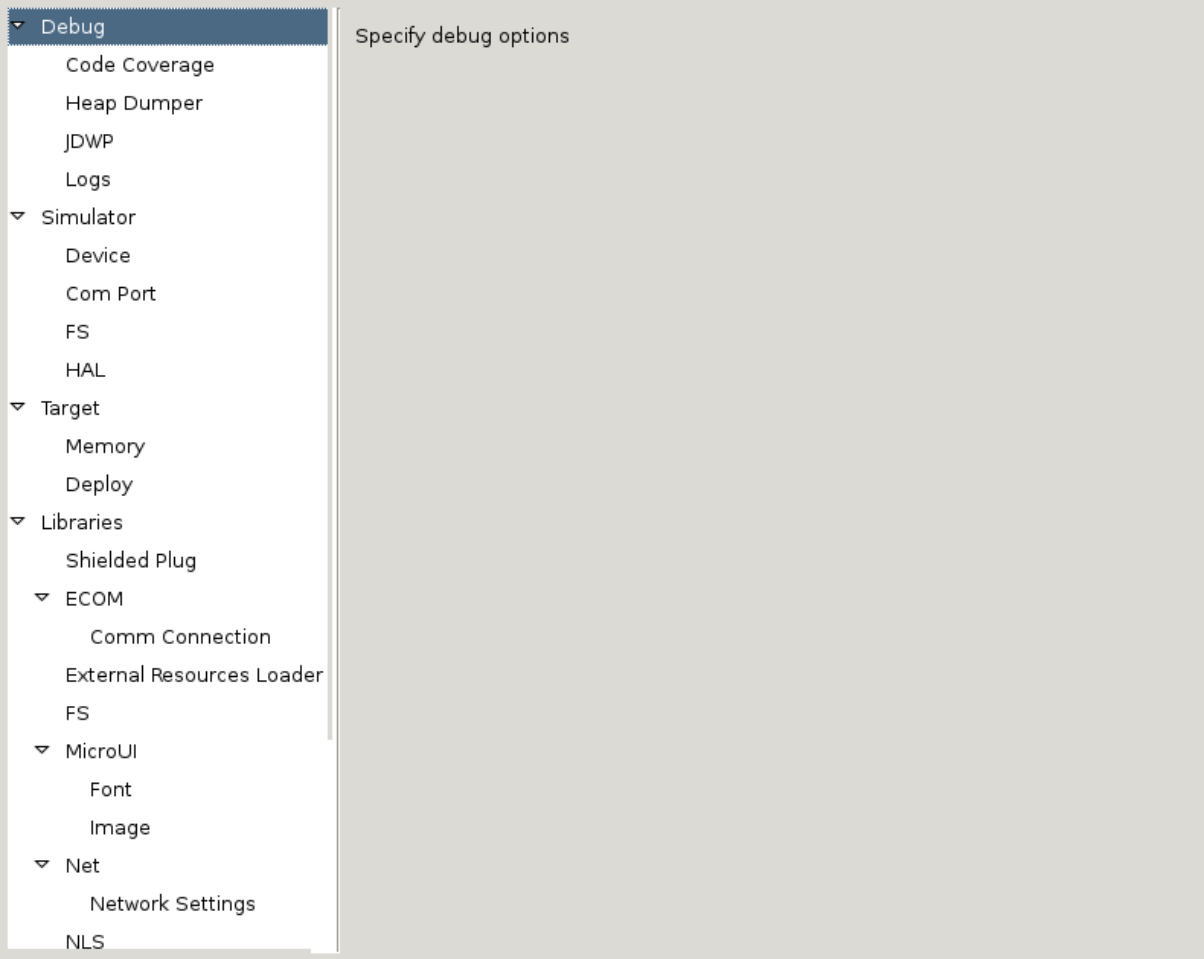
```
Error[Lp029]: instruction validation failure in section "C:\xxx\microejapp.o[.text.__icetea__virtual___1xxx#1126]": nested IT blocks. Code in wrong mode?
```

The option --diag_suppress=Lp029 tells IAR linker to ignore instructions validation errors.

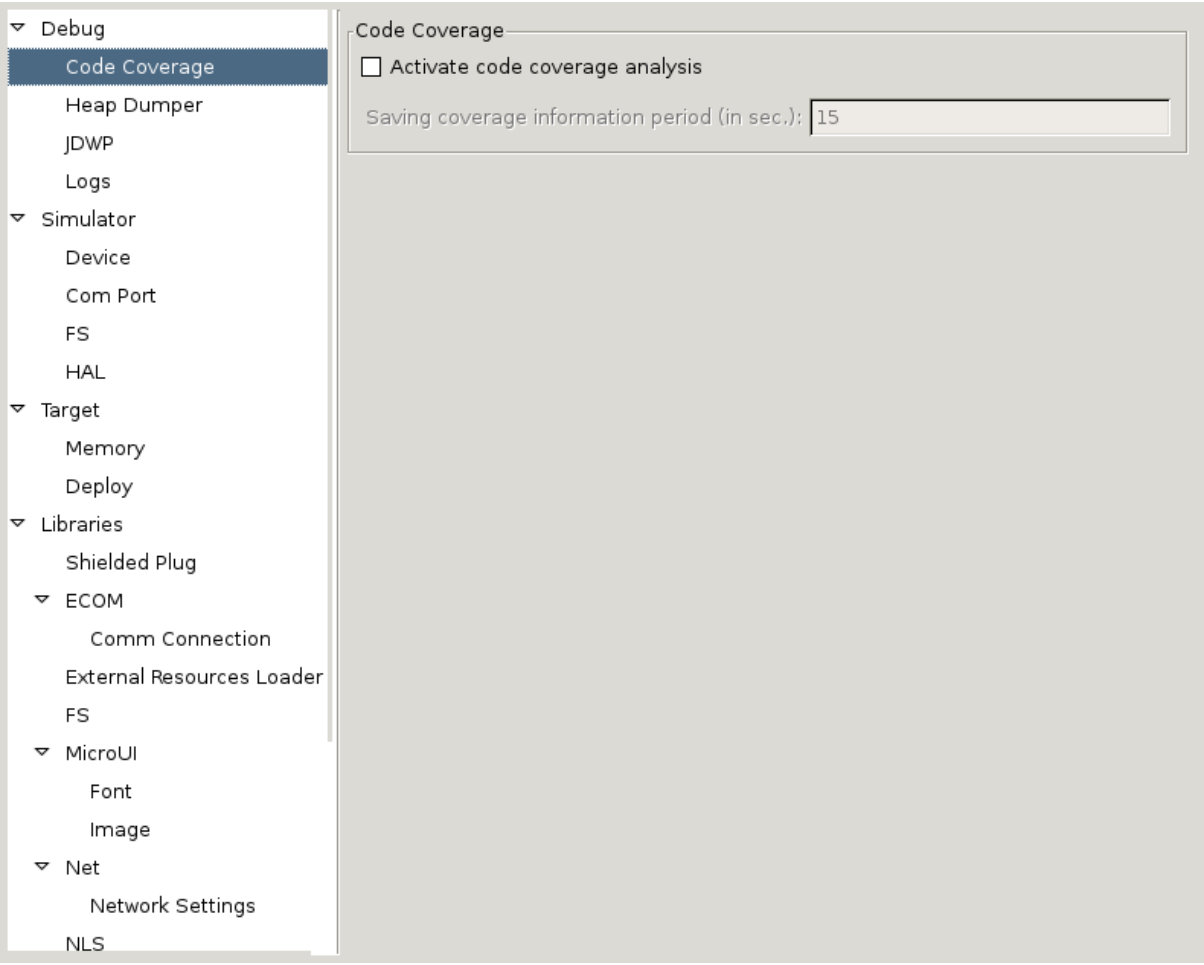
27 Appendix E: Application Launch Options

To run a MicroEJ application on a platform, a MicroEJ launcher is required. This launcher allows to specify the platform to use, the execution kind, fix some options etc. The MicroEJ launcher proposes some several options to customize the platform: some options for each foundation library, some specific options for the embedded target or for the simulator etc. This chapter describes all available options in the MicroEJ launcher. According the targeted platform, some options may be absent or different (default value etc.).

27.1 Category: Debug



27.1.1 Category: Code Coverage



27.1.1.1 Group: Code Coverage

Description:

This group is used to set parameters of the code coverage analysis tool.

27.1.1.1.1 Option(checkbox): Activate code coverage analysis

Default value: unchecked

Description:

When selected it enables the code coverage analysis by the MicroEJ simulator. Resulting files are output in the cc directory inside the output directory.

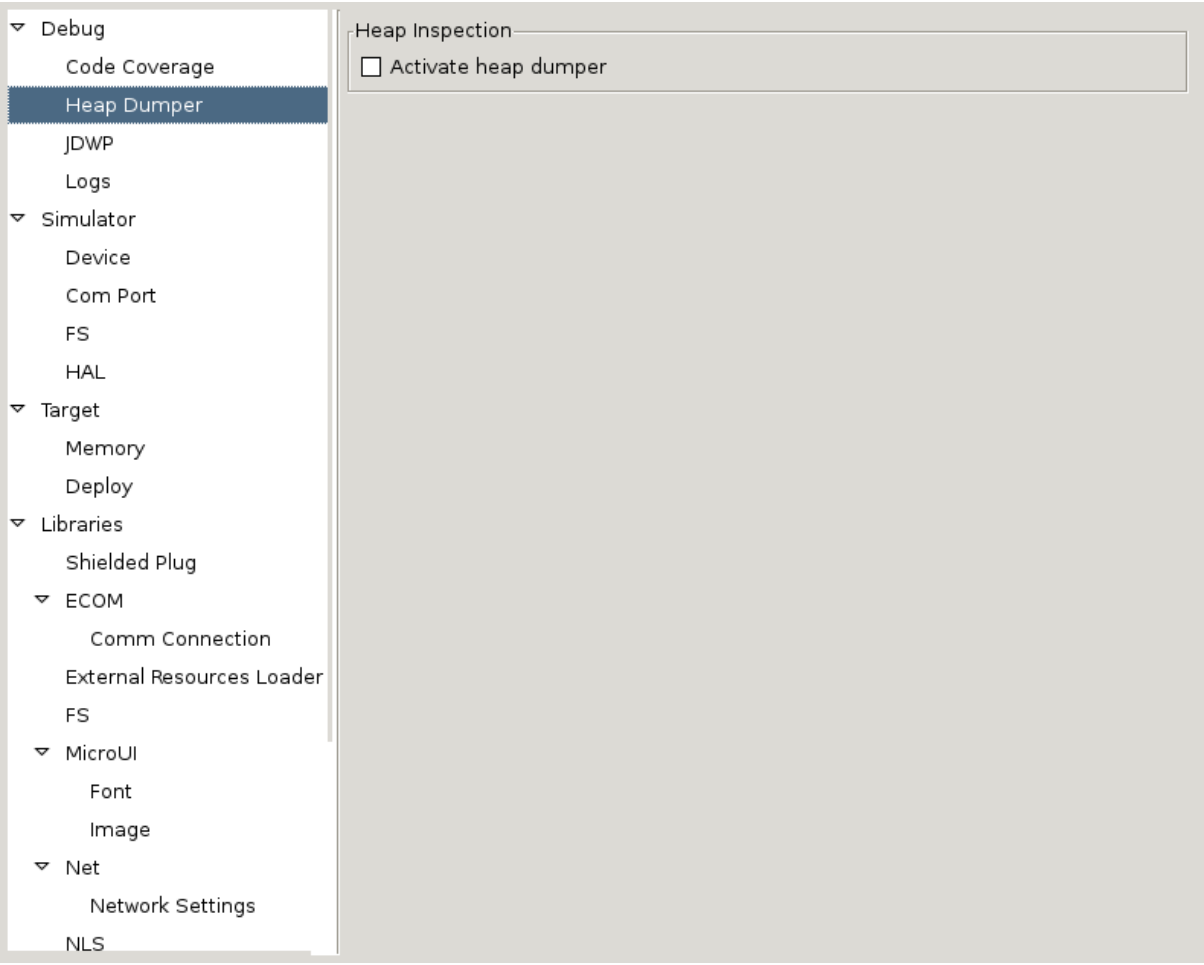
27.1.1.1.2 Option(text): Saving coverage information period (in sec.)

Default value: 15

Description:

It specifies the period between the generation of .cc files.

27.1.2 Category: Heap Dumper



27.1.2.1 Group: Heap Inspection

Description:

This group is used to specify heap inspection properties.

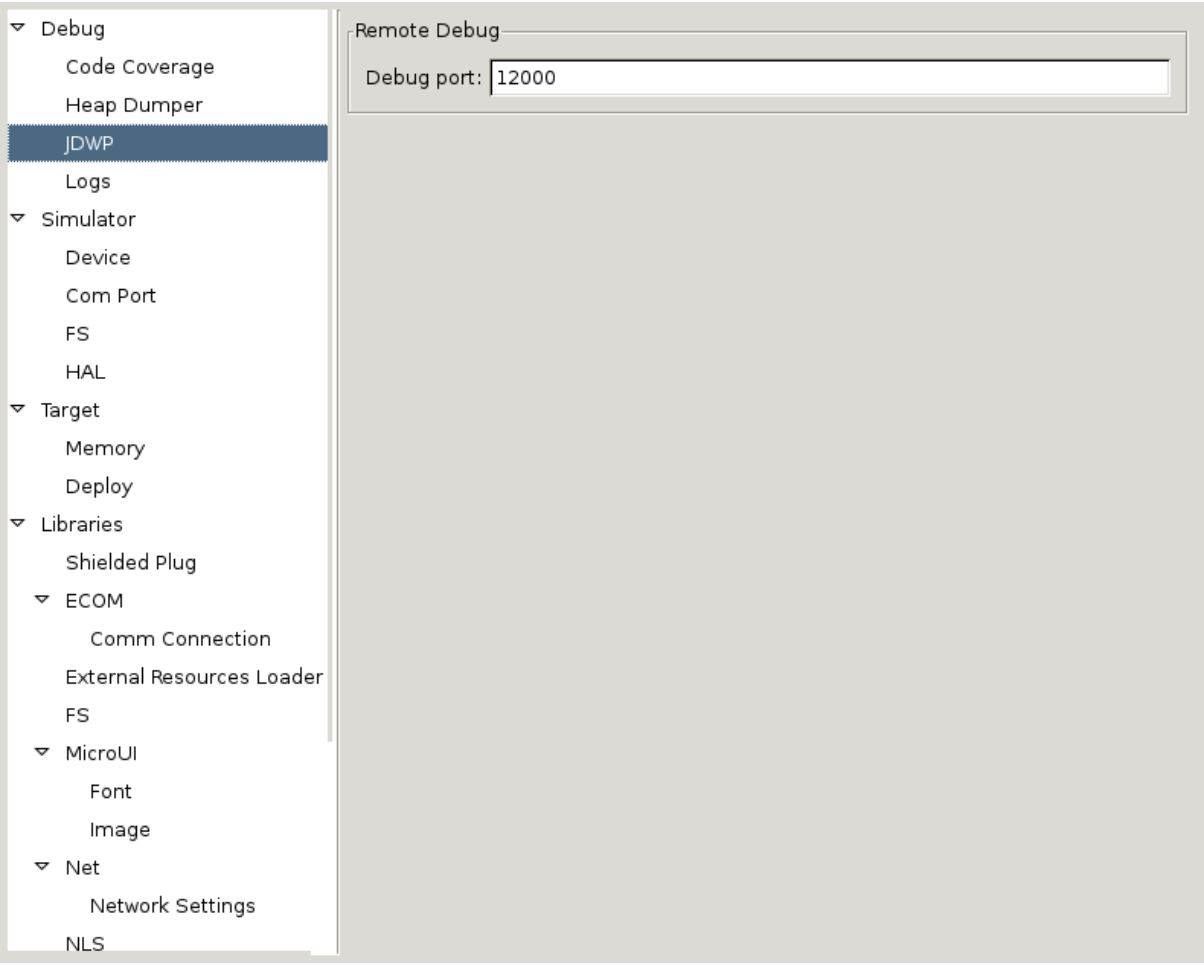
27.1.2.1.1 Option(checkbox): Activate heap dumper

Default value: unchecked

Description:

When selected, this option enables a dump of the heap each time the System.gc() method is called by the MicroEJ application.

27.1.3 Category: JDWP



27.1.3.1 Group: Remote Debug

27.1.3.1.1 Option(text): Debug port

Default value: 12000

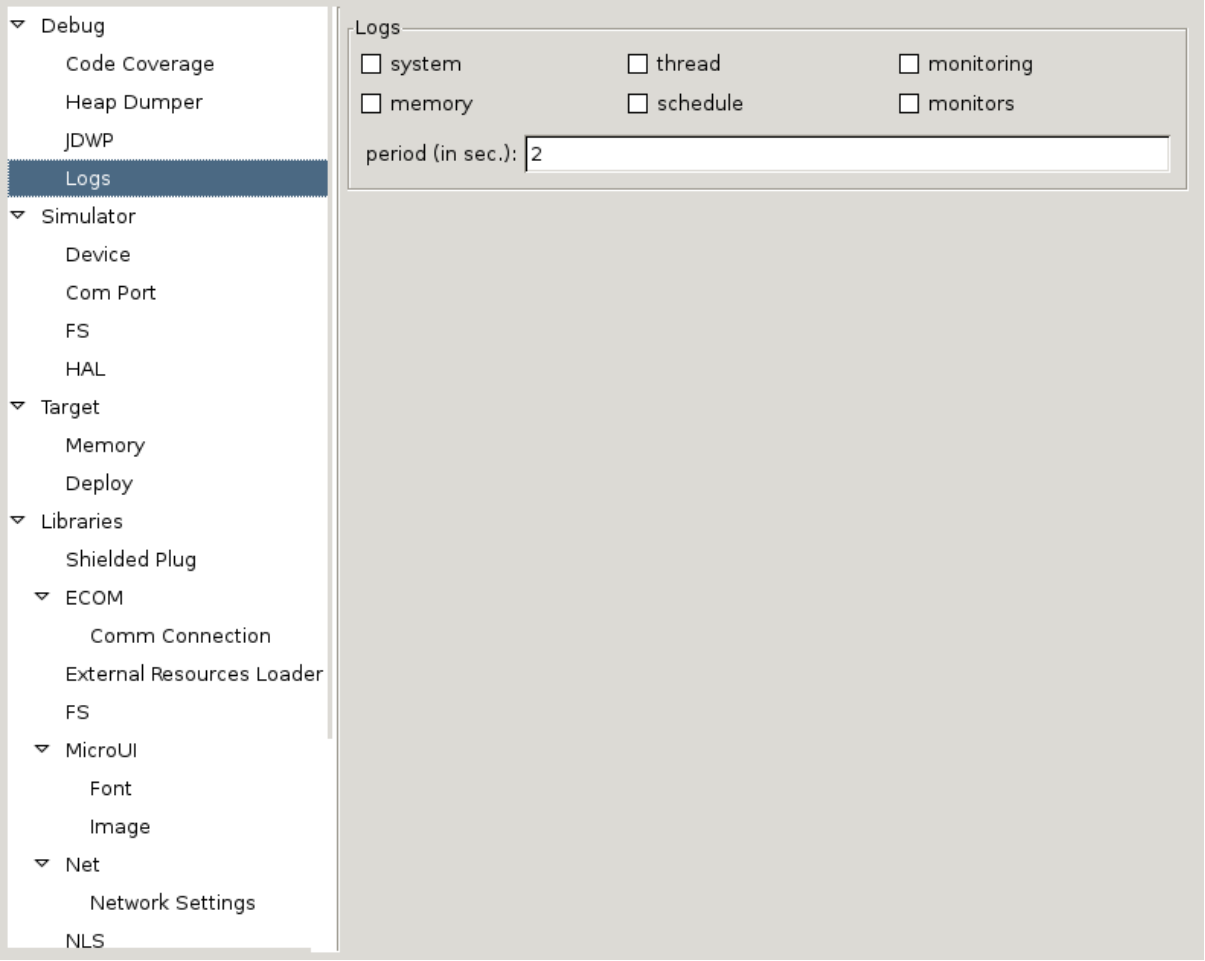
Description:

Configures the JDWP debug port.

Format: Positive integer

Values: [1024-65535]

27.1.4 Category: Logs



27.1.4.1 Group: Logs

Description:

This group defines parameters for MicroEJ simulator log activity. Note that logs can only be generated if the Simulator > Use target characteristics option is selected.

Some logs are sent when the platform executes some specific action (such as start thread, start GC, etc), other logs are sent periodically (according to defined log level and the log periodicity).

27.1.4.1.1 Option(checkbox): system

Default value: unchecked

Description:

When selected, System logs are sent when the platform executes the following actions:

start and terminate a thread

start and terminate a GC

exit

27.1.4.1.2 Option(checkbox): thread

Default value: unchecked

Description:

When selected, thread information is sent periodically. It gives information about alive threads (status, memory allocation, stack size).

27.1.4.1.3 Option(checkbox): monitoring

Default value: unchecked

Description:

When selected, thread monitoring logs are sent periodically. It gives information about time execution of threads.

27.1.4.1.4 Option(checkbox): memory

Default value: unchecked

Description:

When selected, memory allocation logs are sent periodically. This level allows to supervise memory allocation.

27.1.4.1.5 Option(checkbox): schedule

Default value: unchecked

Description:

When selected, a log is sent when the platform schedules a thread.

27.1.4.1.6 Option(checkbox): monitors

Default value: unchecked

Description:

When selected, monitors information is sent periodically. This level permits tracing of all thread state by tracing monitor operations.

27.1.4.1.7 Option(text): period (in sec.)

Default value: 2

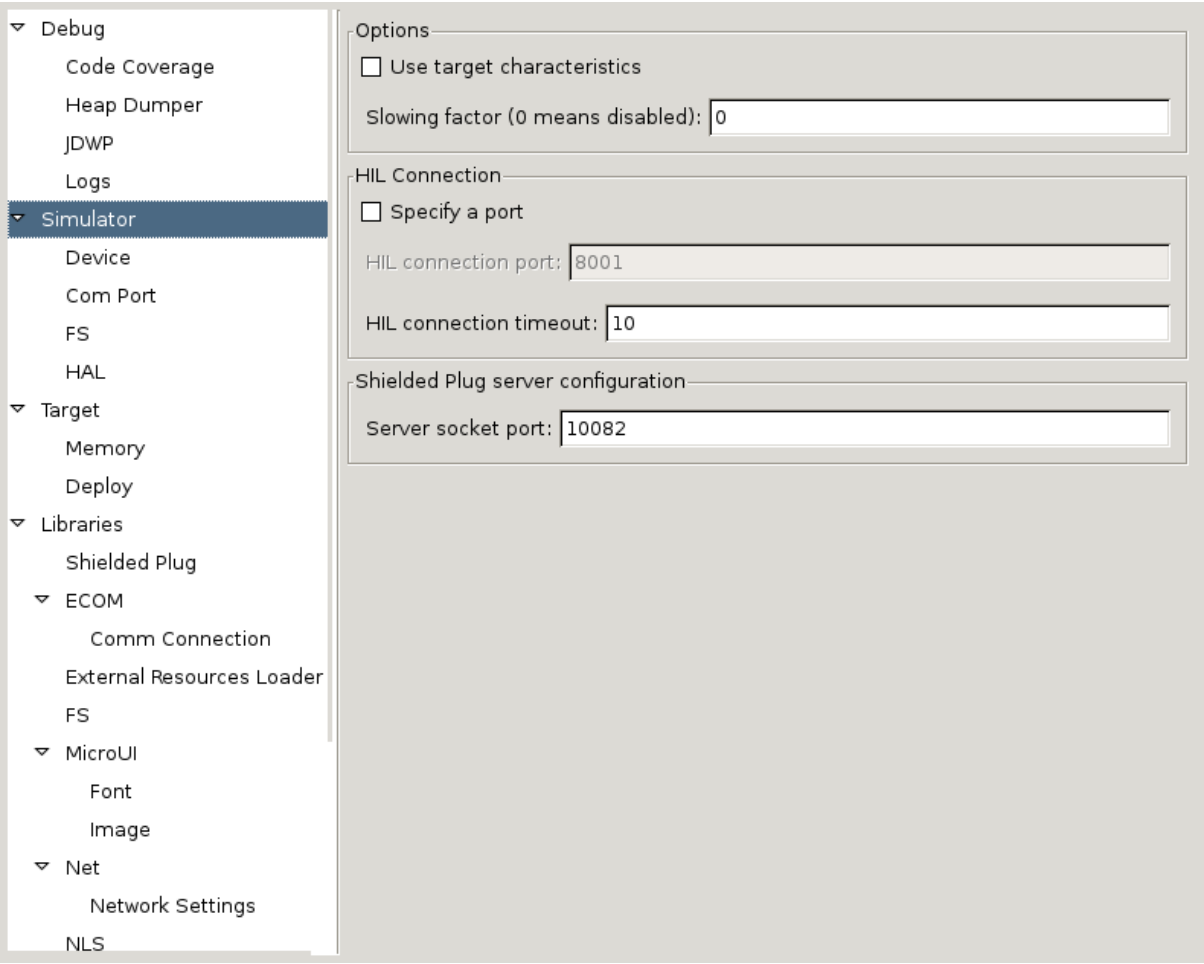
Description:

Format: Positive integer

Values: [0-60]

Defines the periodicity of periodical logs.

27.2 Category: Simulator



27.2.1 Group: Options

Description:

This group specifies options for MicroEJ simulator.

27.2.1.1 Option(checkbox): Use target characteristics

Default value: unchecked

Description:

When selected, this option forces the MicroEJ simulator to use the MicroEJ platform exact characteristics. It sets the MicroEJ simulator scheduling policy according to the MicroEJ platform one. It forces resources to be explicitly specified. It enables log trace and gives information about the RAM memory size the MicroEJ platform uses.

27.2.1.2 Option(text): Slowing factor (0 means disabled)

Default value: 0

Description:

Format: Positive integer

This option allows the MicroEJ simulator to be slowed down in order to match the MicroEJ platform execution speed. The greater the slowing factor, the slower the MicroEJ simulator runs.

27.2.2 Group: HIL Connection

Description:

This group enables the control of HIL (Hardware In the Loop) connection parameters (connection between MicroEJ simulator and the mocks).

27.2.2.1 Option(checkbox): Specify a port

Default value: unchecked

Description:

When selected allows the use of a specific HIL connection port, otherwise a random free port is used.

27.2.2.2 Option(text): HIL connection port

Default value: 8001

Description:

Format: Positive integer

Values: [1024-65535]

It specifies the port used by the MicroEJ simulator to accept HIL connections.

27.2.2.3 Option(text): HIL connection timeout

Default value: 10

Description:

Format: Positive integer

It specifies the time the MicroEJ simulator should wait before failing when it invokes native methods.

27.2.3 Group: Shielded Plug server configuration

Description:

This group allows configuration of the Shielded Plug database.

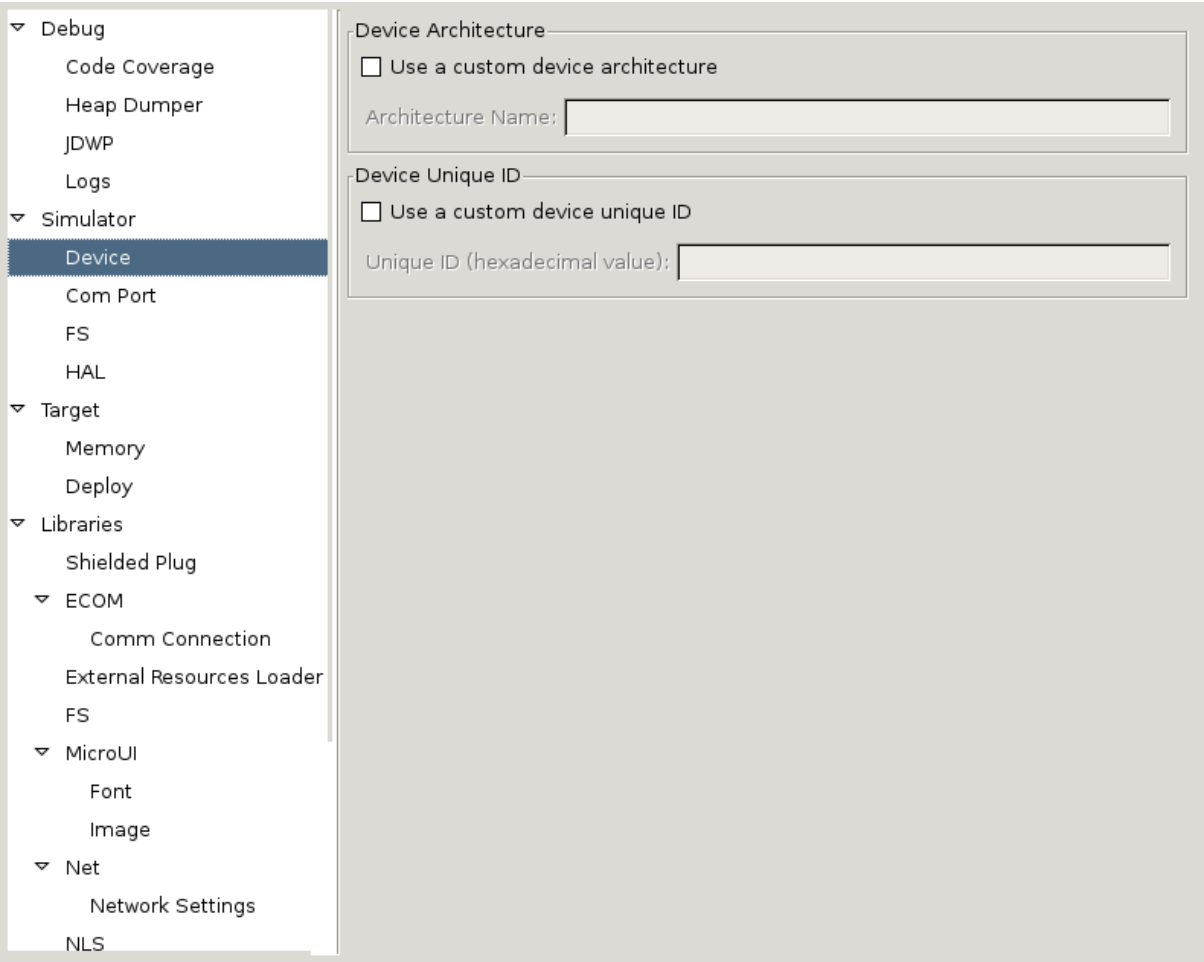
27.2.3.1 Option(text): Server socket port

Default value: 10082

Description:

Set the Shielded Plug server socket port.

27.2.4 Category: Device



27.2.4.1 Group: Device Architecture

27.2.4.1.1 Option(checkbox): Use a custom device architecture

Default value: unchecked

27.2.4.1.2 Option(text): Architecture Name

Default value: (empty)

27.2.4.2 Group: Device Unique ID

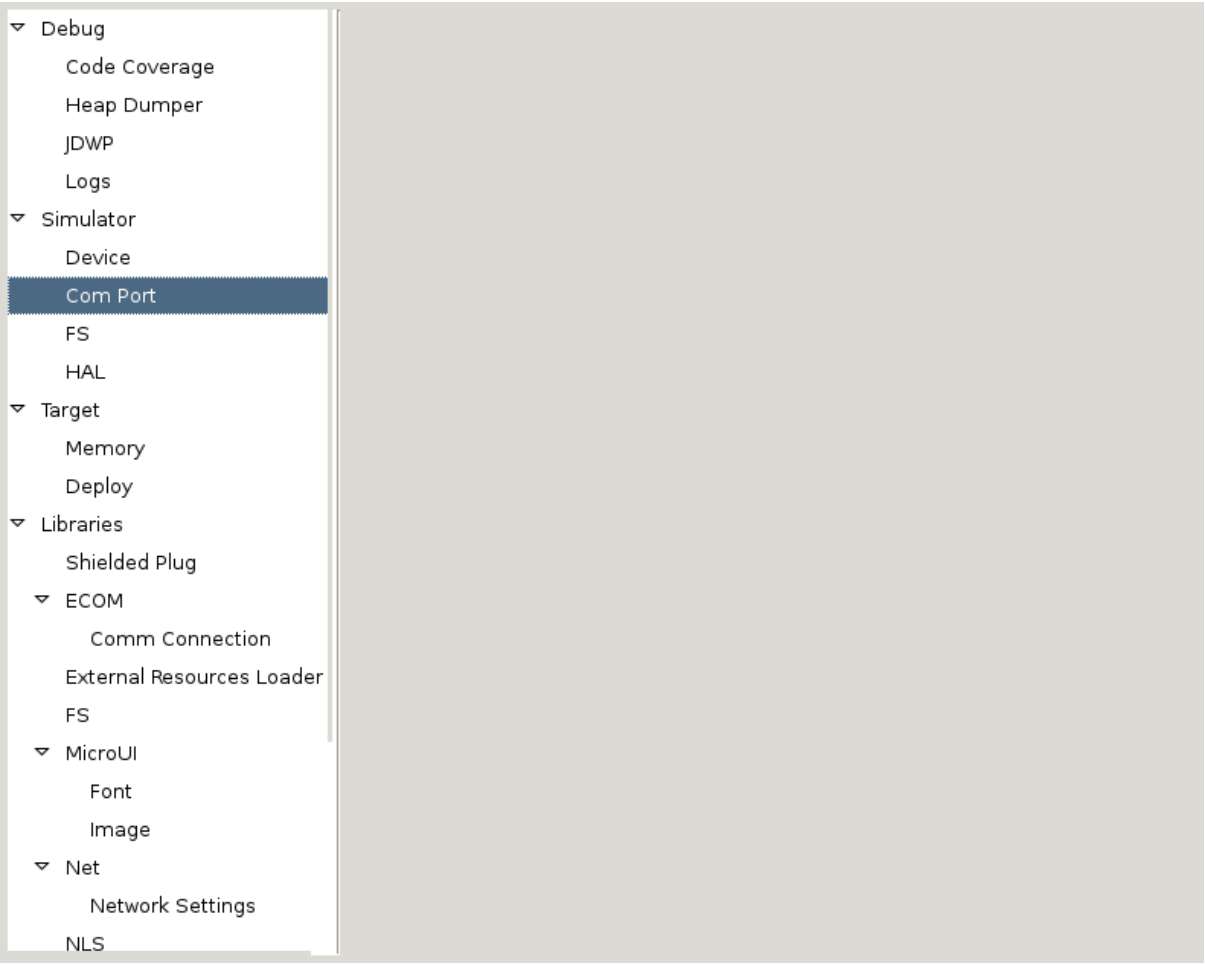
27.2.4.2.1 Option(checkbox): Use a custom device unique ID

Default value: unchecked

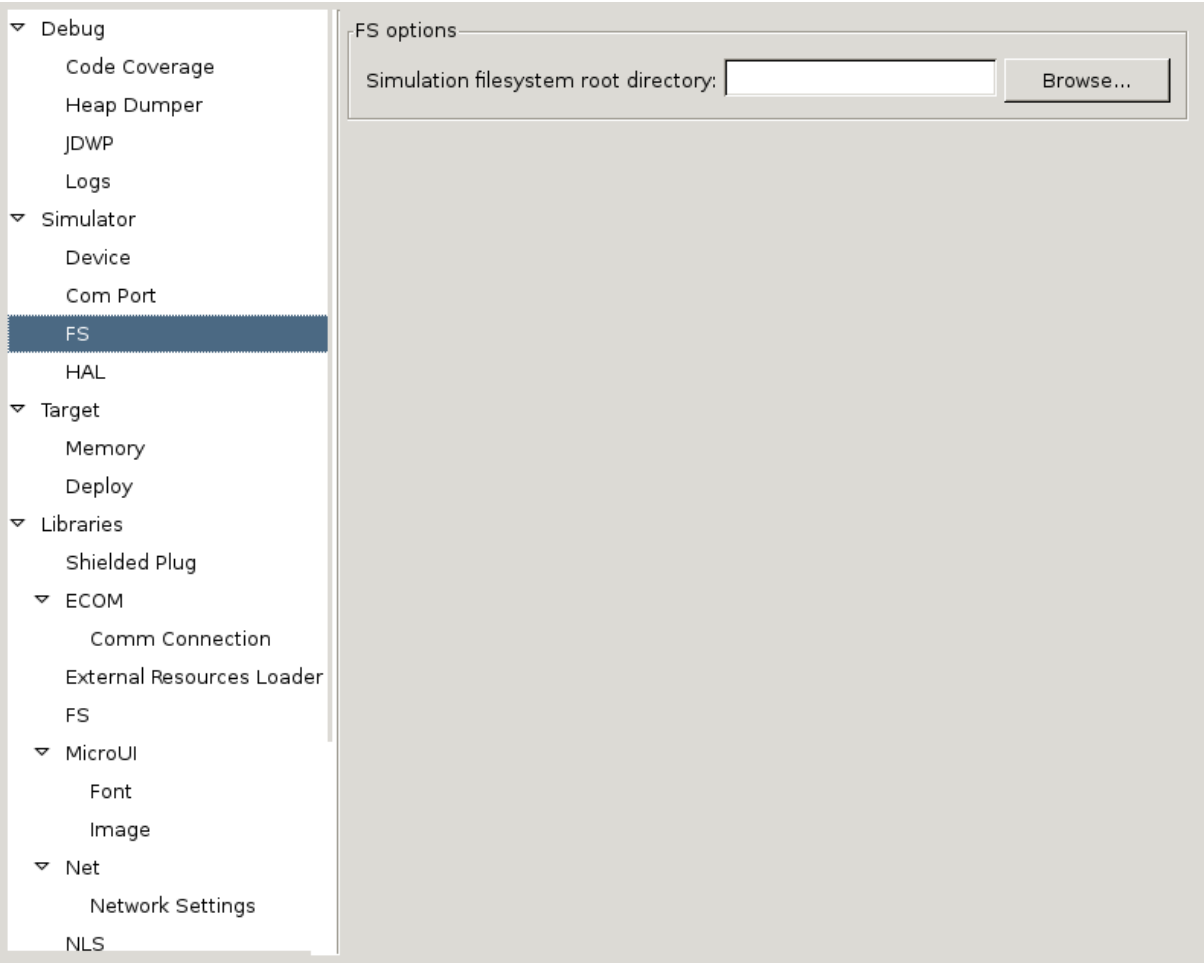
27.2.4.2.2 Option(text): Unique ID (hexadecimal value)

Default value: (empty)

27.2.5 Category: Com Port



27.2.6 Category: FS



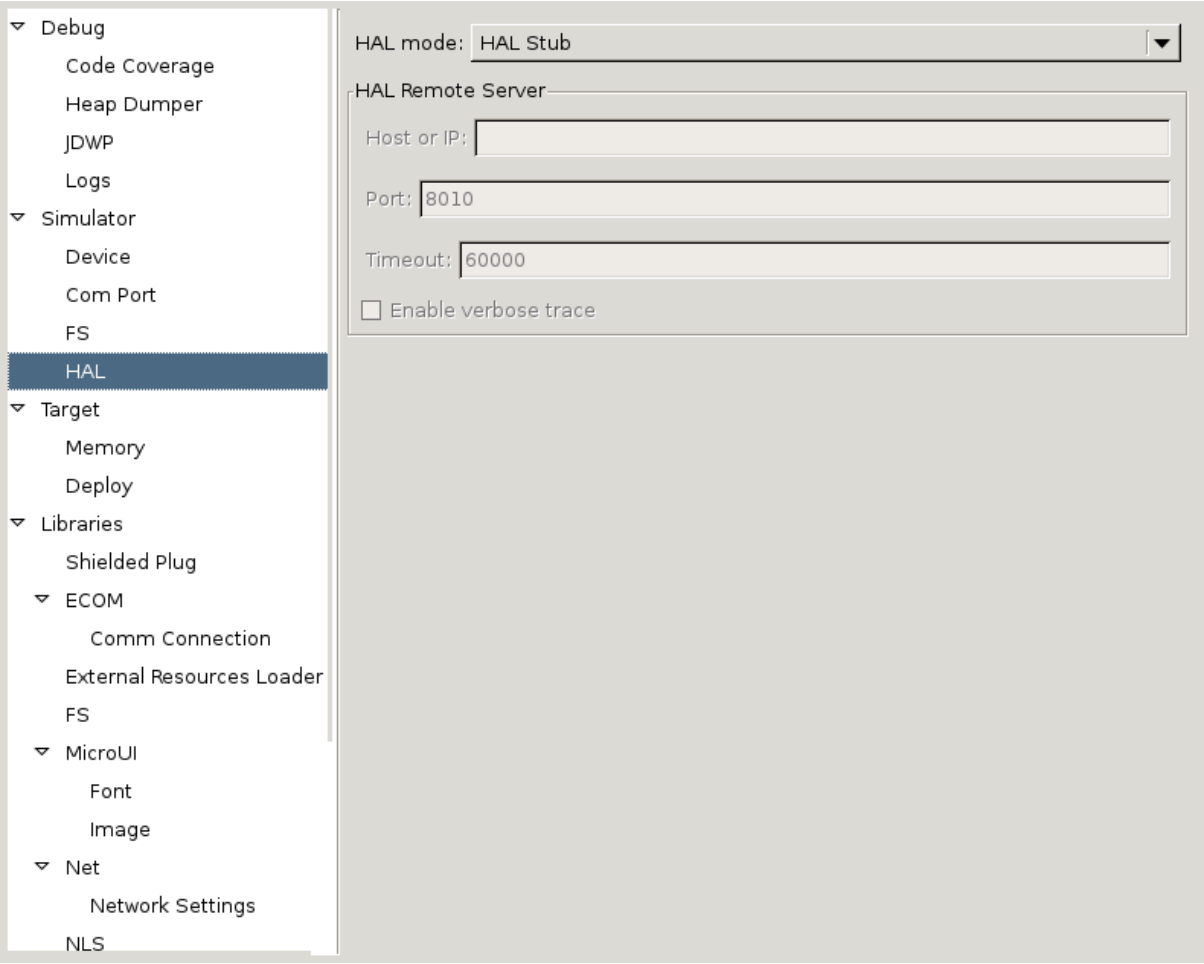
27.2.6.1 Group: FS options

27.2.6.1.1 Option(browse): Simulation filesystem root directory

Default value: (empty)

Description: Host directory used to map the root directory in the MicroEJ application.

27.2.7 Category: HAL



27.2.7.1 Option(combo): HAL mode

Default value: HAL Stub

Available values:

HAL Stub

HAL Remote Server

27.2.7.2 Group: HAL Remote Server

27.2.7.2.1 Option(text): Host or IP

Default value: (empty)

27.2.7.2.2 Option(text): Port

Default value: 8010

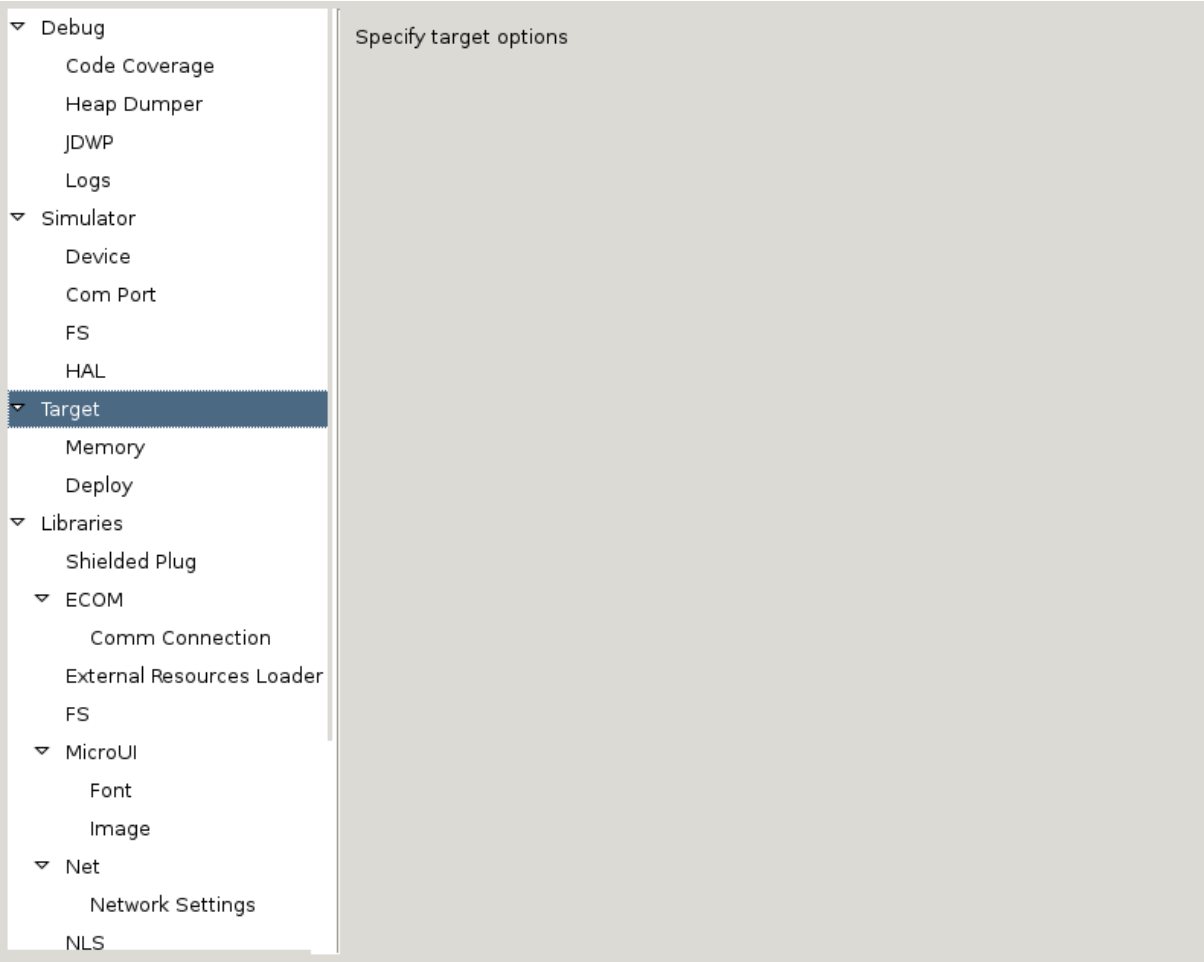
27.2.7.2.3 Option(text): Timeout

Default value: 60000

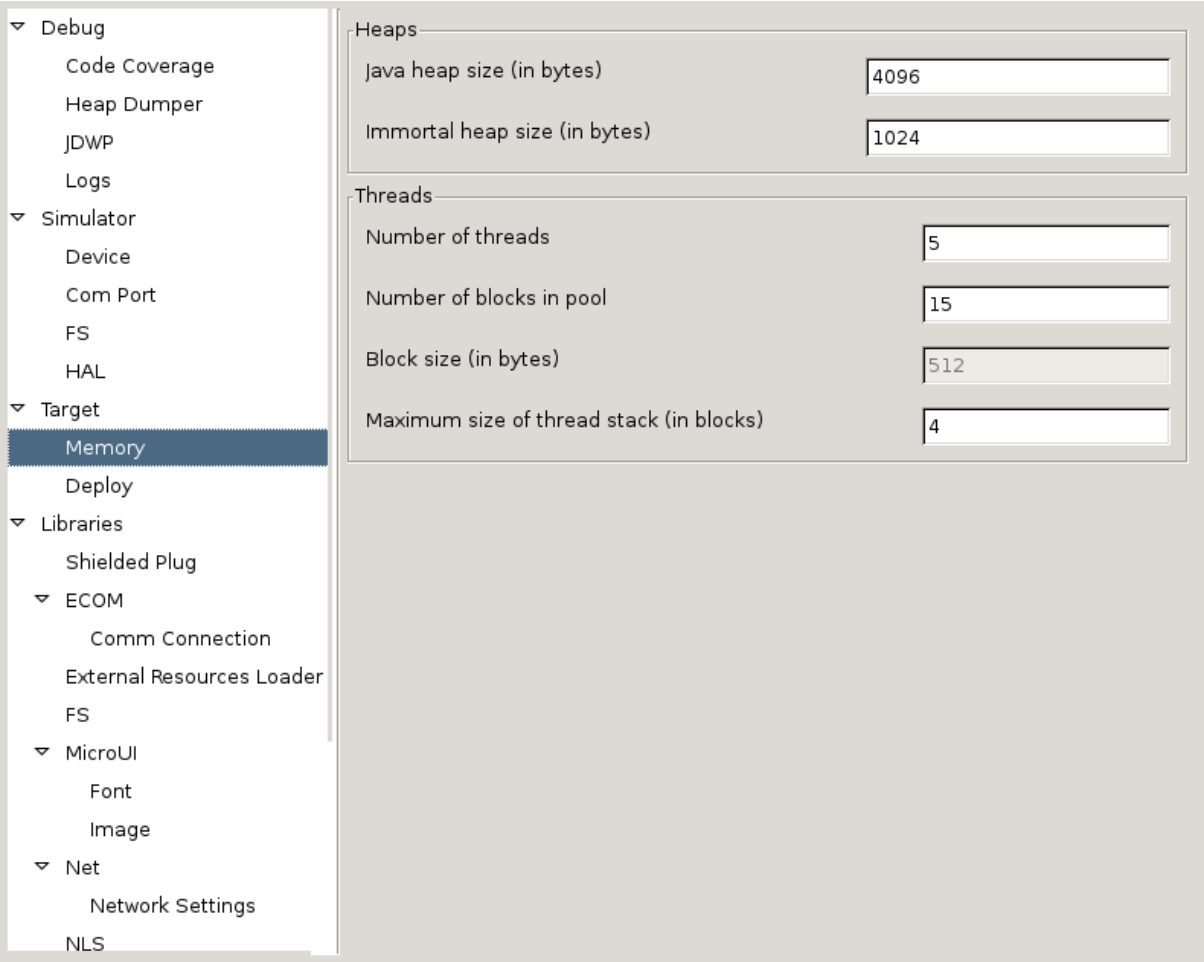
27.2.7.2.4 Option(checkbox): Enable verbose trace

Default value: unchecked

27.3 Category: Target



27.3.1 Category: Memory



27.3.1.1 Group: Heaps

27.3.1.1.1 Option(text): Java heap size (in bytes)

Default value: 4096

Description:

Specifies the Java heap size in bytes.

A Java heap contains live Java objects. An OutOfMemory error can occur if the heap is too small.

27.3.1.1.2 Option(text): Immortal heap size (in bytes)

Default value: 1024

Description:

Specifies the Immortal heap size in bytes.

The Immortal heap contains allocated Immortal objects. An OutOfMemory error can occur if the heap is too small.

27.3.1.2 Group: Threads

Description:

This group allows the configuration of application and library thread(s). A thread needs a stack to run. This stack is allocated from a pool and this pool contains several blocks. Each block has the same size. At thread startup the thread uses only one block for its stack. When the first block is full it uses another block. The maximum number of blocks per thread must be specified. When the maximum number of blocks for a thread is reached or when there is no free block in the pool, a StackOverflow error is thrown. When a thread terminates all associated blocks are freed. These blocks can then be used by other threads.

27.3.1.2.1 Option(text): Number of threads

Default value: 5

Description:

Specifies the number of threads the application will be able to use at the same time.

27.3.1.2.2 Option(text): Number of blocks in pool

Default value: 15

Description:

Specifies the number of blocks in the stacks pool.

27.3.1.2.3 Option(text): Block size (in bytes)

Default value: 512

Description:

Specifies the thread stack block size (in bytes).

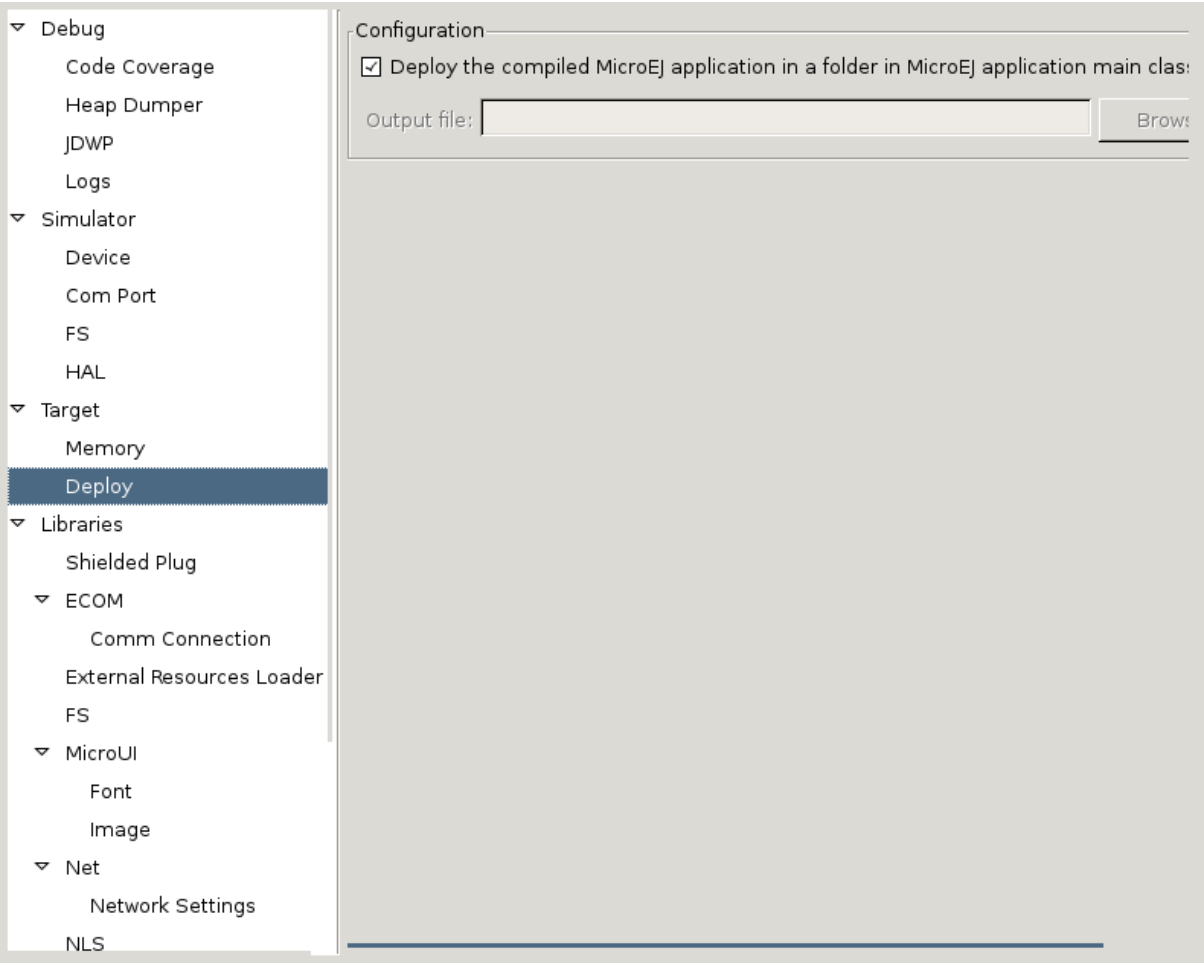
27.3.1.2.4 Option(text): Maximum size of thread stack (in blocks)

Default value: 4

Description:

Specifies the maximum number of blocks a thread can use. If a thread requires more blocks a StackOverflow error will occur.

27.3.2 Category: Deploy



Description:

Configures the output location where store the MicroEJ application.

27.3.2.1 Group: Configuration

27.3.2.1.1 Option(checkbox): Deploy the compiled MicroEJ application in a folder in MicroEJ application main class project

Default value: checked

Description:

Deploy the compiled MicroEJ application in a folder in MicroEJ application's main class project.

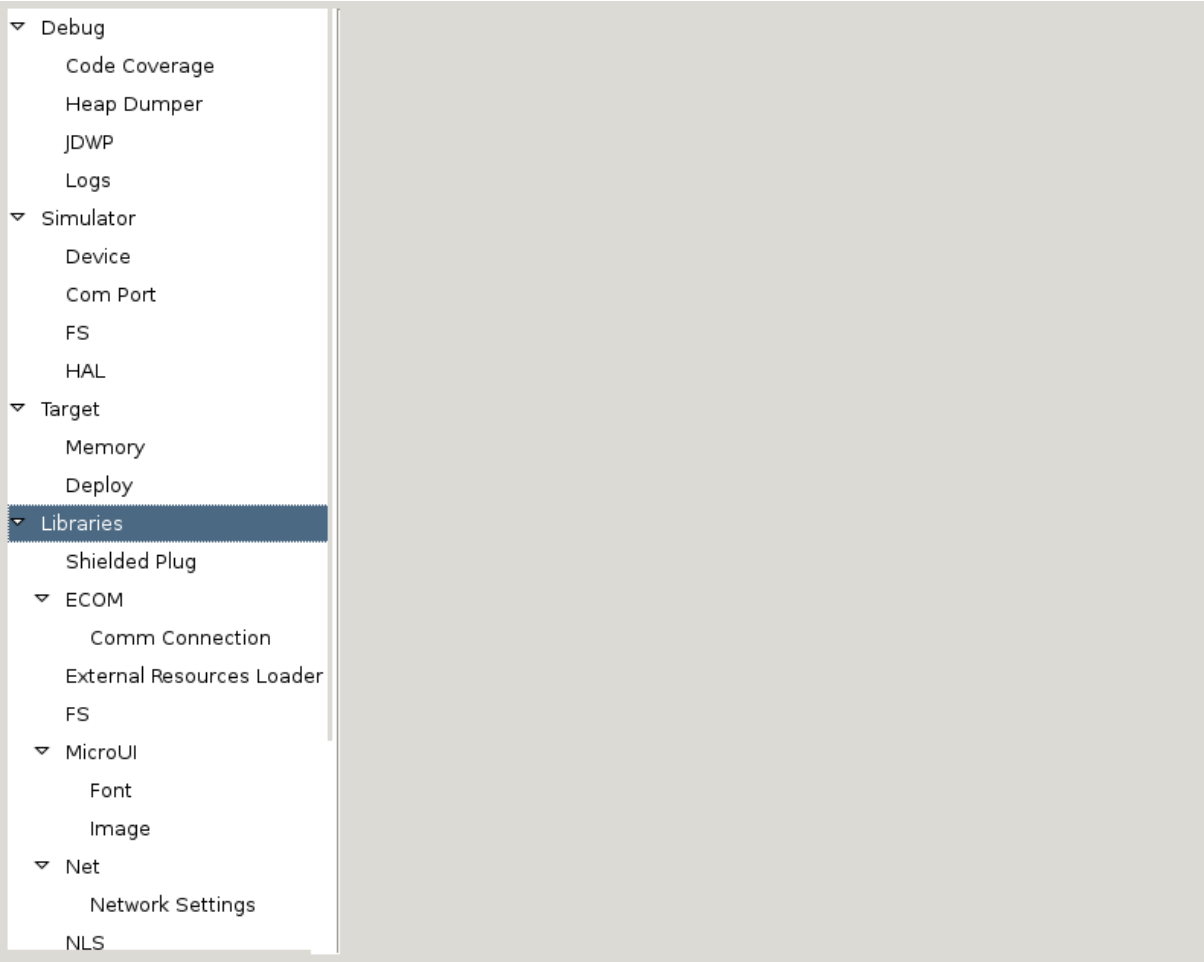
27.3.2.1.2 Option(browse): Output file

Default value: (empty)

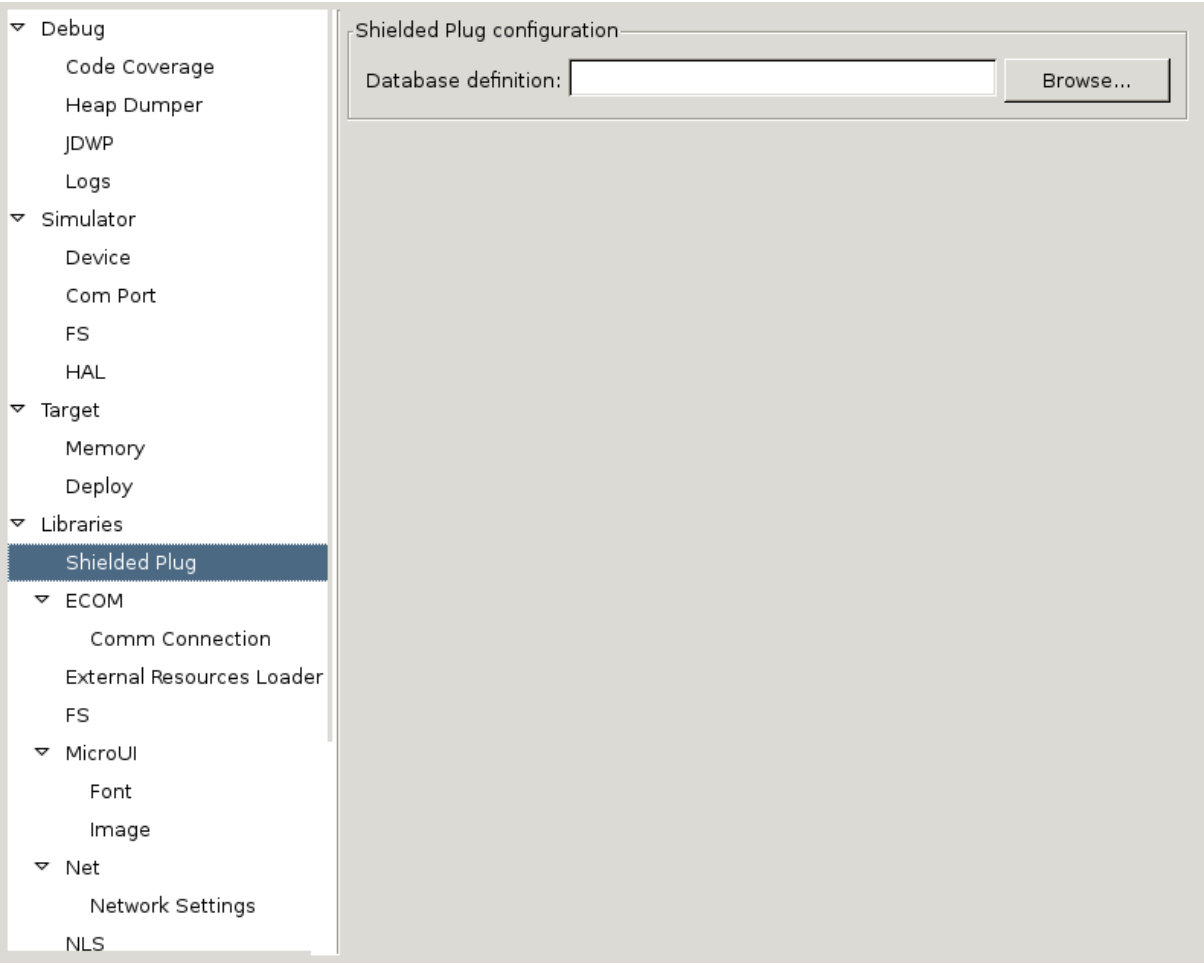
Description:

Choose an output file location where copy the compiled MicroEJ application.

27.4 Category: Libraries



27.4.1 Category: Shielded Plug



27.4.1.1 Group: Shielded Plug configuration

Description:

Choose the database XML definition.

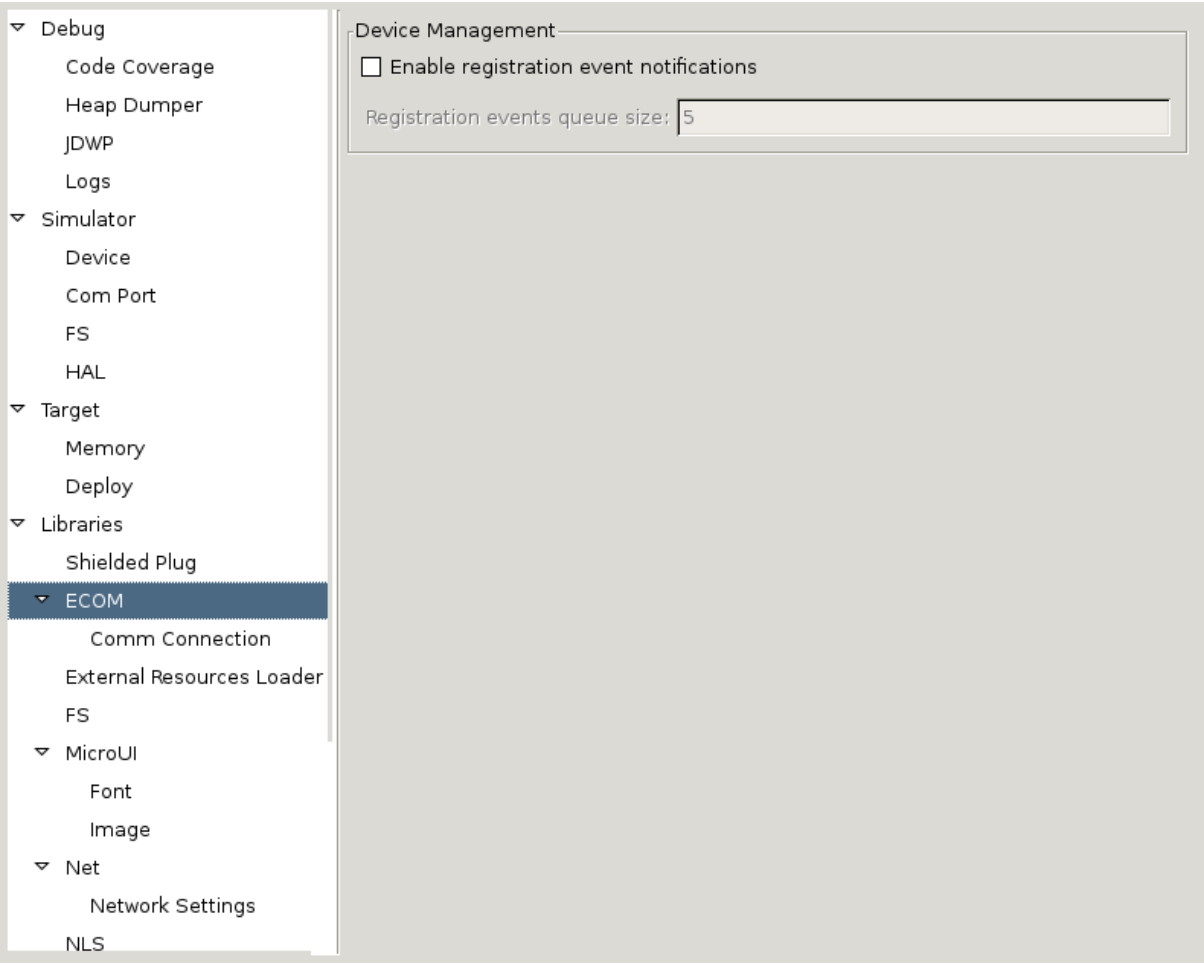
27.4.1.1.1 Option(browse): Database definition

Default value: (empty)

Description:

Choose the database XML definition.

27.4.2 Category: ECOM



27.4.2.1 Group: Device Management

27.4.2.1.1 Option(checkbox): Enable registration event notifications

Default value: unchecked

Description:

Enables notification of listeners when devices are registered or unregistered. When a device is registered or unregistered, a new ej.ecom.io.RegistrationEvent is added to an event queue. Then events are processed by a dedicated thread that notifies registered listeners.

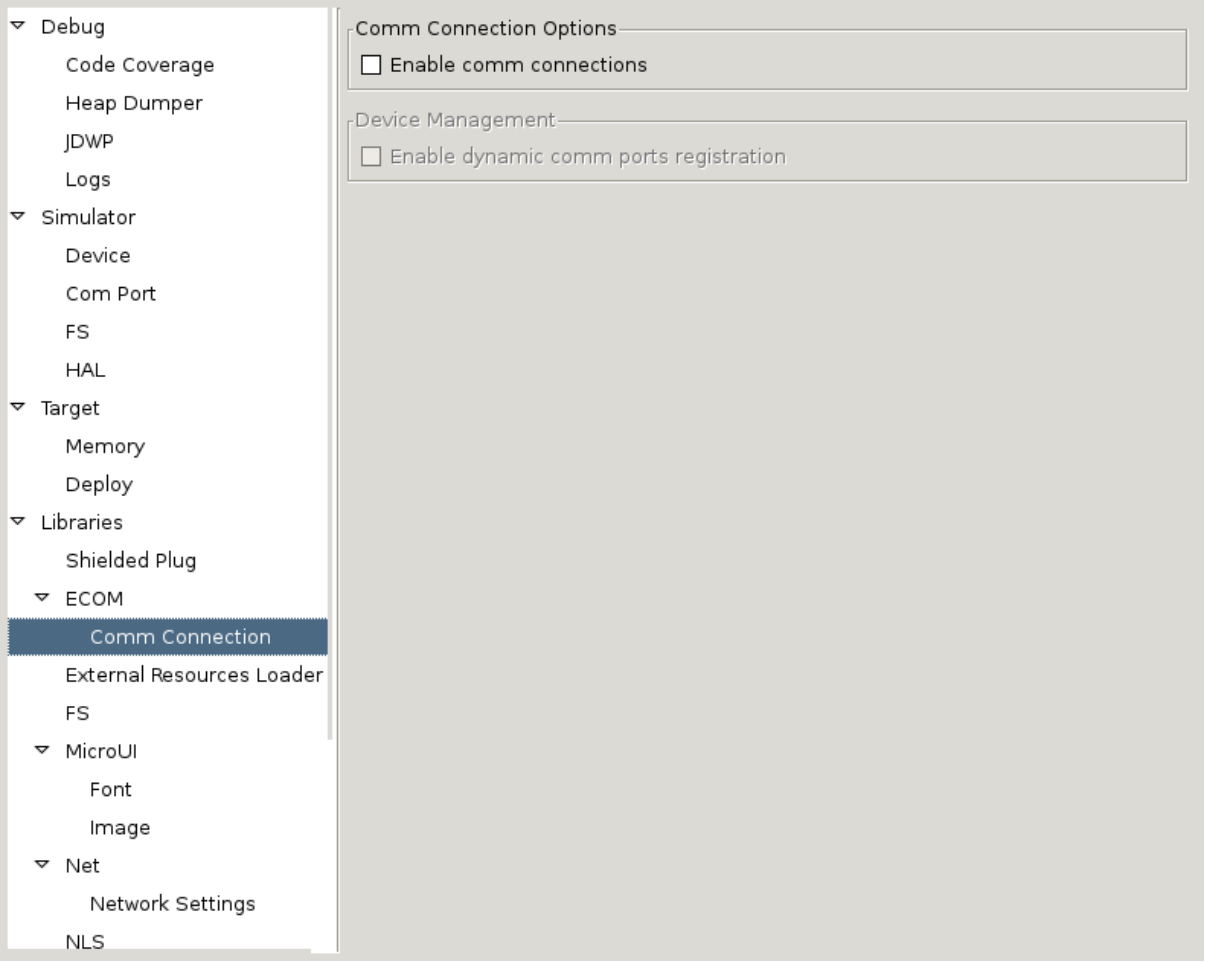
27.4.2.1.2 Option(text): Registration events queue size

Default value: 5

Description:

Specifies the size (in number of events) of the registration events queue.

27.4.2.2 Category: Comm Connection



27.4.2.2.1 Group: Comm Connection Options

Description:

This group allows comm connections to be enabled and application-platform mappings set.

27.4.2.2.1.1 Option(checkbox): Enable comm connections

Default value: unchecked

Description:

When checked application is able to open a CommConnection.

27.4.2.2.2 Group: Device Management

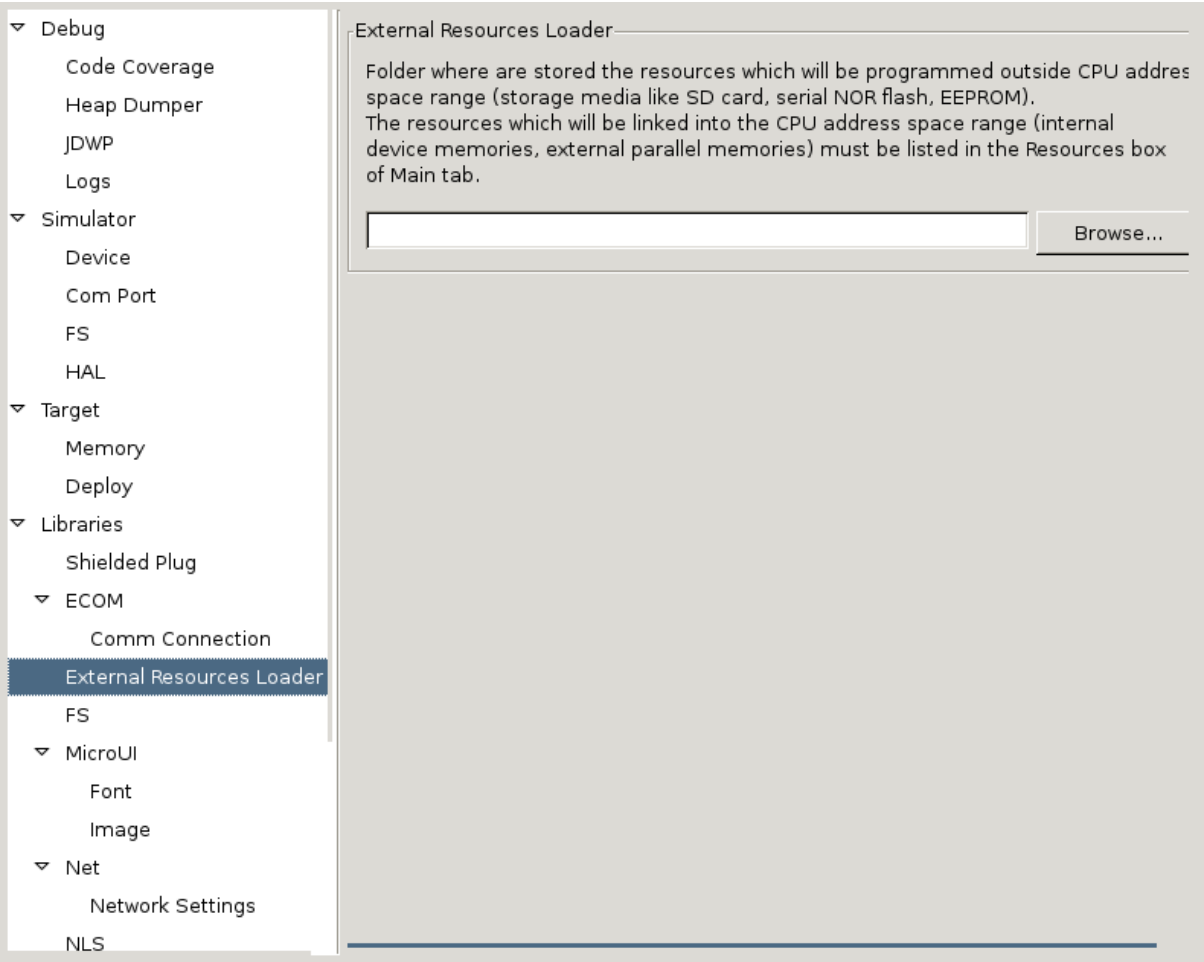
27.4.2.2.2.1 Option(checkbox): Enable dynamic comm ports registration

Default value: unchecked

Description:

Enables registration (or unregistration) of ports dynamically added (or removed) by the platform. A dedicated thread listens for ports dynamically added (or removed) by the platform and adds (or removes) their CommPort representation to the ECOM DeviceManager.

27.4.3 Category: External Resources Loader



27.4.3.1 Group: External Resources Loader

Description:

This group allows to specify the external resources output folder. This folder will be used by third-party tools and by the simulator. If empty, the default location will be [output folder]/externalResources, where [output folder] is the location defined in Execution tab.

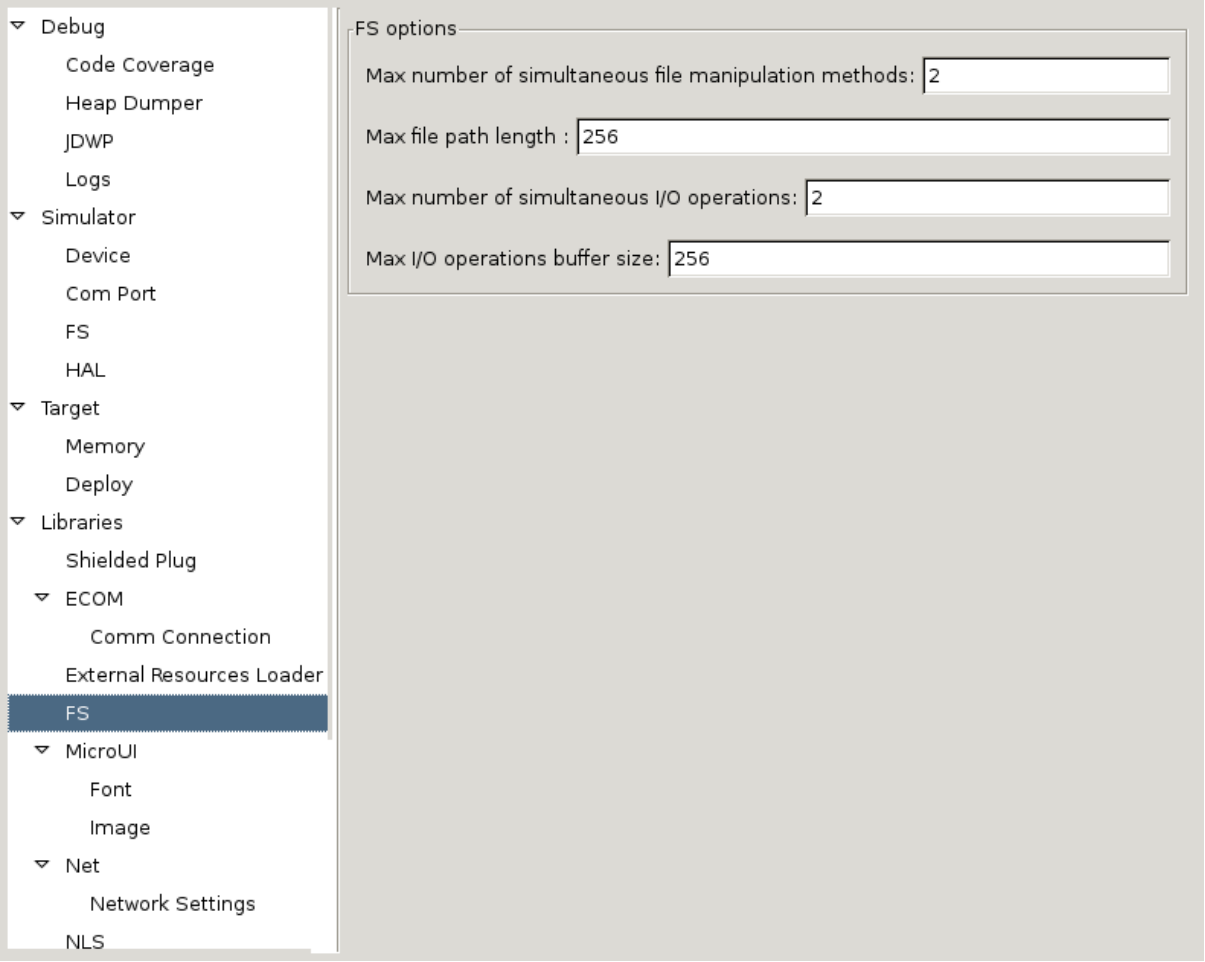
27.4.3.1.1 Option(browse):

Default value: (empty)

Description:

Browse to specify the external resources folder. This folder may not exist (it will be created at build time).

27.4.4 Category: FS



27.4.4.1 Group: FS options

27.4.4.1.1 Option(text): Max number of simultaneous file manipulation methods

Default value: 2

Description: Get the Max number of simultaneous file manipulation methods. Is the maximum number of immortals buffers that will be reserved for handling filename in file manipulation methods (canRead, mkdir, renameTo...). Warning : Allow at least 2 buffers for renameTo file method.

27.4.4.1.2 Option(text): Max file path length

Default value: 256

Description: Get the maximum filename length

27.4.4.1.3 Option(text): Max number of simultaneous I/O operations

Default value: 2

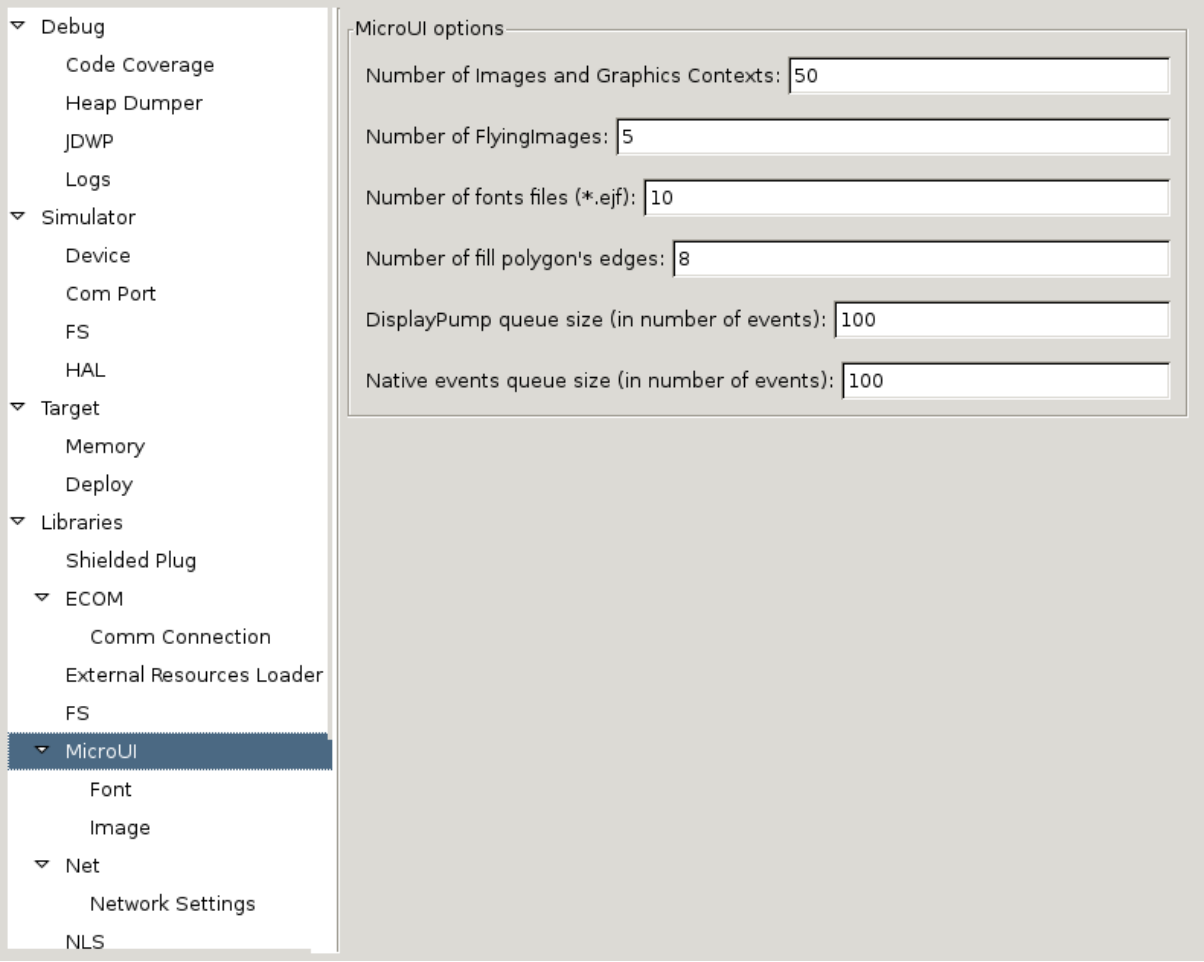
Description: Get the maximum number of simultaneous IO/Operations (FS read/write). Is the maximum number of immortals buffers that will be reserved for handling I/O data

27.4.4.1.4 Option(text): Max I/O operations buffer size

Default value: 256

Description: Get maximum buffer size of IO/Operations (FS read/write max I/O buffer size)

27.4.5 Category: MicroUI



27.4.5.1 Group: MicroUI options

27.4.5.1.1 Option(text): Number of Images and Graphics Contexts

Default value: 50

Description:

Specifies the number of Image the application can open at the same time. If the limit is reached at runtime an OutOfMemory error is thrown.

27.4.5.1.2 Option(text): Number of FlyingImages

Default value: 5

Description:

Specifies the number of Flying Image the application can open at the same time. If the limit is reached at runtime an OutOfMemory error is thrown.

27.4.5.1.3 Option(text): Number of fonts files (*.ejf)

Default value: 10

Description:

Specifies the number of fonts files the platform can load. If the number of fonts files to load is higher than the specified number, a warning is showed and the last fonts files are not loaded.

27.4.5.1.4 Option(text): Number of fill polygon's edges

Default value: 8

Description:

Specifies the number of edges the platform's fill algorithm can manage. If the user tries to fill a polygon with more edges than this value, a MicroUIException will be thrown at runtime.

27.4.5.1.5 Option(text): DisplayPump queue size (in number of events)

Default value: 100

Description: NLS missing message: MicroUIDescDisplayPumpSize in: com.is2t.microui.extension.MicroUIMessages

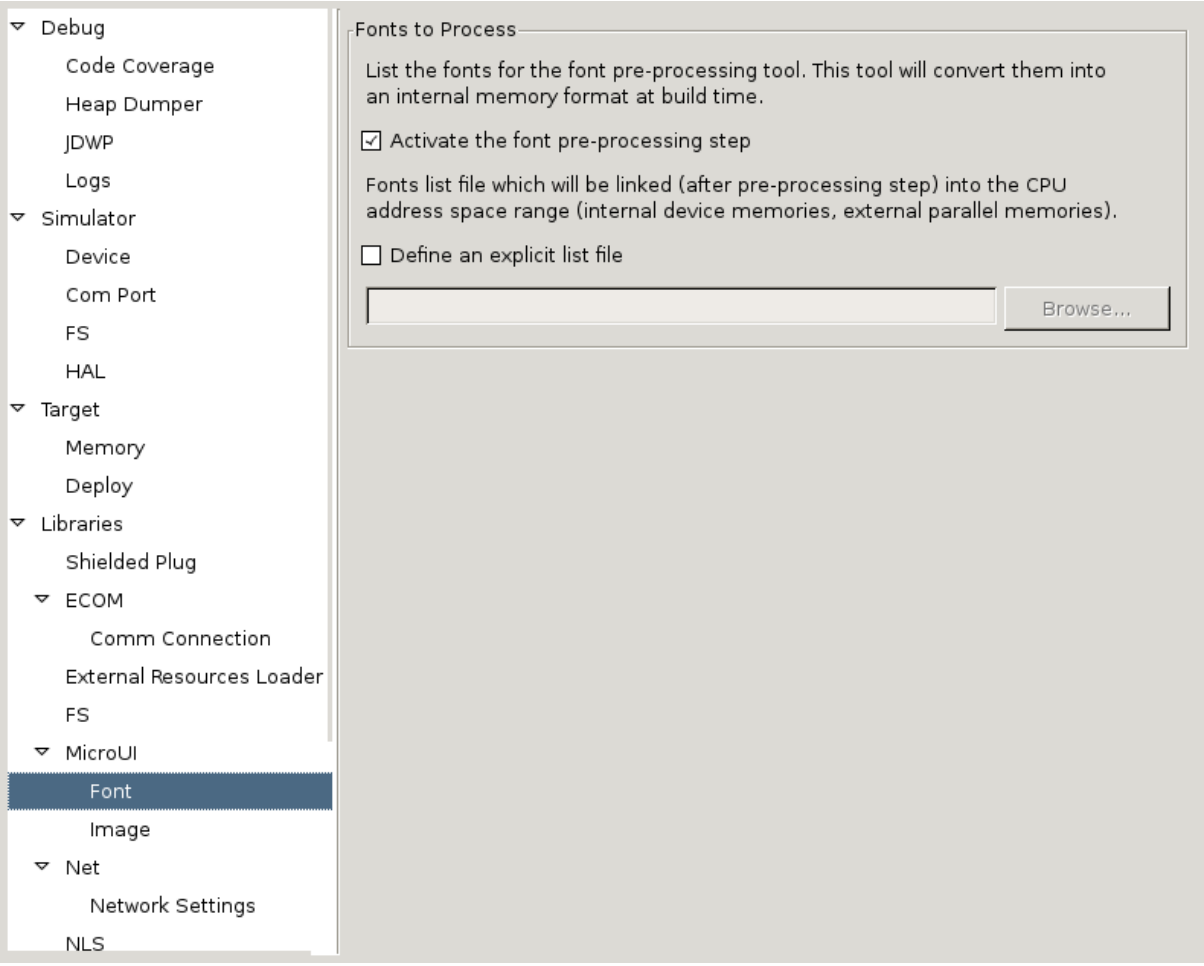
27.4.5.1.6 Option(text): Native events queue size (in number of events)

Default value: 100

Description:

Specifies the size of the native events queue.

27.4.5.2 Category: Font



27.4.5.2.1 Group: Fonts to Process

Description:

This group allows to select a file describing the font files which need to be converted into a RAW format. At MicroUI runtime, the pre-generated fonts will be read from the flash memory without any modifications (see MicroUI specification).

27.4.5.2.1.1 Option(checkbox): Activate the font pre-processing step

Default value: checked

Description:

When checked, enables the next option Fonts list file. When the next option is disabled, there is no check on the file path validity.

27.4.5.2.1.2 Option(checkbox): Define an explicit list file

Default value: unchecked

Description:

By default, list files are loaded from the classpath. When checked, only the next option Fonts list file is processed.

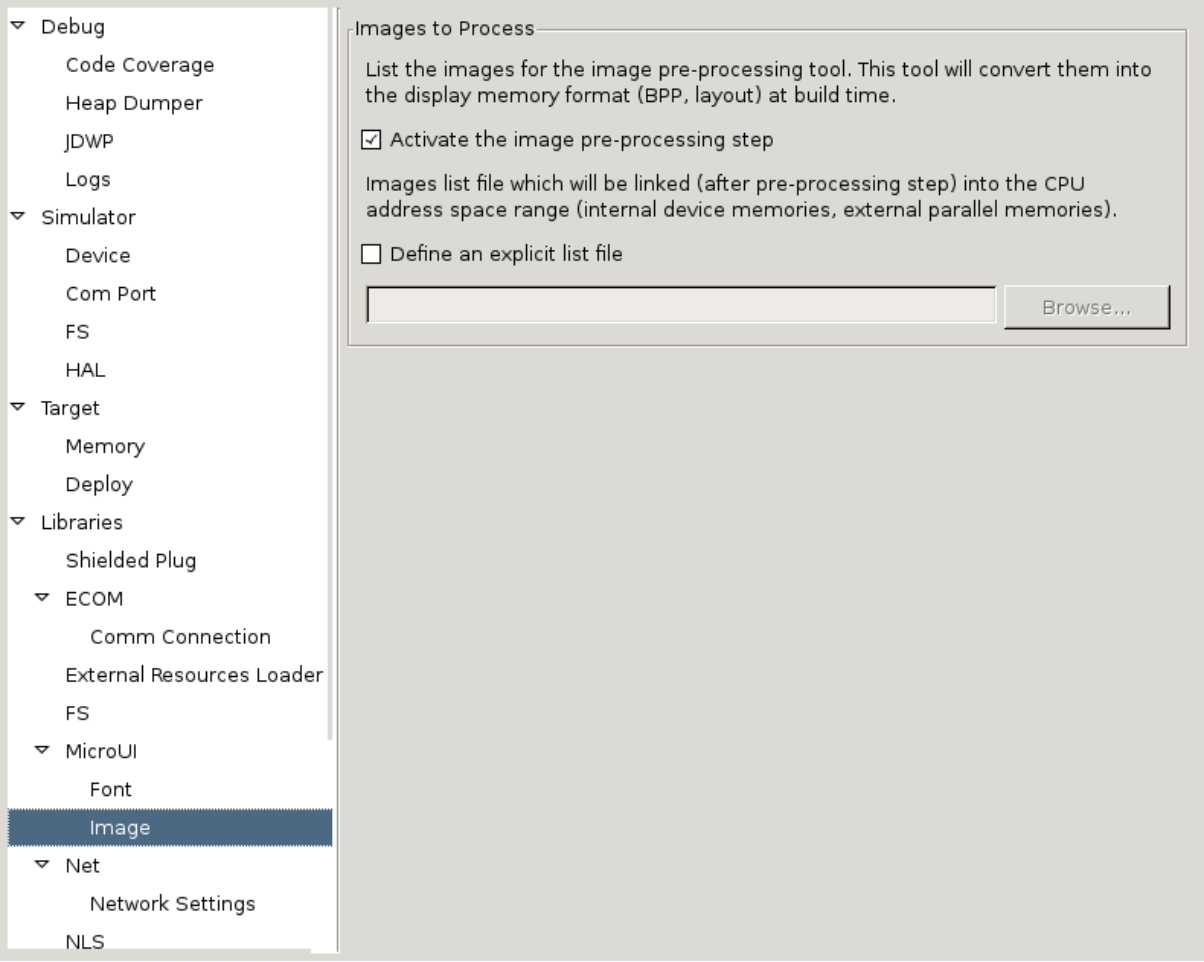
27.4.5.2.1.3 Option(browse):

Default value: (empty)

Description:

Browse to select a font list file. Refer to Font Generator chapter for more information about the font list file format.

27.4.5.3 Category: Image



27.4.5.3.1 Group: Images to Process

Description:

This group allows to select a file describing the image files which need to be converted into a RAW format. At MicroUI runtime, the pre-generated images will be read from the flash memory without any modifications (see MicroUI specification).

27.4.5.3.1.1 Option(checkbox): Activate the image pre-processing step

Default value: checked

Description:

When checked, enables the next option Images list file. When the next option is disabled, there is no check on the file path validity.

27.4.5.3.1.2 Option(checkbox): Define an explicit list file

Default value: unchecked

Description:

By default, list files are loaded from the classpath. When checked, only the next option Images list file is processed.

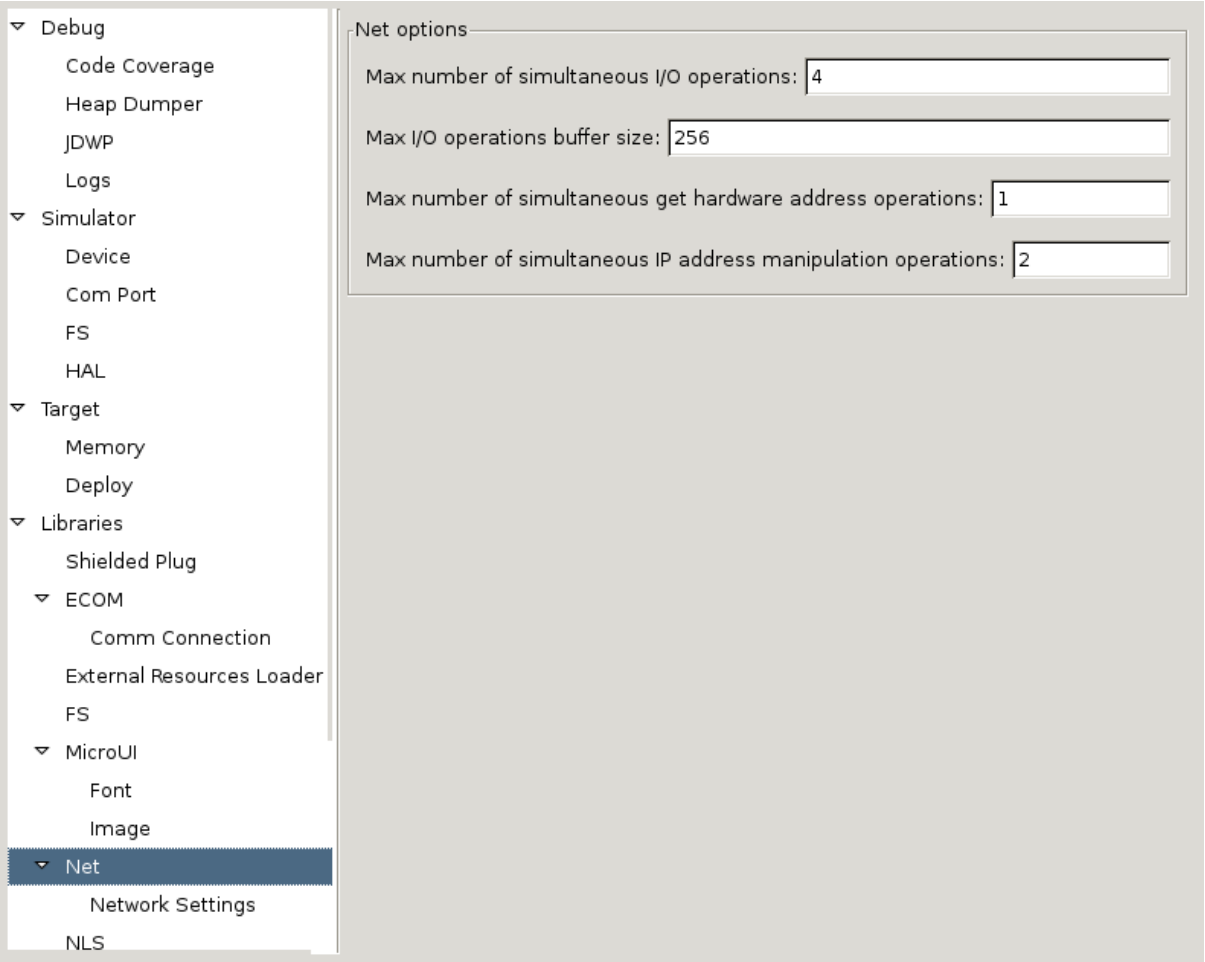
27.4.5.3.1.3 Option(browse):

Default value: (empty)

Description:

Browse to select an image list file. Refer to Image Generator chapter for more information about the image list file format.

27.4.6 Category: Net



27.4.6.1 Group: Net options

27.4.6.1.1 Option(text): Max number of simultaneous I/O operations

Default value: 4

Description: Get the maximum number of simultaneous IO/Operations (read/write/send/receive). Is the maximum number of immortals buffers that will be reserved for handling I/O data

27.4.6.1.2 Option(text): Max I/O operations buffer size

Default value: 256

Description: Get maximum buffer size of IO/Operations (read/write/send/receive max I/O buffer size)

27.4.6.1.3 Option(text): Max number of simultaneous get hardware address operations

Default value: 1

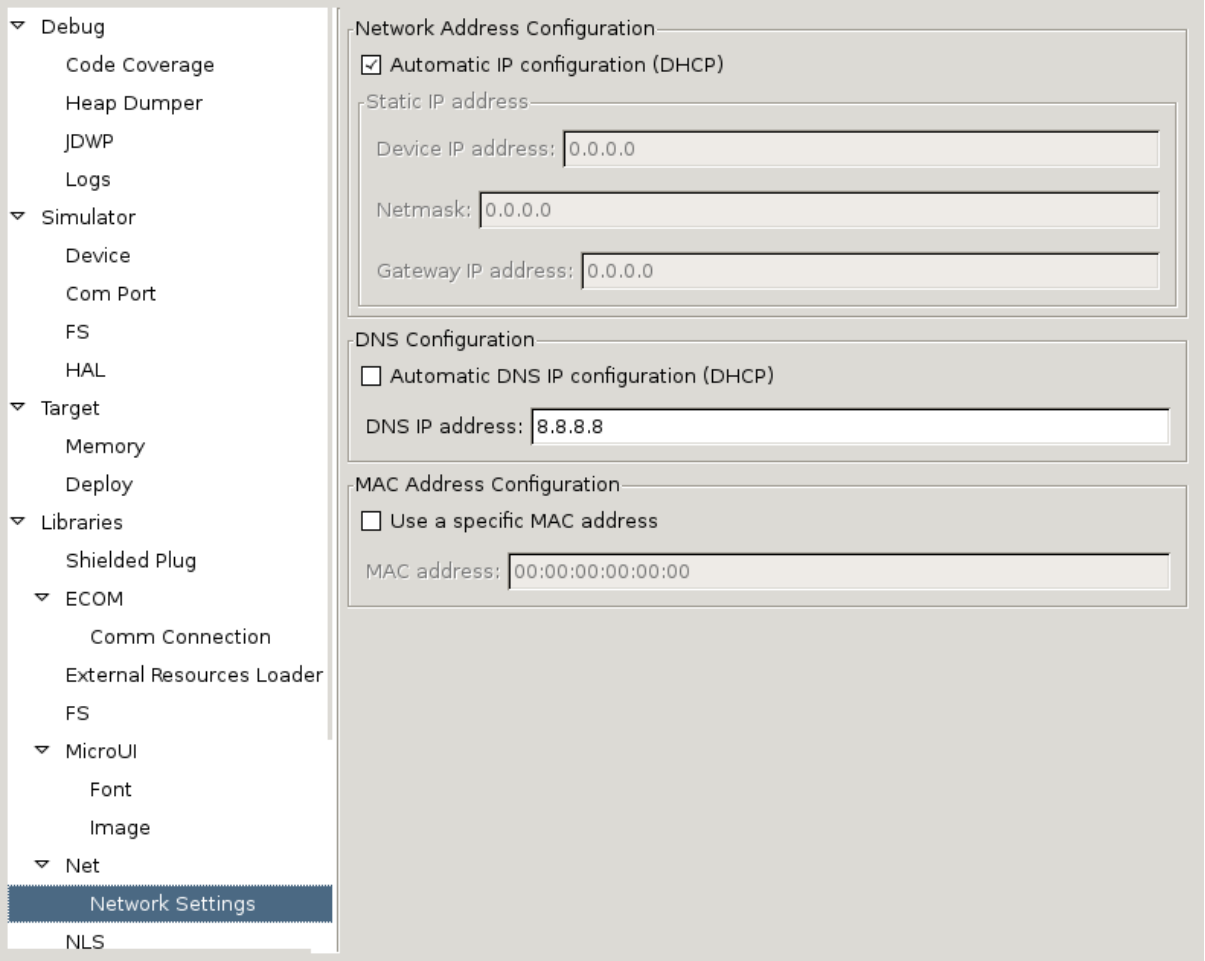
Description: Get maximum number of simultaneous get hardware address operations

27.4.6.1.4 Option(text): Max number of simultaneous IP address manipulation operations

Default value: 2

Description: Get maximum number of simultaneous IP address manipulation

27.4.6.2 Category: Network Settings



27.4.6.2.1 Group: Network Address Configuration

27.4.6.2.1.1 Option(checkbox): Automatic IP configuration (DHCP)

Default value: checked

27.4.6.2.1.2 Group: Static IP address

27.4.6.2.1.2.1 Option(text): Device IP address

Default value: 0.0.0.0

Description: Set device IP address.

27.4.6.2.1.2.2 Option(text): Netmask

Default value: 0.0.0.0

Description: Set netmask.

27.4.6.2.1.2.3 Option(text): Gateway IP address

Default value: 0.0.0.0

Description: Set gateway IP address.

27.4.6.2.2 Group: DNS Configuration

27.4.6.2.2.1 Option(checkbox): Automatic DNS IP configuration (DHCP)

Default value: unchecked

27.4.6.2.2.2 Option(text): DNS IP address

Default value: 8.8.8.8

Description: Set DNS IP address.

27.4.6.2.3 Group: MAC Address Configuration

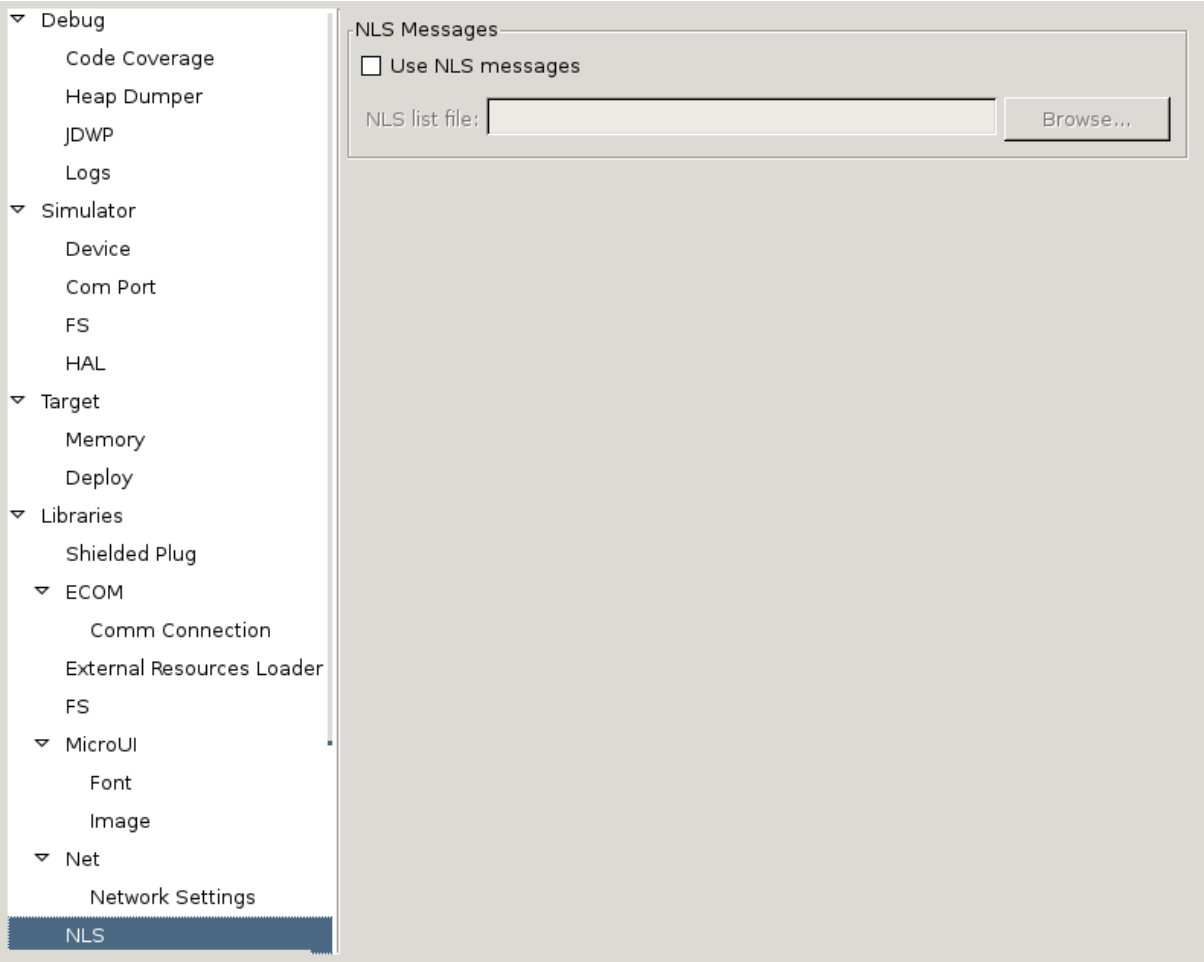
27.4.6.2.3.1 Option(checkbox): Use a specific MAC address

Default value: unchecked

27.4.6.2.3.2 Option(text): MAC address

Default value: 00:00:00:00:00:00

27.4.7 Category: NLS



27.4.7.1 Group: NLS Messages

Description:

This group allows to select a file describing the NLS message which will be converted into a RAW format.

27.4.7.1.1 Option(checkbox): Use NLS messages

Default value: unchecked

Description:

When selected, enables the next option NLS list file file.

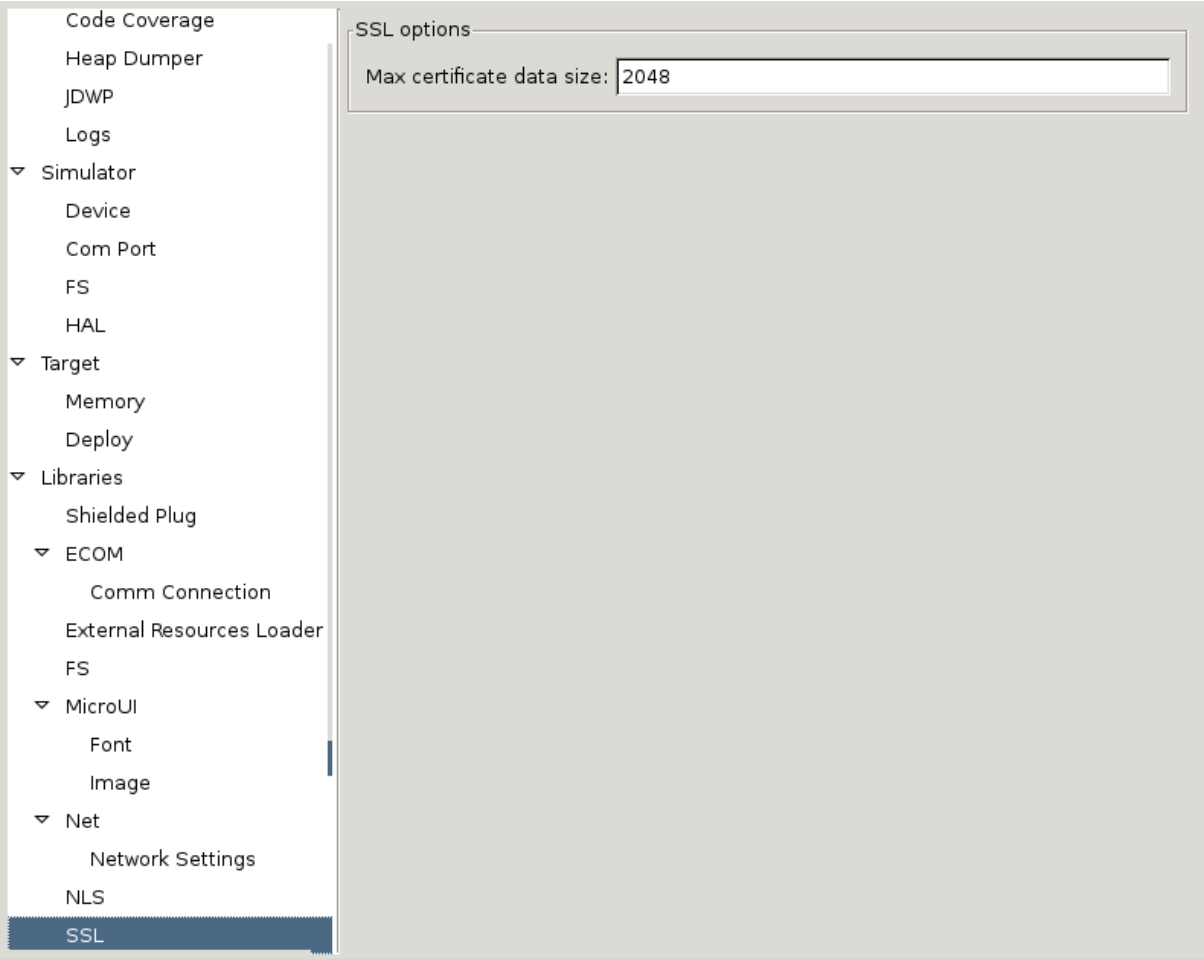
27.4.7.1.2 Option(browse): NLS list file

Default value: (empty)

Description:

Browse to select an NLS list file. Refer to NLS chapter for more information about the NLF list file format.

27.4.8 Category: SSL



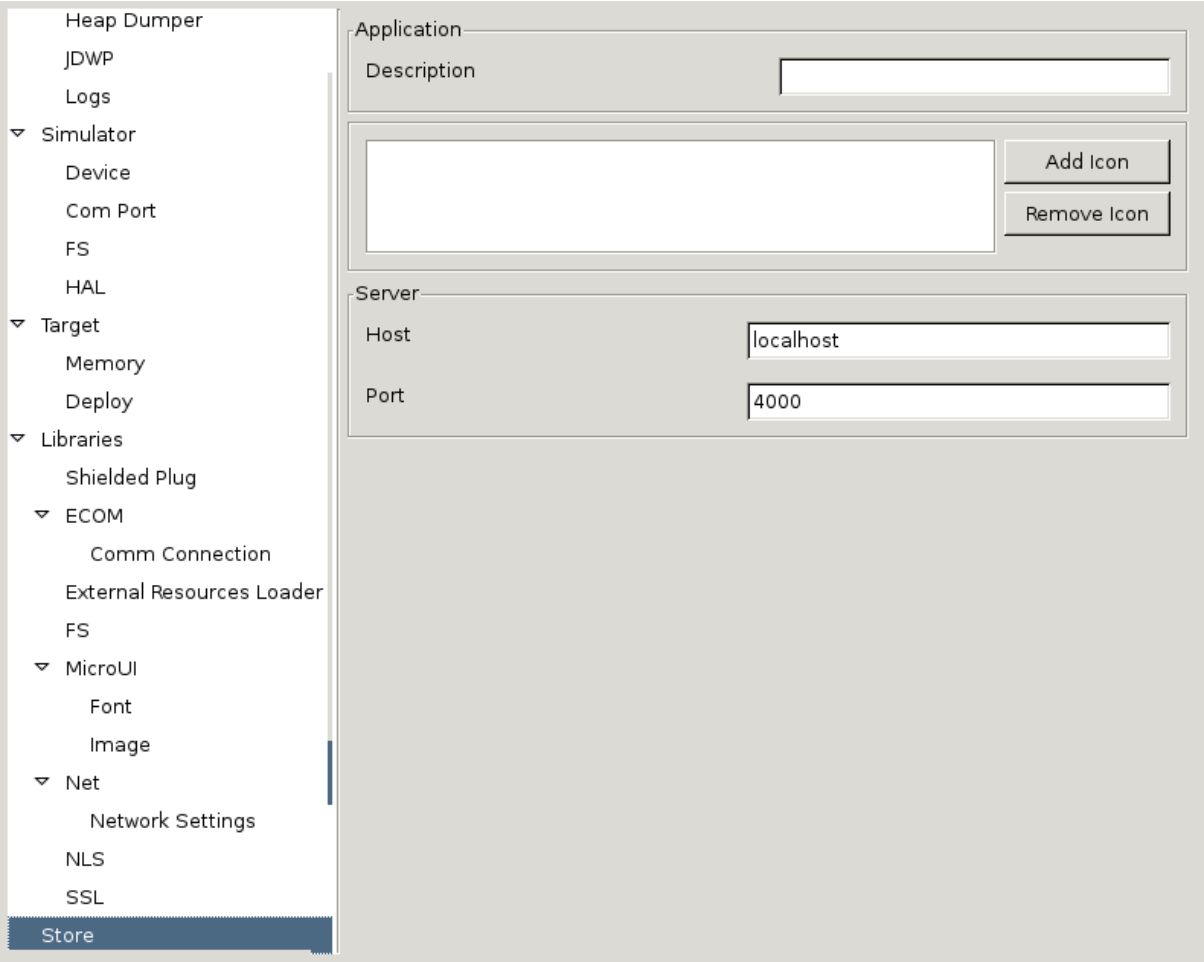
27.4.8.1 Group: SSL options

27.4.8.1.1 Option(text): Max certificate data size

Default value: 2048

Description: Get the maximum certificate data size. Is the size of the immortal buffer that will be reserved to process certificates

27.5 Category: Store



27.5.1 Group: Application

27.5.1.1 Option(text):

Default value: (empty)

27.5.2 Group:

27.5.2.1 Option(list):

Default value: (empty)

27.5.3 Group: Server

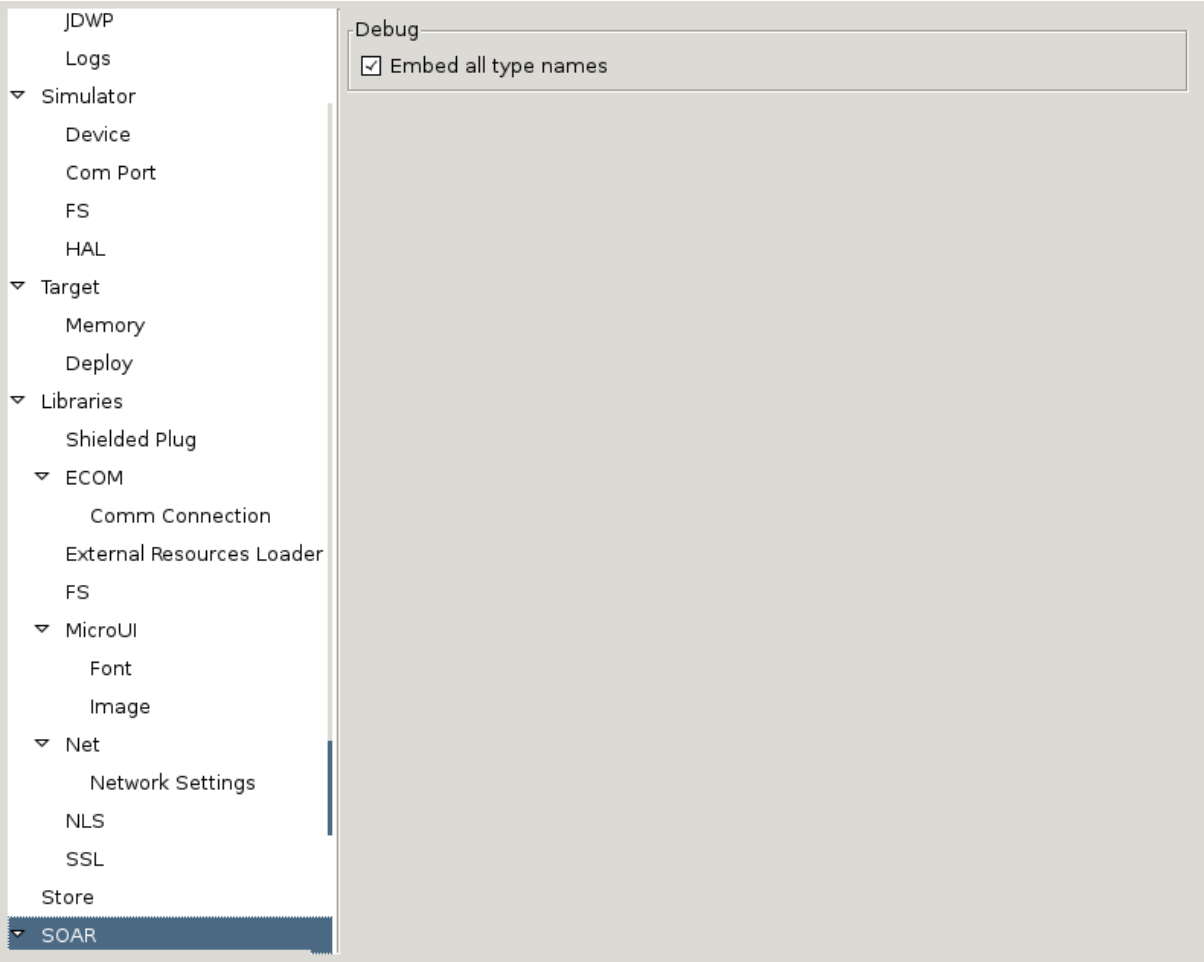
27.5.3.1 Option(text):

Default value: localhost

27.5.3.2 Option(text):

Default value: 4000

27.6 Category: SOAR

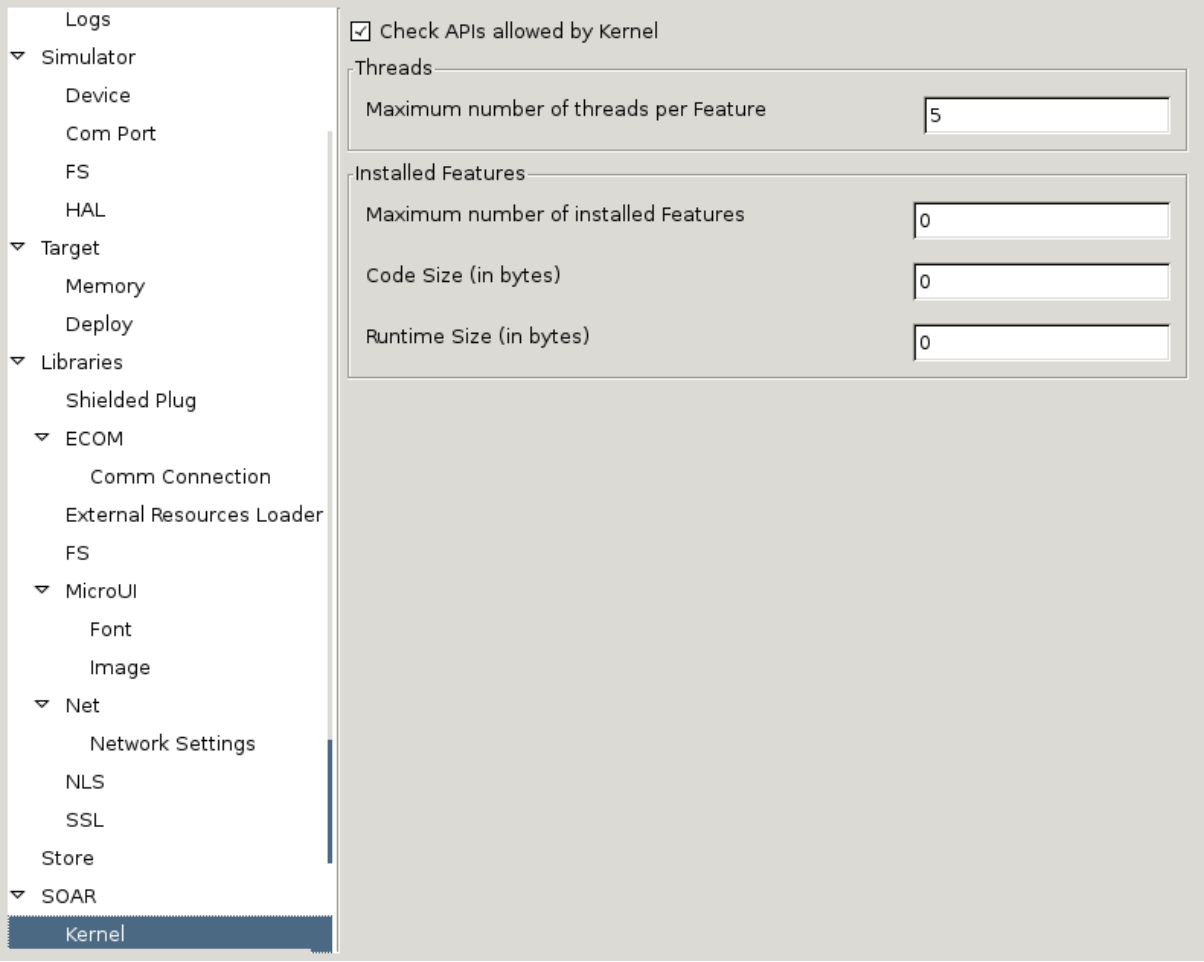


27.6.1 Group: Debug

27.6.1.1 Option(checkbox): Embed all type names

Default value: checked

27.6.2 Category: Kernel



27.6.2.1 Option(checkbox): Check APIs allowed by Kernel

Default value: checked

27.6.2.2 Group: Threads

27.6.2.2.1 Option(text):

Default value: 5

Description:

Specifies the maximum number of threads a Feature is allowed to use at the same time.

27.6.2.3 Group: Installed Features

27.6.2.3.1 Option(text):

Default value: 0

Description:

Specifies the maximum number of installed Features that can be added to this Kernel.

27.6.2.3.2 Option(text):

Default value: 0

Description:

Specifies the size in bytes reserved for installed Features code.

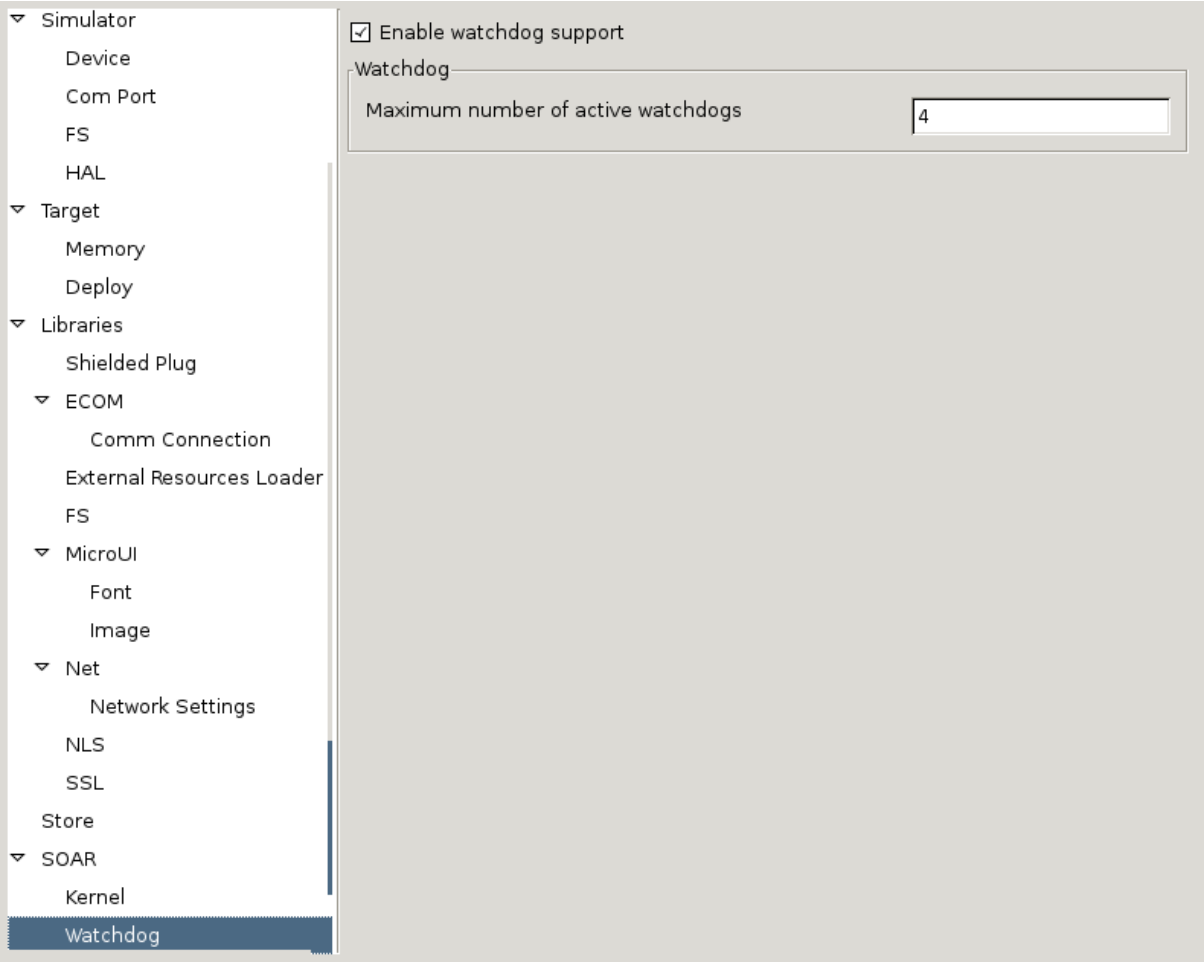
27.6.2.3.3 Option(text):

Default value: 0

Description:

Specifies the size in bytes reserved for installed Features runtime memory.

27.6.3 Category: Watchdog



27.6.3.1 Option(checkbox): Enable watchdog support

Default value: checked

27.6.3.2 Group: Watchdog

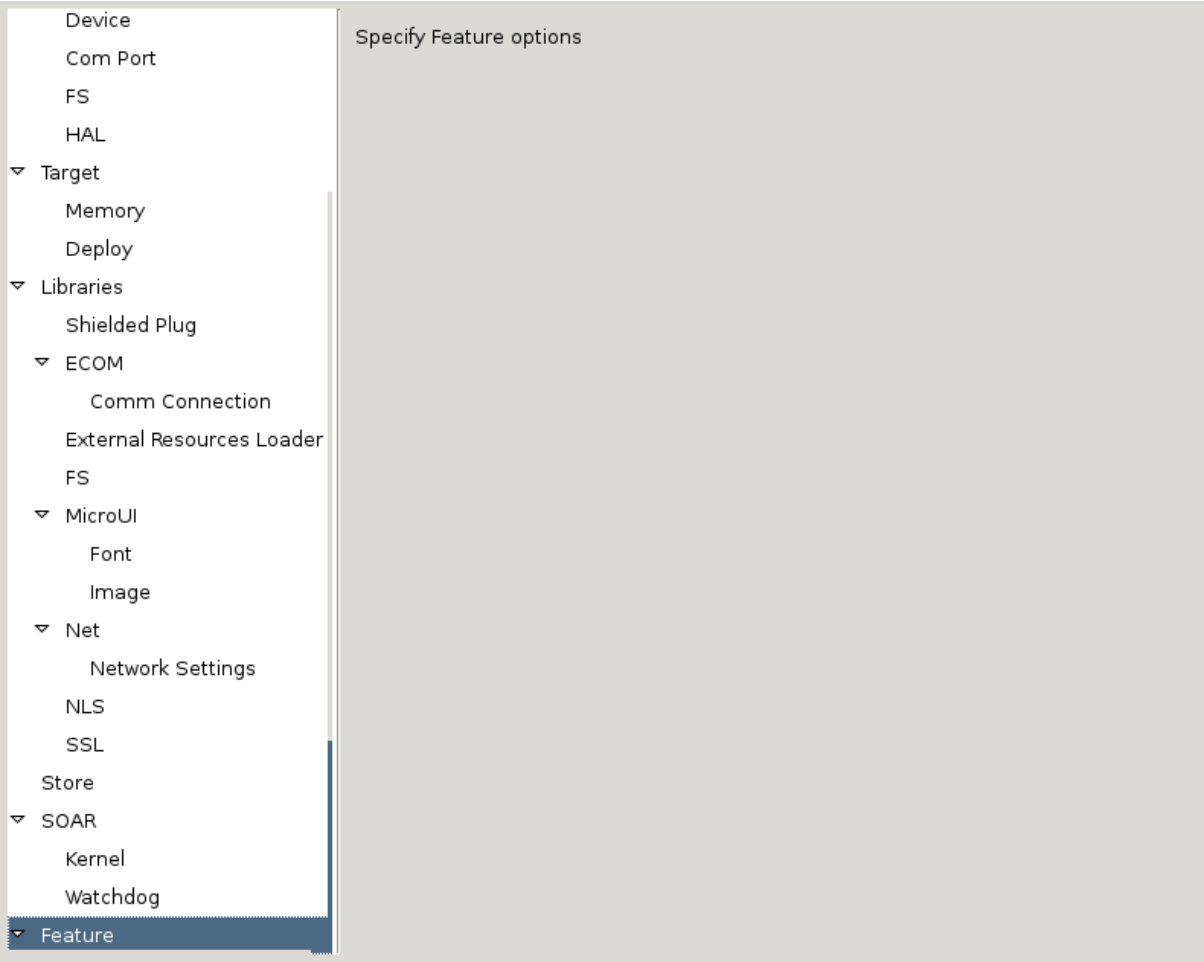
27.6.3.2.1 Option(text):

Default value: 4

Description:

Specifies the maximum number of active watchdogs at the same time.

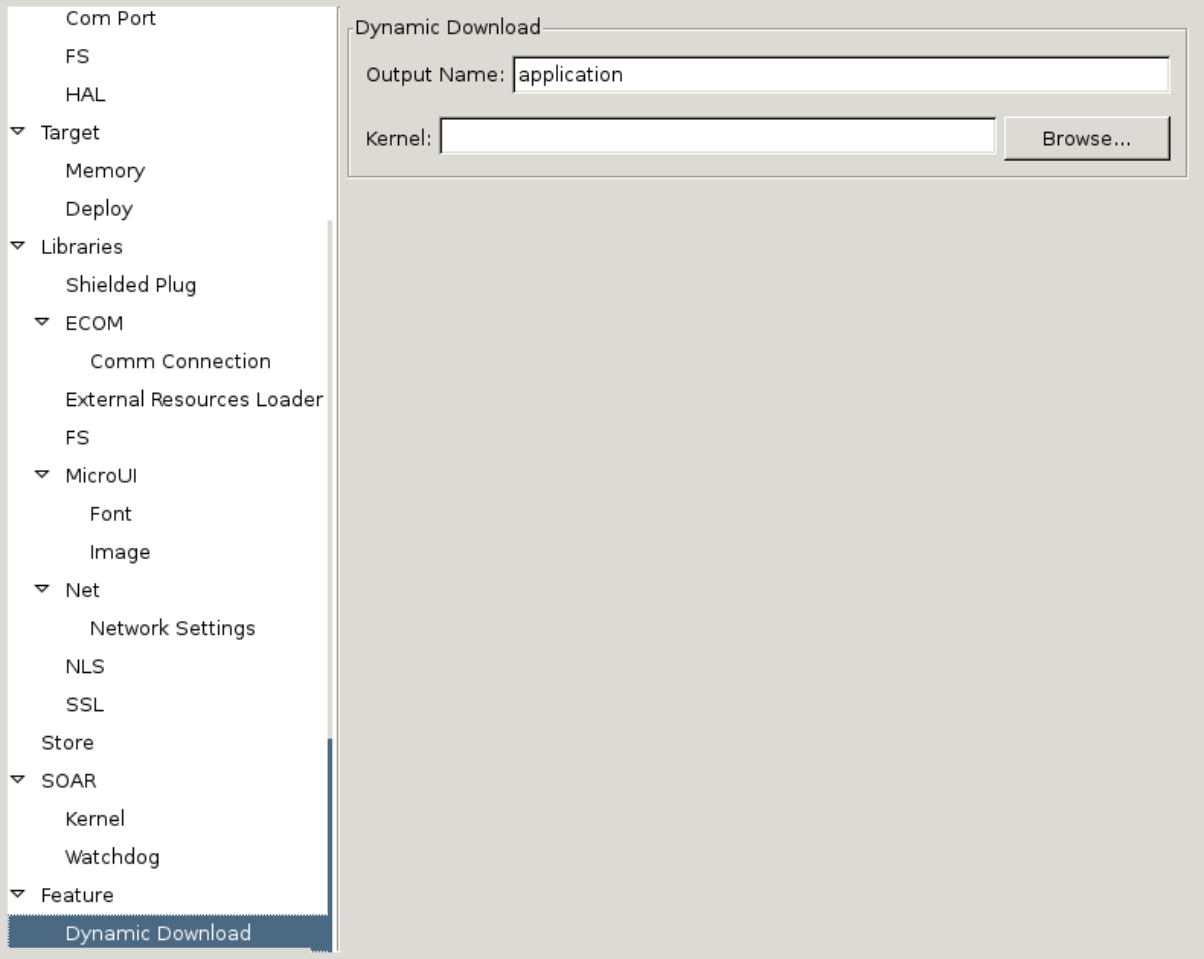
27.7 Category: Feature



Description:

Specify Feature options

27.7.1 Category: Dynamic Download



27.7.1.1 Group: Dynamic Download

27.7.1.1.1 Option(text): Output Name

Default value: application

27.7.1.1.2 Option(browse): Kernel

Default value: (empty)

28 Document History

Date	Revision	Description
June 1st 2017	4.1-Bdraft1	Fix front panel preview
May 30th 2017		Fix UI overview image
May 22nd 2017		Update limitations
March 14th 2017	4.1-A	Update for MicroEJ 4.1
March 25th 2016	4.0-A	Initial version