MCUXpresso SDK Documentation

Release 25.12.00

NXP
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Table of contents

This documentation contains information specific to the mcxw72evk board.

Chapter 1

Middleware

1.1 Boot

1.1.1 MCUXpresso SDK : mcuxsdk-middleware-mcuboot_opensource

Overview

This repository is a fork of MCUboot (https://github.com/mcu-tools/mcuboot) for MCUXpresso SDK delivery and it contains the components officially provided in NXP MCUXpresso SDK. This repository is part of the MCUXpresso SDK overall delivery which is composed of several sub-repositories/projects. Navigate to the top/parent repository (mcuxsdk-manifests) for the complete delivery of MCUXpresso SDK.

Documentation

Overall details can be reviewed here: MCUXpresso SDK Online Documentation

Visit MCUboot - Documentation to review details on the contents in this sub-repo.

Setup

Instructions on how to install the MCUXpresso SDK provided from GitHub via west manifest Getting Started with SDK - Detailed Installation Instructions

Contribution

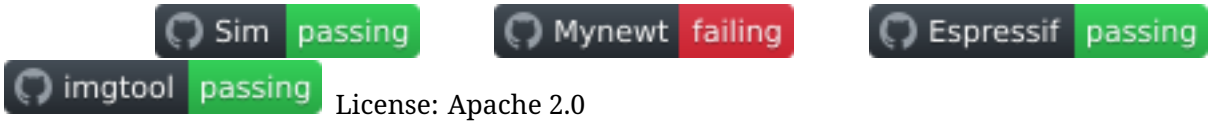
Contributions are not currently accepted. If the intended contribution is not related to NXP specific code, consider contributing directly to the upstream MCUboot project. Once this MCUboot fork is synchronized with the upstream project, such contributions will end up here as well. If the intended contribution is a bugfix or improvement for NXP porting layer or for code added or modified by NXP, please open an issue or contact NXP support.

NXP Fork

This fork of MCUboot contains specific modifications and enhancements for NXP MCUXpresso SDK integration.

See *changelog* for details.

1.1.2 MCUboot



License: Apache 2.0

This is MCUboot version 2.2.0

MCUboot is a secure bootloader for 32-bits microcontrollers. It defines a common infrastructure for the bootloader and the system flash layout on microcontroller systems, and provides a secure bootloader that enables easy software upgrade.

MCUboot is not dependent on any specific operating system and hardware and relies on hardware porting layers from the operating system it works with. Currently, MCUboot works with the following operating systems and SoCs:

- Zephyr
- Apache Mynewt
- Apache NuttX
- RIOT
- Mbed OS
- Espressif
- Cypress/Infineon

RIOT is supported only as a boot target. We will accept any new port contributed by the community once it is good enough.

MCUboot How-tos

See the following pages for instructions on using MCUboot with different operating systems and SoCs:

- Zephyr
- Apache Mynewt
- Apache NuttX
- RIOT
- Mbed OS
- Espressif
- *Cypress/Infineon*

There are also instructions for the *Simulator*.

Roadmap

The issues being planned and worked on are tracked using GitHub issues. To give your input, visit MCUboot GitHub Issues.

Source files

You can find additional documentation on the bootloader in the source files. For more information, use the following links:

- boot/bootutil - The core of the bootloader itself.
- boot/boot_serial - Support for serial upgrade within the bootloader itself.
- boot/zephyr - Port of the bootloader to Zephyr.
- boot/mynewt - Bootloader application for Apache Mynewt.
- boot/nuttx - Bootloader application and port of MCUboot interfaces for Apache NuttX.
- boot/mbed - Port of the bootloader to Mbed OS.
- boot/espressif - Bootloader application and MCUboot port for Espressif SoCs.
- boot/cypress - Bootloader application and MCUboot port for Cypress/Infineon SoCs.
- imgtool - A tool to securely sign firmware images for booting by MCUboot.
- sim - A bootloader simulator for testing and regression.

Joining the project

Developers are welcome!

Use the following links to join or see more about the project:

- Our developer mailing list
- Our Discord channel Get your invite

1.2 File System

1.2.1 FatFs

MCUXpresso SDK : mcuxsdk-middleware-fatfs

Overview This repository is for FatFs middleware delivery and it contains the components officially provided in NXP MCUXpresso SDK. This repository is part of the MCUXpresso SDK overall delivery which is composed of several sub-repositories/projects. Navigate to the top/parent repository (mcuxsdk-manifests) for the complete delivery of MCUXpresso SDK.

Documentation Overall details can be reviewed here: MCUXpresso SDK Online Documentation

Visit FatFs - Documentation to review details on the contents in this sub-repo.

Setup Instructions on how to install the MCUXpresso SDK provided from GitHub via west manifest Getting Started with SDK - Detailed Installation Instructions

Contribution Contributions are not currently accepted. Guidelines to contribute will be posted in the future.

Repo Specific Content This is MCUXpresso SDK fork of FatFs (FAT file system created by ChaN). Official documentation is available at http://elm-chan.org/fsw/ff/

MCUXpresso version is extending original content by following hardware specific porting layers:

- mmc_disk
- nand_disk
- ram_disk
- sd_disk
- sdspi_disk
- usb_disk

Changelog FatFs

All notable changes to this project will be documented in this file.

The format is based on Keep a Changelog

[R0.15_rev0]

- Upgraded to version 0.15
- Applied patches from http://elm-chan.org/fsw/ff/patches.html

[R0.14b_rev1]

- Applied patches from http://elm-chan.org/fsw/ff/patches.html

[R0.14b_rev0]

- Upgraded to version 0.14b

[R0.14a_rev0]

- Upgraded to version 0.14a
- Applied patch ff14a_p1.diff and ff14a_p2.diff

[R0.14_rev0]

- Upgraded to version 0.14
- Applied patch ff14_p1.diff and ff14_p2.diff

[R0.13c_rev0]

- Upgraded to version 0.13c
- Applied patches ff_13c_p1.diff,ff_13c_p2.diff, ff_13c_p3.diff and ff_13c_p4.diff.

[R0.13b_rev0]

- Upgraded to version 0.13b

[R0.13a_rev0]

- Upgraded to version 0.13a. Added patch ff_13a_p1.diff.

[R0.12c_rev1]

- Add NAND disk support.

[R0.12c_rev0]

- Upgraded to version 0.12c and applied patches ff_12c_p1.diff and ff_12c_p2.diff.

[R0.12b_rev0]

- Upgraded to version 0.12b.

[R0.11a]

- Added glue functions for low-level drivers (SDHC, SDSPI, RAM, MMC). Modified diskio.c.
- Added RTOS wrappers to make FatFs thread safe. Modified syscall.c.
- Renamed ffconf.h to ffconf_template.h. Each application should contain its own ffconf.h.
- Included ffconf.h into diskio.c to enable the selection of physical disk from ffconf.h by macro definition.
- Conditional compilation of physical disk interfaces in diskio.c.

1.3 Motor Control

1.3.1 FreeMASTER

Communication Driver User Guide

Introduction

What is FreeMASTER? FreeMASTER is a PC-based application developed by NXP for NXP customers. It is a versatile tool usable as a real-time monitor, visualization tool, and a graphical control panel of embedded applications based on the NXP processing units.

This document describes the embedded-side software driver which implements an interface between the application and the host PC. The interface covers the following communication:

- **Serial** UART communication either over plain RS232 interface or more typically over a USB-to-Serial either external or built in a debugger probe.
- **USB** direct connection to target microcontroller
- **CAN bus**
- **TCP/IP network** wired or WiFi
- **Segger J-Link RTT**

- **JTAG** debug port communication
- ...and all of the above also using a **Zephyr** generic drivers.

The driver also supports so-called "packet-driven BDM" interface which enables a protocol-based communication over a debugging port. The BDM stands for Background Debugging Module and its physical implementation is different on each platform. Some platforms leverage a semi-standard JTAG interface, other platforms provide a custom implementation called BDM. Regardless of the name, this debugging interface enables non-intrusive access to the memory space while the target CPU is running. For basic memory read and write operations, there is no communication driver required on the target when communicating with the host PC. Use this driver to get more advanced FreeMASTER protocol features over the BDM interface. The driver must be configured for the packet-driven BDM mode, in which the host PC uses the debugging interface to write serial command frames directly to the target memory buffer. The same method is then used to read response frames from that memory buffer.

Similar to "packet-driven BDM", the FreeMASTER also supports a communication over [J-Link RTT]((https://www.segger.com/products/debug-probes/j-link/technology/about-real-time-transfer/) interface defined by SEGGER Microcontroller GmbH for ARM CortexM-based microcontrollers. This method also uses JTAG physical interface and enables high-speed real time communication to run over the same channel as used for application debugging.

Driver version 3 This document describes version 3 of the FreeMASTER Communication Driver. This version features the implementation of the new Serial Protocol, which significantly extends the features and security of its predecessor. The new protocol internal number is v4 and its specification is available in the documentation accompanying the driver code.

Driver V3 is deployed to modern 32-bit MCU platforms first, so the portfolio of supported platforms is smaller than for the previous V2 versions. It is recommended to keep using the V2 driver for legacy platforms, such as S08, S12, ColdFire, or Power Architecture. Reach out to FreeMASTER community or to the local NXP representative with requests for more information or to port the V3 driver to legacy MCU devices.

Thanks to a layered approach, the new driver simplifies the porting of the driver to new UART, CAN or networking communication interfaces significantly. Users are encouraged to port the driver to more NXP MCU platforms and contribute the code back to NXP for integration into future releases. Existing code and low-level driver layers may be used as an example when porting to new targets.

Note: Using the FreeMASTER tool and FreeMASTER Communication Driver is only allowed in systems based on NXP microcontroller or microprocessor unit. Use with non-NXP MCU platforms is **not permitted** by the license terms.

Target platforms The driver implementation uses the following abstraction mechanisms which simplify driver porting and supporting new communication modules:

- **General CPU Platform** (see source code in the src/platforms directory). The code in this layer is only specific to native data type sizes and CPU architectures (for example; alignment-aware memory copy routines). This driver version brings two generic implementations of 32-bit platforms supporting both little-endian and big-endian architectures. There are also implementations customized for the 56F800E family of digital signal controllers and S12Z MCUs. **Zephyr** is treated as a specific CPU platform as it brings unified user configuration (Kconfig) and generic hardware device drivers. With Zephyr, the transport layer and low-level communication layers described below are configured automatically using Kconfig and Device Tree technologies.
- **Transport Communication Layer** - The Serial, CAN, Networking, PD-BDM, and other methods of transport logic are implemented as a driver layer called FMSTR_TRANSPORT with a uniform API. A support of the Network transport also extends single-client modes of operation which are native for Serial, USB and CAN by a concept of multiple client sessions.

- **Low-level Communication Driver** - Each type of transport further defines a low-level API used to access the physical communication module. For example, the Serial transport defines a character-oriented API implemented by different serial communication modules like UART, LPUART, USART, and also USB-CDC. Similarly, the CAN transport defines a message-oriented API implemented by the FlexCAN or MCAN modules. Moreover, there are multiple different implementations for the same kind of communication peripherals. The difference between the implementation is in the way the low-level hardware registers are accessed. The *mcuxsdk* folder contains implementations which use MCUXpresso SDK drivers. These drivers should be used in applications based on the NXP MCUXpresso SDK. The "ampsdk" drivers target automotive-specific MCUs and their respective SDKs. The "dreg" implementations use a plain C-language access to hardware register addresses which makes it a universal and the most portable solution. In this case, users are encouraged to add more drivers for other communication modules or other respective SDKs and contribute the code back to NXP for integration.

  The low-level drivers defined for the Networking transport enable datagram-oriented UDP and stream TCP communication. This implementation is demonstrated using the lwIP software stack but shall be portable to other TCP/IP stacks. It may sound surprisingly, but also the Segger J-Link RTT communication driver is linked to the Networking transport (RTT is stream oriented communication handled similarly to TCP).

Replacing existing drivers For all supported platforms, the driver described in this document replaces the V2 implementation and also older driver implementations that were available separately for individual platforms (PC Master SCI drivers).

Clocks, pins, and peripheral initialization The FreeMASTER communication driver is only responsible for runtime processing of the communication and must be integrated with an user application code to function properly. The user application code is responsible for general initialization of clock sources, pin multiplexers, and peripheral registers related to the communication speed. Such initialization should be done before calling the FMSTR_Init function.

It is recommended to develop the user application using one of the Software Development Kits (SDKs) available from third parties or directly from NXP, such as MCUXpresso SDK, MCUXpresso IDE, and related tools. This approach simplifies the general configuration process significantly.

MCUXpresso SDK The MCUXpresso SDK is a software package provided by NXP which contains the device initialization code, linker files, and software drivers with example applications for the NXP family of MCUs. The MCUXpresso Config Tools may be used to generate the clock-setup and pin-multiplexer setup code suitable for the selected processor.

The MCUXpresso SDK also contains this FreeMASTER communication driver as a "middleware" component which may be downloaded along with the example applications from https://mcuxpresso.nxp.com/en/welcome.

MCUXpresso SDK on GitHub The FreeMASTER communication driver is also released as one of the middleware components of the MCUXpresso SDK on the GitHub. This release enables direct integration of the FreeMASTER source code Git repository into a target applications including Zephyr applications.

Related links:

- The official FreeMASTER middleware repository.
- Online version of this document

FreeMASTER in Zephyr The FreeMASTER middleware repository can be used with MCUXpresso SDK as well as a Zephyr module. Zephyr-specific samples which include examples of Kconfig and Device Tree configurations for Serial, USB and Network communications are available in separate repository. West manifest in this sample repository fetches the full Zephyr package including the FreeMASTER middleware repository used as a Zephyr module.

Example applications

MCUX SDK Example applications There are several example applications available for each supported MCU platform.

- **fmstr_uart** demonstrates a plain serial transmission, typically connecting to a computer's physical or virtual COM port. The typical transmission speed is 115200 bps.
- **fmstr_can** demonstrates CAN bus communication. This requires a suitable CAN interface connected to the computer and interconnected with the target MCU using a properly terminated CAN bus. The typical transmission speed is 500 kbps. A FreeMASTER-over-CAN communication plug-in must be used.
- **fmstr_usb_cdc** uses an on-chip USB controller to implement a CDC communication class. It is connected directly to a computer's USB port and creates a virtual COM port device. The typical transmission speed is above 1 Mbps.
- **fmstr_net** demonstrates the Network communication over UDP or TCP protocol. Existing examples use lwIP stack to implement the communication, but in general, it shall be possible to use any other TCP/IP stack to achieve the same functionality.
- **fmstr_wifi** is the fmstr_net application modified to use a WiFi network interface instead of a wired Ethernet connection.
- **fmstr_rtt** demonstrates the communication over SEGGER J-Link RTT interface. Both fmstr_net and fmstr_rtt examples require the FreeMASTER TCP/UDP communication plug-in to be used on the PC host side.
- **fmstr_eonce** uses the real-time data unit on the JTAG EOnCE module of the 56F800E family to implement pseudo-serial communication over the JTAG port. The typical transmission speed is around 10 kbps. This communication requires FreeMASTER JTAG/EOnCE communication plug-in.
- **fmstr_pdbdm** uses JTAG or BDM debugging interface to access the target RAM directly while the CPU is running. Note that such approach can be used with any MCU application, even without any special driver code. The computer reads from and writes into the RAM directly without CPU intervention. The Packet-Driven BDM (PD-BDM) communication uses the same memory access to exchange command and response frames. With PD-BDM, the FreeMASTER tool is able to go beyond basic memory read/write operations and accesses also advanced features like Recorder, TSA, or Pipes. The typical transmission speed is around 10 kbps. A PD-BDM communication plug-in must be used in FreeMASTER and configured properly for the selected debugging interface. Note that this communication cannot be used while a debugging interface is used by a debugger session.
- **fmstr_any** is a special example application which demonstrates how the NXP MCUXpresso Config Tools can be used to configure pins, clocks, peripherals, interrupts, and even the FreeMASTER "middleware" driver features in a graphical and user friendly way. The user can switch between the Serial, CAN, and other ways of communication and generate the required initialization code automatically.

Zephyr sample spplications Zephyr sample applications demonstrate Kconfig and Device Tree configuration which configure the FreeMASTER middleware module for a selected communication option (Serial, CAN, Network or RTT).

Refer to *readme.md* files in each sample directory for description of configuration options required to implement FreeMASTER connectivity.

Description

This section shows how to add the FreeMASTER Communication Driver into application and how to configure the connection to the FreeMASTER visualization tool.

Features The FreeMASTER driver implements the FreeMASTER protocol V4 and provides the following features which may be accessed using the FreeMASTER visualization tool:

- Read/write access to any memory location on the target.
- Optional password protection of the read, read/write, and read/write/flash access levels.
- Atomic bit manipulation on the target memory (bit-wise write access).
- Optimal size-aligned access to memory which is also suitable to access the peripheral register space.
- Oscilloscope access—real-time access to target variables. The sample rate may be limited by the communication speed.
- Recorder— access to the fast transient recorder running on the board as a part of the FreeMASTER driver. The sample rate is only limited by the MCU CPU speed. The length of the data recorded depends on the amount of available memory.
- Multiple instances of Oscilloscopes and Recorders without the limitation of maximum number of variables.
- Application commands—high-level message delivery from the PC to the application.
- TSA tables—describing the data types, variables, files, or hyperlinks exported by the target application. The TSA newly supports also non-memory mapped resources like external EEPROM or SD Card files.
- Pipes—enabling the buffered stream-oriented data exchange for a general-purpose terminal-like communication, diagnostic data streaming, or other data exchange.

The FreeMASTER driver features:

- Full FreeMASTER protocol V4 implementation with a new V4 style of CRC used.
- Layered approach supporting Serial, CAN, Network, PD-BDM, and other transports.
- Layered low-level Serial transport driver architecture enabling to select UART, LPUART, USART, and other physical implementations of serial interfaces, including USB-CDC.
- Layered low-level CAN transport driver architecture enabling to select FlexCAN, msCAN, MCAN, and other physical implementations of the CAN interface.
- Layered low-level Networking transport enabling to select TCP, UDP or J-Link RTT communication.
- TSA support to write-protect memory regions or individual variables and to deny the access to the unsafe memory.
- The pipe callback handlers are invoked whenever new data is available for reading from the pipe.
- Two Serial Single-Wire modes of operation are enabled. The “external” mode has the RX and TX shorted on-board. The “true” single-wire mode interconnects internally when the MCU or UART modules support it.

The following sections briefly describe all FreeMASTER features implemented by the driver. See the PC-based FreeMASTER User Manual for more details on how to use the features to monitor, tune, or control an embedded application.

Board Detection The FreeMASTER protocol V4 defines the standard set of configuration values which the host PC tool reads to identify the target and to access other target resources properly. The configuration includes the following parameters:

- Version of the driver and the version of the protocol implemented.
- MTU as the Maximum size of the Transmission Unit (for example; communication buffer size).
- Application name, description, and version strings.
- Application build date and time as a string.
- Target processor byte ordering (little/big endian).
- Protection level that requires password authentication.
- Number of the Recorder and Oscilloscope instances.
- RAM Base Address for optimized memory access commands.

Memory Read This basic feature enables the host PC to read any data memory location by specifying the address and size of the required memory area. The device response frame must be shorter than the MTU to fit into the outgoing communication buffer. To read a device memory of any size, the host uses the information retrieved during the Board Detection and splits the large-block request to multiple partial requests.

The driver uses size-aligned operations to read the target memory (for example; uses proper read-word instruction when an address is aligned to 4 bytes).

Memory Write Similarly to the Memory Read operation, the Memory Write feature enables to write to any RAM memory location on the target device. A single write command frame must be shorter than the MTU to fit into the target communication buffer. Larger requests must be split into smaller ones.

The driver uses size-aligned operations to write to the target memory (for example; uses proper write-word instruction when an address is aligned to 4 bytes).

Masked Memory Write To implement the write access to a single bit or a group of bits of target variables, the Masked Memory Write feature is available in the FreeMASTER protocol and it is supported by the driver using the Read-Modify-Write approach.

Be careful when writing to bit fields of volatile variables that are also modified in an application interrupt. The interrupt may be serviced in the middle of a read-modify-write operation and it may cause data corruption.

Oscilloscope The protocol and driver enables any number of variables to be read at once with a single request from the host. This feature is called Oscilloscope and the FreeMASTER tool uses it to display a real-time graph of variable values.

The driver can be configured to support any number of Oscilloscope instances and enable simultaneously running graphs to be displayed on the host computer screen.

Recorder The protocol enables the host to select target variables whose values are then periodically recorded into a dedicated on-board memory buffer. After such data sampling stops (either on a host request or by evaluating a threshold-crossing condition), the data buffer is downloaded to the host and displayed as a graph. The data sampling rate is not limited by the speed of the communication line, so it enables displaying the variable transitions in a very high resolution.

The driver can be configured to support multiple Recorder instances and enable multiple recorder graphs to be displayed on the host screen. Having multiple recorders also enables setting the recording point differently for each instance. For example; one instance may be recording data in a general timer interrupt while another instance may record at a specific control algorithm time in the PWM interrupt.

TSA With the TSA feature, data types and variables can be described directly in the application source code. Such information is later provided to the FreeMASTER tool which may use it instead of reading symbol data from the application ELF executable file.

The information is encoded as so-called TSA tables which become direct part of the application code. The TSA tables contain descriptors of variables that shall be visible to the host tool. The descriptors can describe the memory areas by specifying the address and size of the memory block or more conveniently using the C variable names directly. Different set of TSA descriptors can be used to encode information about the structure types, unions, enumerations, or arrays.

The driver also supports special types of TSA table entries to describe user resources like external EEPROM and SD Card files, memory-mapped files, virtual directories, web URL hyperlinks, and constant enumerations.

TSA Safety When the TSA is enabled in the application, the TSA Safety can be enabled and validate the memory accesses directly by the embedded-side driver. When the TSA Safety is turned on, any memory request received from the host is validated and accepted only if it belongs to a TSA-described object. The TSA entries can be declared as Read-Write or Read-Only so that the driver can actively deny the write access to the Read-Only objects.

Application commands The Application Commands are high-level messages that can be delivered from the PC Host to the embedded application for further processing. The embedded application can either poll the status, or be called back when a new Application Command arrives to be processed. After the embedded application acknowledges that the command is handled, the host receives the Result Code and reads the other return data from memory. Both the Application Commands and the Result Codes are specific to a given application and it is user's responsibility to define them. The FreeMASTER protocol and the FreeMASTER driver only implement the delivery channel and a set of API calls to enable the Application Command processing in general.

Pipes The Pipes enable buffered and stream-oriented data exchange between the PC Host and the target application. Any pipe can be written to and read from at both ends (either on the PC or the MCU). The data transmission is acknowledged using the special FreeMASTER protocol commands. It is guaranteed that the data bytes are delivered from the writer to the reader in a proper order and without losses.

Serial single-wire operation The MCU Serial Communication Driver natively supports normal dual-wire operation. Because the protocol is half-duplex only, the driver can also operate in two single-wire modes:

- "External" single-wire operation where the Receiver and Transmitter pins are shorted on the board. This mode is supported by default in the MCU driver because the Receiver and Transmitter units are enabled or disabled whenever needed. It is also easy to extend this operation for the RS485 communication.

- "True" single-wire mode which uses only a single pin and the direction switching is made by the UART module. This mode of operation must be enabled by defining the FMSTR_SERIAL_SINGLEWIRE configuration option.

Multi-session support With networking interface it is possible for multiple clients to access the target MCU simultaneously. Reading and writing of target memory is processed atomically so there is no risk of data corruption. The state-full resources such as Recorders or Oscilloscopes are locked to a client session upon first use and access is denied to other clients until lock is released..

Zephyr-specific

Dedicated communication task FreeMASTER communication may run isolated in a dedicated task. The task automates the FMSTR_Init and FMSTR_Poll calls together with periodic activities enabling the FreeMASTER UI to fetch information about tasks and CPU utilization. The task can be started automatically or manually, and it must be assigned a priority to be able to react on interrupts and other communication events. Refer to Zephyr FreeMASTER sample applications which all use this communication task.

Zephyr shell and logging over FreeMASTER pipe FreeMASTER implements a shell backend which may use FreeMASTER pipe as a I/O terminal and logging output. Refer to Zephyr FreeMASTER sample applications which all use this feature.

Automatic TSA tables TSA tables can be declared as "automatic" in Zephyr which make them automatically registered in the table list. This may be very useful when there are many TSA tables or when the tables are defined in different (often unrelated) libraries linked together. In this case user does not need to build a list of all tables manually.

Driver files The driver source files can be found in a top-level src folder, further divided into the sub-folders:

- ***src/platforms*** platform-specific folder—one folder exists for each supported processor platform (for example; 32-bit Little Endian platform). Each such folder contains a platform header file with data types and a code which implements the potentially platform-specific operations, such as aligned memory access.
- ***src/common*** folder—contains the common driver source files shared by the driver for all supported platforms. All the *.c* files must be added to the project, compiled, and linked together with the application.
  - *freemaster.h* - master driver header file, which declares the common data types, macros, and prototypes of the FreeMASTER driver API functions.
  - *freemaster_cfg.h.example* - this file can serve as an example of the FreeMASTER driver configuration file. Save this file into a project source code folder and rename it to *freemaster_cfg.h*. The FreeMASTER driver code includes this file to get the project-specific configuration options and to optimize the compilation of the driver.
  - *freemaster_defcfg.h* - defines the default values for each FreeMASTER configuration option if the option is not set in the *freemaster_cfg.h* file.
  - *freemaster_protocol.h* - defines the FreeMASTER protocol constants used internally by the driver.
  - *freemaster_protocol.c* - implements the FreeMASTER protocol decoder and handles the basic Get Configuration Value, Memory Read, and Memory Write commands.

  - *freemaster_rec.c* - handles the Recorder-specific commands and implements the Recorder sampling and triggering routines. When the Recorder is disabled by the FreeMASTER driver configuration file, this file only compiles to empty API functions.
  - *freemaster_scope.c* - handles the Oscilloscope-specific commands. If the Oscilloscope is disabled by the FreeMASTER driver configuration file, this file compiles as void.
  - *freemaster_pipes.c* - implements the Pipes functionality when the Pipes feature is enabled.
  - *freemaster_appcmd.c* - handles the communication commands used to deliver and execute the Application Commands within the context of the embedded application. When the Application Commands are disabled by the FreeMASTER driver configuration file, this file only compiles to empty API functions.
  - *freemaster_tsa.c* - handles the commands specific to the TSA feature. This feature enables the FreeMASTER host tool to obtain the TSA memory descriptors declared in the embedded application. If the TSA is disabled by the FreeMASTER driver configuration file, this file compiles as void.
  - *freemaster_tsa.h* - contains the declaration of the macros used to define the TSA memory descriptors. This file is indirectly included into the user application code (via *freemaster.h*).
  - *freemaster_sha.c* - implements the SHA-1 hash code used in the password authentication algorithm.
  - *freemaster_private.h* - contains the declarations of functions and data types used internally in the driver. It also contains the C pre-processor statements to perform the compile-time verification of the user configuration provided in the *freemaster_cfg.h* file.
  - *freemaster_serial.c* - implements the serial protocol logic including the CRC, FIFO queuing, and other communication-related operations. This code calls the functions of the low-level communication driver indirectly via a character-oriented API exported by the specific low-level driver.
  - *freemaster_serial.h* - defines the low-level character-oriented Serial API.
  - *freemaster_can.c* - implements the CAN protocol logic including the CAN message preparation, signalling using the first data byte in the CAN frame, and other communication-related operations. This code calls the functions of the low-level communication driver indirectly via a message-oriented API exported by the specific low-level driver.
  - *freemaster_can.h* - defines the low-level message-oriented CAN API.
  - *freemaster_net.c* - implements the Network protocol transport logic including multiple session management code.
  - *freemaster_net.h* - definitions related to the Network transport.
  - *freemaster_pdbdm.c* - implements the packet-driven BDM communication buffer and other communication-related operations.
  - *freemaster_utils.c* - aligned memory copy routines, circular buffer management and other utility functions
  - *freemaster_utils.h* - definitions related to utility code.

- ***src/drivers/[sdk]/serial*** - contains the code related to the serial communication implemented using one of the supported SDK frameworks.
  - *freemaster_serial_XXX.c* and *.h* - implement low-level access to the communication peripheral registers. Different files exist for the UART, LPUART, USART, and other kinds of Serial communication modules.

- ***src/drivers/[sdk]/can*** - contains the code related to the serial communication implemented using one of the supported SDK frameworks.
  - *freemaster_XXX.c* and *.h* - implement low-level access to the communication peripheral registers. Different files exist for the FlexCAN, msCAN, MCAN, and other kinds of CAN communication modules.
- ***src/drivers/[sdk]/network*** - contains low-level code adapting the FreeMASTER Network transport to an underlying TCP/IP or RTT stack.
  - *freemaster_net_lwip_tcp.c* and *_udp.c* - default networking implementation of TCP and UDP transports using lwIP stack.
  - *freemaster_net_segger_rtt.c* - implementation of network transport using Segger J-Link RTT interface

Driver configuration The driver is configured using a single header file (*freemaster_cfg.h*). Create this file and save it together with other project source files before compiling the driver code. All FreeMASTER driver source files include the *freemaster_cfg.h* file and use the macros defined here for the conditional and parameterized compilation. The C compiler must locate the configuration file when compiling the driver files. Typically, it can be achieved by putting this file into a folder where the other project-specific included files are stored.

As a starting point to create the configuration file, get the *freemaster_cfg.h.example* file, rename it to *freemaster_cfg.h*, and save it into the project area.

Note: It is NOT recommended to leave the *freemaster_cfg.h* file in the FreeMASTER driver source code folder. The configuration file must be placed at a project-specific location, so that it does not affect the other applications that use the same driver.

Configurable items This section describes the configuration options which can be defined in *freemaster_cfg.h*.

Interrupt modes

```
#define FMSTR_LONG_INTR   [0|1]
#define FMSTR_SHORT_INTR  [0|1]
#define FMSTR_POLL_DRIVEN [0|1]
```

Value Type boolean (0 or 1)

Description Exactly one of the three macros must be defined to non-zero. The others must be defined to zero or left undefined. The non-zero-defined constant selects the interrupt mode of the driver. See *Driver interrupt modes*.

- FMSTR_LONG_INTR — long interrupt mode
- FMSTR_SHORT_INTR — short interrupt mode
- FMSTR_POLL_DRIVEN — poll-driven mode

Note: Some options may not be supported by all communication interfaces. For example, the FMSTR_SHORT_INTR option is not supported by the USB_CDC interface.

Protocol transport

```
#define FMSTR_TRANSPORT [identifier]
```

Value Type Driver identifiers are structure instance names defined in FreeMASTER source code. Specify one of existing instances to make use of the protocol transport.

Description Use one of the pre-defined constants, as implemented by the FreeMASTER code. The current driver supports the following transports:

- **FMSTR_SERIAL** - serial communication protocol
- **FMSTR_CAN** - using CAN communication
- **FMSTR_PDBDM** - using packet-driven BDM communication
- **FMSTR_NET** - network communication using TCP or UDP protocol

Serial transport This section describes configuration parameters used when serial transport is used:

```
#define FMSTR_TRANSPORT FMSTR_SERIAL
```

FMSTR_SERIAL_DRV Select what low-level driver interface will be used when implementing the Serial communication.

```
#define FMSTR_SERIAL_DRV [identifier]
```

Value Type Driver identifiers are structure instance names defined in FreeMASTER drivers code. Specify one of existing serial driver instances.

Description When using MCUXpresso SDK, use one of the following constants (see */drivers/mcuxsdk/serial* implementation):

- **FMSTR_SERIAL_MCUX_UART** - UART driver
- **FMSTR_SERIAL_MCUX_LPUART** - LPUART driver
- **FMSTR_SERIAL_MCUX_USART** - USART driver
- **FMSTR_SERIAL_MCUX_MINIUSART** - miniUSART driver
- **FMSTR_SERIAL_MCUX_QSCI** - DSC QSCI driver
- **FMSTR_SERIAL_MCUX_USB** - USB/CDC class driver (also see code in the */support/mcuxsdk_usb* folder)
- **FMSTR_SERIAL_56F800E_EONCE** - DSC JTAG EOnCE driver

Other SDKs or BSPs may define custom low-level driver interface structure which may be used as FMSTR_SERIAL_DRV. For example:

- **FMSTR_SERIAL_DREG_UART** - demonstrates the low-level interface implemented without the MCUXpresso SDK and using direct access to peripheral registers.

FMSTR_SERIAL_BASE

```
#define FMSTR_SERIAL_BASE [address|symbol]
```

Value Type Optional address value (numeric or symbolic)

Description Specify the base address of the UART, LPUART, USART, or other serial peripheral module to be used for the communication. This value is not defined by default. User application should call FMSTR_SetSerialBaseAddress() to select the peripheral module.

FMSTR_COMM_BUFFER_SIZE

```
#define FMSTR_COMM_BUFFER_SIZE [number]
```

Value Type 0 or a value in range 32...255

Description Specify the size of the communication buffer to be allocated by the driver. Default value, which suits all driver features, is used when this option is defined as 0.

FMSTR_COMM_RQUEUE_SIZE

```
#define FMSTR_COMM_RQUEUE_SIZE [number]
```

Value Type Value in range 0...255

Description Specify the size of the FIFO receiver queue used to quickly receive and store characters in the FMSTR_SHORT_INTR interrupt mode.
The default value is 32 B.

FMSTR_SERIAL_SINGLEWIRE

```
#define FMSTR_SERIAL_SINGLEWIRE [0|1]
```

Value Type Boolean 0 or 1.

Description Set to non-zero to enable the “True” single-wire mode which uses a single MCU pin to communicate. The low-level driver enables the pin direction switching when the MCU peripheral supports it.

CAN Bus transport This section describes configuration parameters used when CAN transport is used:

```
#define FMSTR_TRANSPORT FMSTR_CAN
```

FMSTR_CAN_DRV Select what low-level driver interface will be used when implementing the CAN communication.

```
#define FMSTR_CAN_DRV [identifier]
```

Value Type Driver identifiers are structure instance names defined in FreeMASTER drivers code. Specify one of existing CAN driver instances.

Description When using MCUXpresso SDK, use one of the following constants (see */drivers/mcuxsdk/can implementation*):

- **FMSTR_CAN_MCUX_FLEXCAN** - FlexCAN driver
- **FMSTR_CAN_MCUX_MCAN** - MCAN driver
- **FMSTR_CAN_MCUX_MSCAN** - msCAN driver
- **FMSTR_CAN_MCUX_DSCFLEXCAN** - DSC FlexCAN driver
- **FMSTR_CAN_MCUX_DSCMSCAN** - DSC msCAN driver

Other SDKs or BSPs may define the custom low-level driver interface structure which may be used as FMSTR_CAN_DRV.

FMSTR_CAN_BASE

```
#define FMSTR_CAN_BASE [address|symbol]
```

Value Type Optional address value (numeric or symbolic)

Description Specify the base address of the FlexCAN, msCAN, or other CAN peripheral module to be used for the communication. This value is not defined by default. User application should call FMSTR_SetCanBaseAddress() to select the peripheral module.

FMSTR_CAN_CMDID

```
#define FMSTR_CAN_CMDID [number]
```

Value Type CAN identifier (11-bit or 29-bit number)

Description CAN message identifier used for FreeMASTER commands (direction from PC Host tool to target application). When declaring 29-bit identifier, combine the numeric value with FMSTR_CAN_EXTID bit. Default value is 0x7AA.

FMSTR_CAN_RSPID

```
#define FMSTR_CAN_RSPID [number]
```

Value Type CAN identifier (11-bit or 29-bit number)

Description CAN message identifier used for responding messages (direction from target application to PC Host tool). When declaring 29-bit identifier, combine the numeric value with FMSTR_CAN_EXTID bit. Note that both *CMDID* and *RSPID* values may be the same. Default value is 0x7AA.

FMSTR_FLEXCAN_TXMB

```
#define FMSTR_FLEXCAN_TXMB [number]
```

Value Type Number in range of 0..N where N is number of CAN message-buffers supported by HW module.

Description Only used when the FlexCAN low-level driver is used. Define the FlexCAN message buffer for CAN frame transmission. Default value is 0.

FMSTR_FLEXCAN_RXMB

```
#define FMSTR_FLEXCAN_RXMB [number]
```

Value Type Number in range of 0..N where N is number of CAN message-buffers supported by HW module.

Description Only used when the FlexCAN low-level driver is used. Define the FlexCAN message buffer for CAN frame reception. Note that the FreeMASTER driver may also operate with a common message buffer used by both TX and RX directions. Default value is 1.

Network transport This section describes configuration parameters used when Network transport is used:

```
#define FMSTR_TRANSPORT FMSTR_NET
```

FMSTR_NET_DRV Select network interface implementation.

```
#define FMSTR_NET_DRV [identifier]
```

Value Type Identifiers are structure instance names defined in FreeMASTER drivers code. Specify one of existing NET driver instances.

Description When using MCUXpresso SDK, use one of the following constants (see */drivers/mcuxsdk/network implementation*):

- **FMSTR_NET_LWIP_TCP** - TCP communication using lwIP stack
- **FMSTR_NET_LWIP_UDP** - UDP communication using lwIP stack
- **FMSTR_NET_SEGGER_RTT** - Communication using SEGGER J-Link RTT interface

Other SDKs or BSPs may define the custom networking interface which may be used as FMSTR_CAN_DRV.

Add another row below:

FMSTR_NET_PORT

```
#define FMSTR_NET_PORT [number]
```

Value Type TCP or UDP port number (short integer)

Description Specifies the server port number used by TCP or UDP protocols.

FMSTR_NET_BLOCKING_TIMEOUT

```
#define FMSTR_NET_BLOCKING_TIMEOUT [number]
```

Value Type Timeout as number of milliseconds

Description This value specifies a timeout in milliseconds for which the network socket operations may block the execution inside *FMSTR_Poll*. This may be set high (e.g. 250) when a dedicated RTOS task is used to handle FreeMASTER protocol polling. Set to a lower value when the polling task is also responsible for other operations. Set to 0 to attempt to use non-blocking socket operations.

FMSTR_NET_AUTODISCOVERY

```
#define FMSTR_NET_AUTODISCOVERY [0|1]
```

Value Type Boolean 0 or 1.

Description This option enables the FreeMASTER driver to use a separate UDP socket to broadcast auto-discovery messages to network. This helps the FreeMASTER tool to discover the target device address, port and protocol options.

Debugging options

FMSTR_DISABLE

```
#define FMSTR_DISABLE [0|1]
```

Value Type boolean (0 or 1)

Description Define as non-zero to disable all FreeMASTER features, exclude the driver code from build, and compile all its API functions empty. This may be useful to remove FreeMASTER without modifying any application source code. Default value is 0 (false).

FMSTR_DEBUG_TX

```
#define FMSTR_DEBUG_TX [0|1]
```

Value Type Boolean 0 or 1.

Description Define as non-zero to enable the driver to periodically transmit test frames out on the selected communication interface (SCI or CAN). With the debug transmission enabled, it is simpler to detect problems in the baudrate or other communication configuration settings.

The test frames are transmitted until the first valid command frame is received from the PC Host tool. The test frame is a valid error status frame, as defined by the protocol format. On the serial line, the test frame consists of three printable characters (+©W) which are easy to capture using the serial terminal tools.

This feature requires the FMSTR_Poll() function to be called periodically. Default value is 0 (false).

FMSTR_APPLICATION_STR

```
#define FMSTR_APPLICATION_STR
```

Value Type String.

Description Name of the application visible in FreeMASTER host application.

Memory access

FMSTR_USE_READMEM

```
#define FMSTR_USE_READMEM [0|1]
```

Value Type Boolean 0 or 1.

Description Define as non-zero to implement the Memory Read command and enable FreeMASTER to have read access to memory and variables. The access can be further restricted by using a TSA feature.
Default value is 1 (true).

FMSTR_USE_WRITEMEM

```
#define FMSTR_USE_WRITEMEM [0|1]
```

Value Type Boolean 0 or 1.

Description Define as non-zero to implement the Memory Write command.
The default value is 1 (true).

Oscilloscope options

FMSTR_USE_SCOPE

```
#define FMSTR_USE_SCOPE [number]
```

Value Type Integer number.

Description Number of Oscilloscope instances to be supported. Set to 0 to disable the Oscilloscope feature.
Default value is 0.

FMSTR_MAX_SCOPE_VARS

```
#define FMSTR_MAX_SCOPE_VARS [number]
```

Value Type Integer number larger than 2.

Description Number of variables to be supported by each Oscilloscope instance.
Default value is 8.

Recorder options

FMSTR_USE_RECORDER

```
#define FMSTR_USE_RECORDER [number]
```

Value Type Integer number.

Description Number of Recorder instances to be supported. Set to 0 to disable the Recorder feature.
Default value is 0.

FMSTR_REC_BUFF_SIZE

```
#define FMSTR_REC_BUFF_SIZE [number]
```

Value Type Integer number larger than 2.

Description Defines the size of the memory buffer used by the Recorder instance #0.
Default: not defined, user shall call 'FMSTR_RecorderCreate()" API function to specify this parameter in run time.

FMSTR_REC_TIMEBASE

```
#define FMSTR_REC_TIMEBASE [time specification]
```

Value Type Number (nanoseconds time).

Description Defines the base sampling rate in nanoseconds (sampling speed) Recorder instance #0.

Use one of the following macros:

- FMSTR_REC_BASE_SECONDS(x)
- FMSTR_REC_BASE_MILLISEC(x)
- FMSTR_REC_BASE_MICROSEC(x)
- FMSTR_REC_BASE_NANOSEC(x)

Default: not defined, user shall call 'FMSTR_RecorderCreate()" API function to specify this parameter in run time.

FMSTR_REC_FLOAT_TRIG

```
#define FMSTR_REC_FLOAT_TRIG [0|1]
```

Value Type Boolean 0 or 1.

Description Define as non-zero to implement the floating-point triggering. Be aware that floating-point triggering may grow the code size by linking the floating-point standard library.

Default value is 0 (false).

Application Commands options

FMSTR_USE_APPCMD

```
#define FMSTR_USE_APPCMD [0|1]
```

Value Type Boolean 0 or 1.

Description Define as non-zero to implement the Application Commands feature.
Default value is 0 (false).

FMSTR_APPCMD_BUFF_SIZE

```
#define FMSTR_APPCMD_BUFF_SIZE [size]
```

Value Type Numeric buffer size in range 1..255

Description The size of the Application Command data buffer allocated by the driver. The buffer stores the (optional) parameters of the Application Command which waits to be processed.

FMSTR_MAX_APPCMD_CALLS

```
#define FMSTR_MAX_APPCMD_CALLS [number]
```

Value Type Number in range 0..255

Description The number of different Application Commands that can be assigned a callback handler function using FMSTR_RegisterAppCmdCall(). Default value is 0.

TSA options

FMSTR_USE_TSA

```
#define FMSTR_USE_TSA [0|1]
```

Value Type Boolean 0 or 1.

Description Enable the FreeMASTER TSA feature to be used. With this option enabled, the TSA tables defined in the applications are made available to the FreeMASTER host tool.
Default value is 0 (false).

FMSTR_USE_TSA_SAFETY

```
#define FMSTR_USE_TSA_SAFETY [0|1]
```

Value Type Boolean 0 or 1.

Description Enable the memory access validation in the FreeMASTER driver. With this option, the host tool is not able to access the memory which is not described by at least one TSA descriptor. Also a write access is denied for objects defined as read-only in TSA tables.
Default value is 0 (false).

FMSTR_USE_TSA_INROM

```
#define FMSTR_USE_TSA_INROM [0|1]
```

Value Type Boolean 0 or 1.

Description Declare all TSA descriptors as *const*, which enables the linker to put the data into the flash memory. The actual result depends on linker settings or the linker commands used in the project.
Default value is 0 (false).

FMSTR_USE_TSA_DYNAMIC

```
#define FMSTR_USE_TSA_DYNAMIC [0|1]
```

Value Type Boolean 0 or 1.

Description Enable runtime-defined TSA entries to be added to the TSA table by the FMSTR_SetUpTsaBuff() and FMSTR_TsaAddVar() functions.
Default value is 0 (false).

Pipes options

FMSTR_USE_PIPES

```
#define FMSTR_USE_PIPES [0|1]
```

Value Type Boolean 0 or 1.

Description Enable the FreeMASTER Pipes feature to be used.
Default value is 0 (false).

FMSTR_MAX_PIPES_COUNT

```
#define FMSTR_MAX_PIPES_COUNT [number]
```

Value Type Number in range 1..63.

Description The number of simultaneous pipe connections to support.
The default value is 1.

Driver interrupt modes To implement the communication, the FreeMASTER driver handles the Serial or CAN module's receive and transmit requests. Use the *freemaster_cfg.h* configuration file to select whether the driver processes the communication automatically in the interrupt service routine handler or if it only polls the status of the module (typically during the application idle time).

This section describes each of the interrupt mode in more details.

Completely Interrupt-Driven operation Activated using:

```
#define FMSTR_LONG_INTR 1
```

In this mode, both the communication and the FreeMASTER protocol decoding is done in the *FMSTR_SerialIsr*, *FMSTR_CanIsr*, or other interrupt service routine. Because the protocol execution may be a lengthy task (especially with the TSA-Safety enabled) it is recommended to use this mode only if the interrupt prioritization scheme is possible in the application and the FreeMASTER interrupt is assigned to a lower (the lowest) priority.

In this mode, the application code must register its own interrupt handler for all interrupt vectors related to the selected communication interface and call the FMSTR_SerialIsr or FMSTR_CanIsr functions from that handler.

Mixed Interrupt and Polling Modes Activated using:

```
#define FMSTR_SHORT_INTR 1
```

In this mode, the communication processing time is split between the interrupt routine and the main application loop or task. The raw communication is handled by the *FMSTR_SerialIsr, FMSTR_CanIsr*, or other interrupt service routine, while the protocol decoding and execution is handled by the *FMSTR_Poll* routine. Call *FMSTR_Poll* during the idle time in the application main loop.

The interrupt processing in this mode is relatively fast and deterministic. Upon a serial-receive event, the received character is only placed into a FIFO-like queue and it is not further processed. Upon a CAN receive event, the received frame is stored into a receive buffer. When transmitting, the characters are fetched from the prepared transmit buffer.

In this mode, the application code must register its own interrupt handler for all interrupt vectors related to the selected communication interface and call the *FMSTR_SerialIsr* or *FMSTR_CanIsr* functions from that handler.

When the serial interface is used as the serial communication interface, ensure that the *FMSTR_Poll* function is called at least once per *N* character time periods. *N* is the length of the FreeMASTER FIFO queue (*FMSTR_COMM_RQUEUE_SIZE*) and the character time is the time needed to transmit or receive a single byte over the SCI line.

Completely Poll-driven

```
#define FMSTR_POLL_DRIVEN 1
```

In this mode, both the communication and the FreeMASTER protocol decoding are done in the *FMSTR_Poll* routine. No interrupts are needed and the *FMSTR_SerialIsr*, *FMSTR_CanIsr*, and similar handlers compile to an empty code.

When using this mode, ensure that the *FMSTR_Poll* function is called by the application at least once per the serial "character time" which is the time needed to transmit or receive a single character.

In the latter two modes (*FMSTR_SHORT_INTR* and *FMSTR_POLL_DRIVEN*), the protocol handling takes place in the FMSTR_Poll routine. An application interrupt can occur in the middle of the Read Memory or Write Memory commands' execution and corrupt the variable being accessed by the FreeMASTER driver. In these two modes, some issues or glitches may occur when using FreeMASTER to visualize or monitor volatile variables modified in interrupt servicing code.

The same issue may appear even in the full interrupt mode (FMSTR_LONG_INTR), if volatile variables are modified in the interrupt code with a priority higher than the priority of the communication interrupt.

Data types Simple portability was one of the main requirements when writing the FreeMASTER driver. This is why the driver code uses the privately-declared data types and the vast majority of the platform-dependent code is separated in the platform-dependent source files. The data types used in the driver API are all defined in the platform-specific header file.

To prevent name conflicts with the symbols used in the application, all data types, macros, and functions have the FMSTR_ prefix. The only global variables used in the driver are the transport and low-level API structures exported from the driver-implementation layer to upper layers. Other than that, all private variables are declared as static and named using the fmstr_ prefix.

Communication interface initialization The FreeMASTER driver does not perform neither the initialization nor the configuration of the peripheral module that it uses to communicate. It is the application startup code responsibility to configure the communication module before the FreeMASTER driver is initialized by the FMSTR_Init call.

When the Serial communication module is used as the FreeMASTER communication interface, configure the UART receive and transmit pins, the serial communication baud rate, parity (no-parity), the character length (eight bits), and the number of stop bits (one) before initializing the FreeMASTER driver. For either the long or the short interrupt modes of the driver (see *Driver interrupt modes*), configure the interrupt controller and register an application-specific interrupt handler for all interrupt sources related to the selected serial peripheral module. Call the FMSTR_SerialIsr function from the application handler.

When a CAN module is used as the FreeMASTER communication interface, configure the CAN receive and transmit pins and the CAN module bit rate before initializing the FreeMASTER driver. For either the long or the short interrupt modes of the driver (see *Driver interrupt modes*), configure the interrupt controller and register an application-specific interrupt handler for all interrupt sources related to the selected CAN peripheral module. Call the FMSTR_CanIsr function from the application handler.

Note: It is not necessary to enable or unmask the serial nor the CAN interrupts before initializing the FreeMASTER driver. The driver enables or disables the interrupts and communication lines, as required during runtime.

FreeMASTER Recorder calls When using the FreeMASTER Recorder in the application (FMSTR_USE_RECORDER > 0), call the FMSTR_RecorderCreate function early after FMSTR_Init to set

up each recorder instance to be used in the application. Then call the FMSTR_Recorder function periodically in the code where the data recording should occur. A typical place to call the Recorder routine is at the timer or PWM interrupts, but it can be anywhere else. The example applications provided together with the driver code call the FMSTR_Recorder in the main application loop.

In applications where FMSTR_Recorder is called periodically with a constant period, specify the period in the Recorder configuration structure before calling FMSTR_RecorderCreate. This setting enables the PC Host FreeMASTER tool to display the X-axis of the Recorder graph properly scaled for the time domain.

Driver usage Start using or evaluating FreeMASTER by opening some of the example applications available in the driver setup package.

Follow these steps to enable the basic FreeMASTER connectivity in the application:

- Make sure that all **.c* files of the FreeMASTER driver from the *src/common/platforms/[your_platform]* folder are a part of the project. See *Driver files* for more details.
- Configure the FreeMASTER driver by creating or editing the *freemaster_cfg.h* file and by saving it into the application project directory. See *Driver configuration* for more details.
- Include the *freemaster.h* file into any application source file that makes the FreeMASTER API calls.
- Initialize the Serial or CAN modules. Set the baud rate, parity, and other parameters of the communication. Do not enable the communication interrupts in the interrupt mask registers.
- For the FMSTR_LONG_INTR and FMSTR_SHORT_INTR modes, install the application-specific interrupt routine and call the FMSTR_SerialIsr or FMSTR_CanIsr functions from this handler.
- Call the FMSTR_Init function early on in the application initialization code.
- Call the FMSTR_RecorderCreate functions for each Recorder instance to enable the Recorder feature.
- In the main application loop, call the FMSTR_Poll API function periodically when the application is idle.
- For the FMSTR_SHORT_INTR and FMSTR_LONG_INTR modes, enable the interrupts globally so that the interrupts can be handled by the CPU.

Communication troubleshooting The most common problem that causes communication issues is a wrong baud rate setting or a wrong pin multiplexer setting of the target MCU. When a communication between the PC Host running FreeMASTER and the target MCU cannot be established, try enabling the FMSTR_DEBUG_TX option in the *freemaster_cfg.h* file and call the FMSTR_Poll function periodically in the main application task loop.

With this feature enabled, the FreeMASTER driver periodically transmits a test frame through the Serial or CAN lines. Use a logic analyzer or an oscilloscope to monitor the signals at the communication pins of the CPU device to examine whether the bit rate and signal polarity are configured properly.

Driver API

This section describes the driver Application Programmers' Interface (API) needed to initialize and use the FreeMASTER serial communication driver.

Control API There are three key functions to initialize and use the driver.

FMSTR_Init

Prototype

```
FMSTR_BOOL FMSTR_Init(void);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_protocol.c*

Description This function initializes the internal variables of the FreeMASTER driver and enables the communication interface. This function does not change the configuration of the selected communication module. The hardware module must be initialized before the *FMSTR_Init* function is called.

A call to this function must occur before calling any other FreeMASTER driver API functions.

FMSTR_Poll

Prototype

```
void FMSTR_Poll(void);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_protocol.c*

Description In the poll-driven or short interrupt modes, this function handles the protocol decoding and execution (see *Driver interrupt modes*). In the poll-driven mode, this function also handles the communication interface with the PC. Typically, the *FMSTR_Poll* function is called during the "idle" time in the main application task loop.

To prevent the receive data overflow (loss) on a serial interface, make sure that the FMSTR_Poll function is called at least once per the time calculated as:

*N * Tchar*

where:

- *N* is equal to the length of the receive FIFO queue (configured by the FMSTR_COMM_RQUEUE_SIZE macro). *N* is 1 for the poll-driven mode.
- *Tchar* is the character time, which is the time needed to transmit or receive a single byte over the SCI line.

Note: In the long interrupt mode, this function typically compiles as an empty function and can still be called. It is worthwhile to call this function regardless of the interrupt mode used in the application. This approach enables a convenient switching between the different interrupt modes only by changing the configuration macros in the *freemaster_cfg.h* file.

FMSTR_SerialIsr / FMSTR_CanIsr

Prototype

```
void FMSTR_SerialIsr(void);
void FMSTR_CanIsr(void);
```

- Declaration: *freemaster.h*
- Implementation: *hw-specific low-level driver C file*

Description This function contains the interrupt-processing code of the FreeMASTER driver. In long or short interrupt modes (see *Driver interrupt modes*), this function must be called from the application interrupt service routine registered for the communication interrupt vector. On platforms where the communication module uses multiple interrupt vectors, the application should register a handler for all vectors and call this function at each interrupt.

Note: In a poll-driven mode, this function is compiled as an empty function and does not have to be used.

Recorder API

FMSTR_RecorderCreate

Prototype

```
FMSTR_BOOL FMSTR_RecorderCreate(FMSTR_INDEX recIndex, FMSTR_REC_BUFF* buffCfg);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_rec.c*

Description This function registers a recorder instance and enables it to be used by the PC Host tool. Call this function for all recorder instances from 0 to the maximum number defined by the FMSTR_USE_RECORDER configuration option (minus one). An exception to this requirement is the recorder of instance *0* which may be automatically configured by FMSTR_Init when the *freemaster_cfg.h* configuration file defines the *FMSTR_REC_BUFF_SIZE* and *FMSTR_REC_TIMEBASE* options.

For more information, see *Configurable items*.

FMSTR_Recorder

Prototype

```
void FMSTR_Recorder(FMSTR_INDEX recIndex);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_rec.c*

Description This function takes a sample of the variables being recorded using the FreeMASTER Recorder instance *recIndex*. If the selected Recorder is not active when the *FMSTR_Recorder* function is being called, the function returns immediately. When the Recorder is active, the values of the variables being recorded are copied into the recorder buffer and the trigger conditions are evaluated.

If a trigger condition is satisfied, the Recorder enters the post-trigger mode, where it counts down the follow-up samples (number of *FMSTR_Recorder* function calls) and de-activates the Recorder when the required post-trigger samples are finished.

The *FMSTR_Recorder* function is typically called in the timer or PWM interrupt service routines. This function can also be called in the application main loop (for testing purposes).

FMSTR_RecorderTrigger

Prototype

```
void FMSTR_RecorderTrigger(FMSTR_INDEX recIndex);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_rec.c*

Description This function forces the Recorder trigger condition to happen, which causes the Recorder to be automatically deactivated after the post-trigger samples are sampled. Use this function in the application code for programmatic control over the Recorder triggering. This can be useful when a more complex triggering conditions need to be used.

Fast Recorder API The Fast Recorder feature is not available in the FreeMASTER driver version 3. This feature was heavily dependent on the target platform and it was only available for the 56F8xxxx DSCs.

TSA Tables When the TSA is enabled in the FreeMASTER driver configuration file (by setting the FMSTR_USE_TSA macro to a non-zero value), it defines the so-called TSA tables in the application. This section describes the macros that must to be used to define the TSA tables.

There can be any number of TSA tables spread across the application source files. There must be always exactly one TSA Table List defined, which informs the FreeMASTER driver about the active TSA tables.

When there is at least one TSA table and one TSA Table List defined in the application, the TSA information automatically appears in the FreeMASTER symbols list. The symbols can then be used to create FreeMASTER variables for visualization or control.

TSA table definition The TSA table describes the static or global variables together with their address, size, type, and access-protection information. If the TSA-described variables are of a structure type, the TSA table may also describe this type and provide an access to the individual structure members of the variable.

The TSA table definition begins with the FMSTR_TSA_TABLE_BEGIN macro with a *table_id* identifying the table. The *table_id* shall be a valid C-langiage symbol.

```
FMSTR_TSA_TABLE_BEGIN(table_id)
```

After this opening macro, the TSA descriptors are placed using these macros:

```
/* Adding variable descriptors */
FMSTR_TSA_RW_VAR(name, type)  /* read/write variable entry */
FMSTR_TSA_RO_VAR(name, type)  /* read-only variable entry */

/* Description of complex data types */
FMSTR_TSA_STRUCT(struct_name) /* structure or union type entry */
```

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```
FMSTR_TSA_MEMBER(struct_name, member_name, type)  /* structure member entry */

/* Memory blocks */
FMSTR_TSA_RW_MEM(name, type, address, size) /* read/write memory block */
FMSTR_TSA_RO_MEM(name, type, address, size) /* read-only memory block */
```

The table is closed using the FMSTR_TSA_TABLE_END macro:

```
FMSTR_TSA_TABLE_END()
```

TSA descriptor parameters The TSA descriptor macros accept these parameters:

- *name* — variable name. The variable must be defined before the TSA descriptor references it.
- *type* — variable or member type. Only one of the pre-defined type constants may be used (see below).
- *struct_name* — structure type name. The type must be defined (typedef) before the TSA descriptor references it.
- *member_name* — structure member name.

Note: The structure member descriptors (FMSTR_TSA_MEMBER) must immediately follow the parent structure descriptor (FMSTR_TSA_STRUCT) in the table.

Note: To write-protect the variables in the FreeMASTER driver (FMSTR_TSA_RO_VAR), enable the TSA-Safety feature in the configuration file.

TSA variable types The table lists *type* identifiers which can be used in TSA descriptors:

Constant	Description
FMSTR_TSA_UINT*n*	Unsigned integer type of size *n* bits (n=8,16,32,64)
FMSTR_TSA_SINT*n*	Signed integer type of size *n* bits (n=8,16,32,64)
FMSTR_TSA_FRAC*n*	Fractional number of size *n* bits (n=16,32,64).
FMSTR_TSA_FRAC_Q(*m*,*n*)	Signed fractional number in general Q form (m+n+1 total bits)
FMSTR_TSA_FRAC_UQ(*m*,*n*)	Unsigned fractional number in general UQ form (m+n total bits)
FMSTR_TSA_FLOAT	4-byte standard IEEE floating-point type
FMSTR_TSA_DOUBLE	8-byte standard IEEE floating-point type
FMSTR_TSA_POINTER	Generic pointer type defined (platform-specific 16 or 32 bit)
FMSTR_TSA_USERTYPE(*name*)	Structure or union type declared with FMSTR_TSA_STRUCT record

TSA table list There shall be exactly one TSA Table List in the application. The list contains one entry for each TSA table defined anywhere in the application.

The TSA Table List begins with the FMSTR_TSA_TABLE_LIST_BEGIN macro and continues with the TSA table entries for each table.

```
FMSTR_TSA_TABLE_LIST_BEGIN()

FMSTR_TSA_TABLE(table_id)
FMSTR_TSA_TABLE(table_id2)
FMSTR_TSA_TABLE(table_id3)
...
```

The list is closed with the FMSTR_TSA_TABLE_LIST_END macro:

```
FMSTR_TSA_TABLE_LIST_END()
```

TSA Active Content entries FreeMASTER v2.0 and higher supports TSA Active Content, enabling the TSA tables to describe the memory-mapped files, virtual directories, and URL hyperlinks. FreeMASTER can access such objects similarly to accessing the files and folders on the local hard drive.

With this set of TSA entries, the FreeMASTER pages can be embedded directly into the target MCU flash and accessed by FreeMASTER directly over the communication line. The HTML-coded pages rendered inside the FreeMASTER window can access the TSA Active Content resources using a special URL referencing the *fmstr:* protocol.

This example provides an overview of the supported TSA Active Content entries:

```
FMSTR_TSA_TABLE_BEGIN(files_and_links)

/* Directory entry applies to all subsequent MEMFILE entries */
FMSTR_TSA_DIRECTORY("/text_files")     /* entering a new virtual directory */

/* The readme.txt file will be accessible at the fmstr://text_files/readme.txt URL */
FMSTR_TSA_MEMFILE("readme.txt", readme_txt, sizeof(readme_txt)) /* memory-mapped file */

/* Files can also be specified with a full path so the DIRECTORY entry does not apply */
FMSTR_TSA_MEMFILE("/index.htm", index, sizeof(index))          /* memory-mapped file */
FMSTR_TSA_MEMFILE("/prj/demo.pmp", demo_pmp, sizeof(demo_pmp)) /* memory-mapped file */

/* Hyperlinks can point to a local MEMFILE object or to the Internet */
FMSTR_TSA_HREF("Board's Built-in Welcome Page", "/index.htm")
FMSTR_TSA_HREF("FreeMASTER Home Page", "http://www.nxp.com/freemaster")

/* Project file links simplify opening the projects from any URLs */
FMSTR_TSA_PROJECT("Demonstration Project (embedded)", "/prj/demo.pmp")
FMSTR_TSA_PROJECT("Full Project (online)", "http://mycompany.com/prj/demo.pmp")

FMSTR_TSA_TABLE_END()
```

TSA API

FMSTR_SetUpTsaBuff

Prototype

```
FMSTR_BOOL FMSTR_SetUpTsaBuff(FMSTR_ADDR buffAddr, FMSTR_SIZE buffSize);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_tsa.c*

Arguments

- *buffAddr* [in] - address of the memory buffer for the dynamic TSA table
- *buffSize* [in] - size of the memory buffer which determines the maximum number of TSA entries to be added in the runtime

Description This function must be used to assign the RAM memory buffer to the TSA subsystem when FMSTR_USE_TSA_DYNAMIC is enabled. The memory buffer is then used to store the TSA entries added dynamically to the runtime TSA table using the FMSTR_TsaAddVar function call. The runtime TSA table is processed by the FreeMASTER PC Host tool along with all static tables as soon as the communication port is open.

The size of the memory buffer determines the number of TSA entries that can be added dynamically. Depending on the MCU platform, one TSA entry takes either 8 or 16 bytes.

FMSTR_TsaAddVar

Prototype

```
FMSTR_BOOL FMSTR_TsaAddVar(FMSTR_TSATBL_STRPTR tsaName, FMSTR_TSATBL_STRPTR
↪tsaType,
    FMSTR_TSATBL_VOIDPTR varAddr, FMSTR_SIZE32 varSize,
    FMSTR_SIZE flags);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_tsa.c*

Arguments

- *tsaName* [in] - name of the object
- *tsaType* [in] - name of the object type
- *varAddr* [in] - address of the object
- *varSize* [in] - size of the object
- *flags* [in] - access flags; a combination of these values:
  - *FMSTR_TSA_INFO_RO_VAR* — read-only memory-mapped object (typically a variable)
  - *FMSTR_TSA_INFO_RW_VAR* — read/write memory-mapped object
  - *FMSTR_TSA_INFO_NON_VAR* — other entry, describing structure types, structure members, enumerations, and other types

Description This function can be called only when the dynamic TSA table is enabled by the FMSTR_USE_TSA_DYNAMIC configuration option and when the FMSTR_SetUpTsaBuff function call is made to assign the dynamic TSA table memory. This function adds an entry into the dynamic TSA table. It can be used to register a read-only or read/write memory object or describe an item of the user-defined type.

See *TSA table definition* for more details about the TSA table entries.

Application Commands API

FMSTR_GetAppCmd

Prototype

```
FMSTR_APPCMD_CODE FMSTR_GetAppCmd(void);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_appcmd.c*

Description This function can be used to detect if there is an Application Command waiting to be processed by the application. If no command is pending, this function returns the FMSTR_APPCMDRESULT_NOCMD constant. Otherwise, this function returns the code of the Application Command that must be processed. Use the FMSTR_AppCmdAck call to acknowledge the Application Command after it is processed and to return the appropriate result code to the host.

The FMSTR_GetAppCmd function does not report the commands for which a callback handler function exists. If the FMSTR_GetAppCmd function is called when a callback-registered command is pending (and before it is actually processed by the callback function), this function returns FMSTR_APPCMDRESULT_NOCMD.

FMSTR_GetAppCmdData

Prototype

```
FMSTR_APPCMD_PDATA FMSTR_GetAppCmdData(FMSTR_SIZE* dataLen);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_appcmd.c*

Arguments

- *dataLen* [out] - pointer to the variable that receives the length of the data available in the buffer. It can be NULL when this information is not needed.

Description This function can be used to retrieve the Application Command data when the application determines that an Application Command is pending (see *FMSTR_GetAppCmd*).

There is just a single buffer to hold the Application Command data (the buffer length is FMSTR_APPCMD_BUFF_SIZE bytes). If the data are to be used in the application after the command is processed by the FMSTR_AppCmdAck call, copy the data out to a private buffer.

FMSTR_AppCmdAck

Prototype

```
void FMSTR_AppCmdAck(FMSTR_APPCMD_RESULT resultCode);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_appcmd.c*

Arguments

- *resultCode* [in] - the result code which is to be returned to FreeMASTER

Description This function is used when the Application Command processing finishes in the application. The resultCode passed to this function is returned back to the host and the driver is re-initialized to expect the next Application Command.

After this function is called and before the next Application Command arrives, the return value of the FMSTR_GetAppCmd function is FMSTR_APPCMDRESULT_NOCMD.

FMSTR_AppCmdSetResponseData

Prototype

```
void FMSTR_AppCmdSetResponseData(FMSTR_ADDR resultDataAddr, FMSTR_SIZE resultDataLen);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_appcmd.c*

Arguments

- *resultDataAddr* [in] - pointer to the data buffer that is to be copied to the Application Command data buffer
- *resultDataLen* [in] - length of the data to be copied. It must not exceed the FMSTR_APPCMD_BUFF_SIZE value.

Description This function can be used before the Application Command processing finishes, when there are data to be returned back to the PC.

The response data buffer is copied into the Application Command data buffer, from where it is accessed when the host requires it. Do not use FMSTR_GetAppCmdData and the data buffer after FMSTR_AppCmdSetResponseData is called.

Note: The current version of FreeMASTER does not support the Application Command response data.

FMSTR_RegisterAppCmdCall

Prototype

```
FMSTR_BOOL FMSTR_RegisterAppCmdCall(FMSTR_APPCMD_CODE appCmdCode, FMSTR_
↪PAPPCMDFUNC callbackFunc);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_appcmd.c*

Arguments

- *appCmdCode* [in] - the Application Command code for which the callback is to be registered
- *callbackFunc* [in] - pointer to the callback function that is to be registered. Use NULL to unregister a callback registered previously with this Application Command.

Return value This function returns a non-zero value when the callback function was successfully registered or unregistered. It can return zero when trying to register a callback function for more than FMSTR_MAX_APPCMD_CALLS different Application Commands.

Description This function can be used to register the given function as a callback handler for the Application Command. The Application Command is identified using single-byte code. The callback function is invoked automatically by the FreeMASTER driver when the protocol decoder obtains a request to get the application command result code.

The prototype of the callback function is

```
FMSTR_APPCMD_RESULT HandlerFunction(FMSTR_APPCMD_CODE nAppcmd,
    FMSTR_APPCMD_PDATA pData, FMSTR_SIZE nDataLen);
```

Where:

- *nAppcmd* -Application Command code
- *pData* —points to the Application Command data received (if any)
- *nDataLen* —information about the Application Command data length

The return value of the callback function is used as the Application Command Result Code and returned to FreeMASTER.

Note: The FMSTR_MAX_APPCMD_CALLS configuration macro defines how many different Application Commands may be handled by a callback function. When FMSTR_MAX_APPCMD_CALLS is undefined or defined as zero, the FMSTR_RegisterAppCmdCall function always fails.

Pipes API

FMSTR_PipeOpen

Prototype

```
FMSTR_HPIPE FMSTR_PipeOpen(FMSTR_PIPE_PORT pipePort, FMSTR_PPIPEFUNC pipeCallback,
↪
    FMSTR_ADDR pipeRxBuff, FMSTR_PIPE_SIZE pipeRxSize,
    FMSTR_ADDR pipeTxBuff, FMSTR_PIPE_SIZE pipeTxSize,
    FMSTR_U8 type, const FMSTR_CHAR *name);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_pipes.c*

Arguments

- *pipePort* [in] - port number that identifies the pipe for the client
- *pipeCallback* [in] - pointer to the callback function that is called whenever a pipe data status changes
- *pipeRxBuff* [in] - address of the receive memory buffer
- *pipeRxSize* [in] - size of the receive memory buffer
- *pipeTxBuff* [in] - address of the transmit memory buffer
- *pipeTxSize* [in] - size of the transmit memory buffer
- *type* [in] - a combination of FMSTR_PIPE_MODE_xxx and FMSTR_PIPE_SIZE_xxx constants describing primary pipe data format and usage. This type helps FreeMASTER decide how to access the pipe by default. Optional, use 0 when undetermined.
- *name* [in] - user name of the pipe port. This name is visible to the FreeMASTER user when creating the graphical pipe interface.

Description This function initializes a new pipe and makes it ready to accept or send the data to the PC Host client. The receive memory buffer is used to store the received data before they are read out by the FMSTR_PipeRead call. When this buffer gets full, the PC Host client denies the data transmission into this pipe until there is enough free space again. The transmit memory buffer is used to store the data transmitted by the application to the PC Host client using the FMSTR_PipeWrite call. The transmit buffer can get full when the PC Host is disconnected or when it is slow in receiving and reading out the pipe data.

The function returns the pipe handle which must be stored and used in the subsequent calls to manage the pipe object.

The callback function (if specified) is called whenever new data are received through the pipe and available for reading. This callback is also called when the data waiting in the transmit buffer are successfully pushed to the PC Host and the transmit buffer free space increases. The prototype of the callback function provided by the user application must be as follows. The *PipeHandler* name is only a placeholder and must be defined by the application.

```
void PipeHandler(FMSTR_HPIPE pipeHandle);
```

FMSTR_PipeClose

Prototype

```
void FMSTR_PipeClose(FMSTR_HPIPE pipeHandle);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_pipes.c*

Arguments

- *pipeHandle* [in] - pipe handle returned from the FMSTR_PipeOpen function call

Description This function de-initializes the pipe object. No data can be received or sent on the pipe after this call.

FMSTR_PipeWrite

Prototype

```
FMSTR_PIPE_SIZE FMSTR_PipeWrite(FMSTR_HPIPE pipeHandle, FMSTR_ADDR pipeData,
    FMSTR_PIPE_SIZE pipeDataLen, FMSTR_PIPE_SIZE writeGranularity);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_pipes.c*

Arguments

- *pipeHandle* [in] - pipe handle returned from the FMSTR_PipeOpen function call
- *pipeData* [in] - address of the data to be written
- *pipeDataLen* [in] - length of the data to be written
- *writeGranularity* [in] - size of the minimum unit of data which is to be written

Description This function puts the user-specified data into the pipe's transmit memory buffer and schedules it for transmission. This function returns the number of bytes that were successfully written into the buffer. This number may be smaller than the number of the requested bytes if there is not enough free space in the transmit buffer.

The *writeGranularity* argument can be used to split the data into smaller chunks, each of the size given by the *writeGranularity* value. The FMSTR_PipeWrite function writes as many data chunks as possible into the transmit buffer and does not attempt to write an incomplete chunk.

This feature can prove to be useful to avoid the intermediate caching when writing an array of integer values or other multi-byte data items. When making the nGranularity value equal to the nLength value, all data are considered as one chunk which is either written successfully as a whole or not at all. The nGranularity value of 0 or 1 disables the data-chunk approach.

FMSTR_PipeRead

Prototype

```
FMSTR_PIPE_SIZE FMSTR_PipeRead(FMSTR_HPIPE pipeHandle, FMSTR_ADDR pipeData,
    FMSTR_PIPE_SIZE pipeDataLen, FMSTR_PIPE_SIZE readGranularity);
```

- Declaration: *freemaster.h*
- Implementation: *freemaster_pipes.c*

Arguments

- *pipeHandle* [in] - pipe handle returned from the FMSTR_PipeOpen function call
- *pipeData* [in] - address of the data buffer to be filled with the received data
- *pipeDataLen* [in] - length of the data to be read
- *readGranularity* [in] - size of the minimum unit of data which is to be read

Description This function copies the data received from the pipe from its receive buffer to the user buffer for further processing. The function returns the number of bytes that were successfully copied to the buffer. This number may be smaller than the number of the requested bytes if there is not enough data bytes available in the receive buffer.

The readGranularity argument can be used to copy the data in larger chunks in the same way as described in the FMSTR_PipeWrite function.

API data types This section describes the data types used in the FreeMASTER driver. The information provided here can be useful when modifying or porting the FreeMASTER Communication Driver to new NXP platforms.

Note: The licensing conditions prohibit use of FreeMASTER and the FreeMASTER Communication Driver with non-NXP MPU or MCU products.

Public common types The table below describes the public data types used in the FreeMASTER driver API calls. The data types are declared in the *freemaster.h* header file.

Type name	Description
FMSTR_ADDR	Data type used to hold the memory address. On most platforms, this is normally a C-pointer, but it may also be a pure integer type.
For example, this type is defined as long integer on the 56F8xxx platform where the 24-bit addresses must be supported, but the C-pointer may be only 16 bits wide in some compiler configurations.	
FMSTR_SIZE	Data type used to hold the memory block size.
It is required that this type is unsigned and at least 16 bits wide integer.	
FMSTR_BOOL	Data type used as a general boolean type.
This type is used only in zero/non-zero conditions in the driver code.	
FMSTR_APPCM	Data type used to hold the Application Command code.
Generally, this is an unsigned 8-bit value.	
FMSTR_APPCM	Data type used to create the Application Command data buffer.
Generally, this is an unsigned 8-bit value.	
FMSTR_APPCM	Data type used to hold the Application Command result code.
Generally, this is an unsigned 8-bit value.	

Public TSA types The table describes the TSA-specific public data types. These types are declared in the *freemaster_tsa.h* header file, which is included in the user application indirectly by the *freemaster.h* file.

FMSTR_TSA_TI	Data type used to hold a descriptor index in the TSA table or a table index in the list of TSA tables.
By default, this is defined as FMSTR_SIZE.	
FMSTR_TSA_TS	Data type used to hold a memory block size, as used in the TSA descriptors.
By default, this is defined as FMSTR_SIZE.	

Public Pipes types The table describes the data types used by the FreeMASTER Pipes API:

FMSTR_HPIPE	Pipe handle that identifies the open-pipe object.
Generally, this is a pointer to a void type.	
FMSTR_PIPE_P	Integer type required to hold at least 7 bits of data.
Generally, this is an unsigned 8-bit or 16-bit type.	
FMSTR_PIPE_SI	Integer type required to hold at least 16 bits of data.
This is used to store the data buffer sizes.	
FMSTR_PPIPEF	Pointer to the pipe handler function.
See *FMSTR_PipeOpen* for more details.	

Internal types The table describes the data types used internally by the FreeMASTER driver. The data types are declared in the platform-specific header file and they are not available in the application code.

FMSTR_U8	The smallest memory entity. On the vast majority of platforms, this is an unsigned 8-bit integer. On the 56F8xx DSP platform, this is defined as an unsigned 16-bit integer.
FMSTR_U16	Unsigned 16-bit integer.
FMSTR_U32	Unsigned 32-bit integer.
FMSTR_S8	Signed 8-bit integer.
FMSTR_S16	Signed 16-bit integer.
FMSTR_S32	Signed 32-bit integer.
FMSTR_FLOAT	4-byte standard IEEE floating-point type.
FMSTR_FLAGS	Data type forming a union with a structure of flag bit-fields.
FMSTR_SIZE8	Data type holding a general size value, at least 8 bits wide.
FMSTR_INDEX	General for-loop index. Must be signed, at least 16 bits wide.
FMSTR_BCHR	A single character in the communication buffer. Typically, this is an 8-bit unsigned integer, except for the DSP platforms where it is a 16-bit integer.
FMSTR_BPTR	A pointer to the communication buffer (an array of FMSTR_BCHR).

Document references

Links

- This document online: https://mcuxpresso.nxp.com/mcuxsdk/latest/html/middleware/freemaster/doc/index.html

- FreeMASTER tool home: www.nxp.com/freemaster
- FreeMASTER community area: community.nxp.com/community/freemaster
- FreeMASTER GitHub code repo: https://github.com/nxp-mcuxpresso/mcux-freemaster
- MCUXpresso SDK home: www.nxp.com/mcuxpresso
- MCUXpresso SDK builder: mcuxpresso.nxp.com/en

Documents

- *FreeMASTER Usage Serial Driver Implementation* (document AN4752)
- *Integrating FreeMASTER Time Debugging Tool With CodeWarrior For Microcontrollers v10.X Project* (document AN4771)
- *Flash Driver Library For MC56F847xx And MC56F827xx DSC Family* (document AN4860)

Revision history This Table summarizes the changes done to this document since the initial release.

Revision	Date	Description
1.0	03/2006	Limited initial release
2.0	09/2007	Updated for FreeMASTER version. New Freescale document template used.
2.1	12/2007	Added description of the new Fast Recorder feature and its API.
2.2	04/2010	Added support for MPC56xx platform, Added new API for use CAN interface.
2.3	04/2011	Added support for Kxx Kinetis platform and MQX operating system.
2.4	06/2011	Serial driver update, adds support for USB CDC interface.
2.5	08/2011	Added Packet Driven BDM interface.
2.7	12/2013	Added FLEXCAN32 interface, byte access and isr callback configuration option.
2.8	06/2014	Removed obsolete license text, see the software package content for up-to-date license.
2.9	03/2015	Update for driver version 1.8.2 and 1.9: FreeMASTER Pipes, TSA Active Content, LIN Transport Layer support, DEBUG-TX communication troubleshooting, Kinetis SDK support.
3.0	08/2016	Update for driver version 2.0: Added support for MPC56xx, MPC57xx, KEAxx and S32Kxx platforms. New NXP document template as well as new license agreement used. added MCAN interface. Folders structure at the installation destination was rearranged.
4.0	04/2019	Update for driver released as part of FreeMASTER v3.0 and MCUXpresso SDK 2.6. Updated to match new V4 serial communication protocol and new configuration options. This version of the document removes substantial portion of outdated information related to S08, S12, ColdFire, Power and other legacy platforms.
4.1	04/2020	Minor update for FreeMASTER driver included in MCUXpresso SDK 2.8.
4.2	09/2020	Added example applications description and information about the MCUXpresso Config Tools. Fixed the pipe-related API description.
4.3	10/2024	Added description of Network and Segger J-Link RTT interface configuration. Accompanying the MCUXpresso SDK version 24.12.00.
4.4	04/2025	Added Zephyr-specific information. Accompanying the MCUXpresso SDK version 25.06.00.

1.4 MultiCore

1.4.1 Multicore SDK

Multicore Software Development Kit (MCSDK) is a Software Development Kit that provides comprehensive software support for NXP dual/multicore devices. The MCSDK is combined with the MCUXpresso SDK to make the software framework for easy development of multicore applications.

Multicore SDK (MCSDK) Release Notes

Overview These are the release notes for the NXP Multicore Software Development Kit (MCSDK) version 25.12.00.
This software package contains components for efficient work with multicore devices as well as for the
multiprocessor communication.

What is new

- eRPC CHANGELOG
- RPMsg-Lite CHANGELOG
- MCMgr CHANGELOG
- Supported evaluation boards (multicore examples):
  - LPCXpresso55S69
  - FRDM-K32L3A6
  - MIMXRT1170-EVKB
  - MIMXRT1160-EVK
  - MIMXRT1180-EVK
  - MCX-N5XX-EVK
  - MCX-N9XX-EVK
  - FRDM-MCXN947
  - MIMXRT700-EVK
  - KW47-EVK
  - KW47-LOC
  - FRDM-MCXW72
  - MCX-W72-EVK
  - FRDM-IMXRT1186
- Supported evaluation boards (multiprocessor examples):
  - LPCXpresso55S36
  - FRDM-K22F
  - FRDM-K32L2B
  - MIMXRT685-EVK
  - MIMXRT1170-EVKB
  - MIMXRT1180
  - FRDM-MCXN236
  - FRDM-MCXC242
  - FRDM-MCXC444
  - MCX-N9XX-EVK
  - FRDM-MCXN947
  - MIMXRT700-EVK
  - FRDM-IMXRT1186

Development tools The Multicore SDK (MCSDK) was compiled and tested with development tools referred in: Development tools

Release contents This table describes the release contents. Not all MCUXpresso SDK packages contain the whole set of these components.

Deliverable	Location
Multicore SDK location <MCSDK_dir>	<MCUXpressoSDK_install_dir>/middleware/multicore/
Documentation	<MCSDK_dir>/mcuxsdk-doc/
Embedded Remote Procedure Call component	<MCSDK_dir>/erpc/
Multicore Manager component	<MCSDK_dir>/mcmgr/
RPMsg-Lite	<MCSDK_dir>/rpmsg_lite/
Multicore demo applications	<MCUXpressoSDK_install_dir>/examples/multicore_examples/
Multiprocessor demo applications	<MCUXpressoSDK_install_dir>/examples/multiprocessor_examples/

Multicore SDK release overview Together, the Multicore SDK (MCSDK) and the MCUXpresso SDK (SDK) form a framework for the development of software for NXP multicore devices. The MCSDK release consists of the following elementary software components for multicore:

- Embedded Remote Procedure Call (eRPC)
- Multicore Manager (MCMGR) - included just in SDK for multicore devices
- Remote Processor Messaging - Lite (RPMsg-Lite) - included just in SDK for multicore devices

The MCSDK is also accompanied with documentation and several multicore and multiprocessor demo applications.

Demo applications The multicore demo applications demonstrate the usage of the MCSDK software components on supported multicore development boards.
The following multicore demo applications are located together with other MCUXpresso SDK examples in
the <MCUXpressoSDK_install_dir>/examples/multicore_examples subdirectories.

- erpc_matrix_multiply_mu
- erpc_matrix_multiply_mu_rtos
- erpc_matrix_multiply_rpmsg
- erpc_matrix_multiply_rpmsg_rtos
- erpc_two_way_rpc_rpmsg_rtos
- freertos_message_buffers
- hello_world
- multicore_manager
- rpmsg_lite_pingpong
- rpmsg_lite_pingpong_rtos
- rpmsg_lite_pingpong_dsp
- rpmsg_lite_pingpong_tzm

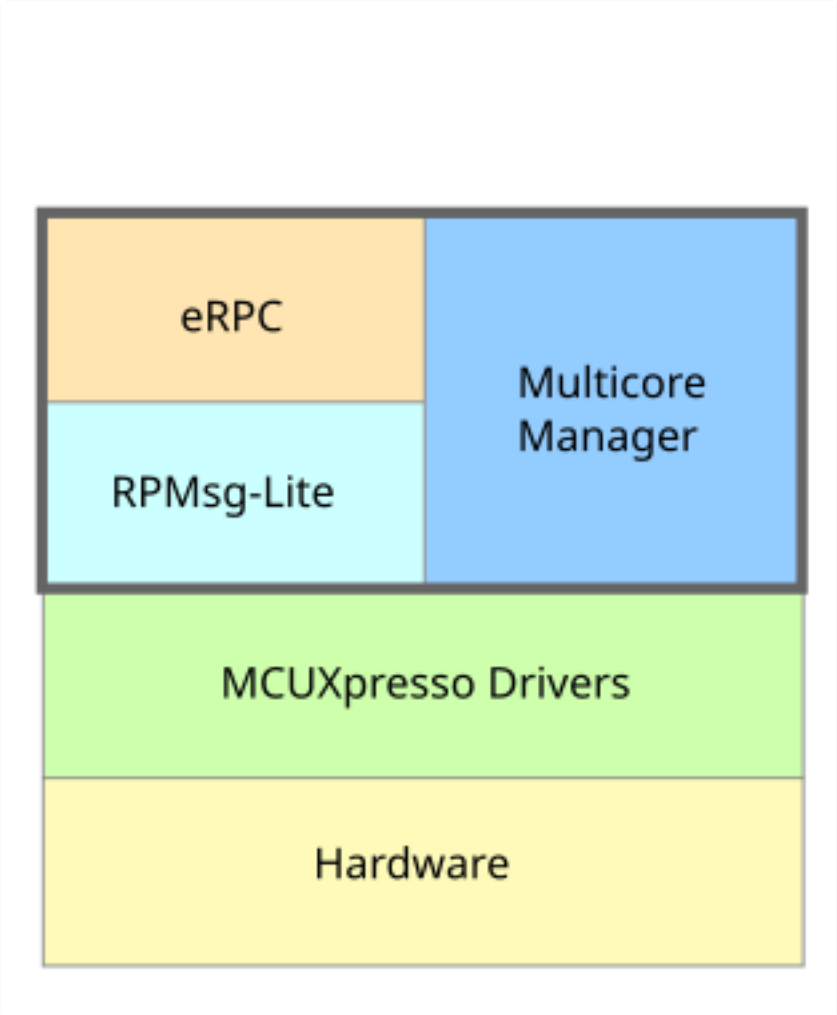
The eRPC multicore component can be leveraged for inter-processor communication and remote procedure calls between SoCs / development boards.
The following multiprocessor demo applications are located together with other MCUXpresso SDK examples in
the <MCUXpressoSDK_install_dir>/examples/multiprocessor_examples subdirectories.

- erpc_client_matrix_multiply_spi
- erpc_server_matrix_multiply_spi
- erpc_client_matrix_multiply_uart
- erpc_server_matrix_multiply_uart
- erpc_server_dac_adc
- erpc_remote_control

Getting Started with Multicore SDK (MCSDK)

Overview Multicore Software Development Kit (MCSDK) is a Software Development Kit that provides comprehensive software support for NXP dual/multicore devices. The MCSDK is combined with the MCUXpresso SDK to make the software framework for easy development of multicore applications.

The following figure highlights the layers and main software components of the MCSDK.

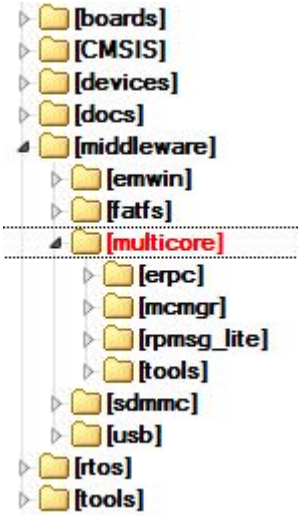


All the MCSDK-related files are located in <MCUXpressoSDK_install_dir>/middleware/multicore folder.

For supported toolchain versions, see the *Multicore SDK v25.12.00 Release Notes* (document MCSDKRN). For the latest version of this and other MCSDK documents, visit www.nxp.com.

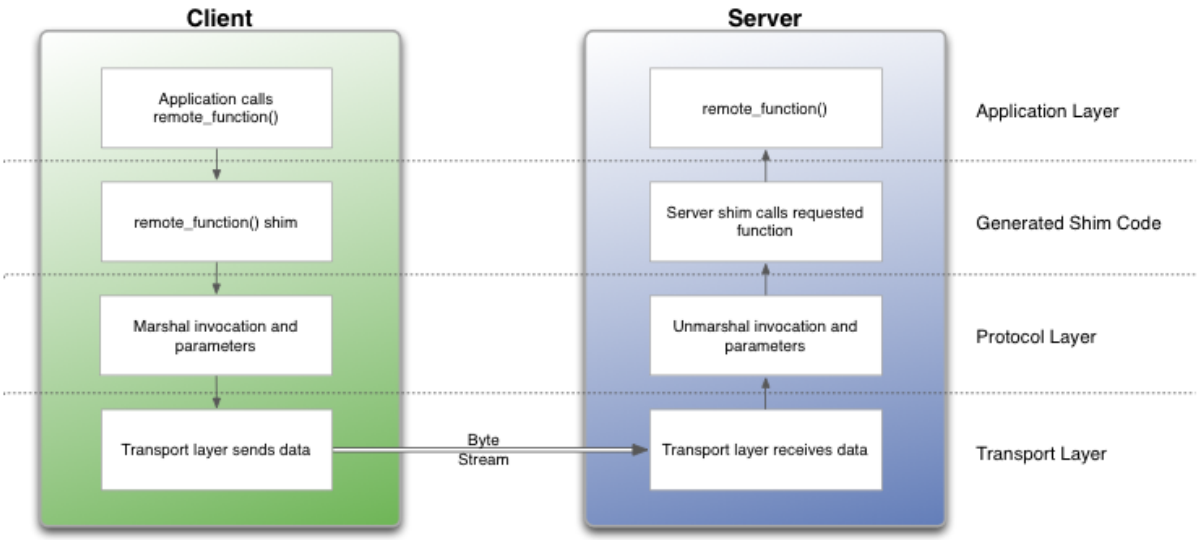
Multicore SDK (MCSDK) components The MCSDK consists of the following software components:

- **Embedded Remote Procedure Call (eRPC):** This component is a combination of a library and code generator tool that implements a transparent function call interface to remote services (running on a different core).
- **Multicore Manager (MCMGR):** This library maintains information about all cores and starts up secondary/auxiliary cores.
- **Remote Processor Messaging - Lite (RPMsg-Lite):** Inter-Processor Communication library.



Embedded Remote Procedure Call (eRPC) The Embedded Remote Procedure Call (eRPC) is the RPC system created by NXP. The RPC is a mechanism used to invoke a software routine on a remote system via a simple local function call.

When a remote function is called by the client, the function's parameters and an identifier for the called routine are marshaled (or serialized) into a stream of bytes. This byte stream is transported to the server through a communications channel (IPC, TPC/IP, UART, and so on). The server unmarshaled the parameters, determines which function was invoked, and calls it. If the function returns a value, it is marshaled and sent back to the client.



RPC implementations typically use a combination of a tool (erpcgen) and IDL (interface definition language) file to generate source code to handle the details of marshaling a function's parameters and building the data stream.

Main eRPC features:

- Scalable from BareMetal to Linux OS - configurable memory and threading policies.
- Focus on embedded systems - intrinsic support for C, modular, and lightweight implementation.
- Abstracted transport interface - RPMsg is the primary transport for multicore, UART, or SPI-based solutions can be used for multichip.

The eRPC library is located in the <MCUXpressoSDK_install_dir>/middleware/multicore/erpc folder. For detailed information about the eRPC, see the documentation available in the <MCUXpressoSDK_install_dir>/middleware/multicore/erpc/doc folder.

Multicore Manager (MCMGR) The Multicore Manager (MCMGR) software library provides a number of services for multicore systems.

The main MCMGR features:

- Maintains information about all cores in system.
- Secondary/auxiliary cores startup and shutdown.
- Remote core monitoring and event handling.

The MCMGR library is located in the <MCUXpressoSDK_install_dir>/middleware/multicore/mcmgr folder. For detailed information about the MCMGR library, see the documentation available in the <MCUXpressoSDK_install_dir>/middleware/multicore/mcmgr/doc folder.

Remote Processor Messaging Lite (RPMsg-Lite) RPMsg-Lite is a lightweight implementation of the RPMsg protocol. The RPMsg protocol defines a standardized binary interface used to communicate between multiple cores in a heterogeneous multicore system. Compared to the legacy OpenAMP implementation, RPMsg-Lite offers a code size reduction, API simplification, and improved modularity.

The main RPMsg protocol features:

- Shared memory interprocessor communication.
- Virtio-based messaging bus.
- Application-defined messages sent between endpoints.

- Portable to different environments/platforms.
- Available in upstream Linux OS.

The RPMsg-Lite library is located in the <MCUXpressoSDK_install_dir>/middleware/multicore/rpmsg-lite folder. For detailed information about the RPMsg-Lite, see the RPMsg-Lite User's Guide located in the <MCUXpressoSDK_install_dir>/middleware/multicore/rpmsg_lite/doc folder.

MCSDK demo applications Multicore and multiprocessor example applications are stored together with other MCUXpresso SDK examples, in the dedicated multicore subfolder.

Location	Folder
Multicore example projects	<MCUXpressoSDK_install_dir>/examples/multicore_examples/<application_name>/
Multiprocessor example projects	<MCUXpressoSDK_install_dir>/examples/multiprocessor_examples/<application_name>/

See the *Getting Started with MCUXpresso SDK* (document MCUXSDKGSUG) and *Getting Started with MCUXpresso SDK for XXX Derivatives* documents for more information about the MCUXpresso SDK example folder structure and the location of individual files that form the example application projects. These documents also contain information about building, running, and debugging multicore demo applications in individual supported IDEs. Each example application also contains a readme file that describes the operation of the example and required setup steps.

Inter-Processor Communication (IPC) levels The MCSDK provides several mechanisms for Inter-Processor Communication (IPC). Particular ways and levels of IPC are described in this chapter.

IPC using low-level drivers

The NXP multicore SoCs are equipped with peripheral modules dedicated for data exchange between individual cores. They deal with the Mailbox peripheral for LPC parts and the Messaging Unit (MU) peripheral for Kinetis and i.MX parts. The common attribute of both modules is the ability to provide a means of IPC, allowing multiple CPUs to share resources and communicate with each other in a simple manner.

The most lightweight method of IPC uses the MCUXpresso SDK low-level drivers for these peripherals. Using the Mailbox/MU driver API functions, it is possible to pass a value from core to core via the dedicated registers (could be a scalar or a pointer to shared memory) and also to trigger inter-core interrupts for notifications.

For details about individual driver API functions, see the MCUXpresso SDK API Reference Manual of the specific multicore device. The MCUXpresso SDK is accompanied with the RPMsg-Lite documentation that shows how to use this API in multicore applications.

Messaging mechanism

On top of Mailbox/MU drivers, a messaging system can be implemented, allowing messages to send between multiple endpoints created on each of the CPUs. The RPMsg-Lite library of the MCSDK provides this ability and serves as the preferred MCUXpresso SDK messaging library. It implements ring buffers in shared memory for messages exchange without the need of a locking mechanism.

The RPMsg-Lite provides the abstraction layer and can be easily ported to different multicore platforms and environments (Operating Systems). The advantages of such a messaging system are ease of use (there is no need to study behavior of the used underlying hardware) and smooth application code portability between platforms due to unified messaging API.

However, this costs several kB of code and data memory. The MCUXpresso SDK is accompanied by the RPMsg-Lite documentation and several multicore examples. You can also obtain the latest RPMsg-Lite code from the GitHub account github.com/nxp-mcuxpresso/rpmsg-lite.

Remote procedure calls

To facilitate the IPC even more and to allow the remote functions invocation, the remote procedure call mechanism can be implemented. The eRPC of the MCSDK serves for these purposes and allows the ability to invoke a software routine on a remote system via a simple local function call. Utilizing different transport layers, it is possible to communicate between individual cores of multicore SoCs (via RPMsg-Lite) or between separate processors (via SPI, UART, or TCP/IP). The eRPC is mostly applicable to the MPU parts with enough of memory resources like i.MX parts.

The eRPC library allows you to export existing C functions without having to change their prototypes (in most cases). It is accompanied by the code generator tool that generates the shim code for serialization and invocation based on the IDL file with definitions of data types and remote interfaces (API).

If the communicating peer is running as a Linux OS user-space application, the generated code can be either in C/C++ or Python.

Using the eRPC simplifies the access to services implemented on individual cores. This way, the following types of applications running on dedicated cores can be easily interfaced:

- Communication stacks (USB, Thread, Bluetooth Low Energy, Zigbee)
- Sensor aggregation/fusion applications
- Encryption algorithms
- Virtual peripherals

The eRPC is publicly available from the following GitHub account: github.com/EmbeddedRPC/erpc. Also, the MCUXpresso SDK is accompanied by the eRPC code and several multicore and multiprocessor eRPC examples.

The mentioned IPC levels demonstrate the scalability of the Multicore SDK library. Based on application needs, different IPC techniques can be used. It depends on the complexity, required speed, memory resources, system design, and so on. The MCSDK brings users the possibility for quick and easy development of multicore and multiprocessor applications.

Changelog Multicore SDK

All notable changes to this project will be documented in this file.

The format is based on Keep a Changelog, and this project adheres to Semantic Versioning.

[25.12.00]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.14.0
  - eRPC generator (erpcgen) v1.14.0
  - Multicore Manager (MCMgr) v5.0.2
  - RPMsg-Lite v5.3.0

[25.09.00]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.14.0

  - eRPC generator (erpcgen) v1.14.0
  - Multicore Manager (MCMgr) v5.0.1
  - RPMsg-Lite v5.2.1

[25.06.00]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.14.0
  - eRPC generator (erpcgen) v1.14.0
  - Multicore Manager (MCMgr) v5.0.0
  - RPMsg-Lite v5.2.0

[25.03.00]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.13.0
  - eRPC generator (erpcgen) v1.13.0
  - Multicore Manager (MCMgr) v4.1.7
  - RPMsg-Lite v5.1.4

[24.12.00]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.13.0
  - eRPC generator (erpcgen) v1.13.0
  - Multicore Manager (MCMgr) v4.1.6
  - RPMsg-Lite v5.1.3

[2.16.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.13.0
  - eRPC generator (erpcgen) v1.13.0
  - Multicore Manager (MCMgr) v4.1.5
  - RPMsg-Lite v5.1.2

[2.15.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.12.0
  - eRPC generator (erpcgen) v1.12.0
  - Multicore Manager (MCMgr) v4.1.5
  - RPMsg-Lite v5.1.1

[2.14.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.11.0
  - eRPC generator (erpcgen) v1.11.0
  - Multicore Manager (MCMgr) v4.1.4
  - RPMsg-Lite v5.1.0

[2.13.0_imxrt1180a0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.10.0
  - eRPC generator (erpcgen) v1.10.0
  - Multicore Manager (MCMgr) v4.1.3
  - RPMsg-Lite v5.0.0

[2.13.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.10.0
  - eRPC generator (erpcgen) v1.10.0
  - Multicore Manager (MCMgr) v4.1.3
  - RPMsg-Lite v5.0.0

[2.12.0_imx93]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.9.1
  - eRPC generator (erpcgen) v1.9.1
  - Multicore Manager (MCMgr) v4.1.2
  - RPMsg-Lite v4.0.1

[2.12.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.9.1
  - eRPC generator (erpcgen) v1.9.1
  - Multicore Manager (MCMgr) v4.1.2
  - RPMsg-Lite v4.0.0

[2.11.1]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.9.0
  - eRPC generator (erpcgen) v1.9.0
  - Multicore Manager (MCMgr) v4.1.1
  - RPMsg-Lite v3.2.1

[2.11.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.9.0
  - eRPC generator (erpcgen) v1.9.0
  - Multicore Manager (MCMgr) v4.1.1
  - RPMsg-Lite v3.2.0

[2.10.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.8.1
  - eRPC generator (erpcgen) v1.8.1
  - Multicore Manager (MCMgr) v4.1.1
  - RPMsg-Lite v3.1.2

[2.9.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.8.0
  - eRPC generator (erpcgen) v1.8.0
  - Multicore Manager (MCMgr) v4.1.1
  - RPMsg-Lite v3.1.1

[2.8.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.7.4
  - eRPC generator (erpcgen) v1.7.4
  - Multicore Manager (MCMgr) v4.1.0
  - RPMsg-Lite v3.1.0

[2.7.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.7.3
  - eRPC generator (erpcgen) v1.7.3
  - Multicore Manager (MCMgr) v4.1.0
  - RPMsg-Lite v3.0.0

[2.6.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.7.2
  - eRPC generator (erpcgen) v1.7.2
  - Multicore Manager (MCMgr) v4.0.3
  - RPMsg-Lite v2.2.0

[2.5.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.7.1
  - eRPC generator (erpcgen) v1.7.1
  - Multicore Manager (MCMgr) v4.0.2
  - RPMsg-Lite v2.0.2

[2.4.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.7.0
  - eRPC generator (erpcgen) v1.7.0
  - Multicore Manager (MCMgr) v4.0.1
  - RPMsg-Lite v2.0.1

[2.3.1]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.6.0
  - eRPC generator (erpcgen) v1.6.0
  - Multicore Manager (MCMgr) v4.0.0
  - RPMsg-Lite v1.2.0

[2.3.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.5.0
  - eRPC generator (erpcgen) v1.5.0
  - Multicore Manager (MCMgr) v3.0.0
  - RPMsg-Lite v1.2.0

[2.2.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.4.0
  - eRPC generator (erpcgen) v1.4.0
  - Multicore Manager (MCMgr) v2.0.1
  - RPMsg-Lite v1.1.0

[2.1.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.3.0
  - eRPC generator (erpcgen) v1.3.0

[2.0.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.2.0
  - eRPC generator (erpcgen) v1.2.0
  - Multicore Manager (MCMgr) v2.0.0
  - RPMsg-Lite v1.0.0

[1.1.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.1.0
  - Multicore Manager (MCMgr) v1.1.0
  - Open-AMP / RPMsg based on SHA1 ID 44b5f3c0a6458f3cf80 rev01

[1.0.0]

- Multicore SDK component versions:
  - embedded Remote Procedure Call (eRPC) v1.0.0
  - Multicore Manager (MCMgr) v1.0.0
  - Open-AMP / RPMsg based on SHA1 ID 44b5f3c0a6458f3cf80 rev00

Multicore SDK Components

RPMSG-Lite

MCUXpresso SDK : mcuxsdk-middleware-rpmsg-lite

Overview This repository is for MCUXpresso SDK RPMSG-Lite middleware delivery and it contains RPMSG-Lite component officially provided in NXP MCUXpresso SDK. This repository is part of the MCUXpresso SDK overall delivery which is composed of several sub-repositories/projects. Navigate to the top/parent repository mcuxsdk for the complete delivery of MCUXpresso SDK to be able to build and run RPMSG-Lite examples that are based on mcux-sdk-middleware-rpmsg-lite component.

Documentation Overall details can be reviewed here: MCUXpresso SDK Online Documentation

Visit RPMSG-Lite - Documentation to review details on the contents in this sub-repo.

For Further API documentation, please look at doxygen documentation

Setup Instructions on how to install the MCUXpresso SDK provided from GitHub via west manifest Getting Started with SDK - Detailed Installation Instructions

Contribution We welcome and encourage the community to submit patches directly to the rpmsg-lite project placed on github. Contributing can be managed via pull-requests. Before a pull-request is created the code should be tested and properly formatted.

RPMSG-Lite This documentation describes the RPMsg-Lite component, which is a lightweight implementation of the Remote Processor Messaging (RPMsg) protocol. The RPMsg protocol defines a standardized binary interface used to communicate between multiple cores in a heterogeneous multicore system.

Compared to the RPMsg implementation of the Open Asymmetric Multi Processing (OpenAMP) framework (https://github.com/OpenAMP/open-amp), the RPMsg-Lite offers a code size reduction, API simplification, and improved modularity. On smaller Cortex-M0+ based systems, it is recommended to use RPMsg-Lite.

The RPMsg-Lite is an open-source component developed by NXP Semiconductors and released under the BSD-compatible license.

For overview please read RPMSG-Lite VirtIO Overview.

For RPMSG-Lite Design Considerations please read RPMSG-Lite Design Considerations.

Motivation to create RPMsg-Lite There are multiple reasons why RPMsg-Lite was developed. One reason is the need for the small footprint of the RPMsg protocol-compatible communication component, another reason is the simplification of extensive API of OpenAMP RPMsg implementation.

RPMsg protocol was not documented, and its only definition was given by the Linux Kernel and legacy OpenAMP implementations. This has changed with [1] which is a standardization protocol allowing multiple different implementations to coexist and still be mutually compatible.

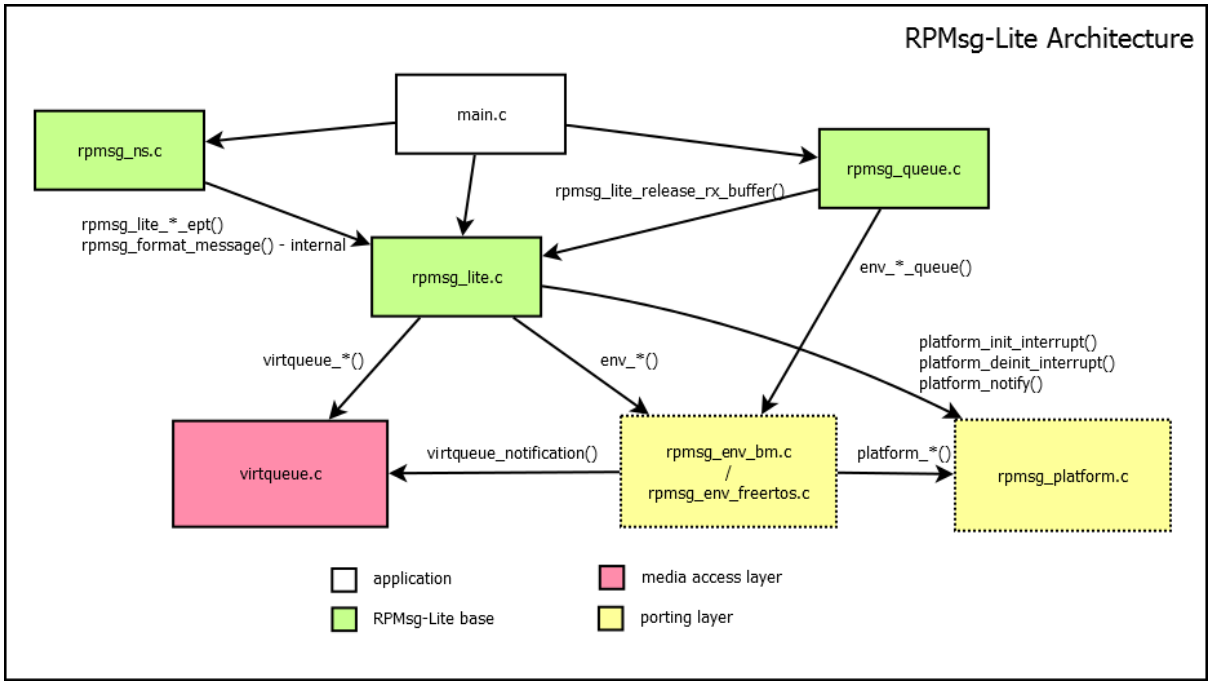
Small MCU-based systems often do not implement dynamic memory allocation. The creation of static API in RPMsg-Lite enables another reduction of resource usage. Not only does the dynamic allocation adds another 5 KB of code size, but also communication is slower and less deterministic, which is a property introduced by dynamic memory. The following table shows some rough comparison data between the OpenAMP RPMsg implementation and new RPMsg-Lite implementation:

Component / Configuration	Flash [B]	RAM [B]
OpenAMP RPMsg / Release (reference)	5547	456 + dynamic
RPMsg-Lite / Dynamic API, Release	3462	56 + dynamic
Relative Difference [%]	~62.4%	~12.3%
RPMsg-Lite / Static API (no malloc), Release	2926	352
Relative Difference [%]	~52.7%	~77.2%

Implementation The implementation of RPMsg-Lite can be divided into three subcomponents, from which two are optional. The core component is situated in rpmsg_lite.c. Two optional components are used to implement a blocking receive API (in rpmsg_queue.c) and dynamic "named" endpoint creation and deletion announcement service (in rpmsg_ns.c).

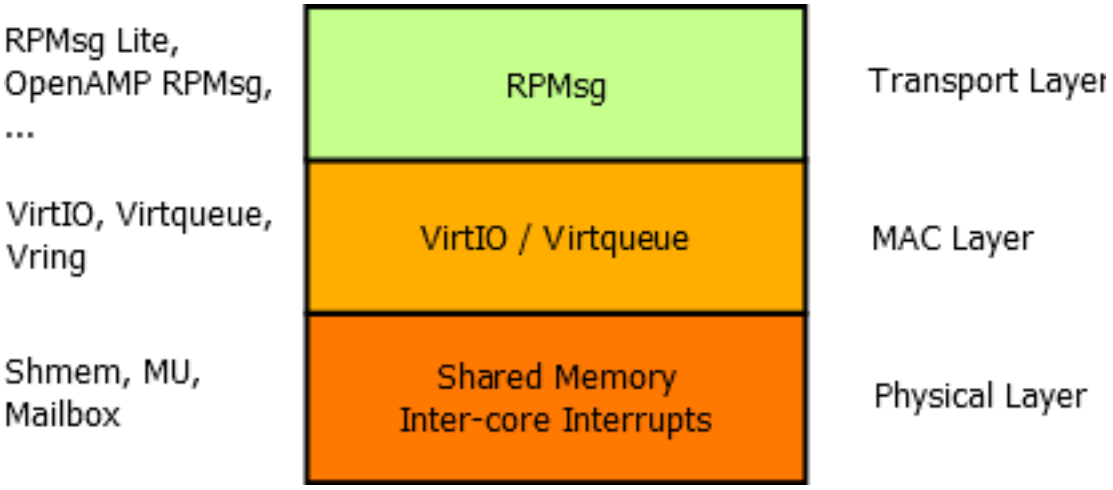
The actual "media access" layer is implemented in virtqueue.c, which is one of the few files shared with the OpenAMP implementation. This layer mainly defines the shared memory model, and internally defines used components such as vring or virtqueue.

The porting layer is split into two sub-layers: the environment layer and the platform layer. The first sublayer is to be implemented separately for each environment. (The bare metal environment already exists and is implemented in rpmsg_env_bm.c, and the FreeRTOS environment is implemented in rpmsg_env_freertos.c etc.) Only the source file, which matches the used environment, is included in the target application project. The second sublayer is implemented in rpmsg_platform.c and defines low-level functions for interrupt enabling, disabling, and triggering mainly. The situation is described in the following figure:



RPMsg-Lite core sub-component This subcomponent implements a blocking send API and callback-based receive API. The RPMsg protocol is part of the transport layer. This is realized by using so-called endpoints. Each endpoint can be assigned a different receive callback function.

However, it is important to notice that the callback is executed in an interrupt environment in current design. Therefore, certain actions like memory allocation are discouraged to execute in the callback. The following figure shows the role of RPMsg in an ISO/OSI-like layered model:



Queue sub-component (optional) This subcomponent is optional and requires implementation of the env_*_queue() functions in the environment porting layer. It uses a blocking receive API, which is common in RTOS-environments. It supports both copy and nocopy blocking receive functions.

Name Service sub-component (optional) This subcomponent is a minimum implementation of the name service which is present in the Linux Kernel implementation of RPMsg. It allows the communicating node both to send announcements about "named" endpoint (in other words, channel) creation or deletion and to receive these announcement taking any user-defined action in an application callback. The endpoint address used to receive name service announcements is arbitrarily fixed to be 53 (0x35).

Usage The application should put the /rpmsg_lite/lib/include directory to the include path and in the application, include either the rpmsg_lite.h header file, or optionally also include the rpmsg_queue.h and/or rpmsg_ns.h files. Both porting sublayers should be provided for you by NXP, but if you plan to use your own RTOS, all you need to do is to implement your own environment layer (in other words, rpmsg_env_myrtos.c) and to include it in the project build.

The initialization of the stack is done by calling the rpmsg_lite_master_init() on the master side and the rpmsg_lite_remote_init() on the remote side. This initialization function must be called prior to any RPMsg-Lite API call. After the init, it is wise to create a communication endpoint, otherwise communication is not possible. This can be done by calling the rpmsg_lite_create_ept() function. It optionally accepts a last argument, where an internal context of the endpoint is created, just in case the RL_USE_STATIC_API option is set to 1. If not, the stack internally calls env_alloc() to allocate dynamic memory for it. In case a callback-based receiving is to be used, an ISR-callback is registered to each new endpoint with user-defined callback data pointer. If a blocking receive is desired (in case of RTOS environment), the rpmsg_queue_create() function must be called before calling rpmsg_lite_create_ept(). The queue handle is passed to the endpoint creation function as a callback data argument and the callback function is set to rpmsg_queue_rx_cb(). Then, it is possible to use rpmsg_queue_receive() function to listen on a queue object for incoming messages. The rpmsg_lite_send() function is used to send messages to the other side.

The RPMsg-Lite also implements no-copy mechanisms for both sending and receiving operations. These methods require specifics that have to be considered when used in an application.

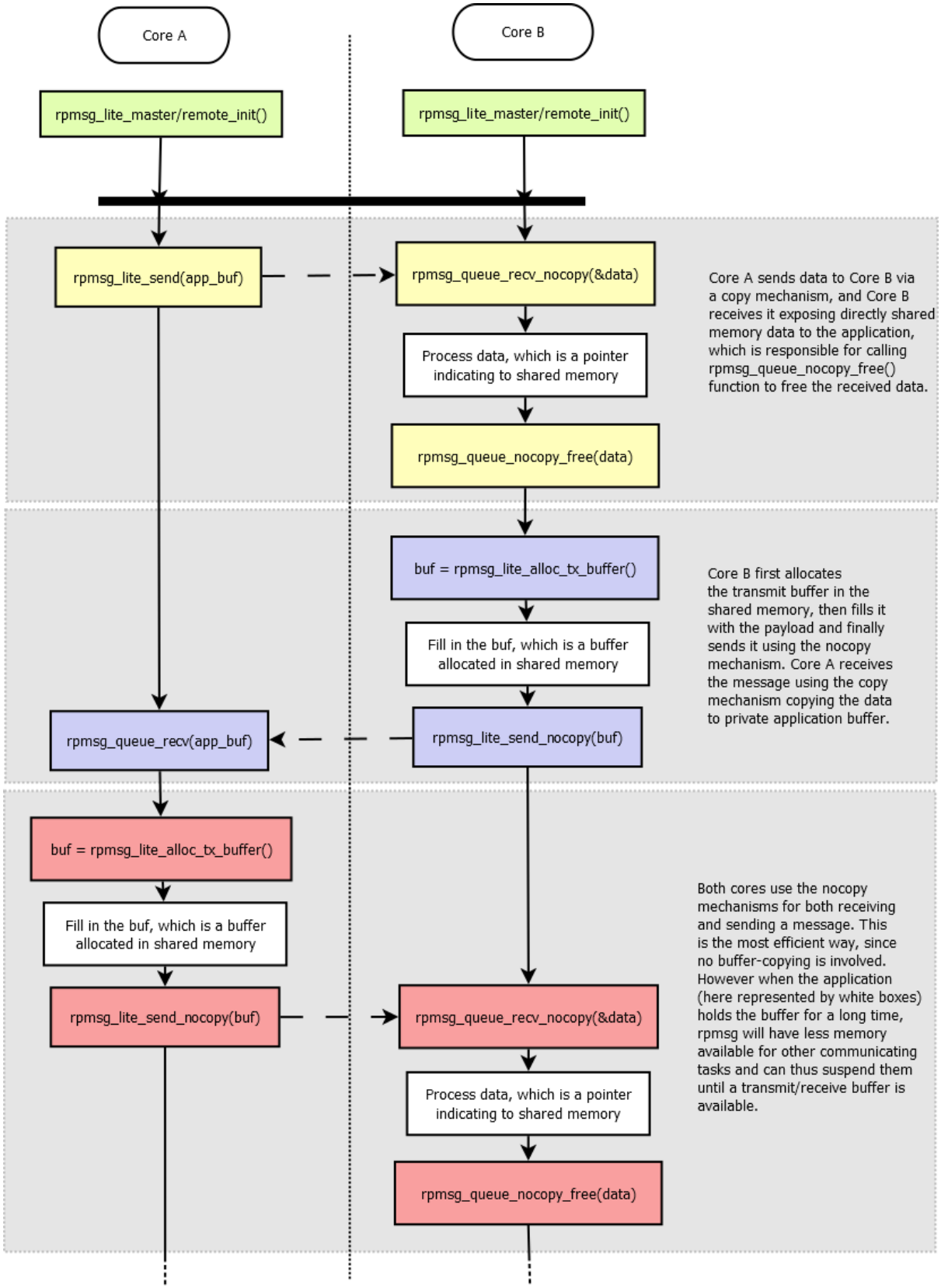
no-copy-send mechanism: This mechanism allows sending messages without the cost for copying data from the application buffer to the RPMsg/virtio buffer in the shared memory. The sequence of no-copy sending steps to be performed is as follows:

- Call the rpmsg_lite_alloc_tx_buffer() function to get the virtio buffer and provide the buffer pointer to the application.
- Fill the data to be sent into the pre-allocated virtio buffer. Ensure that the filled data does not exceed the buffer size (provided as the rpmsg_lite_alloc_tx_buffer() size output parameter).
- Call the rpmsg_lite_send_nocopy() function to send the message to the destination endpoint. Consider the cache functionality and the virtio buffer alignment. See the rpmsg_lite_send_nocopy() function description below.

no-copy-receive mechanism: This mechanism allows reading messages without the cost for copying data from the virtio buffer in the shared memory to the application buffer. The sequence of no-copy receiving steps to be performed is as follows:

- Call the rpmsg_queue_recv_nocopy() function to get the virtio buffer pointer to the received data.
- Read received data directly from the shared memory.
- Call the rpmsg_queue_nocopy_free() function to release the virtio buffer and to make it available for the next data transfer.

The user is responsible for destroying any RPMsg-Lite objects he has created in case of deinitialization. In order to do this, the function rpmsg_queue_destroy() is used to destroy a queue, rpmsg_lite_destroy_ept() is used to destroy an endpoint and finally, rpmsg_lite_deinit() is used to deinitialize the RPMsg-Lite intercore communication stack. Deinitialize all endpoints using a queue before deinitializing the queue. Otherwise, you are actively invalidating the used queue handle, which is not allowed. RPMsg-Lite does not check this internally, since its main aim is to be lightweight.



Examples RPMsg_Lite multicore examples are part of NXP MCUXpressoSDK packages. Visit https://mcuxpresso.nxp.com to configure, build and download these packages. To get the board list with multicore support (RPMsg_Lite included) use filtering based on Middleware and search for 'multicore' string. Once the selected package with the multicore middleware is downloaded,

see

<MCUXpressoSDK_install_dir>/boards/<board_name>/multicore_examples for RPMsg_Lite multicore examples with 'rpmsg_lite_' name prefix.

Another way of getting NXP MCUXpressoSDK RPMsg_Lite multicore examples is using the mcuxsdk-manifests Github repo. Follow the description how to use the West tool to clone and update the mcuxsdk-manifests repo in readme section. Once done the armgcc rpmsg_lite examples can be found in

mcuxsdk/examples/_<board_name>/multicore_examples

You can use the evkmimxrt1170 as the board_name for instance. Similar to MCUXpressoSDK packages the RPMsg_Lite examples use the 'rpmsg_lite_' name prefix.

Notes

Environment layers implementation Several environment layers are provided in lib/rpmsg_lite/porting/environment folder. Not all of them are fully tested however. Here is the list of environment layers that passed testing:

- rpmsg_env_bm.c
- rpmsg_env_freertos.c
- rpmsg_env_xos.c
- rpmsg_env_threadx.c

The rest of environment layers has been created and used in some experimental projects, it has been running well at the time of creation but due to the lack of unit testing there is no guarantee it is still fully functional.

Shared memory configuration It is important to correctly initialize/configure the shared memory for data exchange in the application. The shared memory must be accessible from both the master and the remote core and it needs to be configured as Non-Cacheable memory. Dedicated shared memory section in liker file is also a good practise, it is recommended to use linker files from MCUXpressSDK packages for NXP devices based applications. It needs to be ensured no other application part/component is unintentionally accessing this part of memory.

Configuration options The RPMsg-Lite can be configured at the compile time. The default configuration is defined in the rpmsg_default_config.h header file. This configuration can be customized by the user by including rpmsg_config.h file with custom settings. The following table summarizes all possible RPMsg-Lite configuration options.

Configuration option	Default value	Usage
RL_MS_PE	(1)	Delay in milliseconds used in non-blocking API functions for polling.
RL_BUFFE	(496)	Size of the buffer payload, it must be more than 1 byte, and has to be word align (including rpmsg header size 16 bytes), if not it will be aligned up
RL_BUFFE	(2)	Number of the buffers, it must be power of two (2, 4, ...)
RL_API_H	(1)	Zero-copy API functions enabled/disabled.
RL_USE_S	(0)	Static API functions (no dynamic allocation) enabled/disabled.
RL_USE_D	(0)	Memory cache management of shared memory. Use in case of data cache is enabled for shared memory.
RL_CLEAF	(0)	Clearing used buffers before returning back to the pool of free buffers enabled/disabled.
RL_USE_M	(0)	When enabled IPC interrupts are managed by the Multicore Manager (IPC interrupts router), when disabled RPMsg-Lite manages IPC interrupts by itself.
RL_USE_E	(0)	When enabled the environment layer uses its own context. Required for some environments (QNX). The default value is 0 (no context, saves some RAM).
RL_DEBU(	(0)	When enabled buffer pointers passed to rpmsg_lite_send_nocopy() and rpmsg_lite_release_rx_buffer() functions (enabled by RL_API_HAS_ZEROCOPY config) are checked to avoid passing invalid buffer pointer. The default value is 0 (disabled). Do not use in RPMsg-Lite to Linux configuration.
RL_ALLO\	(0)	When enabled the opposite side is notified each time received buffers are consumed and put into the queue of available buffers. Enable this option in RPMsg-Lite to Linux configuration to allow unblocking of the Linux blocking send. The default value is 0 (RPMsg-Lite to RPMsg-Lite communication).
RL_ALLO\	(0)	It allows to define custom shared memory configuration and replacing the shared memory related global settings from rpmsg_config.h This is useful when multiple instances are running in parallel but different shared memory arrangement (vring size & alignment, buffers size & count) is required. The default value is 0 (all RPMsg_Lite instances use the same shared memory arrangement as defined by common config macros).
RL_ASSER	see rpmsg	Assert implementation.

How to format rpmsg-lite code To format code, use the application developed by Google, named *clang-format*. This tool is part of the llvm project. Currently, the clang-format 10.0.0 version is used for rpmsg-lite. The set of style settings used for clang-format is defined in the .clang-format file, placed in a root of the rpmsg-lite directory where Python script run_clang_format.py can be executed. This script executes the application named *clang-format.exe*. You need to have the path of this application in the OS's environment path, or you need to change the script.

References

[1] M. Novak, M. Cingel, Lockless Shared Memory Based Multicore Communication Protocol

Changelog RPMSG-Lite All notable changes to this project will be documented in this file.

The format is based on Keep a Changelog, and this project adheres to Semantic Versioning.

[v5.3.0]

Added

- RT700 porting layer added support to send rpmsg messages between CM33_0 <-> Hifi1 and CM33_1 <-> Hifi4 cores.
- Add new platform macro RL_PLATFORM_MAX_ISR_COUNT this will set number of IRQ count per platform. This macro is then used in environment layers to set isr_table size where irq handles are registered. It size should match the bit length of VQ_ID so all combinations can fit into table.
- Unit tests updated to improve code coverage, new unit tests added covering static allocations in rtos environment layers.

Fixed

- virtio.h removed typedef uint8_t boolean and in its place use standard C99 bool type to avoid potential type conflicts.
- env_acquire_sync_lock() and env_release_sync_lock() synchronization primitives removed
- Kconfig consolidation, when RL_ALLOW_CUSTOM_SHMEM_CONFIG enabled the platform_get_custom_shmem_config() function needs to be implemented in platform layer to provide custom shared memory configuration for RPMsg-Lite instance.

v5.2.1

Added

- Doc added RPMSG-Lite VirtIO Overview
- Doc added RPSMG-Lite Design Considerations
- Added frdmimxrt1186 unit testing

Changed

- Remove limitation that RL_BUFFER_SIZE needs to be power of 2. It just has to be more than 16 bytes, e.g. 16 bytes of rpmsg header and payload size at least 1 byte and word aligned, if not it will be aligned up.

Fixed

- Fixed CERT-C INT31-C violation in platform_notify function in rpmsg_platform.c for imxrt700_m33, imxrt700_hifi4, imxrt700_hifi1 platforms

v5.2.0

Added

- Add MCXL20 porting layer and unit testing
- New utility macro RL_CALCULATE_BUFFER_COUNT_DOWN_SAFE to safely determine maximum buffer count within shared memory while preventing integer underflow.
- RT700 platform add support for MCMGR in DSPs

Changed

- Change rpmsg_platform.c to support new MCMGR API
- Improved input validation in initialization functions to properly handle insufficient memory size conditions.
- Refactored repeated buffer count calculation pattern for better code maintainability.
- To make sure that remote has already registered IRQ there is required App level IPC mechanism to notify master about it

Fixed

- Fixed env_wait_for_link_up function to handle timeout in link state checks for baremetal and qnx environment, RL_BLOCK mode can be used to wait indefinitely.
- Fixed CERT-C INT31-C violation by adding compile-time check to ensure RL_PLATFORM_HIGHEST_LINK_ID remains within safe range for 16-bit casting in virtqueue ID creation.
- Fixed CERT-C INT30-C violations by adding protection against unsigned integer underflow in shared memory calculations, specifically in shmem_length - (uint32_t)RL_VRING_OVERHEAD and shmem_length - 2U * shmem_config.vring_size expressions.
- Fixed CERT INT31-C violation in platform_interrupt_disable() and similar functions by replacing unsafe cast from uint32_t to int32_t with a return of 0 constant.
- Fixed unsigned integer underflow in rpmsg_lite_alloc_tx_buffer() where subtracting header size from buffer size could wrap around if buffer was too small, potentially leading to incorrect buffer sizing.
- Fixed CERT-C INT31-C violation in rpmsg_lite.c where size parameter was cast from uint32_t to uint16_t without proper validation.
  - Applied consistent masking approach to both size and flags parameters: (uint16_t)(value & 0xFFFFU).
  - This fix prevents potential data loss when size values exceed 65535.
- Fixed CERT INT31-C violation in env_memset functions by explicitly converting int32_t values to unsigned char using bit masking. This prevents potential data loss or misinterpretation when passing values outside the unsigned char range (0-255) to the standard memset() function.
- Fixed CERT-C INT31-C violations in RPMsg-Lite environment porting: Added validation checks for signed-to-unsigned integer conversions to prevent data loss and misinterpretation.
  - rpmsg_env_freertos.c: Added validation before converting int32_t to UBaseType_t.
  - rpmsg_env_qnx.c: Fixed format string and added validation before assigning to mqstat fields.
  - rpmsg_env_threadx.c: Added validation to prevent integer overflow and negative values.
  - rpmsg_env_xos.c: Added range checking before casting to uint16_t.
  - rpmsg_env_zephyr.c: Added validation before passing values to k_msgq_init.
- Fixed a CERT INT31-C compliance issue in env_get_current_queue_size() function where an unsigned queue count was cast to a signed int32_t without proper validation, which could lead to lost or misinterpreted data if queue size exceeded INT32_MAX.
- Fixed CERT INT31-C violation in rpmsg_platform.c where memcmp() return value (signed int) was compared with unsigned constant without proper type handling.

- Fixed CERT INT31-C violation in rpmsg_platform.c where casting from uint32_t to uint16_t could potentially result in data loss. Changed length variable type from uint16_t to uint32_t to properly handle memory address differences without truncation.
- Fixed potential integer overflow in env_sleep_msec() function in ThreadX environment implementation by rearranging calculation order in the sleep duration formula.
- Fixed CERT-C INT31-C violation in RPMsg-Lite where bitwise NOT operations on integer constants were performed in signed integer context before being cast to unsigned. This could potentially lead to misinterpreted data on imx943 platform.
- Added RL_MAX_BUFFER_COUNT (32768U) and RL_MAX_VRING_ALIGN (65536U) limit to ensure alignment values cannot contribute to integer overflow
- Fixed CERT INT31-C violation in vring_need_event(), added cast to uint16_t for each operand.

v5.1.4 - 27-Mar-2025

Added

- Add KW43B43 porting layer

Changed

- Doxygen bump to version 1.9.6

v5.1.3 - 13-Jan-2025

Added

- Memory cache management of shared memory. Enable with #define RL_USE_DCACHE (1) in rpmsg_config.h in case of data cache is used.
- Cmake/Kconfig support added.
- Porting layers for imx95, imxrt700, mcmxw71x, mcmxw72x, kw47b42 added.

v5.1.2 - 08-Jul-2024

Changed

- Zephyr-related changes.
- Minor Misra corrections.

v5.1.1 - 19-Jan-2024

Added

- Test suite provided.
- Zephyr support added.

Changed

- Minor changes in platform and env. layers, minor test code updates.

v5.1.0 - 02-Aug-2023

Added

- RPMsg-Lite: Added aarch64 support.

Changed

- RPMsg-Lite: Increased the queue size to (2 * RL_BUFFER_COUNT) to cover zero copy cases.
- Code formatting using LLVM16.

Fixed

- Resolved issues in ThreadX env. layer implementation.

v5.0.0 - 19-Jan-2023

Added

- Timeout parameter added to rpmsg_lite_wait_for_link_up API function.

Changed

- Improved debug check buffers implementation - instead of checking the pointer fits into shared memory check the presence in the VirtIO ring descriptors list.
- VRING_SIZE is set based on number of used buffers now (as calculated in vring_init) - updated for all platforms that are not communicating to Linux rpmsg counterpart.

Fixed

- Fixed wrong RL_VRING_OVERHEAD macro comment in platform.h files
- Misra corrections.

v4.0.0 - 20-Jun-2022

Added

- Added support for custom shared memory arrangement per the RPMsg_Lite instance.
- Introduced new rpmsg_lite_wait_for_link_up() API function - this allows to avoid using busy loops in rtos environments, GitHub PR #21.

Changed

- Adjusted rpmsg_lite_is_link_up() to return RL_TRUE/RL_FALSE.

v3.2.0 - 17-Jan-2022

Added

- Added support for i.MX8 MP multicore platform.

Changed

- Improved static allocations - allow OS-specific objects being allocated statically, GitHub PR #14.
- Aligned rpmsg_env_xos.c and some platform layers to latest static allocation support.

Fixed

- Minor Misra and typo corrections, GitHub PR #19, #20.

v3.1.2 - 16-Jul-2021

Added

- Addressed MISRA 21.6 rule violation in rpmsg_env.h (use SDK's PRINTF in MCUXpressoSDK examples, otherwise stdio printf is used).
- Added environment layers for XOS.
- Added support for i.MX RT500, i.MX RT1160 and i.MX RT1170 multicore platforms.

Fixed

- Fixed incorrect description of the rpmsg_lite_get_endpoint_from_addr function.

Changed

- Updated RL_BUFFER_COUNT documentation (issue #10).
- Updated imxrt600_hifi4 platform layer.

v3.1.1 - 15-Jan-2021

Added

- Introduced RL_ALLOW_CONSUMED_BUFFERS_NOTIFICATION config option to allow opposite side notification sending each time received buffers are consumed and put into the queue of available buffers.
- Added environment layers for Threadx.
- Added support for i.MX8QM multicore platform.

Changed

- Several MISRA C-2012 violations addressed.

v3.1.0 - 22-Jul-2020

Added

- Added support for several new multicore platforms.

Fixed

- MISRA C-2012 violations fixed (7.4).
- Fixed missing lock in rpmsg_lite_rx_callback() for QNX env.
- Correction of rpmsg_lite_instance structure members description.
- Address -Waddress-of-packed-member warnings in GCC9.

Changed

- Clang update to v10.0.0, code re-formatted.

v3.0.0 - 20-Dec-2019

Added

- Added support for several new multicore platforms.

Fixed

- MISRA C-2012 violations fixed, incl. data types consolidation.
- Code formatted.

v2.2.0 - 20-Mar-2019

Added

- Added configuration macro RL_DEBUG_CHECK_BUFFERS.
- Several MISRA violations fixed.
- Added environment layers for QNX and Zephyr.
- Allow environment context required for some environment (controlled by the RL_USE_ENVIRONMENT_CONTEXT configuration macro).
- Data types consolidation.

v1.1.0 - 28-Apr-2017

Added

- Supporting i.MX6SX and i.MX7D MPU platforms.
- Supporting LPC5411x MCU platform.
- Baremental and FreeRTOS support.
- Support of copy and zero-copy transfer.
- Support of static API (without dynamic allocations).

Multicore Manager

MCUXpresso SDK : mcuxsdk-middleware-mcmgr (Multicore Manager)

Overview This repository is for MCUXpresso SDK Multicore Manager middleware delivery and it contains Multicore Manager component officially provided in NXP MCUXpresso SDK. This repository is part of the MCUXpresso SDK overall delivery which is composed of several sub-repositories/projects. Navigate to the top/parent repository mcuxsdk for the complete delivery of MCUXpresso SDK to be able to build and run Multicore Manager examples that are based on mcux-sdk-middleware-mcmgr component.

Documentation Overall details can be reviewed here: MCUXpresso SDK Online Documentation

Visit Multicore Manager - Documentation to review details on the contents in this sub-repo.

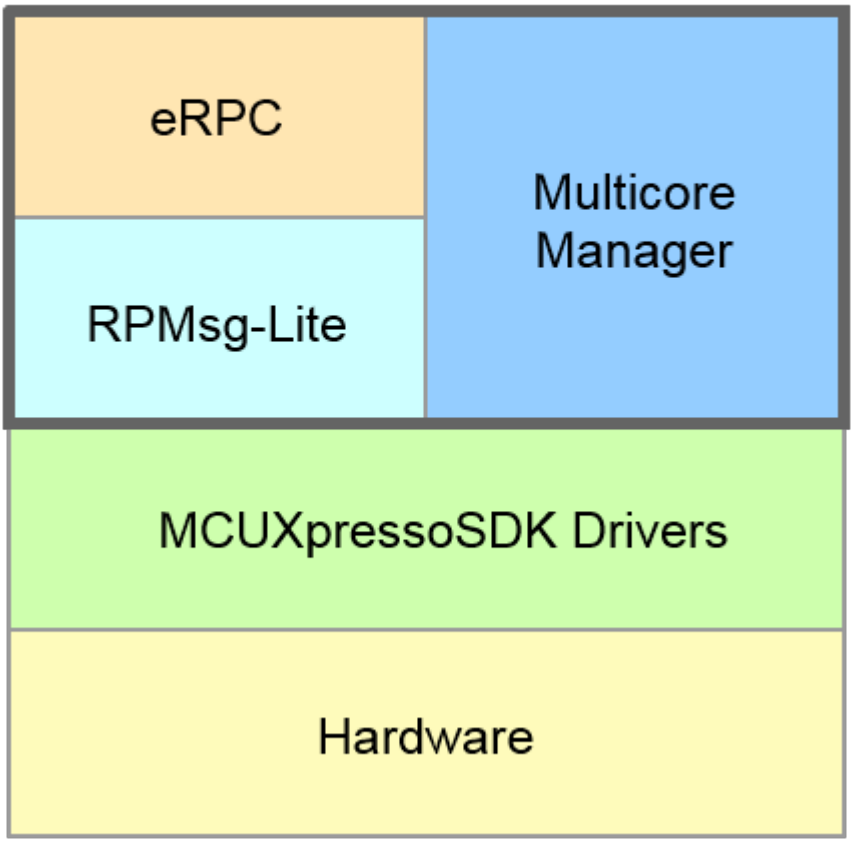
For Further API documentation, please look at doxygen documentation

Setup Instructions on how to install the MCUXpresso SDK provided from GitHub via west manifest Getting Started with SDK - Detailed Installation Instructions

Contribution We welcome and encourage the community to submit patches directly to the mcmgr project placed on github. Contributing can be managed via pull-requests. Before a pull-request is created the code should be tested and properly formatted.

Multicore Manager (MCMGR) The Multicore Manager (MCMGR) software library provides a number of services for multicore systems. This library is distributed as a part of the Multicore SDK (MCSDK). Together, the MCSDK and the MCUXpresso SDK (SDK) form a framework for development of software for NXP multicore devices.

The MCMGR component is located in the <MCUXpressoSDK_install_dir>/middleware/multicore/mcmgr directory.



The Multicore Manager provides the following major functions:

- Maintains information about all cores in system.
- Secondary/auxiliary core(s) startup and shutdown.
- Remote core monitoring and event handling.

Usage of the MCMGR software component The main use case of MCMGR is the secondary/auxiliary core start. This functionality is performed by the public API function.

Example of MCMGR usage to start secondary core:

```
#include "mcmgr.h"

void main()
{
    /* Initialize MCMGR - low level multicore management library.
       Call this function as close to the reset entry as possible,
       (into the startup sequence) to allow CoreUp event triggering. */
    MCMGR_EarlyInit();

    /* Initialize MCMGR, install generic event handlers */
    MCMGR_Init();
```

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```
    /* Boot secondary core application from the CORE1_BOOT_ADDRESS, pass "1" as startup data,␣
↪starting synchronously. */
    MCMGR_StartCore(kMCMGR_Core1, CORE1_BOOT_ADDRESS, 1, kMCMGR_Start_Synchronous);
.
.
.
    /* Stop secondary core execution. */
    MCMGR_StopCore(kMCMGR_Core1);
}
```

Some platforms allow stopping and re-starting the secondary core application again, using the MCMGR_StopCore / MCMGR_StartCore API calls. It is necessary to ensure the initially loaded image is not corrupted before re-starting, especially if it deals with the RAM target. Cache coherence has to be considered/ensured as well.

It could also happen that the secondary core application stops running correctly and the primary core application does not know about that situation. Therefore, it is beneficial to implement a mechanism for core health monitoring. The *test_heartbeat* unit test can serve as an example how to ensure that: secondary core could periodically send heartbeat signals to the primary core using MCMGR_TriggerEvent() API to indicate that it is alive and functioning properly.

Another important MCMGR feature is the ability for remote core monitoring and handling of events such as reset, exception, and application events. Application-specific callback functions for events are registered by the MCMGR_RegisterEvent() API. Triggering these events is done using the MCMGR_TriggerEvent() API. mcmgr_event_type_t enums all possible event types.

An example of MCMGR usage for remote core monitoring and event handling. Code for the primary side:

```
#include "mcmgr.h"

#define APP_RPMSG_READY_EVENT_DATA  (1)
#define APP_NUMBER_OF_CORES (2)
#define APP_SECONDARY_CORE kMCMGR_Core1

/* Callback function registered via the MCMGR_RegisterEvent() and triggered by MCMGR_TriggerEvent()␣
↪called on the secondary core side */
void RPMsgRemoteReadyEventHandler(mcmgr_core_t coreNum, uint16_t eventData, void *context)
{
    uint16_t *data = &((uint16_t *)context)[coreNum];

    *data = eventData;
}

void main()
{
    uint16_t RPMsgRemoteReadyEventData[NUMBER_OF_CORES] = {0};

    /* Initialize MCMGR - low level multicore management library.
       Call this function as close to the reset entry as possible,
       (into the startup sequence) to allow CoreUp event triggering. */
    MCMGR_EarlyInit();

    /* Initialize MCMGR, install generic event handlers */
    MCMGR_Init();

    /* Register the application event before starting the secondary core */
    MCMGR_RegisterEvent(kMCMGR_RemoteApplicationEvent, RPMsgRemoteReadyEventHandler, (void␣
↪*)RPMsgRemoteReadyEventData);
```

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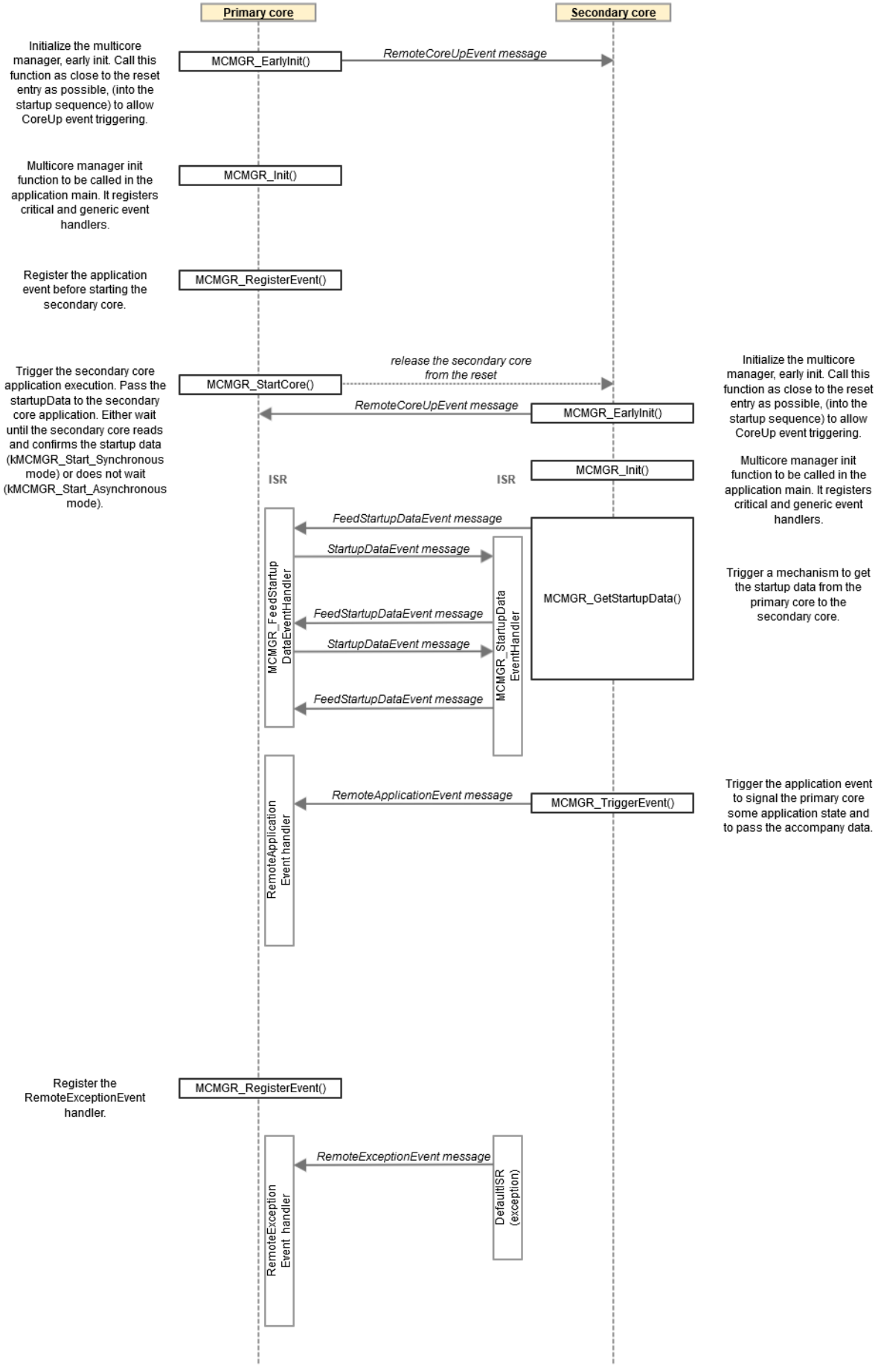
```
    /* Boot secondary core application from the CORE1_BOOT_ADDRESS, pass rpmsg_lite_base address␣
↪as startup data, starting synchronously. */
    MCMGR_StartCore(APP_SECONDARY_CORE, CORE1_BOOT_ADDRESS, (uint32_t)rpmsg_lite_
↪base, kMCMGR_Start_Synchronous);

    /* Wait until the secondary core application signals the rpmsg remote has been initialized and is ready to␣
↪communicate. */
    while(APP_RPMSG_READY_EVENT_DATA != RPMsgRemoteReadyEventData[APP_SECONDARY_
↪CORE]) {};
.
.
.
}
```

Code for the secondary side:

```
#include "mcmgr.h"

#define APP_RPMSG_READY_EVENT_DATA  (1)

void main()
{
    /* Initialize MCMGR - low level multicore management library.
       Call this function as close to the reset entry as possible,
       (into the startup sequence) to allow CoreUp event triggering. */
    MCMGR_EarlyInit();

    /* Initialize MCMGR, install generic event handlers */
    MCMGR_Init();
.
.
.

    /* Signal the to other core that we are ready by triggering the event and passing the APP_RPMSG_
↪READY_EVENT_DATA */
    MCMGR_TriggerEvent(kMCMGR_Core0, kMCMGR_RemoteApplicationEvent, APP_RPMSG_
↪READY_EVENT_DATA);
.
.
.
}
```

MCMGR Data Exchange Diagram The following picture shows how the handshakes are supposed to work between the two cores in the MCMGR software.


Primary core
Secondary core
Initialize the multicore manager, early init. Call this function as close to the reset entry as possible, (into the startup sequence) to allow CoreUp event triggering.
MCMGR_EarlyInit()
RemoteCoreUpEvent message
Multicore manager init function to be called in the application main. It registers critical and generic event handlers.
MCMGR_Init()
Register the application event before starting the secondary core.
MCMGR_RegisterEvent()
Trigger the secondary core application execution. Pass the startupData to the secondary core application. Either wait until the secondary core reads and confirms the startup data (kMCMGR_Start_Synchronous mode) or does not wait (kMCMGR_Start_Asynchronous mode).
MCMGR_StartCore()
release the secondary core from the reset
RemoteCoreUpEvent message
MCMGR_EarlyInit()
Initialize the multicore manager, early init. Call this function as close to the reset entry as possible, (into the startup sequence) to allow CoreUp event triggering.
MCMGR_Init()
Multicore manager init function to be called in the application main. It registers critical and generic event handlers.
ISR
ISR
FeedStartupDataEvent message
StartupDataEvent message
FeedStartupDataEvent message
StartupDataEvent message
FeedStartupDataEvent message
MCMGR_FeedStartup DataEventHandler
MCMGR_StartupData EventHandler
MCMGR_GetStartupData()
Trigger a mechanism to get the startup data from the primary core to the secondary core.
RemoteApplicationEvent message
MCMGR_TriggerEvent()
RemoteApplication Event handler
Trigger the application event to signal the primary core some application state and to pass the accompany data.
Register the RemoteExceptionEvent handler.
MCMGR_RegisterEvent()
RemoteExceptionEvent message
RemoteException Event handler
DefaultISR (exception)

Changelog Multicore Manager All notable changes to this project will be documented in this file.

The format is based on Keep a Changelog, and this project adheres to Semantic Versioning.

[v5.0.2]

Added

- Added gcov options and configs to support mcmgr code coverage
- Added new test_weak_mu_isr testcase for devices with MU peripheral
- Added new test_heartbeat testcase showing heartbeat mechanism between primary and secondary cores using the MCMGR

v5.0.1

Added

- Added frdmimxrt1186 unit testing

Changed

- [KW43] Rename core#1 reset control register

Fixed

- Added CX flag into CMakeLists.txt to allow c++ build compatibility.
- Fix path to mcmgr headers directory in doxyfile

v5.0.0

Added

- Added MCMGR_BUSY_POLL_COUNT macro to prevent infinite polling loops in MCMGR operations.
- Implemented timeout mechanism for all polling loops in MCMGR code.
- Added support to handle more then two cores. Breaking API change by adding parameter coreNum specifying core number in functions bellow.
  - MCMGR_GetStartupData(uint32_t *startupData, mcmgr_core_t coreNum)
  - MCMGR_TriggerEvent(mcmgr_event_type_t type, uint16_t eventData, mcmgr_core_t coreNum)
  - MCMGR_TriggerEventForce(mcmgr_event_type_t type, uint16_t eventData, mcmgr_core_t coreNum)
  - typedef void (*mcmgr_event_callback_t)(uint16_t data, void *context, mcmgr_core_t coreNum);

When registering the event with function MCMGR_RegisterEvent() user now needs to provide callbackData pointer to array of elements per every core in system (see README.md for example).In case of systems with only two cores the coreNum in callback can be ignored as events can arrive only from one core. Please see Porting guide for more details: Porting-GuideTo_v5.md

- Updated all porting files to support new MCMGR API.
- Added new platform specific include file mcmgr_platform.h. It will contain common platform specific macros that can be then used in mcmgr and application. e.g. platform core count MCMGR_CORECOUNT 4.
- Move all header files to new inc directory.
- Added new platform-specific include files inc/platform/<platform_name>/mcmgr_platform.h.

Added

- Add MCXL20 porting layer and unit testing

v4.1.7

Fixed

- mcmgr_stop_core_internal() function now returns kStatus_MCMGR_NotImplemented status code instead of kStatus_MCMGR_Success when device does not support stop of secondary core. Ports affected: kw32w1, kw45b41, kw45b42, mcxw716, mcxw727.

[v4.1.6]

Added

- Multicore Manager moved to standalone repository.
- Add porting layers for imxrt700, mcmxw727, kw47b42.
- New MCMGR_ProcessDeferredRxIsr() API added.

[v4.1.5]

Added

- Add notification into MCMGR_EarlyInit and mcmgr_early_init_internal functions to avoid using uninitialized data in their implementations.

[v4.1.4]

Fixed

- Avoid calling tx isr callbacks when respective Messaging Unit Transmit Interrupt Enable flag is not set in the CR/TCR register.
- Messaging Unit RX and status registers are cleared after the initialization.

[v4.1.3]

Added

- Add porting layers for imxrt1180.

Fixed

- mu_isr() updated to avoid calling tx isr callbacks when respective Transmit Interrupt Enable flag is not set in the CR/TCR register.
- mcmgr_mu_internal.c code adaptation to new supported SoCs.

[v4.1.2]

Fixed

- Update mcmgr_stop_core_internal() implementations to set core state to kMCMGR_ResetCoreState.

[v4.1.0]

Fixed

- Code adjustments to address MISRA C-2012 Rules

[v4.0.3]

Fixed

- Documentation updated to describe handshaking in a graphic form.
- Minor code adjustments based on static analysis tool findings

[v4.0.2]

Fixed

- Align porting layers to the updated MCUXpressoSDK feature files.

[v4.0.1]

Fixed

- Code formatting, removed unused code

[v4.0.0]

Added

- Add new MCMGR_TriggerEventForce() API.

[v3.0.0]

Removed

- Removed MCMGR_LoadApp(), MCMGR_MapAddress() and MCMGR_SignalReady()

Modified

- Modified MCMGR_GetStartupData()

Added

- Added MCMGR_EarlyInit(), MCMGR_RegisterEvent() and MCMGR_TriggerEvent()
- Added the ability for remote core monitoring and event handling

[v2.0.1]

Fixed

- Updated to be Misra compliant.

[v2.0.0]

Added

- Support for lpcxpresso54114 board.

[v1.1.0]

Fixed

- Ported to KSDK 2.0.0.

[v1.0.0]

Added

- Initial release.

eRPC

MCUXpresso SDK : mcuxsdk-middleware-erpc

Overview This repository is for MCUXpresso SDK eRPC middleware delivery and it contains eRPC component officially provided in NXP MCUXpresso SDK. This repository is part of the MCUXpresso SDK overall delivery which is composed of several sub-repositories/projects. Navigate to the top/parent repository mcuxsdk for the complete delivery of MCUXpresso SDK to be able to build and run eRPC examples that are based on mcux-sdk-middleware-erpc component.

Documentation Overall details can be reviewed here: MCUXpresso SDK Online Documentation

Visit eRPC - Documentation to review details on the contents in this sub-repo.

Setup Instructions on how to install the MCUXpresso SDK provided from GitHub via west manifest Getting Started with SDK - Detailed Installation Instructions

Contribution We welcome and encourage the community to submit patches directly to the eRPC project placed on github. Contributing can be managed via pull-requests. Before a pull-request is created the code should be tested and properly formatted.

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eRPC

About

eRPC (Embedded RPC) is an open source Remote Procedure Call (RPC) system for multichip embedded systems and heterogeneous multicore SoCs.

Unlike other modern RPC systems, such as the excellent Apache Thrift, eRPC distinguishes itself by being designed for tightly coupled systems, using plain C for remote functions, and having a small code size (<5kB). It is not intended for high performance distributed systems over a network.

eRPC does not force upon you any particular API style. It allows you to export existing C functions, without having to change their prototypes. (There are limits, of course.) And although the internal infrastructure is written in C++, most users will be able to use only the simple C setup APIs shown in the examples below.

A code generator tool called erpcgen is included. It accepts input IDL files, having an .erpc extension, that have definitions of your data types and remote interfaces, and generates the shim code that handles serialization and invocation. erpcgen can generate either C/C++ or Python code.

Example .erpc file:

```
// Define a data type.
enum LEDName { kRed, kGreen, kBlue }

// An interface is a logical grouping of functions.
interface IO {
    // Simple function declaration with an empty reply.
    set_led(LEDName whichLed, bool onOrOff) -> void
}
```

Client side usage:

```
void example_client(void) {
    erpc_transport_t transport;
    erpc_mbf_t message_buffer_factory;
    erpc_client_t client_manager;

    /* Init eRPC client infrastructure */
    transport = erpc_transport_cmsis_uart_init(Driver_USART0);
    message_buffer_factory = erpc_mbf_dynamic_init();
    client_manager = erpc_client_init(transport, message_buffer_factory);

    /* init eRPC client IO service */
    initIO_client(client_manager);

    // Now we can call the remote function to turn on the green LED.
    set_led(kGreen, true);

    /* deinit objects */
    deinitIO_client();
    erpc_client_deinit(client_manager);
    erpc_mbf_dynamic_deinit(message_buffer_factory);
```

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```
    erpc_transport_tcp_deinit(transport);
}
```

```
void example_client(void) {
    erpc_transport_t transport;
    erpc_mbf_t message_buffer_factory;
    erpc_client_t client_manager;

    /* Init eRPC client infrastructure */
    transport = erpc_transport_cmsis_uart_init(Driver_USART0);
    message_buffer_factory = erpc_mbf_dynamic_init();
    client_manager = erpc_client_init(transport, message_buffer_factory);

    /* scope for client service */
    {
        /* init eRPC client IO service */
        IO_client client(client_manager);

        // Now we can call the remote function to turn on the green LED.
        client.set_led(kGreen, true);
    }

    /* deinit objects */
    erpc_client_deinit(client_manager);
    erpc_mbf_dynamic_deinit(message_buffer_factory);
    erpc_transport_tcp_deinit(transport);
}
```

Server side usage:

```
// Implement the remote function.
void set_led(LEDName whichLed, bool onOrOff) {
    // implementation goes here
}

void example_server(void) {
    erpc_transport_t transport;
    erpc_mbf_t message_buffer_factory;
    erpc_server_t server;
    erpc_service_t service = create_IO_service();

    /* Init eRPC server infrastructure */
    transport = erpc_transport_cmsis_uart_init(Driver_USART0);
    message_buffer_factory = erpc_mbf_dynamic_init();
    server = erpc_server_init(transport, message_buffer_factory);

    /* add custom service implementation to the server */
    erpc_add_service_to_server(server, service);

    // Run the server.
    erpc_server_run();

    /* deinit objects */
    destroy_IO_service(service);
    erpc_server_deinit(server);
    erpc_mbf_dynamic_deinit(message_buffer_factory);
    erpc_transport_tcp_deinit(transport);
}
```

```
// Implement the remote function.
class IO : public IO_interface
```

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```
{
    /* eRPC call definition */
    void set_led(LEDName whichLed, bool onOrOff) override {
        // implementation goes here
    }
}

void example_server(void) {
    erpc_transport_t transport;
    erpc_mbf_t message_buffer_factory;
    erpc_server_t server;
    IO IOImpl;
    IO_service io(&IOImpl);

    /* Init eRPC server infrastructure */
    transport = erpc_transport_cmsis_uart_init(Driver_USART0);
    message_buffer_factory = erpc_mbf_dynamic_init();
    server = erpc_server_init(transport, message_buffer_factory);

    /* add custom service implementation to the server */
    erpc_add_service_to_server(server, &io);

    /* poll for requests */
    erpc_status_t err = server.run();

    /* deinit objects */
    erpc_server_deinit(server);
    erpc_mbf_dynamic_deinit(message_buffer_factory);
    erpc_transport_tcp_deinit(transport);
}
```

A number of transports are supported, and new transport classes are easy to write.

Supported transports can be found in *erpc/erpc_c/transport* folder. E.g:

- CMSIS UART
- NXP Kinetis SPI and DSPI
- POSIX and Windows serial port
- TCP/IP (mostly for testing)
- NXP RPMsg-Lite / RPMsg TTY
- SPIdev Linux
- USB CDC
- NXP Messaging Unit

eRPC is available with an unrestrictive BSD 3-clause license. See the LICENSE file for the full license text.

Releases eRPC releases

Edge releases Edge releases can by found on eRPC CircleCI webpage. Choose build of interest, then platform target and choose ARTIFACTS tab. Here you can find binary application from chosen build.

Documentation Documentation is in the wiki section.

eRPC Infrastructure documentation

Examples *Example IDL* is available in the *examples/* folder.

Plenty of eRPC multicore and multiprocessor examples can be also found in NXP MCUXpressoSDK packages. Visit https://mcuxpresso.nxp.com to configure, build and download these packages.

To get the board list with multicore support (eRPC included) use filtering based on Middleware and search for 'multicore' string. Once the selected package with the multicore middleware is downloaded, see

<MCUXpressoSDK_install_dir>/boards/<board_name>/multicore_examples for eRPC multicore examples (RPMsg_Lite or Messaging Unit transports used) or

<MCUXpressoSDK_install_dir>/boards/<board_name>/multiprocessor_examples for eRPC multiprocessor examples (UART or SPI transports used).

eRPC examples use the 'erpc_' name prefix.

Another way of getting NXP MCUXpressoSDK eRPC multicore and multiprocessor examples is using the mcux-sdk Github repo. Follow the description how to use the West tool to clone and update the mcuxsdk repo in readme Overview section. Once done the armgcc eRPC examples can be found in

mcuxsdk/examples/<board_name>/multicore_examples or in

mcuxsdk/examples/<board_name>/multiprocessor_examples folders.

You can use the evkmimxrt1170 as the board_name for instance. Similar to MCUXpressoSDK packages the eRPC examples use the 'erpc_' name prefix.

References This section provides links to interesting erpc-based projects, articles, blogs or guides:

- erpc (EmbeddedRPC) getting started notes
- ERPC Linux Local Environment Construction and Use
- The New Wio Terminal eRPC Firmware

Directories *doc* - Documentation.

doxygen - Configuration and support files for running Doxygen over the eRPC C++ infrastructure and erpcgen code.

erpc_c - Holds C/C++ infrastructure for eRPC. This is the code you will include in your application.

erpc_python - Holds Python version of the eRPC infrastructure.

erpcgen - Holds source code for erpcgen and makefiles or project files to build erpcgen on Windows, Linux, and OS X.

erpcsniffer - Holds source code for erpcsniffer application.

examples - Several example IDL files.

mk - Contains common makefiles for building eRPC components.

test - Client/server tests. These tests verify the entire communications path from client to server and back.

utilities - Holds utilities which bring additional benefit to eRPC apps developers.

Building and installing These build instructions apply to host PCs and embedded Linux. For bare metal or RTOS embedded environments, you should copy the *erpc_c* directory into your application sources.

CMake and KConfig build:

It builds a static library of the eRPC C/C++ infrastructure, the erpcgen executable, and optionally the unit tests and examples.

CMake is compatible with gcc and clang. On Windows local MingGW downloaded by *script* can be used.

Make build:

It builds a static library of the eRPC C/C++ infrastructure, the erpcgen executable, and optionally the unit tests.

The makefiles are compatible with gcc or clang on Linux, OS X, and Cygwin. A Windows build of erpcgen using Visual Studio is also available in the *erpcgen/VisualStudio_v14* directory. There is also an Xcode project file in the *erpcgen* directory, which can be used to build erpcgen for OS X.

Requirements eRPC now support building **erpcgen**, **erpc_lib**, **tests** and **C examples** using CMake.

Requirements when using CMake:

- **CMake** (minimal version 3.20.0)
- Generator - **Make**, **Ninja**, ...
- **C/C++ compiler** - **GCC**, **CLANG**, ...
- **Binson** - https://www.gnu.org/software/bison/
- **Flex** - https://github.com/westes/flex/

Requirements when using Make:

- **Make**
- **C/C++ compiler** - **GCC**, **CLANG**, ...
- **Binson** - https://www.gnu.org/software/bison/
- **Flex** - https://github.com/westes/flex/

Windows Related steps to build **erpcgen** using **Visual Studio** are described in erpcgen/VisualStudio_v14/readme_erpcgen.txt.

To install MinGW, Bison, Flex locally on Windows:

```
./install_dependencies.ps1
* ```

#### Linux

```bash
./install_dependencies.sh
```

Mandatory for case, when build for different architecture is needed

- gcc-multilib, g++-multilib

Mac OS X
```

```
./install_dependencies.sh
```

Building

CMake and KConfig eRPC use CMake and KConfig to configurate and build eRPC related targets. KConfig can be edited by *prj.conf* or *menuconfig* when building.

Generate project, config and build. In *erpc/* execute:

```
cmake -B ./build # in erpc/build generate cmake project
cmake --build ./build --target menuconfig # Build menuconfig and configurate erpcgen, erpc_lib, tests and␣
↪examples
cmake --build ./build # Build all selected target from prj.conf/menuconfig
```

**CMake will use the system's default compilers and generator

If you want to use Windows and locally installed MinGW, use *CMake preset* :

```
cmake --preset mingw64 # Generate project in ./build using mingw64's make and compilers
cmake --build ./build --target menuconfig # Build menuconfig and configurate erpcgen, erpc_lib, tests and␣
↪examples
cmake --build ./build # Build all selected target from prj.conf/menuconfig
```

Make To build the library and erpcgen, run from the repo root directory:

```
make
```

To install the library, erpcgen, and include files, run:

```
make install
```

You may need to sudo the `make install`.

By default this will install into `/usr/local`. If you want to install elsewhere, set the `PREFIX` environment variable. Example for installing into `/opt`:

```
make install PREFIX=/opt
```

List of top level Makefile targets:

- `erpc`: build the liberpc.a static library
- `erpcgen`: build the erpcgen tool
- `erpcsniffer`: build the sniffer tool
- `test`: build the unit tests under the *test* directory
- `all`: build all of the above
- `install`: install liberpc.a, erpcgen, and include files

eRPC code is validated with respect to the C++ 11 standard.

Installing for Python To install the Python infrastructure for eRPC see instructions in the *erpc python readme*.

Known issues and limitations

- Static allocations controlled by the ERPC_ALLOCATION_POLICY config macro are not fully supported yet, i.e. not all erpc objects can be allocated statically now. It deals with the ongoing process and the full static allocations support will be added in the future.

Code providing Repository on Github contains two main branches: **main** and **develop**. Code is developed on **develop** branch. Release version is created via merging **develop** branch into **main** branch.

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eRPC Getting Started

Overview This *Getting Started User Guide* shows software developers how to use Remote Procedure Calls (RPC) in embedded multicore microcontrollers (eRPC).

The eRPC documentation is located in the *<MCUXpressoSDK_install_dir>/ middleware/multicore/erpc/doc* folder.

Create an eRPC application This section describes a generic way to create a client/server eRPC application:

1. **Design the eRPC application:** Decide which data types are sent between applications, and define functions that send/receive this data.
2. **Create the IDL file:** The IDL file contains information about data types and functions used in an eRPC application, and is written in the IDL language.
3. **Use the eRPC generator tool:** This tool takes an IDL file and generates the shim code for the client and the server-side applications.
4. **Create an eRPC application:**
    1. Create two projects, where one project is for the client side (primary core) and the other project is for the server side (secondary core).
    2. Add generated files for the client application to the client project, and add generated files for the server application to the server project.
    3. Add infrastructure files.
    4. Add user code for client and server applications.
    5. Set the client and server project options.
5. **Run the eRPC application:** Run both the server and the client applications. Make sure that the server has been run before the client request was sent.

A specific example follows in the next section.

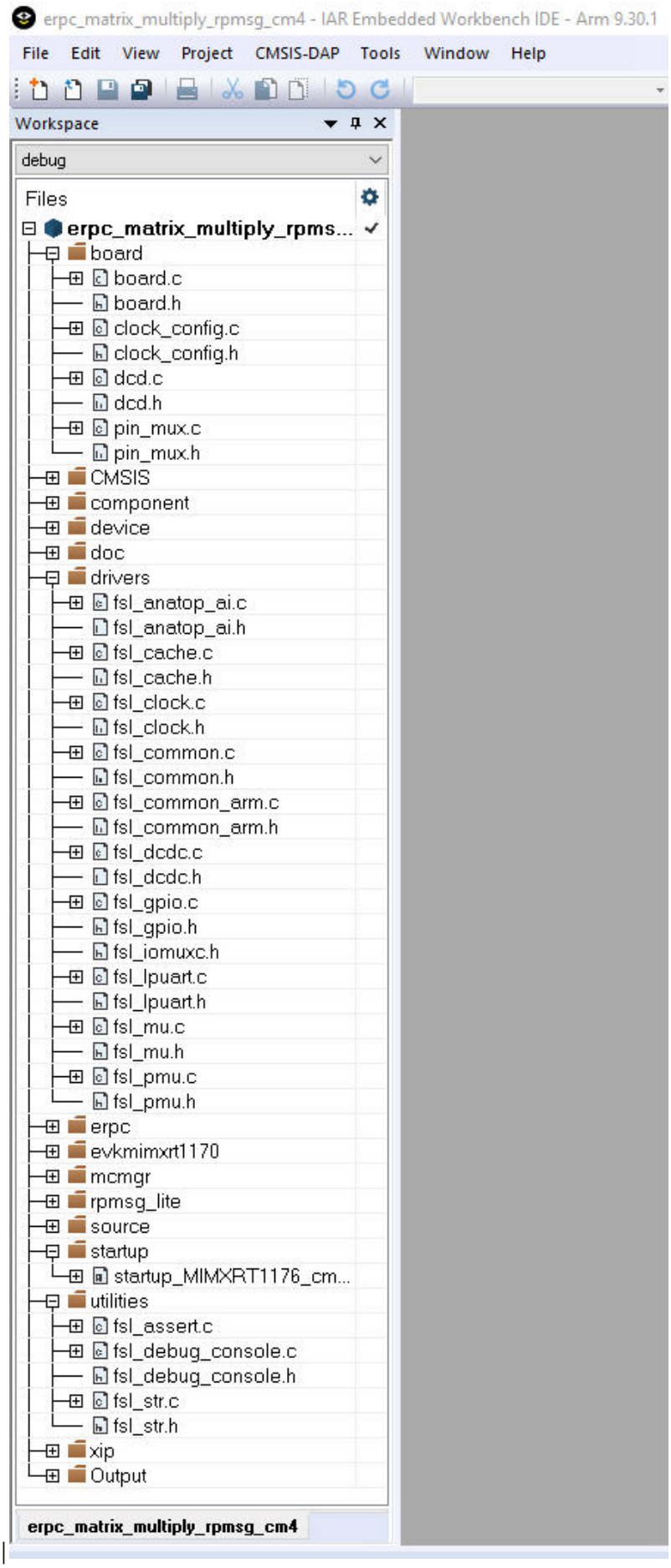
Multicore server application The “Matrix multiply” eRPC server project is located in the following folder:

<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_matrix_multiply_rpmsg/cm4/iar

The project files for the eRPC server have the _cm4 suffix.

Server project basic source files The startup files, board-related settings, peripheral drivers, and utilities belong to the basic project source files and form the skeleton of all MCUXpresso SDK applications. These source files are located in:

- *<MCUXpressoSDK_install_dir>/devices/<device>*
- *<MCUXpressoSDK_install_dir>/boards/<board_name>/multicore_examples/<example_name>/*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fsl_dcdc.c
fsl_dcdc.h
fsl_gpio.c
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fsl_iomuxc.h
fsl_lpuart.c
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fsl_mu.c
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erpc
evkmimxrt1170
mcmgr
rpmsg_lite
source
startup
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utilities
fsl_assert.c
fsl_debug_console.c
fsl_debug_console.h
fsl_str.c
fsl_str.h
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erpc_matrix_multiply_rpmsg_cm4

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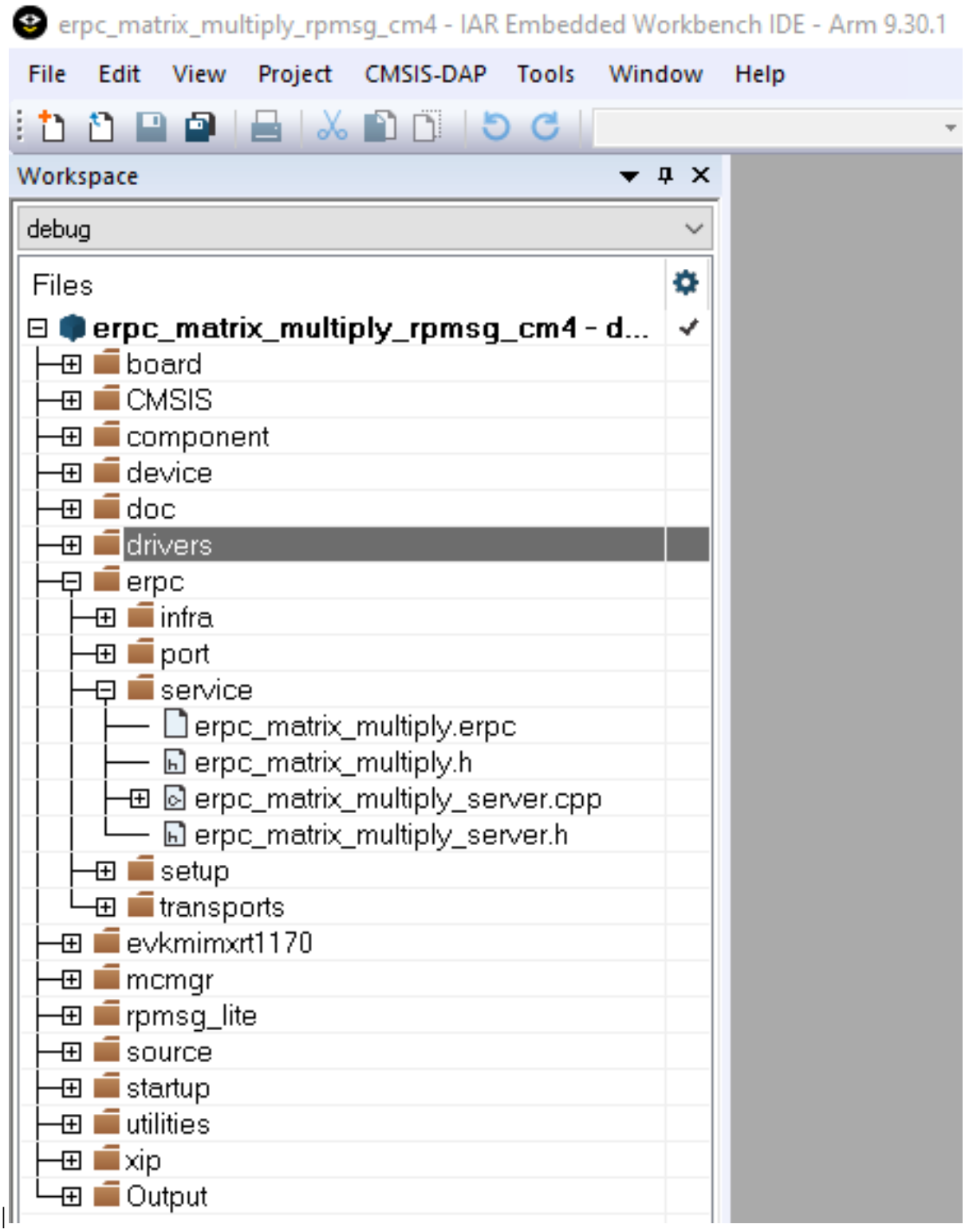
Parent topic: Multicore server application

Server related generated files The server-related generated files are:

- erpc_matric_multiply.h
- erpc_matrix_multiply_server.h
- erpc_matrix_multiply_server.cpp

The server-related generated files contain the shim code for functions and data types declared in the IDL file. These files also contain functions for the identification of client requested functions, data deserialization, calling requested function's implementations, and data serialization and return, if requested by the client. These shim code files can be found in the following folder:

<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_common/erpc_matrix_multiply/s



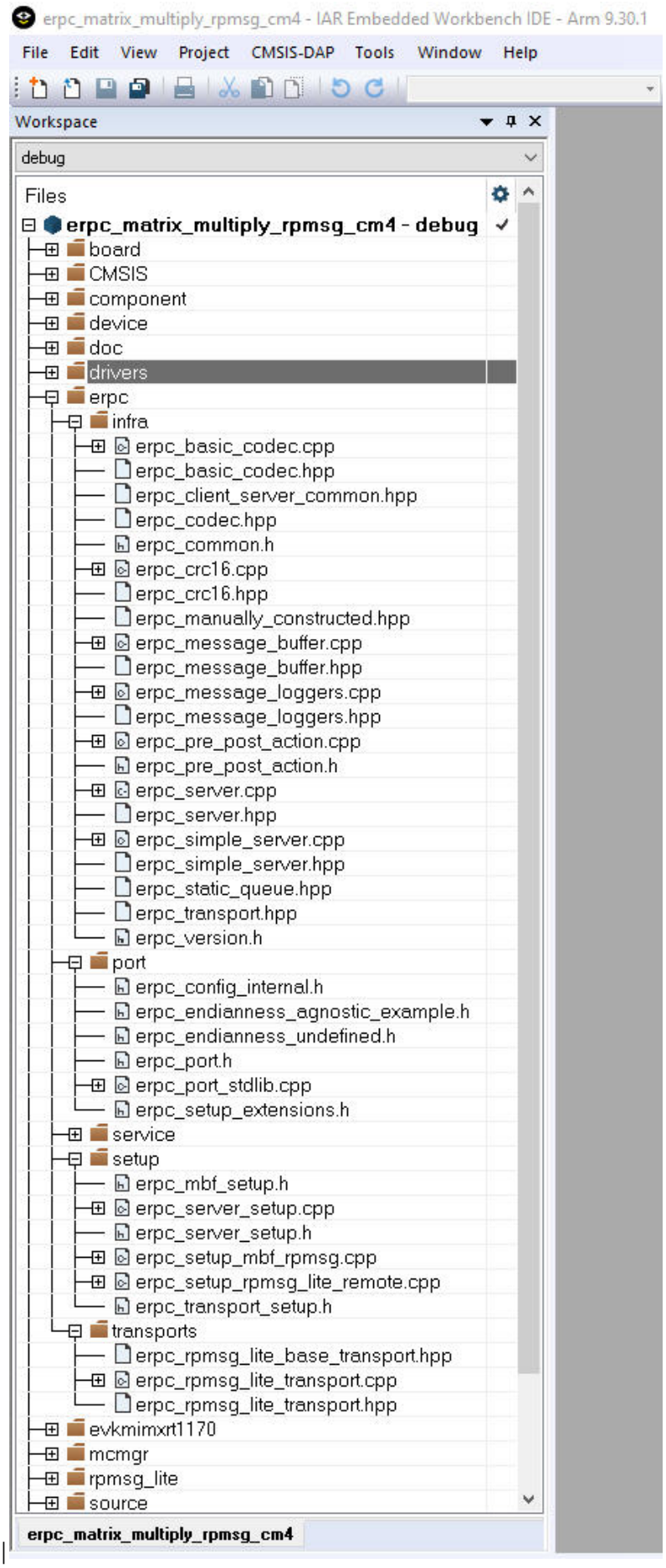
Parent topic: Multicore server application

Server infrastructure files The eRPC infrastructure files are located in the following folder:

<MCUXpressoSDK_install_dir>/middleware/multicore/erpc/erpc_c

The **erpc_c** folder contains files for creating eRPC client and server applications in the *C/C++* language. These files are distributed into subfolders.

- The **infra** subfolder contains C++ infrastructure code used to build server and client applications.
  - Four files, erpc_server.hpp, erpc_server.cpp, erpc_simple_server.hpp, and erpc_simple_server.cpp, are used for running the eRPC server on the server-side applications. The simple server is currently the only implementation of the server, and its role is to catch client requests, identify and call requested functions, and send data back when requested.
  - Three files (erpc_codec.hpp, erpc_basic_codec.hpp, and erpc_basic_codec.cpp) are used for codecs. Currently, the basic codec is the initial and only implementation of the codecs.
  - The erpc_common.hpp file is used for common eRPC definitions, typedefs, and enums.
  - The erpc_manually_constructed.hpp file is used for allocating static storage for the used objects.
  - Message buffer files are used for storing serialized data: erpc_message_buffer.h and erpc_message_buffer.cpp.
  - The erpc_transport.h file defines the abstract interface for transport layer.
- The **port** subfolder contains the eRPC porting layer to adapt to different environments.
  - erpc_port.h file contains definition of erpc_malloc() and erpc_free() functions.
  - erpc_port_stdlib.cpp file ensures adaptation to stdlib.
  - erpc_config_internal.h internal erpc configuration file.
- The **setup** subfolder contains a set of plain C APIs that wrap the C++ infrastructure, providing client and server init and deinit routines that greatly simplify eRPC usage in C-based projects. No knowledge of C++ is required to use these APIs.
  - The erpc_server_setup.h and erpc_server_setup.cpp files needs to be added into the "Matrix multiply" example project to demonstrate the use of C-wrapped functions in this example.
  - The erpc_transport_setup.h and erpc_setup_rpmsg_lite_remote.cpp files needs to be added into the project in order to allow the C-wrapped function for transport layer setup.
  - The erpc_mbf_setup.h and erpc_setup_mbf_rpmsg.cpp files needs to be added into the project in order to allow message buffer factory usage.
- The **transports** subfolder contains transport classes for the different methods of communication supported by eRPC. Some transports are applicable only to host PCs, while others are applicable only to embedded or multicore systems. Most transports have corresponding client and server setup functions in the setup folder.
  - RPMsg-Lite is used as the transport layer for the communication between cores, erpc_rpmsg_lite_base_transport.hpp, erpc_rpmsg_lite_transport.hpp, and erpc_rpmsg_lite_transport.cpp files need to be added into the server project.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erpc_transport.hpp
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erpc_endianness_agnostic_example.h
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erpc_port.h
erpc_port_stdlib.cpp
erpc_setup_extensions.h
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erpc_setup_rpmsg_lite_remote.cpp
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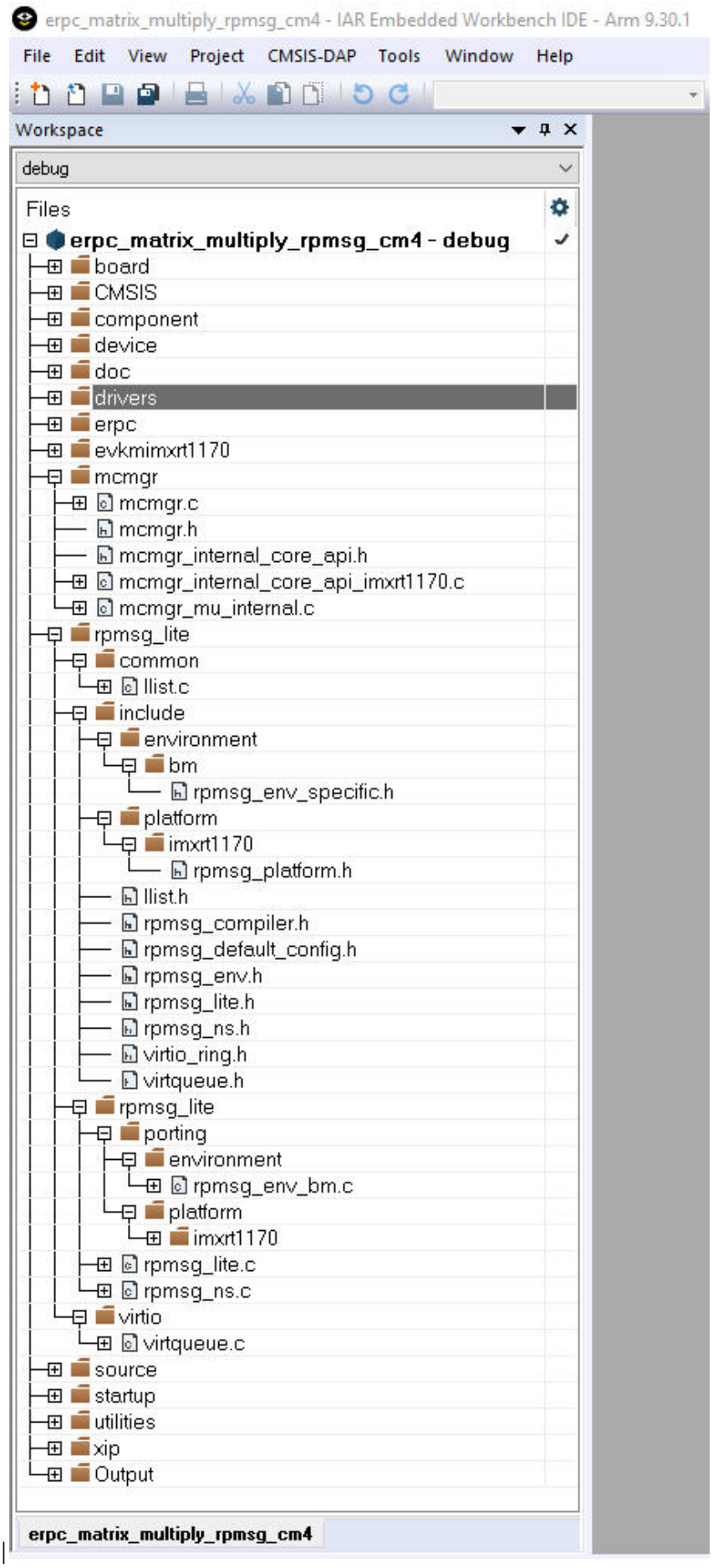
Parent topic: Multicore server application

Server multicore infrastructure files Because of the RPMsg-Lite (transport layer), it is also necessary to include RPMsg-Lite related files, which are in the following folder:

<MCUXpressoSDK_install_dir>/middleware/multicore/rpmsg_lite/

The multicore example applications also use the Multicore Manager software library to control the secondary core startup and shutdown. These source files are located in the following folder:

<MCUXpressoSDK_install_dir>/middleware/multicore/mcmgr/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drivers
erpc
evkmimxrt1170
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mcmgr.c
mcmgr.h
mcmgr_internal_core_api.h
mcmgr_internal_core_api_imxrt1170.c
mcmgr_mu_internal.c
rpmsg_lite
common
llist.c
include
environment
bm
rpmsg_env_specific.h
platform
imxrt1170
rpmsg_platform.h
llist.h
rpmsg_compiler.h
rpmsg_default_config.h
rpmsg_env.h
rpmsg_lite.h
rpmsg_ns.h
virtio_ring.h
virtqueue.h
rpmsg_lite
porting
environment
rpmsg_env_bm.c
platform
imxrt1170
rpmsg_lite.c
rpmsg_ns.c
virtio
virtqueue.c
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startup
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Output
erpc_matrix_multiply_rpmsg_cm4

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Parent topic: Multicore server application

Server user code The server's user code is stored in the main_core1.c file, located in the following folder:

<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_matrix_multiply_rpmsg/cm4

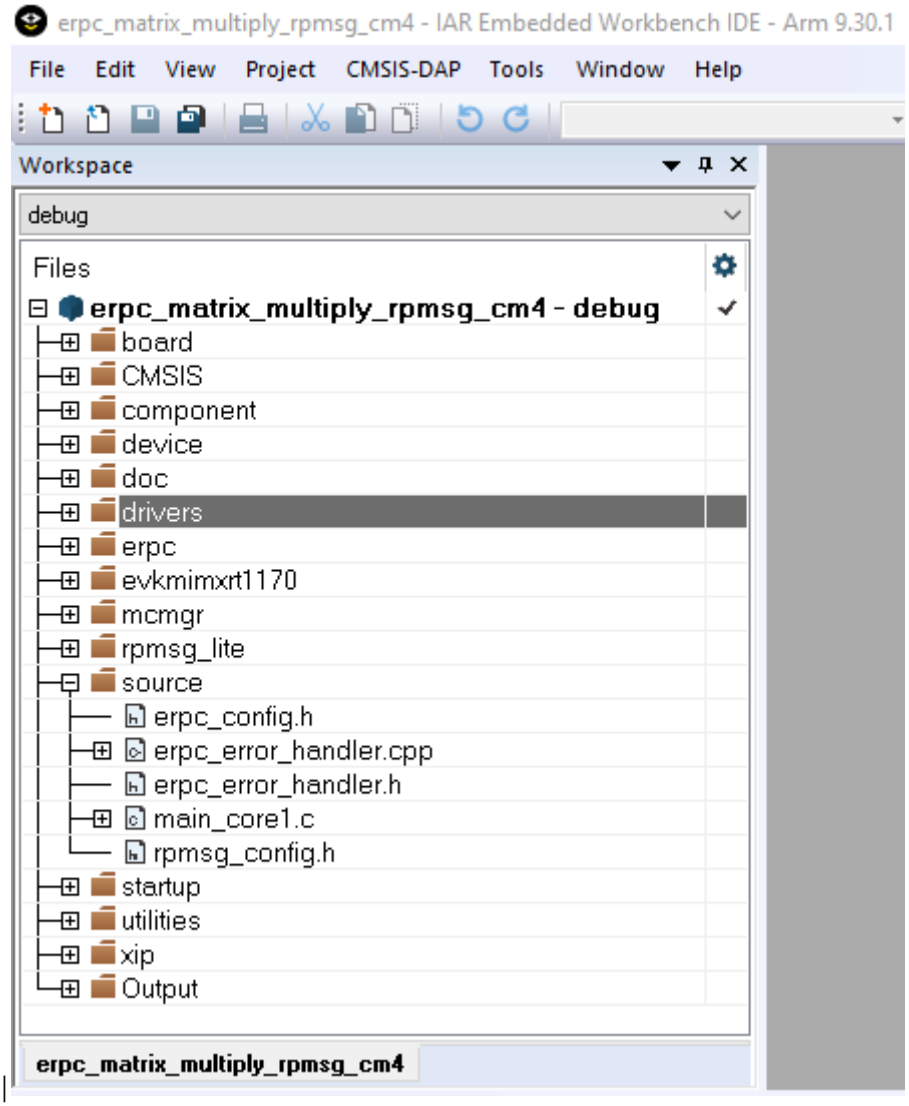
The main_core1.c file contains two functions:

- The **main()** function contains the code for the target board and eRPC server initialization. After the initialization, the matrix multiply service is added and the eRPC server waits for client's requests in the while loop.
- The **erpcMatrixMultiply()** function is the user implementation of the eRPC function defined in the IDL file.
- There is the possibility to write the application-specific eRPC error handler. The eRPC error handler of the matrix multiply application is implemented in the erpc_error_handler.h and erpc_error_handler.cpp files.

The eRPC-relevant code is captured in the following code snippet:

```
/* erpcMatrixMultiply function user implementation */
void erpcMatrixMultiply(const Matrix *matrix1, const Matrix *matrix2, Matrix *result_matrix)
{
  ...
}
int main()
{
  ...
  /* RPMsg-Lite transport layer initialization */
  erpc_transport_t transport;
  transport = erpc_transport_rpmsg_lite_remote_init(src, dst, (void*)startupData,
  ERPC_TRANSPORT_RPMSG_LITE_LINK_ID, SignalReady, NULL);
  ...
  /* MessageBufferFactory initialization */
  erpc_mbf_t message_buffer_factory;
  message_buffer_factory = erpc_mbf_rpmsg_init(transport);
  ...
  /* eRPC server side initialization */
  erpc_server_t server;
  server = erpc_server_init(transport, message_buffer_factory);
  ...
  /* Adding the service to the server */
  erpc_service_t service = create_MatrixMultiplyService_service();
  erpc_add_service_to_server(server, service);
  ...
  while (1)
  {
    /* Process eRPC requests */
    erpc_status_t status = erpc_server_poll(server);
    /* handle error status */
    if (status != kErpcStatus_Success)
    {
      /* print error description */
      erpc_error_handler(status, 0);
      ...
    }
    ...
  }
}
```

Except for the application main file, there are configuration files for the RPMsg-Lite (rpmsg_config.h) and eRPC (erpc_config.h), located in the *<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_matrix_multiply_rpmsg* folder.



Parent topic: Multicore server application

Parent topic:*Create an eRPC application*

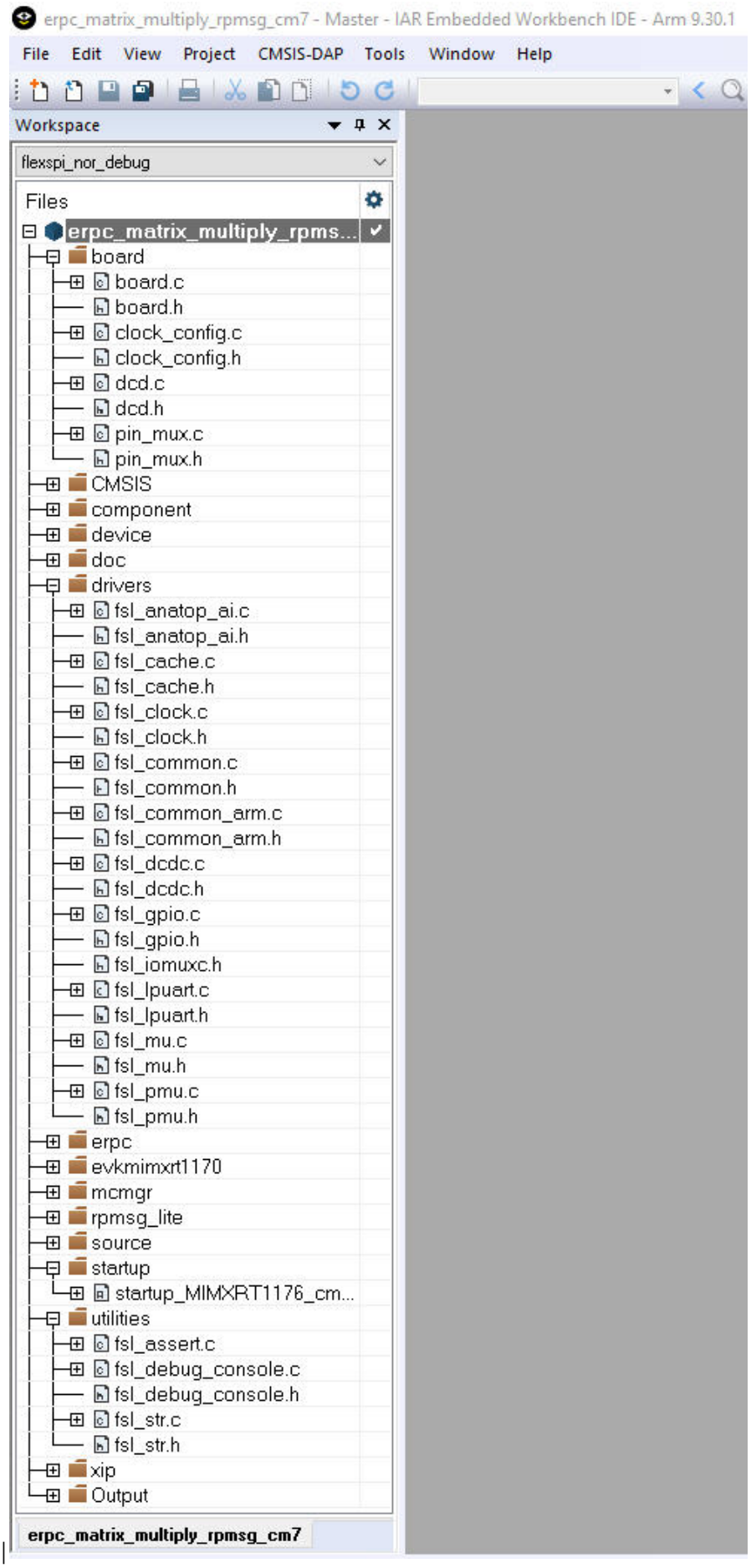
Multicore client application The "Matrix multiply" eRPC client project is located in the following folder:

<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_matrix_multiply_rpmsg/cm7/iar

Project files for the eRPC client have the _cm7 suffix.

Client project basic source files The startup files, board-related settings, peripheral drivers, and utilities belong to the basic project source files and form the skeleton of all MCUXpresso SDK applications. These source files are located in the following folders:

- *<MCUXpressoSDK_install_dir>/devices/<device>*
- *<MCUXpressoSDK_install_dir>/boards/<board_name>/multicore_examples/<example_name>/*


erpc_matrix_multiply_rpmsg_cm7 - Master - IAR Embedded Workbench IDE - Arm 9.30.1
File Edit View Project CMSIS-DAP Tools Window Help
Workspace
flexspi_nor_debug
Files
erpc_matrix_multiply_rpms...
board
board.c
board.h
clock_config.c
clock_config.h
dcd.c
dcd.h
pin_mux.c
pin_mux.h
CMSIS
component
device
doc
drivers
fsl_anatop_ai.c
fsl_anatop_ai.h
fsl_cache.c
fsl_cache.h
fsl_clock.c
fsl_clock.h
fsl_common.c
fsl_common.h
fsl_common_arm.c
fsl_common_arm.h
fsl_dcdc.c
fsl_dcdc.h
fsl_gpio.c
fsl_gpio.h
fsl_iomuxc.h
fsl_lpuart.c
fsl_lpuart.h
fsl_mu.c
fsl_mu.h
fsl_pmu.c
fsl_pmu.h
erpc
evkmimxrt1170
mcmgr
rpmsg_lite
source
startup
startup_MIMXRT1176_cm...
utilities
fsl_assert.c
fsl_debug_console.c
fsl_debug_console.h
fsl_str.c
fsl_str.h
xip
Output
erpc_matrix_multiply_rpmsg_cm7

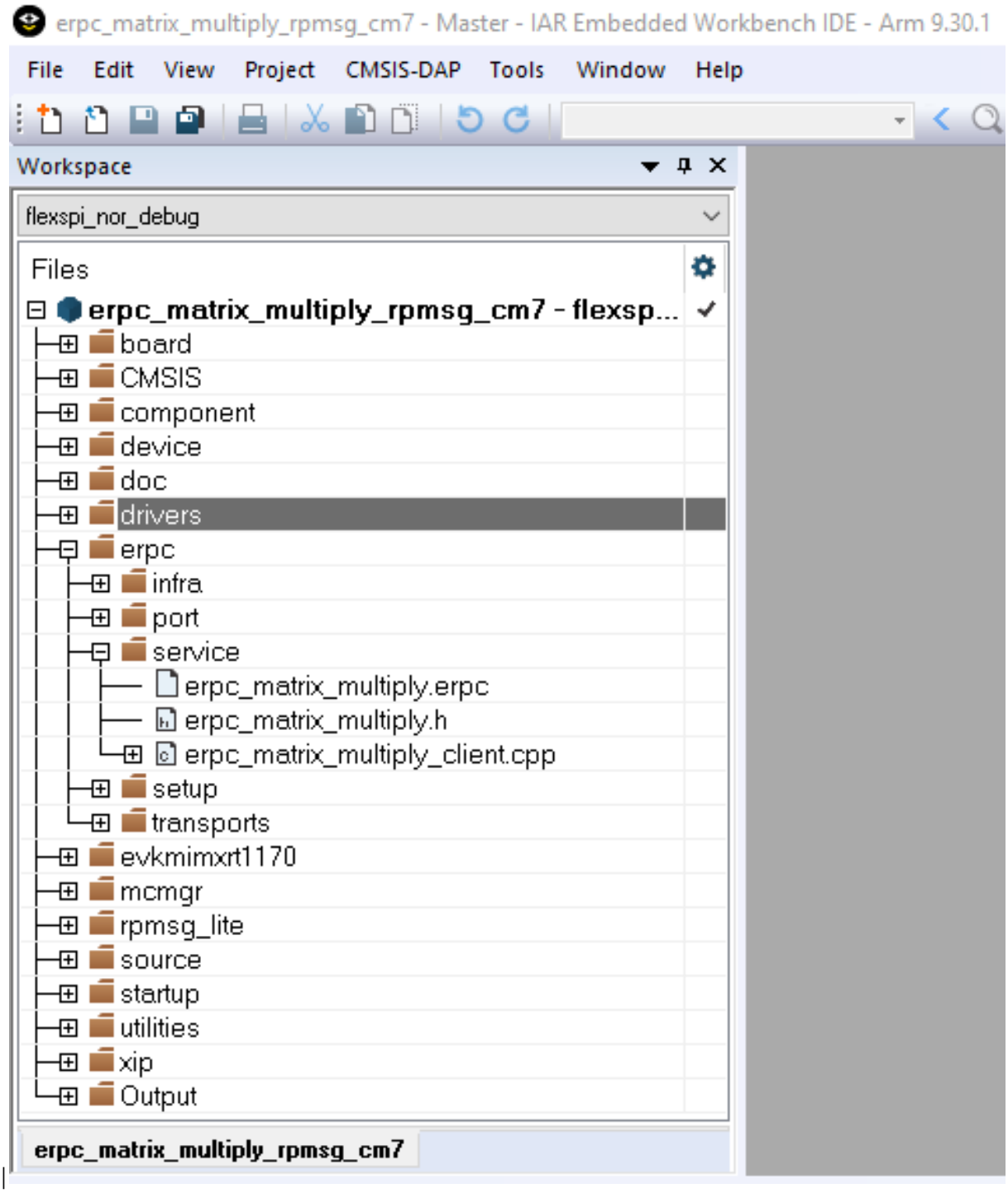
|

Parent topic: Multicore client application

Client-related generated files The client-related generated files are:

- erpc_matric_multiply.h
- erpc_matrix_multiply_client.cpp

These files contain the shim code for the functions and data types declared in the IDL file. These functions also call methods for codec initialization, data serialization, performing eRPC requests, and de-serializing outputs into expected data structures (if return values are expected). These shim code files can be found in the *<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_common/erpc_matrix_multiply/service/* folder.



Parent topic: Multicore client application

Client infrastructure files The eRPC infrastructure files are located in the following folder:

<MCUXpressoSDK_install_dir>/middleware/multicore/erpc/erpc_c

The **erpc_c** folder contains files for creating eRPC client and server applications in the C/C++ language. These files are distributed into subfolders.

- The **infra** subfolder contains C++ infrastructure code used to build server and client applications.

- Two files, erpc_client_manager.h and erpc_client_manager.cpp, are used for managing the client-side application. The main purpose of the client files is to create, perform, and release eRPC requests.
- Three files (erpc_codec.hpp, erpc_basic_codec.hpp, and erpc_basic_codec.cpp) are used for codecs. Currently, the basic codec is the initial and only implementation of the codecs.
- erpc_common.h file is used for common eRPC definitions, typedefs, and enums.
- erpc_manually_constructed.hpp file is used for allocating static storage for the used objects.
- Message buffer files are used for storing serialized data: erpc_message_buffer.hpp and erpc_message_buffer.cpp.
- erpc_transport.hpp file defines the abstract interface for transport layer.

The **port** subfolder contains the eRPC porting layer to adapt to different environments.

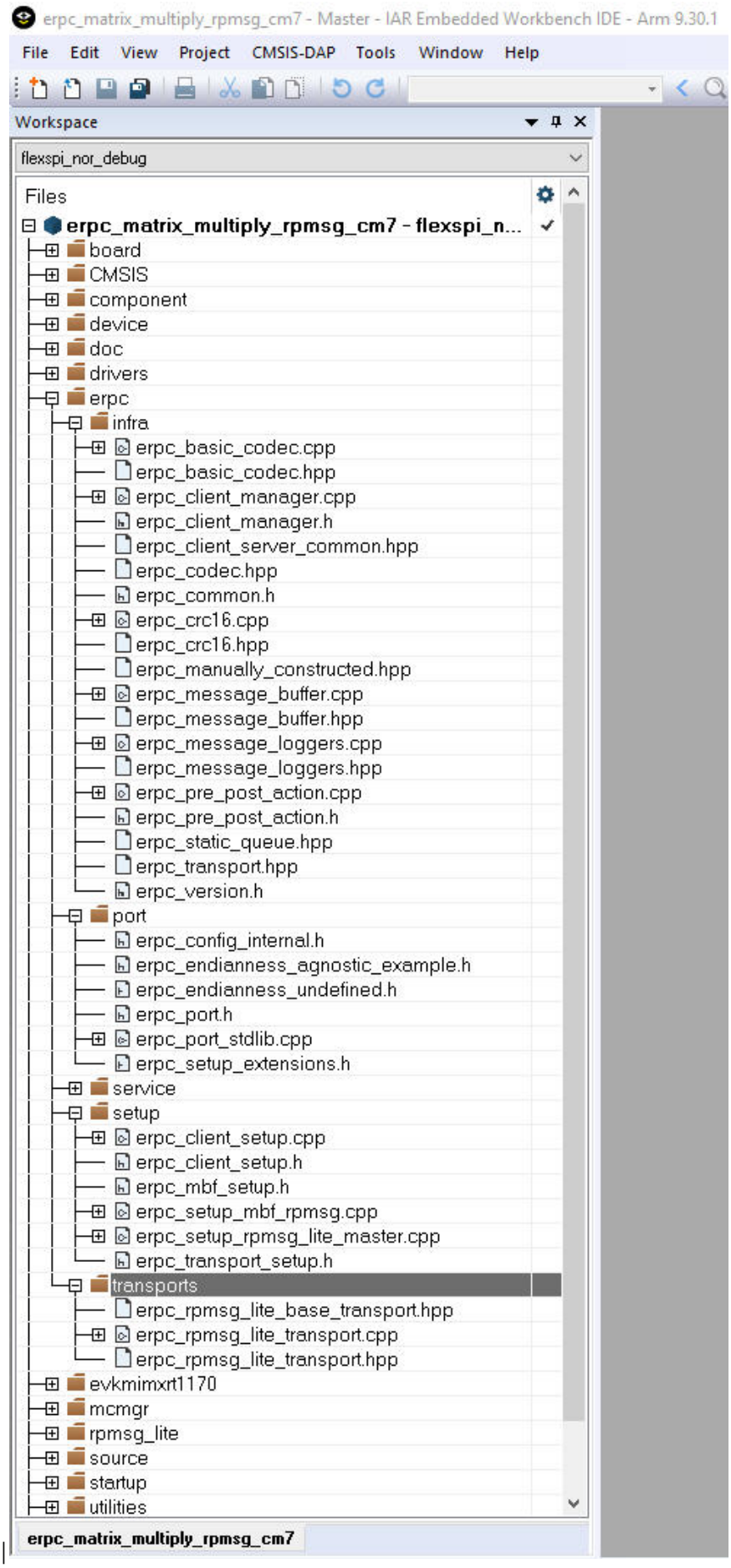
- erpc_port.h file contains definition of erpc_malloc() and erpc_free() functions.
- erpc_port_stdlib.cpp file ensures adaptation to stdlib.
- erpc_config_internal.h internal eRPC configuration file.

The **setup** subfolder contains a set of plain C APIs that wrap the C++ infrastructure, providing client and server init and deinit routines that greatly simplify eRPC usage in C-based projects. No knowledge of C++ is required to use these APIs.

- erpc_client_setup.h and erpc_client_setup.cpp files needs to be added into the "Matrix multiply" example project to demonstrate the use of C-wrapped functions in this example.
- erpc_transport_setup.h and erpc_setup_rpmsg_lite_master.cpp files needs to be added into the project in order to allow C-wrapped function for transport layer setup.
- erpc_mbf_setup.h and erpc_setup_mbf_rpmsg.cpp files needs to be added into the project in order to allow message buffer factory usage.

The **transports** subfolder contains transport classes for the different methods of communication supported by eRPC. Some transports are applicable only to host PCs, while others are applicable only to embedded or multicore systems. Most transports have corresponding client and server setup functions, in the setup folder.

- RPMsg-Lite is used as the transport layer for the communication between cores, erpc_rpmsg_lite_base_transport.hpp, erpc_rpmsg_lite_transport.hpp, and erpc_rpmsg_lite_transport.cpp files needs to be added into the client project.


erpc_matrix_multiply_rpmsg_cm7 - Master - IAR Embedded Workbench IDE - Arm 9.30.1
File Edit View Project CMSIS-DAP Tools Window Help
Workspace
flexspi_nor_debug
Files
erpc_matrix_multiply_rpmsg_cm7 - flexspi_n...
board
CMSIS
component
device
doc
drivers
erpc
infra
erpc_basic_codec.cpp
erpc_basic_codec.hpp
erpc_client_manager.cpp
erpc_client_manager.h
erpc_client_server_common.hpp
erpc_codec.hpp
erpc_common.h
erpc_crc16.cpp
erpc_crc16.hpp
erpc_manually_constructed.hpp
erpc_message_buffer.cpp
erpc_message_buffer.hpp
erpc_message_loggers.cpp
erpc_message_loggers.hpp
erpc_pre_post_action.cpp
erpc_pre_post_action.h
erpc_static_queue.hpp
erpc_transport.hpp
erpc_version.h
port
erpc_config_internal.h
erpc_endianness_agnostic_example.h
erpc_endianness_undefined.h
erpc_port.h
erpc_port_stdlib.cpp
erpc_setup_extensions.h
service
setup
erpc_client_setup.cpp
erpc_client_setup.h
erpc_mbf_setup.h
erpc_setup_mbf_rpmsg.cpp
erpc_setup_rpmsg_lite_master.cpp
erpc_transport_setup.h
transports
erpc_rpmsg_lite_base_transport.hpp
erpc_rpmsg_lite_transport.cpp
erpc_rpmsg_lite_transport.hpp
evkmimxrt1170
mcmgr
rpmsg_lite
source
startup
utilities
erpc_matrix_multiply_rpmsg_cm7

|

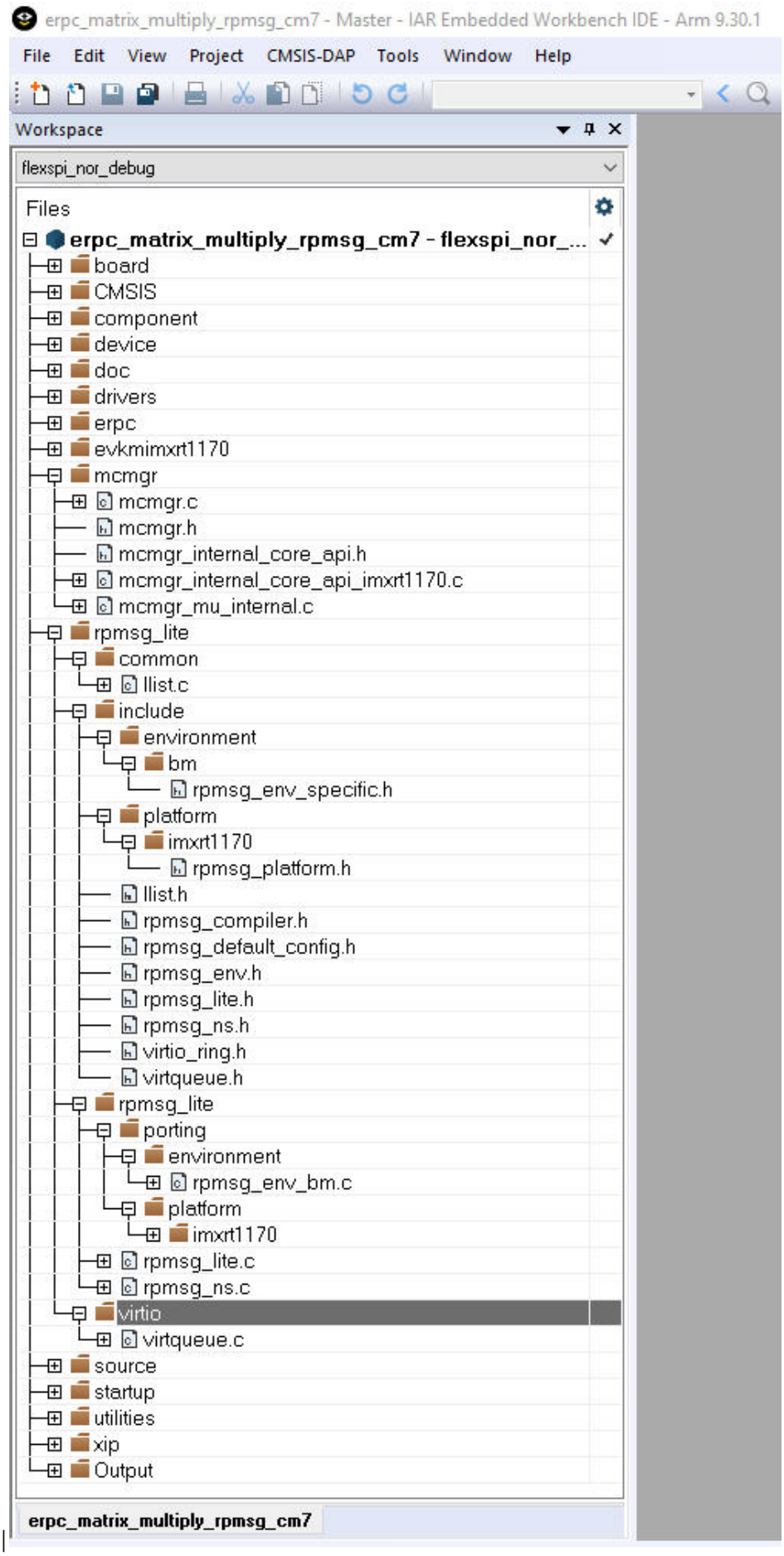
Parent topic: Multicore client application

Client multicore infrastructure files Because of the RPMsg-Lite (transport layer), it is also necessary to include RPMsg-Lite related files, which are in the following folder:

<MCUXpressoSDK_install_dir>/middleware/multicore/rpmsg_lite/

The multicore example applications also use the Multicore Manager software library to control the secondary core startup and shutdown. These source files are located in the following folder:

<MCUXpressoSDK_install_dir>/middleware/multicore/mcmgr/


erpc_matrix_multiply_rpmsg_cm7 - Master - IAR Embedded Workbench IDE - Arm 9.30.1
File Edit View Project CMSIS-DAP Tools Window Help
Workspace
flexspi_nor_debug
Files
erpc_matrix_multiply_rpmsg_cm7 - flexspi_nor_...
board
CMSIS
component
device
doc
drivers
erpc
evkmimxrt1170
mcmgr
mcmgr.c
mcmgr.h
mcmgr_internal_core_api.h
mcmgr_internal_core_api_imxrt1170.c
mcmgr_mu_internal.c
rpmsg_lite
common
llist.c
include
environment
bm
rpmsg_env_specific.h
platform
imxrt1170
rpmsg_platform.h
llist.h
rpmsg_compiler.h
rpmsg_default_config.h
rpmsg_env.h
rpmsg_lite.h
rpmsg_ns.h
virtio_ring.h
virtqueue.h
rpmsg_lite
porting
environment
rpmsg_env_bm.c
platform
imxrt1170
rpmsg_lite.c
rpmsg_ns.c
virtio
virtqueue.c
source
startup
utilities
xip
Output
erpc_matrix_multiply_rpmsg_cm7

|

Parent topic: Multicore client application

Client user code The client's user code is stored in the main_core0.c file, located in the following folder:

<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_example/erpc_matrix_multiply_rpmsg/cm7

The main_core0.c file contains the code for target board and eRPC initialization.

- After initialization, the secondary core is released from reset.
- When the secondary core is ready, the primary core initializes two matrix variables.
- The erpcMatrixMultiply eRPC function is called to issue the eRPC request and get the result.

It is possible to write the application-specific eRPC error handler. The eRPC error handler of the matrix multiply application is implemented in erpc_error_handler.h and erpc_error_handler.cpp files.

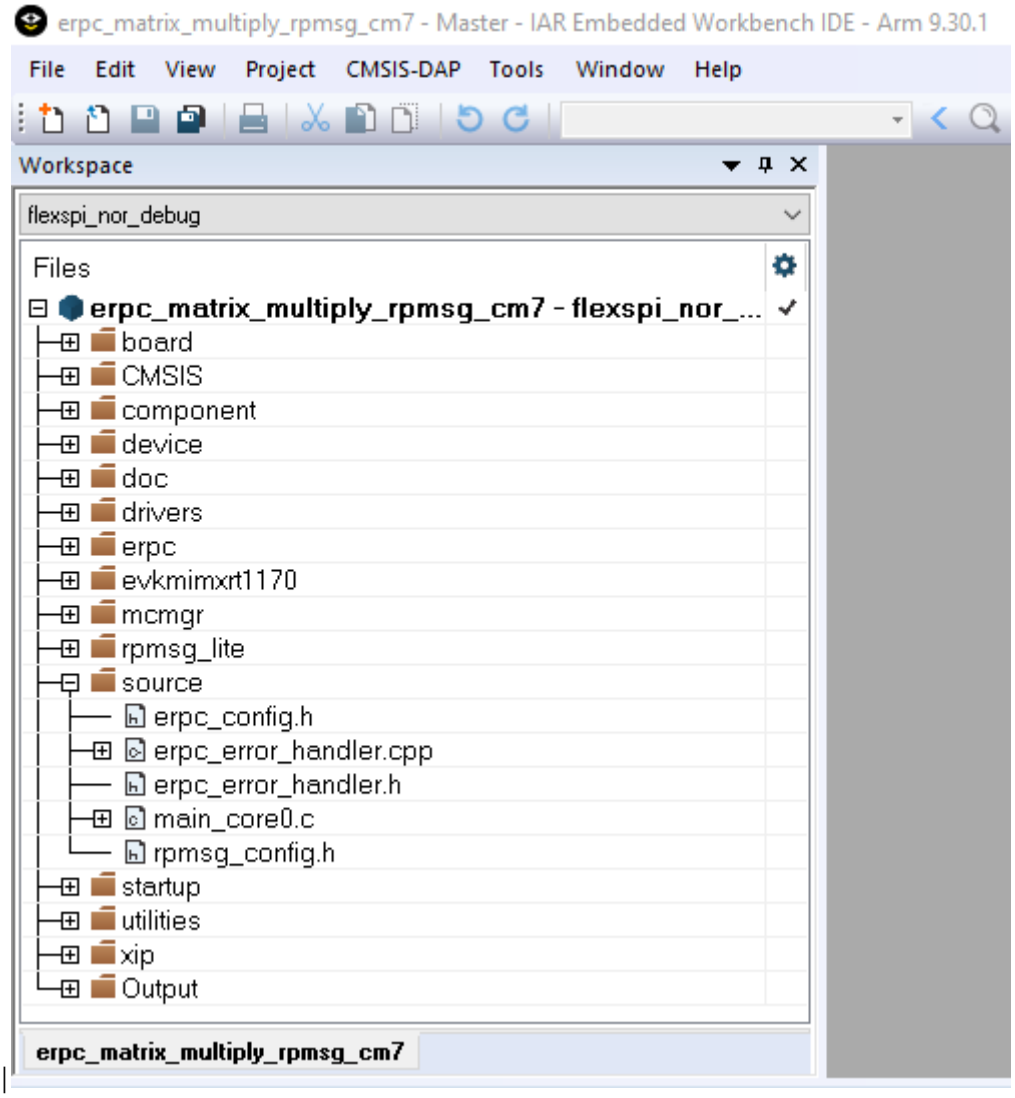
The matrix multiplication can be issued repeatedly, when pressing a software board button.

The eRPC-relevant code is captured in the following code snippet:

```
...
extern bool g_erpc_error_occurred;
...
/* Declare matrix arrays */
Matrix matrix1 = {0}, matrix2 = {0}, result_matrix = {0};
...
/* RPMsg-Lite transport layer initialization */
erpc_transport_t transport;
transport = erpc_transport_rpmsg_lite_master_init(src, dst,
ERPC_TRANSPORT_RPMSG_LITE_LINK_ID);
...
/* MessageBufferFactory initialization */
erpc_mbf_t message_buffer_factory;
message_buffer_factory = erpc_mbf_rpmsg_init(transport);
...
/* eRPC client side initialization */
erpc_client_t client;
client = erpc_client_init(transport, message_buffer_factory);
...
/* Set default error handler */
erpc_client_set_error_handler(client, erpc_error_handler);
...
while (1)
{
  /* Invoke the erpcMatrixMultiply function */
  erpcMatrixMultiply(matrix1, matrix2, result_matrix);
  ...
  /* Check if some error occured in eRPC */
  if (g_erpc_error_occurred)
  {
    /* Exit program loop */
    break;
  }
  ...
}
```

Except for the application main file, there are configuration files for the RPMsg-Lite (rpmsg_config.h) and eRPC (erpc_config.h), located in the following folder:

<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_matrix_multiply_rpmsg



Parent topic: Multicore client application

Parent topic:*Create an eRPC application*

Multiprocessor server application The "Matrix multiply" eRPC server project for multiprocessor applications is located in the *<MCUXpressoSDK_install_dir»/boards/<board_name>/multiprocessor_examples/erpc_server_matrix_multiply_<transport_layer>* folder.

Most of the multiprocessor application setup is the same as for the multicore application. The multiprocessor server application requires server-related generated files (server shim code), server infrastructure files, and the server user code. There is no need for server multicore infrastructure files (MCMGR and RPMsg-Lite). The RPMsg-Lite transport layer is replaced either by SPI or UART transports. The following table shows the required transport-related files per each transport type.

|SPI|<eRPC base directory>/erpc_c/setup/erpc_setup_(d)spi_slave.cpp

<eRPC base directory>/erpc_c/transports/erpc_(d)spi_slave_transport.hpp

<eRPC base directory>/erpc_c/transports/erpc_(d)spi_slave_transport.cpp

| |UART|<eRPC base directory>/erpc_c/setup/erpc_setup_uart_cmsis.cpp

<eRPC base directory>/erpc_c/transports/erpc_uart_cmsis_transport.hpp

<eRPC base directory>/erpc_c/transports/erpc_uart_cmsis_transport.cpp

|

Server user code The server's user code is stored in the main_server.c file, located in the *<MCUXpressoSDK_install_dir>/boards/<board_name>/multiprocessor_examples/erpc_server_matrix_multiply_<transport_layer>/* folder.

The eRPC-relevant code with UART as a transport is captured in the following code snippet:

```
/* erpcMatrixMultiply function user implementation */
void erpcMatrixMultiply(Matrix matrix1, Matrix matrix2, Matrix result_matrix)
{
  ...
}
int main()
{
  ...
  /* UART transport layer initialization, ERPC_DEMO_UART is the structure of CMSIS UART driver␣
↪operations */
  erpc_transport_t transport;
  transport = erpc_transport_cmsis_uart_init((void *)&ERPC_DEMO_UART);
  ...
  /* MessageBufferFactory initialization */
  erpc_mbf_t message_buffer_factory;
  message_buffer_factory = erpc_mbf_dynamic_init();
  ...
  /* eRPC server side initialization */
  erpc_server_t server;
  server = erpc_server_init(transport, message_buffer_factory);
  ...
  /* Adding the service to the server */
  erpc_service_t service = create_MatrixMultiplyService_service();
  erpc_add_service_to_server(server, service);
  ...
  while (1)
  {
    /* Process eRPC requests */
    erpc_status_t status = erpc_server_poll(server)
    /* handle error status */
    if (status != kErpcStatus_Success)
    {
      /* print error description */
      erpc_error_handler(status, 0);
      ...
    }
    ...
  }
}
```

Parent topic: Multiprocessor server application

Multiprocessor client application The "Matrix multiply" eRPC client project for multiprocessor applications is located in the *<MCUXpressoSDK_install_dir>/boards/<board_name>/multiprocessor_examples/erpc_client_matrix_multiply_<transport_layer>/iar/* folder.

Most of the multiprocessor application setup is the same as for the multicore application. The multiprocessor server application requires client-related generated files (server shim code),

client infrastructure files, and the client user code. There is no need for client multicore infrastructure files (MCMGR and RPMsg-Lite). The RPMsg-Lite transport layer is replaced either by SPI or UART transports. The following table shows the required transport-related files per each transport type.

|SPI|<eRPC base directory>/erpc_c/setup/erpc_setup_(d)spi_master.cpp

<eRPC base directory>/erpc_c/transports/ erpc_(d)spi_master_transport.hpp

<eRPC base directory>/erpc_c/transports/ erpc_(d)spi_master_transport.cpp

| |UART|<eRPC base directory>/erpc_c/setup/erpc_setup_uart_cmsis.cpp

<eRPC base directory>/erpc_c/transports/erpc_uart_cmsis_transport.hpp

<eRPC base directory>/erpc_c/transports/erpc_uart_cmsis_transport.cpp

|

Client user code The client's user code is stored in the main_client.c file, located in the *<MCUXpressoSDK_install_dir>/boards/<board_name>/multiprocessor_examples/erpc_client_matrix_multiply_<transport_layer>/* folder.

The eRPC-relevant code with UART as a transport is captured in the following code snippet:

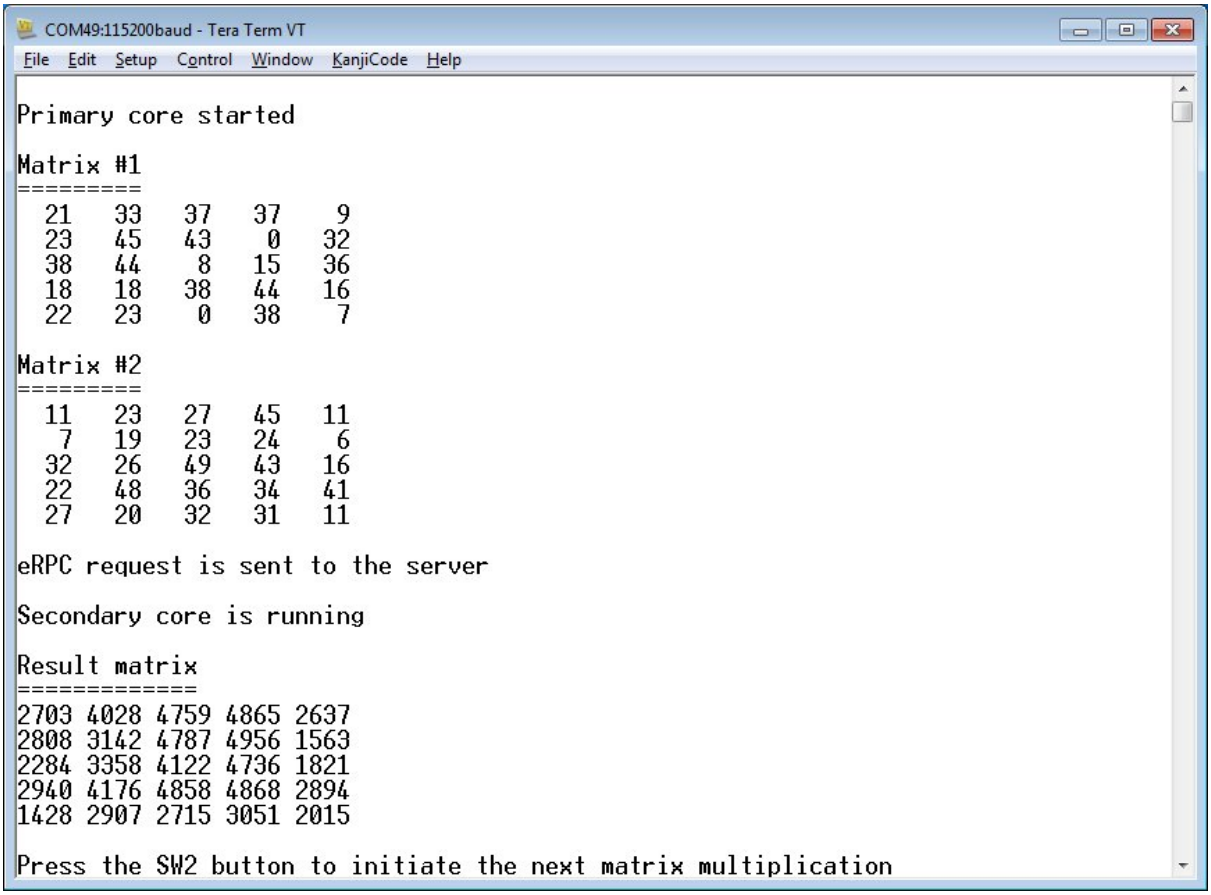
```
...
extern bool g_erpc_error_occurred;
...
/* Declare matrix arrays */
Matrix matrix1 = {0}, matrix2 = {0}, result_matrix = {0};
...
/* UART transport layer initialization, ERPC_DEMO_UART is the structure of CMSIS UART driver␣
↪operations */
erpc_transport_t transport;
transport = erpc_transport_cmsis_uart_init((void *)&ERPC_DEMO_UART);
...
/* MessageBufferFactory initialization */
erpc_mbf_t message_buffer_factory;
message_buffer_factory = erpc_mbf_dynamic_init();
...
/* eRPC client side initialization */
erpc_client_t client;
client = erpc_client_init(transport,message_buffer_factory);
...
/* Set default error handler */
erpc_client_set_error_handler(client, erpc_error_handler);
...
while (1)
{
  /* Invoke the erpcMatrixMultiply function */
  erpcMatrixMultiply(matrix1, matrix2, result_matrix);
  ...
  /* Check if some error occured in eRPC */
  if (g_erpc_error_occurred)
  {
    /* Exit program loop */
    break;
  }
  ...
}
```

Parent topic: Multiprocessor client application

Parent topic: Multiprocessor server application

Parent topic:*Create an eRPC application*

Running the eRPC application Follow the instructions in *Getting Started with MCUXpresso SDK* (document MCUXSDKGSUG) (located in the *<MCUXpressoSDK_install_dir>/docs* folder), to load both the primary and the secondary core images into the on-chip memory, and then effectively debug the dual-core application. After the application is running, the serial console should look like:



For multiprocessor applications that are running between PC and the target evaluation board or between two boards, follow the instructions in the accompanied example readme files that provide details about the proper board setup and the PC side setup (Python).

Parent topic:*Create an eRPC application*

Parent topic:*eRPC example*

eRPC example This section shows how to create an example eRPC application called “Matrix multiply”, which implements one eRPC function (matrix multiply) with two function parameters (two matrices). The client-side application calls this eRPC function, and the server side performs the multiplication of received matrices. The server side then returns the result.

For example, use the NXP MIMXRT1170-EVK board as the target dual-core platform, and the IAR Embedded Workbench for ARM (EWARM) as the target IDE for developing the eRPC example.

- The primary core (CM7) runs the eRPC client.
- The secondary core (CM4) runs the eRPC server.
- RPMsg-Lite (Remote Processor Messaging Lite) is used as the eRPC transport layer.

The “Matrix multiply” application can be also run in the multi-processor setup. In other words, the eRPC client running on one SoC comunicates with the eRPC server that runs on anothe SoC, utilizing different transport channels. It is possible to run the board-to-PC example (PC as the eRPC server and a board as the eRPC client, and vice versa) and also the board-to-board example. These multiprocessor examples are prepared for selected boards only.

|Multicore application source and project files|*<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore*
|Multiprocessor application source and project files|*<MCUXpressoSDK_install_dir>/boards/<board_name>/multi*

<MCUXpressoSDK_install_dir>/boards/<board_name>/multiprocessor_examples/erpc_server_matrix_multiply_<tr

| |eRPC source files|*<MCUXpressoSDK_install_dir>/middleware/multicore/erpc/*| |RPMsg-Lite source files|*<MCUXpressoSDK_install_dir>/middleware/multicore/rpmsg_lite/*|

Designing the eRPC application The matrix multiply application is based on calling single eRPC function that takes 2 two-dimensional arrays as input and returns matrix multiplication results as another 2 two-dimensional array. The IDL file syntax supports arrays with the dimension length set by the number only (in the current eRPC implementation). Because of this, a variable is declared in the IDL dedicated to store information about matrix dimension length, and to allow easy maintenance of the user and server code.

For a simple use of the two-dimensional array, the alias name (new type definition) for this data type has is declared in the IDL. Declaring this alias name ensures that the same data type can be used across the client and server applications.

Parent topic:*eRPC example*

Creating the IDL file The created IDL file is located in the following folder:

<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_common/erpc_matrix_multiply/s

The created IDL file contains the following code:

```
program erpc_matrix_multiply
/*! This const defines the matrix size. The value has to be the same as the
Matrix array dimension. Do not forget to re-generate the erpc code once the
matrix size is changed in the erpc file */
const int32 matrix_size = 5;
/*! This is the matrix array type. The dimension has to be the same as the
matrix size const. Do not forget to re-generate the erpc code once the
matrix size is changed in the erpc file */
type Matrix = int32[matrix_size][matrix_size];
interface MatrixMultiplyService {
erpcMatrixMultiply(in Matrix matrix1, in Matrix matrix2, out Matrix result_matrix) ->
void
}
```

Details:

- The IDL file starts with the program name (*erpc_matrix_multiply*), and this program name is used in the naming of all generated outputs.
- The declaration and definition of the constant variable named *matrix_size* follows next. The *matrix_size* variable is used for passing information about the length of matrix dimensions to the client/server user code.
- The alias name for the two-dimensional array type (*Matrix*) is declared.
- The interface group *MatrixMultiplyService* is located at the end of the IDL file. This interface group contains only one function declaration *erpcMatrixMultiply*.
- As shown above, the function’s declaration contains three parameters of Matrix type: *matrix1* and *matrix2* are input parameters, while *result_matrix* is the output parameter. Additionally, the returned data type is declared as void.

When writing the IDL file, the following order of items is recommended:

1. Program name at the top of the IDL file.
2. New data types and constants declarations.
3. Declarations of interfaces and functions at the end of the IDL file.

Parent topic:*eRPC example*

Using the eRPC generator tool |Windows OS|<MCUXpressoSDK_install_dir>/middleware/multicore/tools/erp
|Linux OS|<MCUXpressoSDK_install_dir>/middleware/multicore/tools/erpcgen/Linux_x64

<MCUXpressoSDK_install_dir>/middleware/multicore/tools/erpcgen/Linux_x86

| |Mac OS|<MCUXpressoSDK_install_dir>/middleware/multicore/tools/erpcgen/Mac|

The files for the "Matrix multiply" example are pre-generated and already a part of the application projects. The following section describes how they have been created.

- The easiest way to create the shim code is to copy the erpcgen application to the same folder where the IDL file (*.erpc) is located; then run the following command:

  erpcgen <IDL_file>.erpc

- In the "Matrix multiply" example, the command should look like:

  erpcgen erpc_matrix_multiply.erpc

Additionally, another method to create the shim code is to execute the eRPC application using input commands:

- "-?"/"—help" – Shows supported commands.
- "-o <filePath>"/"—output<filePath>" – Sets the output directory.

For example,

```
<path_to_erpcgen>/erpcgen –o <path_to_output>
<path_to_IDL>/<IDL_file_name>.erpc
```

For the "Matrix multiply" example, when the command is executed from the default erpcgen location, it looks like:

erpcgen –o

../../../../../boards/evkmimxrt1170/multicore_examples/erpc_common/erpc_matrix_multiply/service
../../../../../boards/evkmimxrt1170/multicore_examples/erpc_common/erpc_matrix_multiply/service/erpc_matrix_mu

In both cases, the following four files are generated into the *<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_common/erpc_matrix_multiply/service folder.*

- erpc_matrix_multiply.h
- erpc_matrix_multiply_client.cpp
- erpc_matrix_multiply_server.h
- erpc_matrix_multiply_server.cpp

For multiprocessor examples, the eRPC file and pre-generated files can be found in the *<MCUXpressoSDK_install_dir>/boards/<board_name>/multiprocessor_examples/erpc_common/erpc_matrix_multiply/serv* folder.

For Linux OS users:

- Do not forget to set the permissions for the eRPC generator application.
- Run the application as ./erpcgen... instead of as erpcgen ....

Parent topic:*eRPC example*

Create an eRPC application This section describes a generic way to create a client/server eRPC application:

1. **Design the eRPC application:** Decide which data types are sent between applications, and define functions that send/receive this data.
2. **Create the IDL file:** The IDL file contains information about data types and functions used in an eRPC application, and is written in the IDL language.
3. **Use the eRPC generator tool:** This tool takes an IDL file and generates the shim code for the client and the server-side applications.
4. **Create an eRPC application:**
    1. Create two projects, where one project is for the client side (primary core) and the other project is for the server side (secondary core).
    2. Add generated files for the client application to the client project, and add generated files for the server application to the server project.
    3. Add infrastructure files.
    4. Add user code for client and server applications.
    5. Set the client and server project options.
5. **Run the eRPC application:** Run both the server and the client applications. Make sure that the server has been run before the client request was sent.

A specific example follows in the next section.

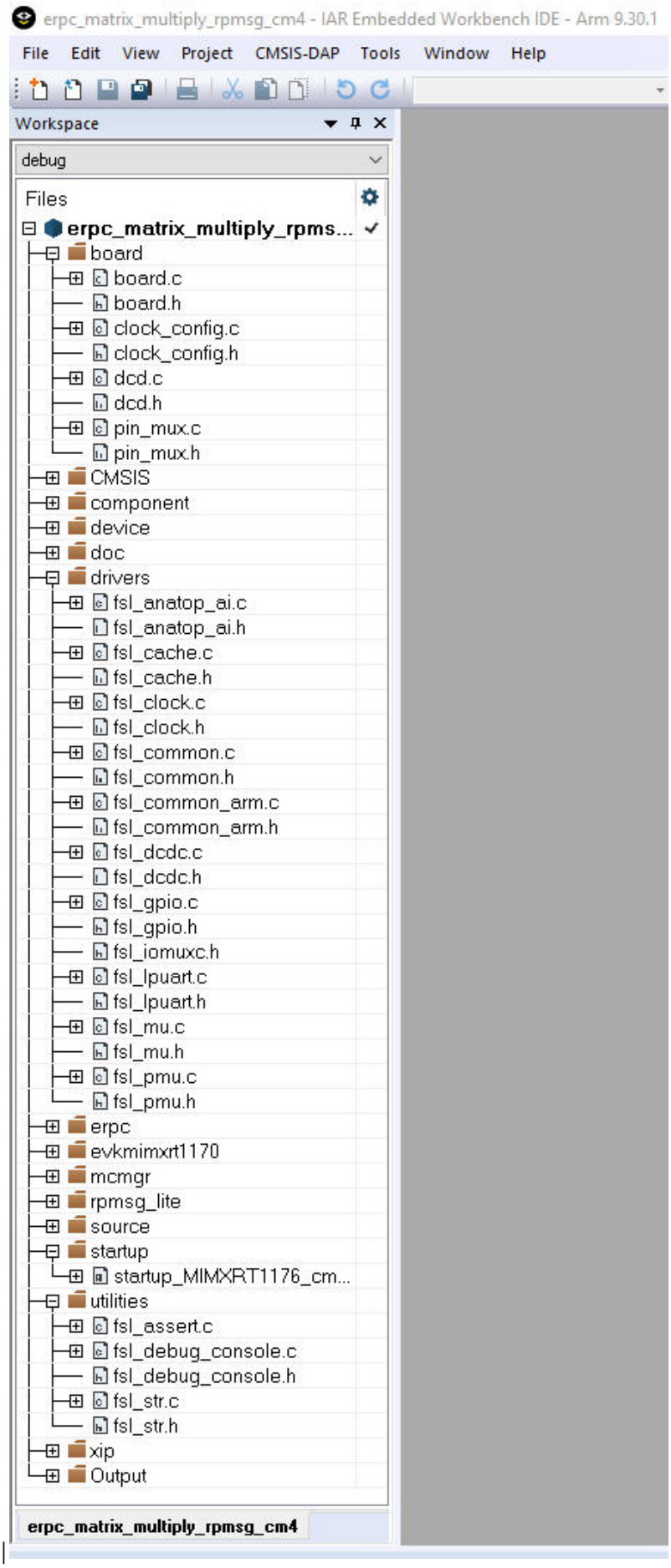
Multicore server application The “Matrix multiply” eRPC server project is located in the following folder:

<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_matrix_multiply_rpmsg/cm4/iar

The project files for the eRPC server have the `_cm4` suffix.

Server project basic source files The startup files, board-related settings, peripheral drivers, and utilities belong to the basic project source files and form the skeleton of all MCUXpresso SDK applications. These source files are located in:

- *<MCUXpressoSDK_install_dir>/devices/<device>*
- *<MCUXpressoSDK_install_dir>/boards/<board_name>/multicore_examples/<example_name>/*


erpc_matrix_multiply_rpmsg_cm4 - IAR Embedded Workbench IDE - Arm 9.30.1
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fsl_common_arm.c
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fsl_dcdc.c
fsl_dcdc.h
fsl_gpio.c
fsl_gpio.h
fsl_iomuxc.h
fsl_lpuart.c
fsl_lpuart.h
fsl_mu.c
fsl_mu.h
fsl_pmu.c
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erpc
evkmimxrt1170
mcmgr
rpmsg_lite
source
startup
startup_MIMXRT1176_cm...
utilities
fsl_assert.c
fsl_debug_console.c
fsl_debug_console.h
fsl_str.c
fsl_str.h
xip
Output
erpc_matrix_multiply_rpmsg_cm4

|

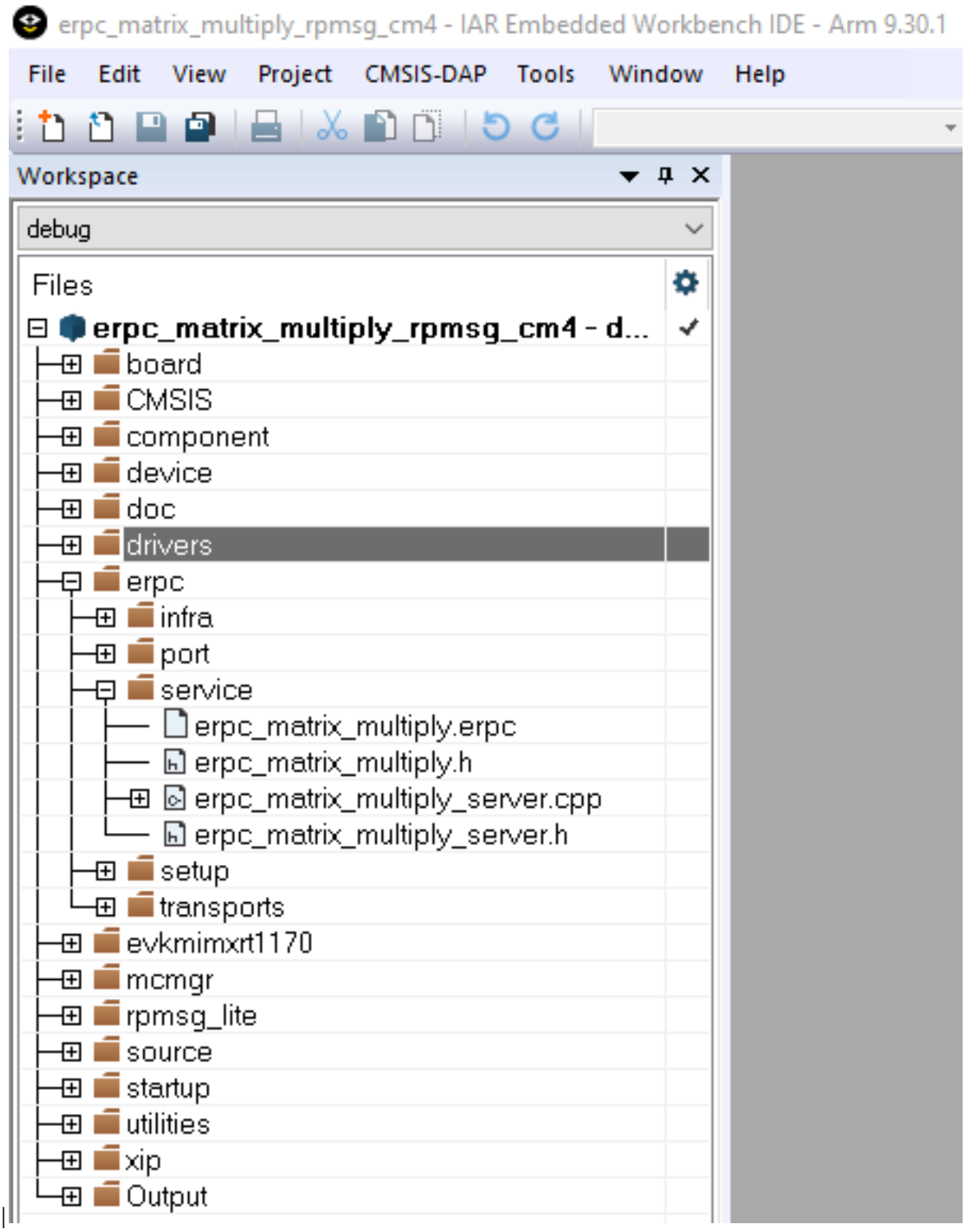
Parent topic: Multicore server application

Server related generated files The server-related generated files are:

- erpc_matric_multiply.h
- erpc_matrix_multiply_server.h
- erpc_matrix_multiply_server.cpp

The server-related generated files contain the shim code for functions and data types declared in the IDL file. These files also contain functions for the identification of client requested functions, data deserialization, calling requested function's implementations, and data serialization and return, if requested by the client. These shim code files can be found in the following folder:

<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_common/erpc_matrix_multiply/s



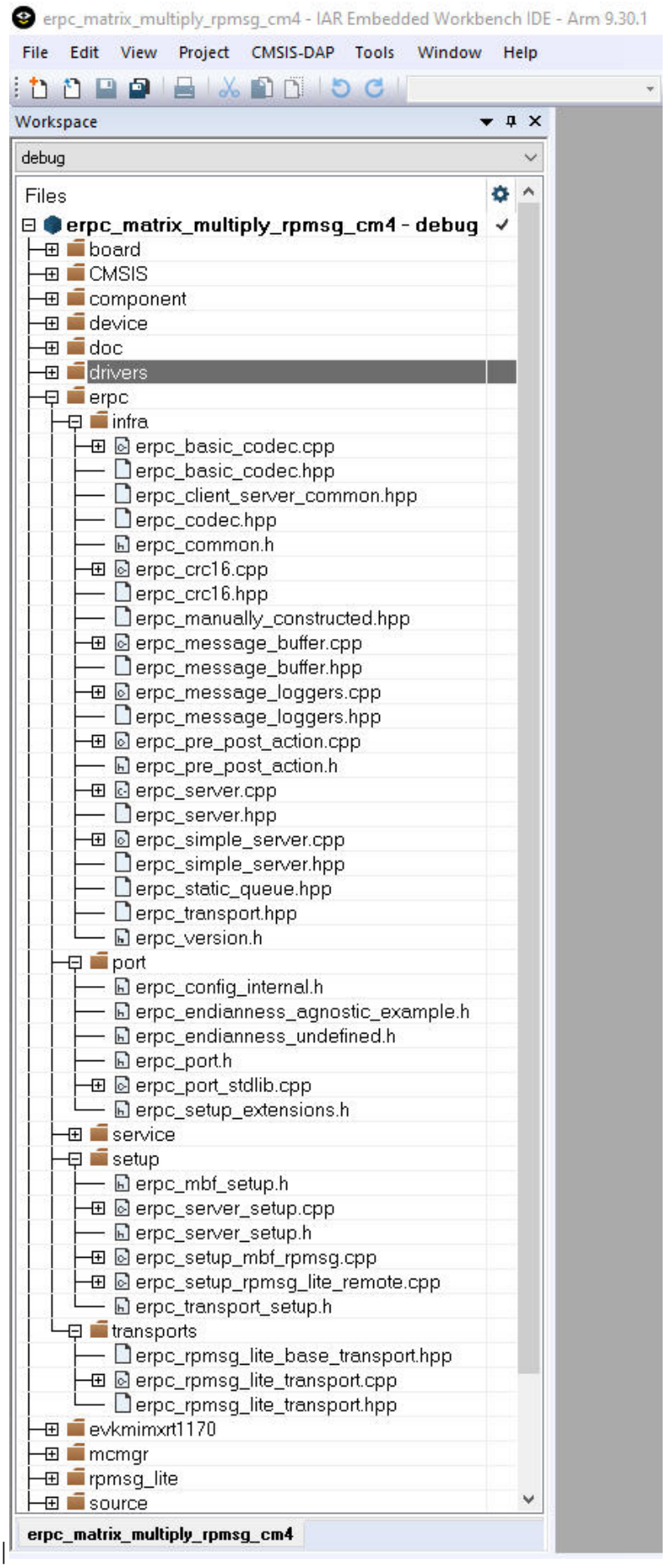
Parent topic: Multicore server application

Server infrastructure files The eRPC infrastructure files are located in the following folder:

<MCUXpressoSDK_install_dir>/middleware/multicore/erpc/erpc_c

The **erpc_c** folder contains files for creating eRPC client and server applications in the *C/C++* language. These files are distributed into subfolders.

- The **infra** subfolder contains C++ infrastructure code used to build server and client applications.
  - Four files, erpc_server.hpp, erpc_server.cpp, erpc_simple_server.hpp, and erpc_simple_server.cpp, are used for running the eRPC server on the server-side applications. The simple server is currently the only implementation of the server, and its role is to catch client requests, identify and call requested functions, and send data back when requested.
  - Three files (erpc_codec.hpp, erpc_basic_codec.hpp, and erpc_basic_codec.cpp) are used for codecs. Currently, the basic codec is the initial and only implementation of the codecs.
  - The erpc_common.hpp file is used for common eRPC definitions, typedefs, and enums.
  - The erpc_manually_constructed.hpp file is used for allocating static storage for the used objects.
  - Message buffer files are used for storing serialized data: erpc_message_buffer.h and erpc_message_buffer.cpp.
  - The erpc_transport.h file defines the abstract interface for transport layer.
- The **port** subfolder contains the eRPC porting layer to adapt to different environments.
  - erpc_port.h file contains definition of erpc_malloc() and erpc_free() functions.
  - erpc_port_stdlib.cpp file ensures adaptation to stdlib.
  - erpc_config_internal.h internal erpc configuration file.
- The **setup** subfolder contains a set of plain C APIs that wrap the C++ infrastructure, providing client and server init and deinit routines that greatly simplify eRPC usage in C-based projects. No knowledge of C++ is required to use these APIs.
  - The erpc_server_setup.h and erpc_server_setup.cpp files needs to be added into the "Matrix multiply" example project to demonstrate the use of C-wrapped functions in this example.
  - The erpc_transport_setup.h and erpc_setup_rpmsg_lite_remote.cpp files needs to be added into the project in order to allow the C-wrapped function for transport layer setup.
  - The erpc_mbf_setup.h and erpc_setup_mbf_rpmsg.cpp files needs to be added into the project in order to allow message buffer factory usage.
- The **transports** subfolder contains transport classes for the different methods of communication supported by eRPC. Some transports are applicable only to host PCs, while others are applicable only to embedded or multicore systems. Most transports have corresponding client and server setup functions in the setup folder.
  - RPMsg-Lite is used as the transport layer for the communication between cores, erpc_rpmsg_lite_base_transport.hpp, erpc_rpmsg_lite_transport.hpp, and erpc_rpmsg_lite_transport.cpp files need to be added into the server project.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doc
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erpc_static_queue.hpp
erpc_transport.hpp
erpc_version.h
port
erpc_config_internal.h
erpc_endianness_agnostic_example.h
erpc_endianness_undefined.h
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erpc_port_stdlib.cpp
erpc_setup_extensions.h
service
setup
erpc_mbf_setup.h
erpc_server_setup.cpp
erpc_server_setup.h
erpc_setup_mbf_rpmsg.cpp
erpc_setup_rpmsg_lite_remote.cpp
erpc_transport_setup.h
transports
erpc_rpmsg_lite_base_transport.hpp
erpc_rpmsg_lite_transport.cpp
erpc_rpmsg_lite_transport.hpp
evkmimxrt1170
mcmgr
rpmsg_lite
source
erpc_matrix_multiply_rpmsg_cm4

|

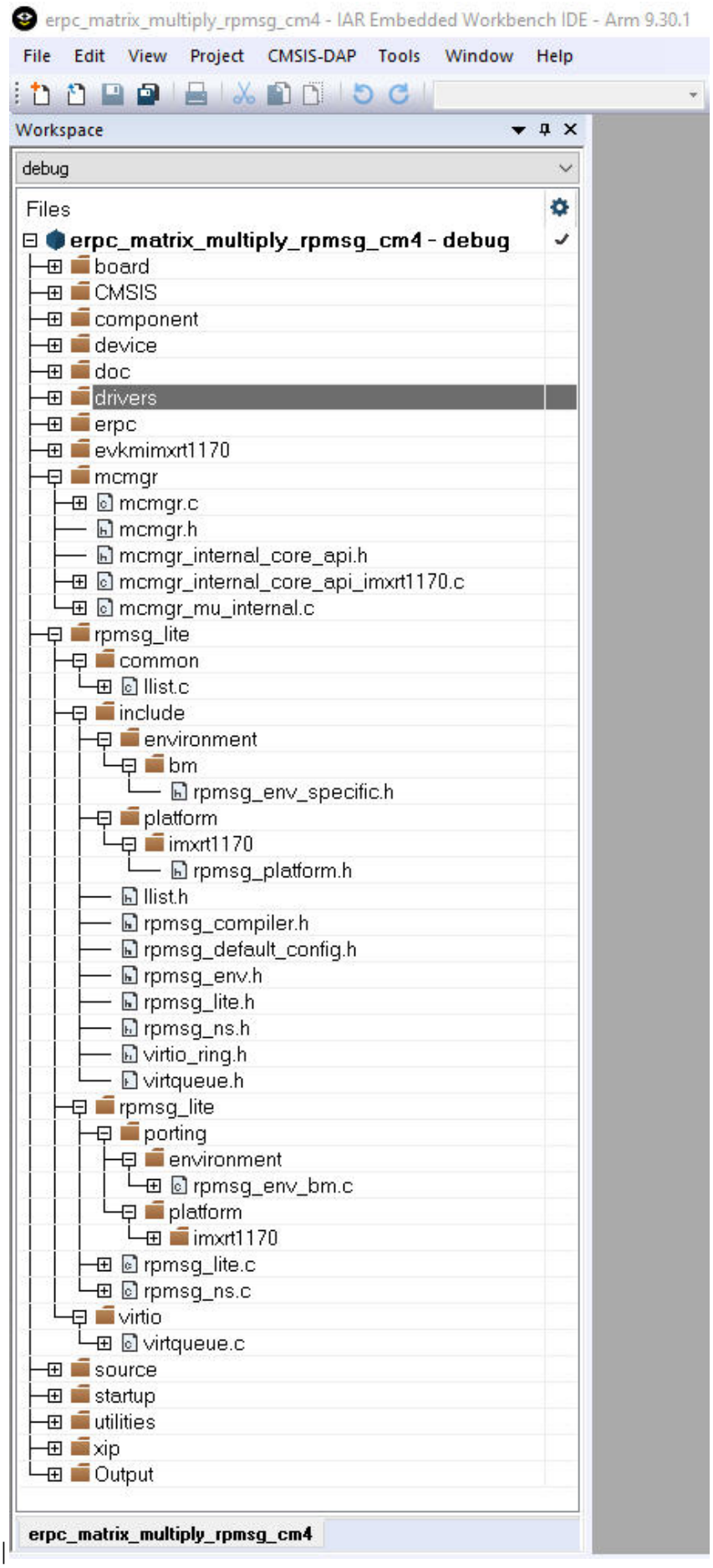
Parent topic: Multicore server application

Server multicore infrastructure files Because of the RPMsg-Lite (transport layer), it is also necessary to include RPMsg-Lite related files, which are in the following folder:

<MCUXpressoSDK_install_dir>/middleware/multicore/rpmsg_lite/

The multicore example applications also use the Multicore Manager software library to control the secondary core startup and shutdown. These source files are located in the following folder:

<MCUXpressoSDK_install_dir>/middleware/multicore/mcmgr/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doc
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mcmgr
mcmgr.c
mcmgr.h
mcmgr_internal_core_api.h
mcmgr_internal_core_api_imxrt1170.c
mcmgr_mu_internal.c
rpmsg_lite
common
llist.c
include
environment
bm
rpmsg_env_specific.h
platform
imxrt1170
rpmsg_platform.h
llist.h
rpmsg_compiler.h
rpmsg_default_config.h
rpmsg_env.h
rpmsg_lite.h
rpmsg_ns.h
virtio_ring.h
virtqueue.h
rpmsg_lite
porting
environment
rpmsg_env_bm.c
platform
imxrt1170
rpmsg_lite.c
rpmsg_ns.c
virtio
virtqueue.c
source
startup
utilities
xip
Output
erpc_matrix_multiply_rpmsg_cm4

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Parent topic: Multicore server application

Server user code The server's user code is stored in the main_core1.c file, located in the following folder:

<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_matrix_multiply_rpmsg/cm4

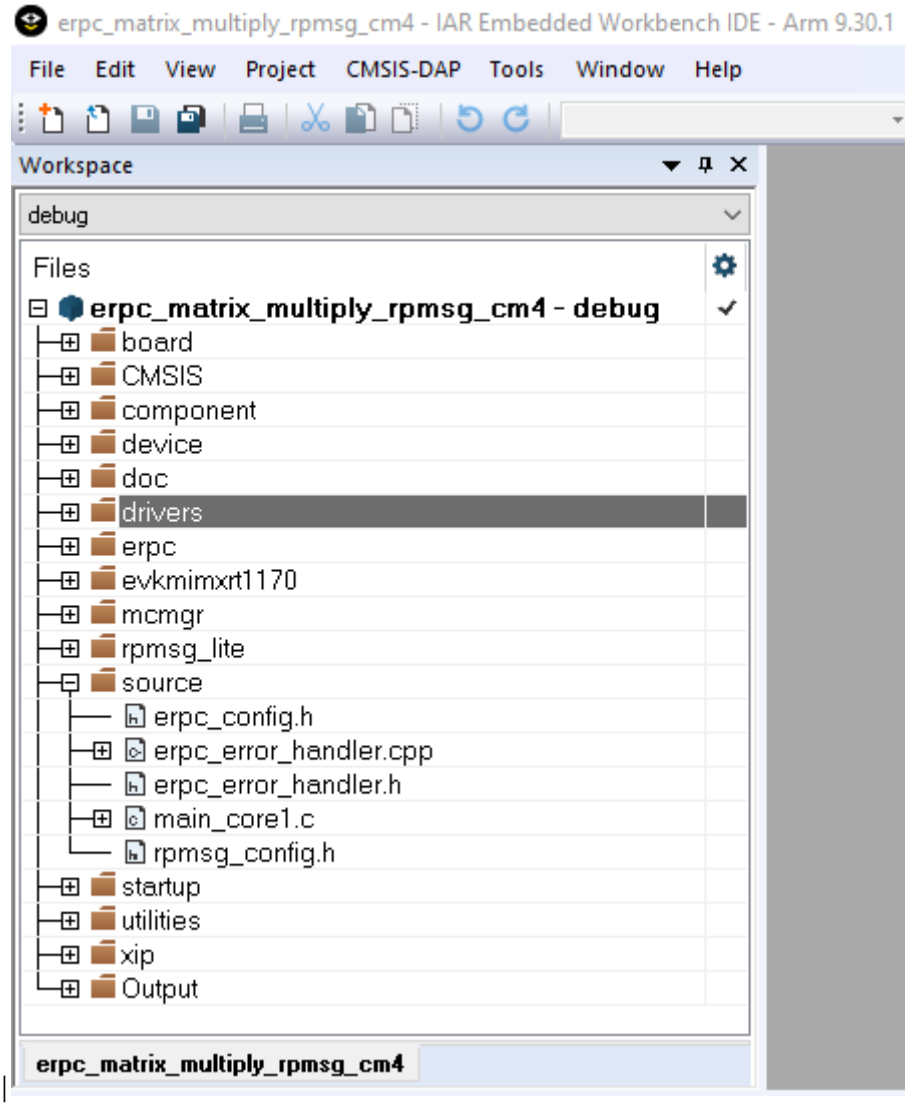
The main_core1.c file contains two functions:

- The **main()** function contains the code for the target board and eRPC server initialization. After the initialization, the matrix multiply service is added and the eRPC server waits for client's requests in the while loop.
- The **erpcMatrixMultiply()** function is the user implementation of the eRPC function defined in the IDL file.
- There is the possibility to write the application-specific eRPC error handler. The eRPC error handler of the matrix multiply application is implemented in the erpc_error_handler.h and erpc_error_handler.cpp files.

The eRPC-relevant code is captured in the following code snippet:

```
/* erpcMatrixMultiply function user implementation */
void erpcMatrixMultiply(const Matrix *matrix1, const Matrix *matrix2, Matrix *result_matrix)
{
  ...
}
int main()
{
  ...
  /* RPMsg-Lite transport layer initialization */
  erpc_transport_t transport;
  transport = erpc_transport_rpmsg_lite_remote_init(src, dst, (void*)startupData,
  ERPC_TRANSPORT_RPMSG_LITE_LINK_ID, SignalReady, NULL);
  ...
  /* MessageBufferFactory initialization */
  erpc_mbf_t message_buffer_factory;
  message_buffer_factory = erpc_mbf_rpmsg_init(transport);
  ...
  /* eRPC server side initialization */
  erpc_server_t server;
  server = erpc_server_init(transport, message_buffer_factory);
  ...
  /* Adding the service to the server */
  erpc_service_t service = create_MatrixMultiplyService_service();
  erpc_add_service_to_server(server, service);
  ...
  while (1)
  {
    /* Process eRPC requests */
    erpc_status_t status = erpc_server_poll(server);
    /* handle error status */
    if (status != kErpcStatus_Success)
    {
      /* print error description */
      erpc_error_handler(status, 0);
      ...
    }
    ...
  }
}
```

Except for the application main file, there are configuration files for the RPMsg-Lite (rpmsg_config.h) and eRPC (erpc_config.h), located in the *<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_matrix_multiply_rpmsg* folder.



Parent topic: Multicore server application

Parent topic:*Create an eRPC application*

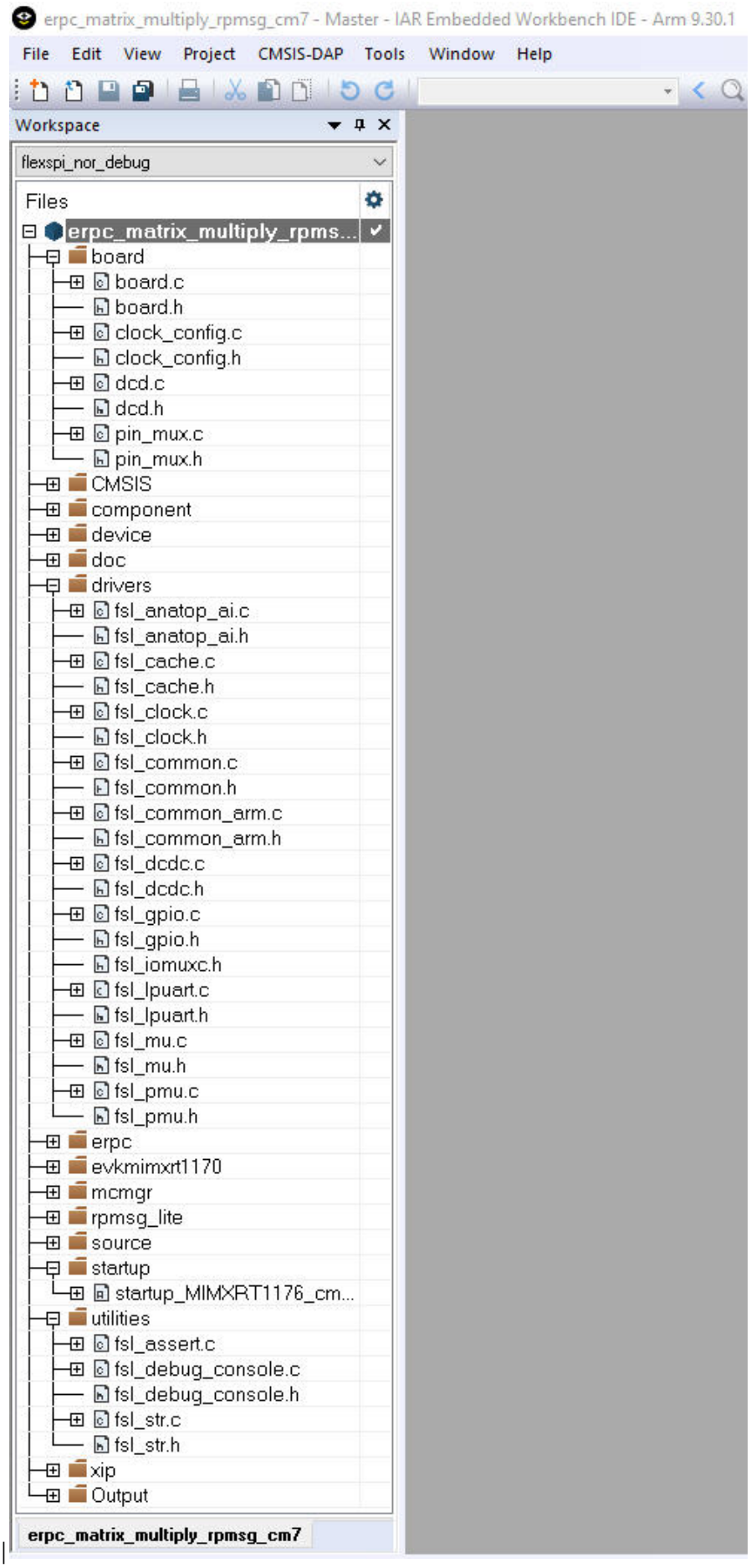
Multicore client application The "Matrix multiply" eRPC client project is located in the following folder:

<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_matrix_multiply_rpmsg/cm7/iar

Project files for the eRPC client have the _cm7 suffix.

Client project basic source files The startup files, board-related settings, peripheral drivers, and utilities belong to the basic project source files and form the skeleton of all MCUXpresso SDK applications. These source files are located in the following folders:

- *<MCUXpressoSDK_install_dir>/devices/<device>*
- *<MCUXpressoSDK_install_dir>/boards/<board_name>/multicore_examples/<example_name>/*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fsl_anatop_ai.c
fsl_anatop_ai.h
fsl_cache.c
fsl_cache.h
fsl_clock.c
fsl_clock.h
fsl_common.c
fsl_common.h
fsl_common_arm.c
fsl_common_arm.h
fsl_dcdc.c
fsl_dcdc.h
fsl_gpio.c
fsl_gpio.h
fsl_iomuxc.h
fsl_lpuart.c
fsl_lpuart.h
fsl_mu.c
fsl_mu.h
fsl_pmu.c
fsl_pmu.h
erpc
evkmimxrt1170
mcmgr
rpmsg_lite
source
startup
startup_MIMXRT1176_cm...
utilities
fsl_assert.c
fsl_debug_console.c
fsl_debug_console.h
fsl_str.c
fsl_str.h
xip
Output
erpc_matrix_multiply_rpmsg_cm7

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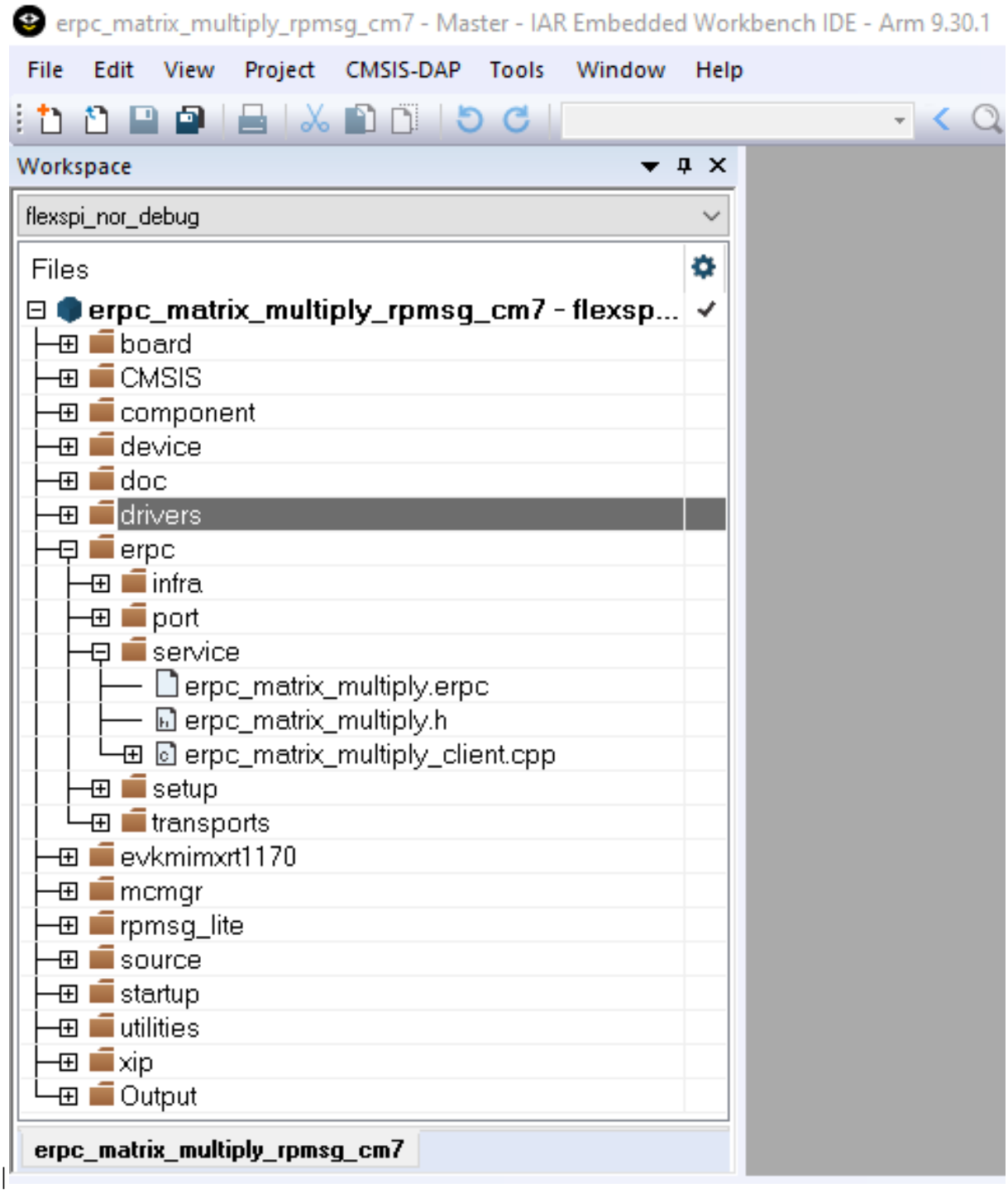
Parent topic: Multicore client application

Client-related generated files The client-related generated files are:

- erpc_matric_multiply.h
- erpc_matrix_multiply_client.cpp

These files contain the shim code for the functions and data types declared in the IDL file. These functions also call methods for codec initialization, data serialization, performing eRPC requests, and de-serializing outputs into expected data structures (if return values are expected). These shim code files can be found in the *<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_common/erpc_matrix_multiply/service/* folder.



Parent topic: Multicore client application

Client infrastructure files The eRPC infrastructure files are located in the following folder:

<MCUXpressoSDK_install_dir>/middleware/multicore/erpc/erpc_c

The **erpc_c** folder contains files for creating eRPC client and server applications in the C/C++ language. These files are distributed into subfolders.

- The **infra** subfolder contains C++ infrastructure code used to build server and client applications.

- Two files, erpc_client_manager.h and erpc_client_manager.cpp, are used for managing the client-side application. The main purpose of the client files is to create, perform, and release eRPC requests.
- Three files (erpc_codec.hpp, erpc_basic_codec.hpp, and erpc_basic_codec.cpp) are used for codecs. Currently, the basic codec is the initial and only implementation of the codecs.
- erpc_common.h file is used for common eRPC definitions, typedefs, and enums.
- erpc_manually_constructed.hpp file is used for allocating static storage for the used objects.
- Message buffer files are used for storing serialized data: erpc_message_buffer.hpp and erpc_message_buffer.cpp.
- erpc_transport.hpp file defines the abstract interface for transport layer.

The **port** subfolder contains the eRPC porting layer to adapt to different environments.

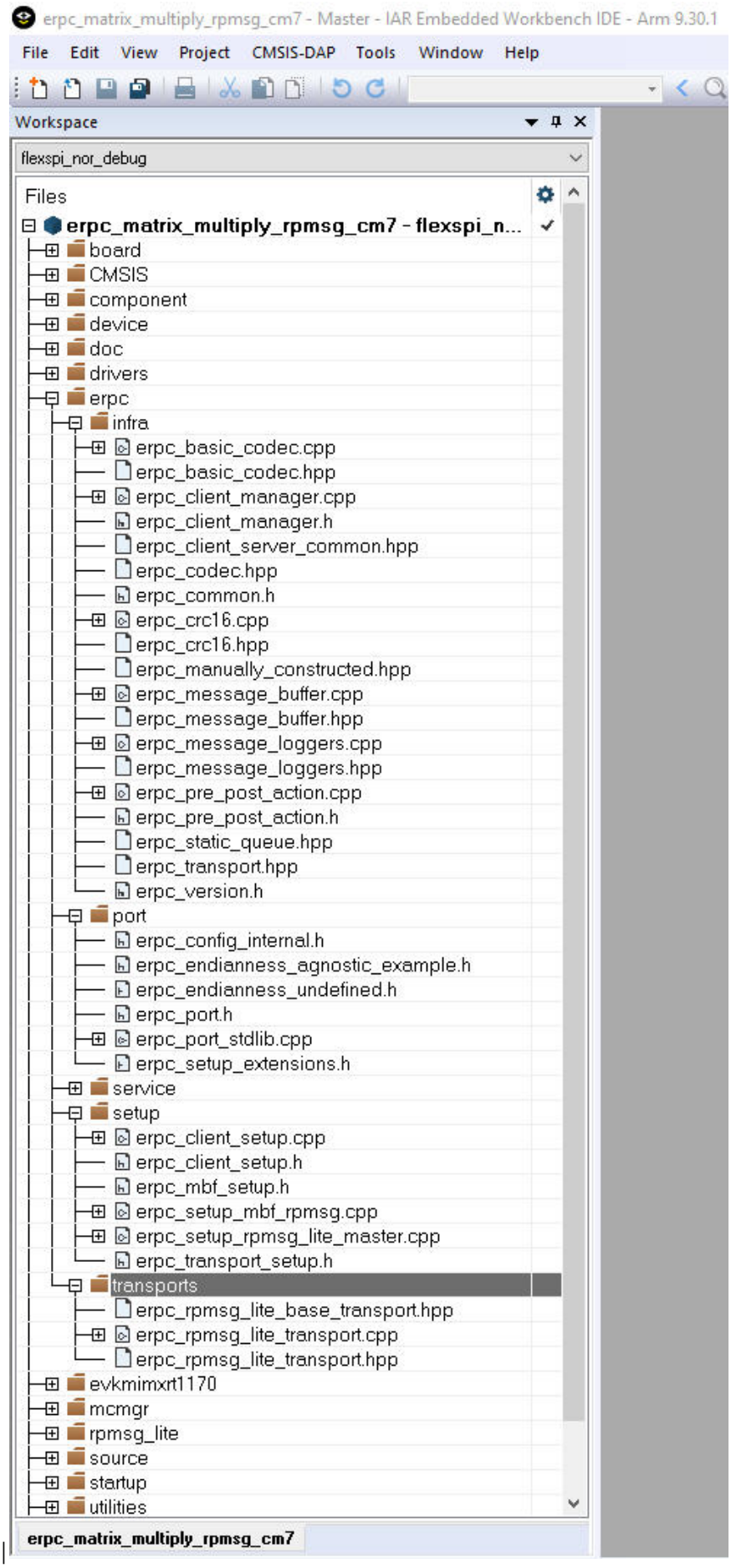
- erpc_port.h file contains definition of erpc_malloc() and erpc_free() functions.
- erpc_port_stdlib.cpp file ensures adaptation to stdlib.
- erpc_config_internal.h internal eRPC configuration file.

The **setup** subfolder contains a set of plain C APIs that wrap the C++ infrastructure, providing client and server init and deinit routines that greatly simplify eRPC usage in C-based projects. No knowledge of C++ is required to use these APIs.

- erpc_client_setup.h and erpc_client_setup.cpp files needs to be added into the "Matrix multiply" example project to demonstrate the use of C-wrapped functions in this example.
- erpc_transport_setup.h and erpc_setup_rpmsg_lite_master.cpp files needs to be added into the project in order to allow C-wrapped function for transport layer setup.
- erpc_mbf_setup.h and erpc_setup_mbf_rpmsg.cpp files needs to be added into the project in order to allow message buffer factory usage.

The **transports** subfolder contains transport classes for the different methods of communication supported by eRPC. Some transports are applicable only to host PCs, while others are applicable only to embedded or multicore systems. Most transports have corresponding client and server setup functions, in the setup folder.

- RPMsg-Lite is used as the transport layer for the communication between cores, erpc_rpmsg_lite_base_transport.hpp, erpc_rpmsg_lite_transport.hpp, and erpc_rpmsg_lite_transport.cpp files needs to be added into the client project.


erpc_matrix_multiply_rpmsg_cm7 - Master - IAR Embedded Workbench IDE - Arm 9.30.1
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infra
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erpc_basic_codec.hpp
erpc_client_manager.cpp
erpc_client_manager.h
erpc_client_server_common.hpp
erpc_codec.hpp
erpc_common.h
erpc_crc16.cpp
erpc_crc16.hpp
erpc_manually_constructed.hpp
erpc_message_buffer.cpp
erpc_message_buffer.hpp
erpc_message_loggers.cpp
erpc_message_loggers.hpp
erpc_pre_post_action.cpp
erpc_pre_post_action.h
erpc_static_queue.hpp
erpc_transport.hpp
erpc_version.h
port
erpc_config_internal.h
erpc_endianness_agnostic_example.h
erpc_endianness_undefined.h
erpc_port.h
erpc_port_stdlib.cpp
erpc_setup_extensions.h
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erpc_client_setup.cpp
erpc_client_setup.h
erpc_mbf_setup.h
erpc_setup_mbf_rpmsg.cpp
erpc_setup_rpmsg_lite_master.cpp
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transports
erpc_rpmsg_lite_base_transport.hpp
erpc_rpmsg_lite_transport.cpp
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evkmimxrt1170
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rpmsg_lite
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startup
utilities
erpc_matrix_multiply_rpmsg_cm7

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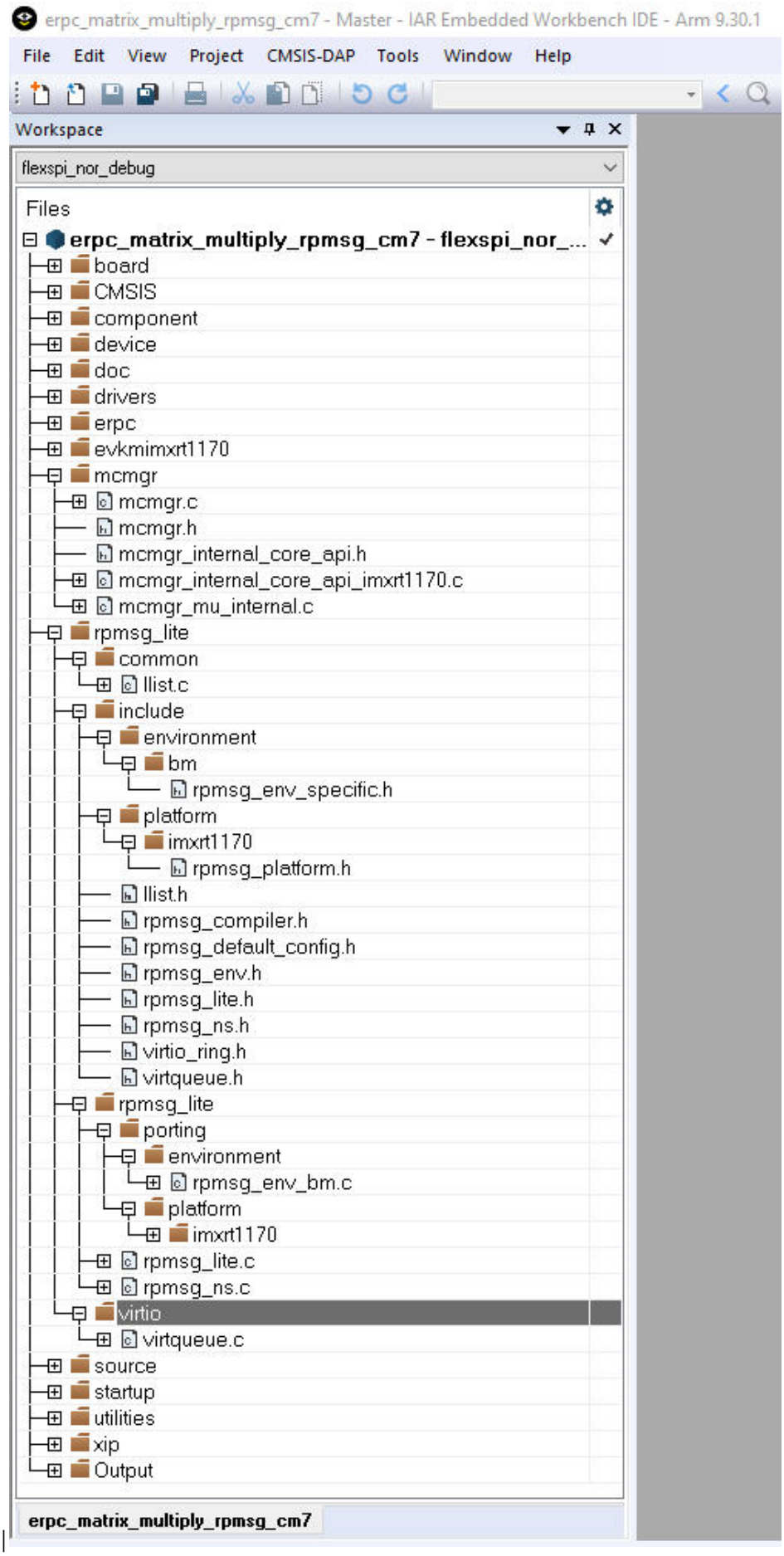
Parent topic: Multicore client application

Client multicore infrastructure files Because of the RPMsg-Lite (transport layer), it is also necessary to include RPMsg-Lite related files, which are in the following folder:

<MCUXpressoSDK_install_dir>/middleware/multicore/rpmsg_lite/

The multicore example applications also use the Multicore Manager software library to control the secondary core startup and shutdown. These source files are located in the following folder:

<MCUXpressoSDK_install_dir>/middleware/multicore/mcmgr/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board
CMSIS
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drivers
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mcmgr.h
mcmgr_internal_core_api.h
mcmgr_internal_core_api_imxrt1170.c
mcmgr_mu_internal.c
rpmsg_lite
common
llist.c
include
environment
bm
rpmsg_env_specific.h
platform
imxrt1170
rpmsg_platform.h
llist.h
rpmsg_compiler.h
rpmsg_default_config.h
rpmsg_env.h
rpmsg_lite.h
rpmsg_ns.h
virtio_ring.h
virtqueue.h
rpmsg_lite
porting
environment
rpmsg_env_bm.c
platform
imxrt1170
rpmsg_lite.c
rpmsg_ns.c
virtio
virtqueue.c
source
startup
utilities
xip
Output
erpc_matrix_multiply_rpmsg_cm7

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Parent topic: Multicore client application

Client user code The client's user code is stored in the main_core0.c file, located in the following folder:

<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_example/erpc_matrix_multiply_rpmsg/cm7

The main_core0.c file contains the code for target board and eRPC initialization.

- After initialization, the secondary core is released from reset.
- When the secondary core is ready, the primary core initializes two matrix variables.
- The erpcMatrixMultiply eRPC function is called to issue the eRPC request and get the result.

It is possible to write the application-specific eRPC error handler. The eRPC error handler of the matrix multiply application is implemented in erpc_error_handler.h and erpc_error_handler.cpp files.

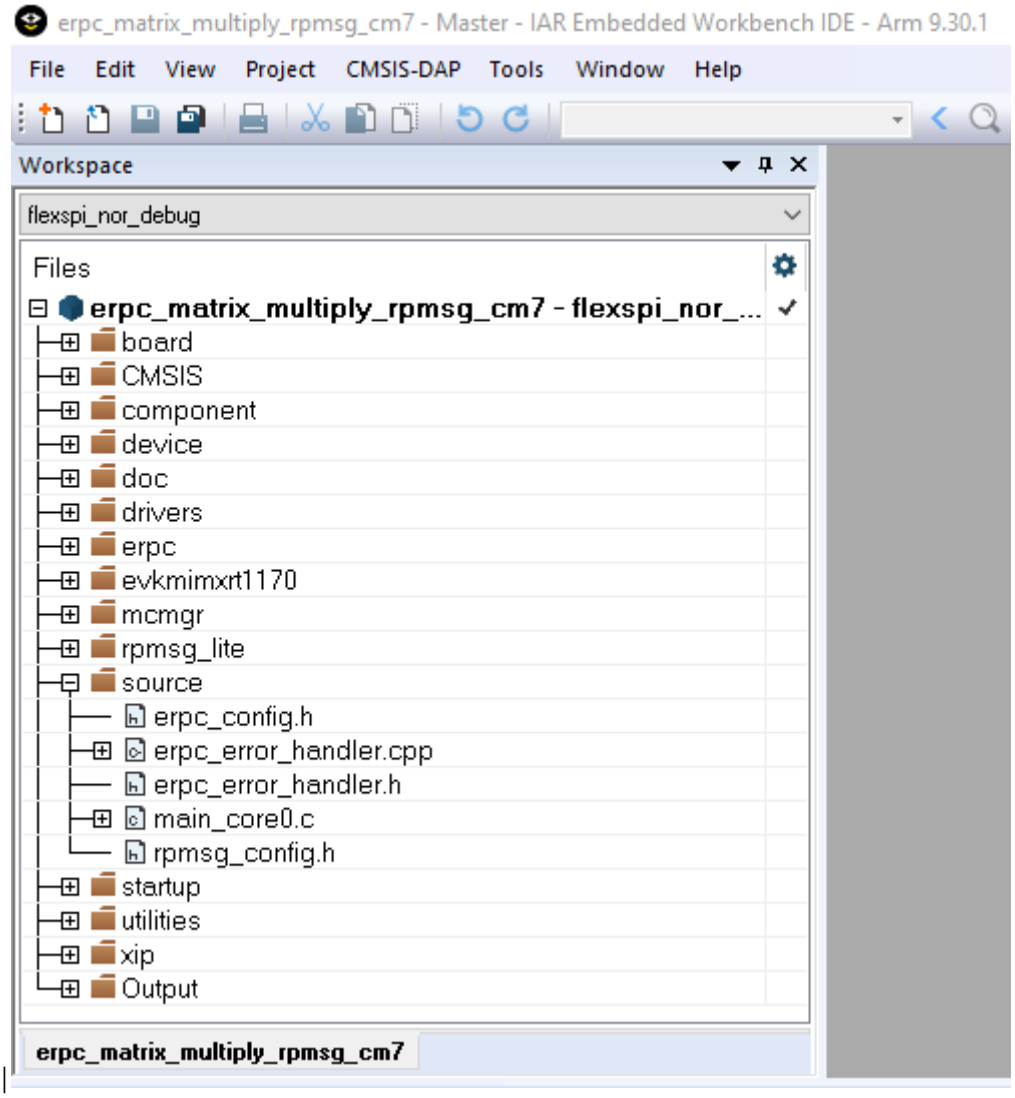
The matrix multiplication can be issued repeatedly, when pressing a software board button.

The eRPC-relevant code is captured in the following code snippet:

```
...
extern bool g_erpc_error_occurred;
...
/* Declare matrix arrays */
Matrix matrix1 = {0}, matrix2 = {0}, result_matrix = {0};
...
/* RPMsg-Lite transport layer initialization */
erpc_transport_t transport;
transport = erpc_transport_rpmsg_lite_master_init(src, dst,
ERPC_TRANSPORT_RPMSG_LITE_LINK_ID);
...
/* MessageBufferFactory initialization */
erpc_mbf_t message_buffer_factory;
message_buffer_factory = erpc_mbf_rpmsg_init(transport);
...
/* eRPC client side initialization */
erpc_client_t client;
client = erpc_client_init(transport, message_buffer_factory);
...
/* Set default error handler */
erpc_client_set_error_handler(client, erpc_error_handler);
...
while (1)
{
  /* Invoke the erpcMatrixMultiply function */
  erpcMatrixMultiply(matrix1, matrix2, result_matrix);
  ...
  /* Check if some error occured in eRPC */
  if (g_erpc_error_occurred)
  {
    /* Exit program loop */
    break;
  }
  ...
}
```

Except for the application main file, there are configuration files for the RPMsg-Lite (rpmsg_config.h) and eRPC (erpc_config.h), located in the following folder:

<MCUXpressoSDK_install_dir>/boards/evkmimxrt1170/multicore_examples/erpc_matrix_multiply_rpmsg



Parent topic: Multicore client application

Parent topic:*Create an eRPC application*

Multiprocessor server application The "Matrix multiply" eRPC server project for multiprocessor applications is located in the *<MCUXpressoSDK_install_dir»/boards/<board_name>/multiprocessor_examples/erpc_server_matrix_multiply_<transport_layer>* folder.

Most of the multiprocessor application setup is the same as for the multicore application. The multiprocessor server application requires server-related generated files (server shim code), server infrastructure files, and the server user code. There is no need for server multicore infrastructure files (MCMGR and RPMsg-Lite). The RPMsg-Lite transport layer is replaced either by SPI or UART transports. The following table shows the required transport-related files per each transport type.

|SPI|<eRPC base directory>/erpc_c/setup/erpc_setup_(d)spi_slave.cpp

<eRPC base directory>/erpc_c/transports/erpc_(d)spi_slave_transport.hpp

<eRPC base directory>/erpc_c/transports/erpc_(d)spi_slave_transport.cpp

| |UART|<eRPC base directory>/erpc_c/setup/erpc_setup_uart_cmsis.cpp

<eRPC base directory>/erpc_c/transports/erpc_uart_cmsis_transport.hpp

<eRPC base directory>/erpc_c/transports/erpc_uart_cmsis_transport.cpp

|

Server user code The server's user code is stored in the main_server.c file, located in the *<MCUXpressoSDK_install_dir>/boards/<board_name>/multiprocessor_examples/erpc_server_matrix_multiply_<transport_layer>/* folder.

The eRPC-relevant code with UART as a transport is captured in the following code snippet:

```
/* erpcMatrixMultiply function user implementation */
void erpcMatrixMultiply(Matrix matrix1, Matrix matrix2, Matrix result_matrix)
{
  ...
}
int main()
{
  ...
  /* UART transport layer initialization, ERPC_DEMO_UART is the structure of CMSIS UART driver␣
↪operations */
  erpc_transport_t transport;
  transport = erpc_transport_cmsis_uart_init((void *)&ERPC_DEMO_UART);
  ...
  /* MessageBufferFactory initialization */
  erpc_mbf_t message_buffer_factory;
  message_buffer_factory = erpc_mbf_dynamic_init();
  ...
  /* eRPC server side initialization */
  erpc_server_t server;
  server = erpc_server_init(transport, message_buffer_factory);
  ...
  /* Adding the service to the server */
  erpc_service_t service = create_MatrixMultiplyService_service();
  erpc_add_service_to_server(server, service);
  ...
  while (1)
  {
    /* Process eRPC requests */
    erpc_status_t status = erpc_server_poll(server)
    /* handle error status */
    if (status != kErpcStatus_Success)
    {
      /* print error description */
      erpc_error_handler(status, 0);
      ...
    }
    ...
  }
}
```

Parent topic: Multiprocessor server application

Multiprocessor client application The "Matrix multiply" eRPC client project for multiprocessor applications is located in the *<MCUXpressoSDK_install_dir>/boards/<board_name>/multiprocessor_examples/erpc_client_matrix_multiply_<transport_layer>/iar/* folder.

Most of the multiprocessor application setup is the same as for the multicore application. The multiprocessor server application requires client-related generated files (server shim code),

client infrastructure files, and the client user code. There is no need for client multicore infrastructure files (MCMGR and RPMsg-Lite). The RPMsg-Lite transport layer is replaced either by SPI or UART transports. The following table shows the required transport-related files per each transport type.

|SPI|<eRPC base directory>/erpc_c/setup/erpc_setup_(d)spi_master.cpp

<eRPC base directory>/erpc_c/transports/ erpc_(d)spi_master_transport.hpp

<eRPC base directory>/erpc_c/transports/ erpc_(d)spi_master_transport.cpp

| |UART|<eRPC base directory>/erpc_c/setup/erpc_setup_uart_cmsis.cpp

<eRPC base directory>/erpc_c/transports/erpc_uart_cmsis_transport.hpp

<eRPC base directory>/erpc_c/transports/erpc_uart_cmsis_transport.cpp

|

Client user code The client's user code is stored in the main_client.c file, located in the *<MCUXpressoSDK_install_dir>/boards/<board_name>/multiprocessor_examples/erpc_client_matrix_multiply_<transport_layer>/* folder.

The eRPC-relevant code with UART as a transport is captured in the following code snippet:

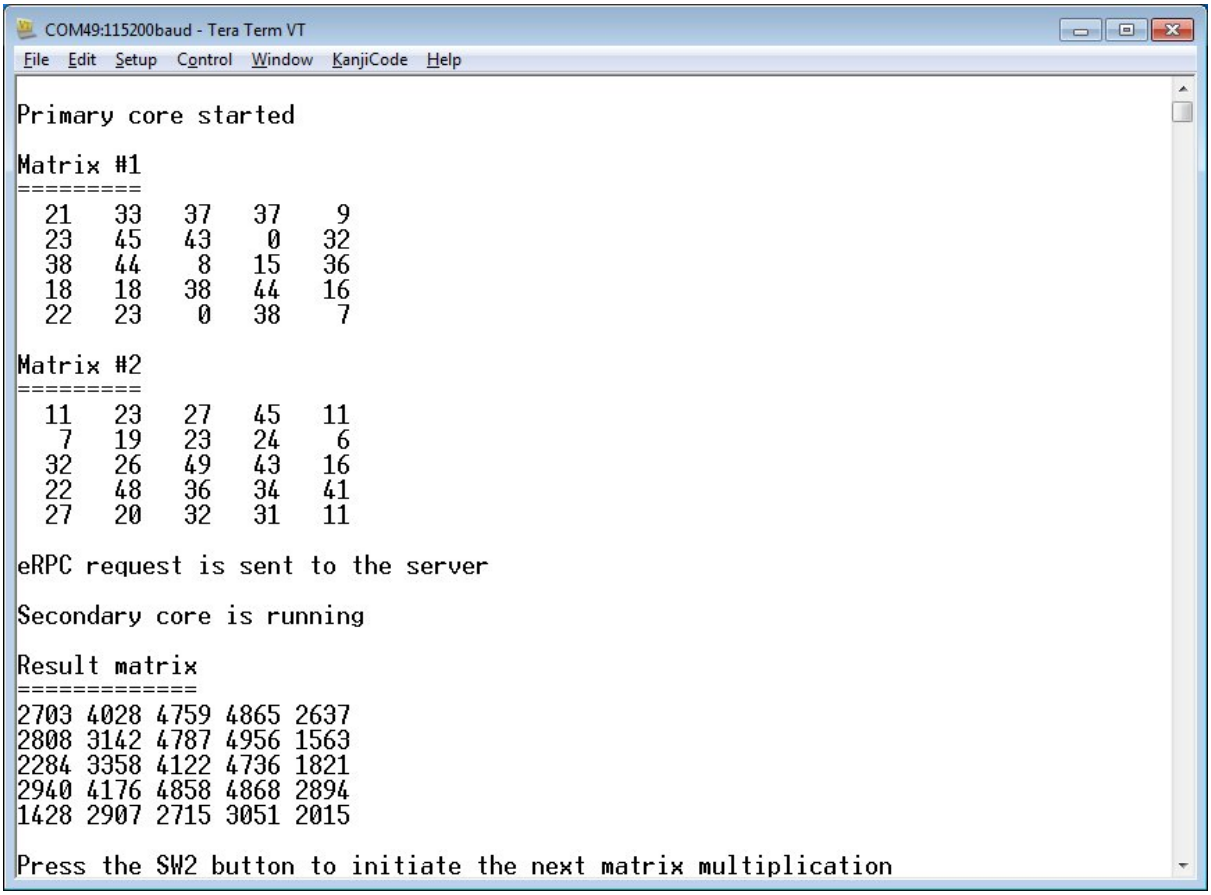
```
...
extern bool g_erpc_error_occurred;
...
/* Declare matrix arrays */
Matrix matrix1 = {0}, matrix2 = {0}, result_matrix = {0};
...
/* UART transport layer initialization, ERPC_DEMO_UART is the structure of CMSIS UART driver␣
↪operations */
erpc_transport_t transport;
transport = erpc_transport_cmsis_uart_init((void *)&ERPC_DEMO_UART);
...
/* MessageBufferFactory initialization */
erpc_mbf_t message_buffer_factory;
message_buffer_factory = erpc_mbf_dynamic_init();
...
/* eRPC client side initialization */
erpc_client_t client;
client = erpc_client_init(transport,message_buffer_factory);
...
/* Set default error handler */
erpc_client_set_error_handler(client, erpc_error_handler);
...
while (1)
{
  /* Invoke the erpcMatrixMultiply function */
  erpcMatrixMultiply(matrix1, matrix2, result_matrix);
  ...
  /* Check if some error occured in eRPC */
  if (g_erpc_error_occurred)
  {
    /* Exit program loop */
    break;
  }
  ...
}
```

Parent topic: Multiprocessor client application

Parent topic: Multiprocessor server application

Parent topic:*Create an eRPC application*

Running the eRPC application Follow the instructions in *Getting Started with MCUXpresso SDK* (document MCUXSDKGSUG) (located in the *<MCUXpressoSDK_install_dir>/docs* folder), to load both the primary and the secondary core images into the on-chip memory, and then effectively debug the dual-core application. After the application is running, the serial console should look like:



For multiprocessor applications that are running between PC and the target evaluation board or between two boards, follow the instructions in the accompanied example readme files that provide details about the proper board setup and the PC side setup (Python).

Parent topic:*Create an eRPC application*

Parent topic:*eRPC example*

Other uses for an eRPC implementation The eRPC implementation is generic, and its use is not limited to just embedded applications. When creating an eRPC application outside the embedded world, the same principles apply. For example, this manual can be used to create an eRPC application for a PC running the Linux operating system. Based on the used type of transport medium, existing transport layers can be used, or new transport layers can be implemented.

For more information and erpc updates see the github.com/EmbeddedRPC.

Note about the source code in the document Example code shown in this document has the following copyright and BSD-3-Clause license:

Changelog eRPC All notable changes to this project will be documented in this file.

The format is based on Keep a Changelog, and this project adheres to Semantic Versioning.

Unreleased

Added

Fixed

- Python code of the eRPC infrastructure was updated to match the proper python code style, add type annotations and improve readability.

1.14.0

Added

- Added Cmake/Kconfig support.
- Made java code jdk11 compliant, GitHub PR #432.
- Added imxrt1186 support into mu transport layer.
- erpcgen: Added assert for listType before usage, GitHub PR #406.

Fixed

- eRPC: Sources reformatted.
- erpc: Fixed typo in semaphore get (mutex -> semaphore), and write it can fail in case of timeout, GitHub PR #446.
- erpc: Free the arbitrated client token from client manager, GitHub PR #444.

- erpc: Fixed Makefile, install the erpc_simple_server header, GitHub PR #447.
- erpc_python: Fixed possible AttributeError and OSError on calling TCPTransport.close(), GitHub PR #438.
- Examples and tests consolidated.

1.13.0

Added

- erpc: Add BSD-3 license to endianness agnostic files, GitHub PR #417.
- eRPC: Add new Zephyr-related transports (zephyr_uart, zephyr_mbox).
- eRPC: Add new Zephyr-related examples.

Fixed

- eRPC,erpcgen: Fixing/improving markdown files, GitHub PR #395.
- eRPC: Fix Python client TCPTransports not being able to close, GitHub PR #390.
- eRPC,erpcgen: Align switch brackets, GitHub PR #396.
- erpc: Fix zephyr uart transport, GitHub PR #410.
- erpc: UART ZEPHYR Transport stop to work after a few transactions when using USB-CDC resolved, GitHub PR #420.

Removed

- eRPC,erpcgen: Remove cstbool library, GitHub PR #403.

1.12.0

Added

- eRPC: Add dynamic/static option for transport init, GitHub PR #361.
- eRPC,erpcgen: Winsock2 support, GitHub PR #365.
- eRPC,erpcgen: Feature/support multiple clients, GitHub PR #271.
- eRPC,erpcgen: Feature/buffer head - Framed transport header data stored in MessageBuffer, GitHub PR #378.
- eRPC,erpcgen: Add experimental Java support.

Fixed

- eRPC: Fix receive error value for spidev, GitHub PR #363.
- eRPC: UartTransport::init adaptation to changed driver.
- eRPC: Fix typo in assert, GitHub PR #371.
- eRPC,erpcgen: Move enums to enum classes, GitHub PR #379.
- eRPC: Fixed rpmsg tty transport to work with serial transport, GitHub PR #373.

1.11.0

Fixed

- eRPC: Makefiles update, GitHub PR #301.
- eRPC: Resolving warnings in Python, GitHub PR #325.
- eRPC: Python3.8 is not ready for usage of typing.Any type, GitHub PR #325.
- eRPC: Improved codec function to use reference instead of address, GitHub PR #324.
- eRPC: Fix NULL check for pending client creation, GitHub PR #341.
- eRPC: Replace sprintf with snprintf, GitHub PR #343.
- eRPC: Use MU_SendMsg blocking call in MU transport.
- eRPC: New LPSPI and LPI2C transport layers.
- eRPC: Freeing static objects, GitHub PR #353.
- eRPC: Fixed casting in deinit functions, GitHub PR #354.
- eRPC: Align LIBUSBSIO.GetNumPorts API use with libusbsio python module v. 2.1.11.
- erpcgen: Renamed temp variable to more generic one, GitHub PR #321.
- erpcgen: Add check that string read is not more than max length, GitHub PR #328.
- erpcgen: Move to g++ in pytest, GitHub PR #335.
- erpcgen: Use build=release for make, GitHub PR #334.
- erpcgen: Removed boost dependency, GitHub PR #346.
- erpcgen: Mingw support, GitHub PR #344.
- erpcgen: VS build update, GitHub PR #347.
- erpcgen: Modified name for common types macro scope, GitHub PR #337.
- erpcgen: Fixed memcpy for template, GitHub PR #352.
- eRPC,erpcgen: Change default build target to release + adding artefacts, GitHub PR #334.
- eRPC,erpcgen: Remove redundant includes, GitHub PR #338.
- eRPC,erpcgen: Many minor code improvements, GitHub PR #323.

1.10.0

Fixed

- eRPC: MU transport layer switched to blocking MU_SendMsg() API use.

1.10.0

Added

- eRPC: Add TCP_NODELAY option to python, GitHub PR #298.

Fixed

- eRPC: MUTransport adaptation to new supported SoCs.
- eRPC: Simplifying CI with installing dependencies using shell script, GitHub PR #267.
- eRPC: Using event for waiting for sock connection in TCP python server, formatting python code, C specific includes, GitHub PR #269.
- eRPC: Endianness agnostic update, GitHub PR #276.
- eRPC: Assertion added for functions which are returning status on freeing memory, GitHub PR #277.
- eRPC: Fixed closing arbitrator server in unit tests, GitHub PR #293.
- eRPC: Makefile updated to reflect the correct header names, GitHub PR #295.
- eRPC: Compare value length to used length() in reading data from message buffer, GitHub PR #297.
- eRPC: Replace EXPECT_TRUE with EXPECT_EQ in unit tests, GitHub PR #318.
- eRPC: Adapt rpmsg_lite based transports to changed rpmsg_lite_wait_for_link_up() API parameters.
- eRPC, erpcgen: Better distuingish which file can and cannot by linked by C linker, GitHub PR #266.
- eRPC, erpcgen: Stop checking if pointer is NULL before sending it to the erpc_free function, GitHub PR #275.
- eRPC, erpcgen: Changed api to count with more interfaces, GitHub PR #304.
- erpcgen: Check before reading from heap the buffer boundaries, GitHub PR #287.
- erpcgen: Several fixes for tests and CI, GitHub PR #289.
- erpcgen: Refactoring erpcgen code, GitHub PR #302.
- erpcgen: Fixed assigning const value to enum, GitHub PR #309.
- erpcgen: Enable runTesttest_enumErrorCode_allDirection, serialize enums as int32 instead of uint32.

1.9.1

Fixed

- eRPC: Construct the USB CDC transport, rather than a client, GitHub PR #220.
- eRPC: Fix premature import of package, causing failure when attempting installation of Python library in a clean environment, GitHub PR #38, #226.
- eRPC: Improve python detection in make, GitHub PR #225.
- eRPC: Fix several warnings with deprecated call in pytest, GitHub PR #227.
- eRPC: Fix freeing union members when only default need be freed, GitHub PR #228.
- eRPC: Fix making test under Linux, GitHub PR #229.
- eRPC: Assert costumizing, GitHub PR #148.
- eRPC: Fix corrupt clientList bug in TransportArbitrator, GitHub PR #199.
- eRPC: Fix build issue when invoking g++ with -Wno-error=free-nonheap-object, GitHub PR #233.
- eRPC: Fix inout cases, GitHub PR #237.

- eRPC: Remove ERPC_PRE_POST_ACTION dependency on return type, GitHub PR #238.
- eRPC: Adding NULL to ptr when codec function failed, fixing memcpy when fail is present during deserialization, GitHub PR #253.
- eRPC: MessageBuffer usage improvement, GitHub PR #258.
- eRPC: Get rid for serial and enum34 dependency (enum34 is in python3 since 3.4 (from 2014)), GitHub PR #247.
- eRPC: Several MISRA violations addressed.
- eRPC: Fix timeout for Freertos semaphore, GitHub PR #251.
- eRPC: Use of rpmsg_lite_wait_for_link_up() in rpmsg_lite based transports, GitHub PR #223.
- eRPC: Fix codec nullptr dereferencing, GitHub PR #264.
- erpcgen: Fix two syntax errors in erpcgen Python output related to non-encapsulated unions, improved test for union, GitHub PR #206, #224.
- erpcgen: Fix serialization of list/binary types, GitHub PR #240.
- erpcgen: Fix empty list parsing, GitHub PR #72.
- erpcgen: Fix templates for malloc errors, GitHub PR #110.
- erpcgen: Get rid of encapsulated union declarations in global scale, improve enum usage in unions, GitHub PR #249, #250.
- erpcgen: Fix compile error:UniqueIdChecker.cpp:156:104:'sort' was not declared, GitHub PR #265.

1.9.0

Added

- eRPC: Allow used LIBUSBSIO device index being specified from the Python command line argument.

Fixed

- eRPC: Improving template usage, GitHub PR #153.
- eRPC: run_clang_format.py cleanup, GitHub PR #177.
- eRPC: Build TCP transport setup code into liberpc, GitHub PR #179.
- eRPC: Fix multiple definitions of g_client error, GitHub PR #180.
- eRPC: Fix memset past end of buffer in erpc_setup_mbf_static.cpp, GitHub PR #184.
- eRPC: Fix deprecated error with newer pytest version, GitHub PR #203.
- eRPC, erpcgen: Static allocation support and usage of rpmsg static FreeRTOSs related APi, GitHub PR #168, #169.
- erpcgen: Remove redundant module imports in erpcgen, GitHub PR #196.

1.8.1

Added

- eRPC: New i2c_slave_transport trasnport introduced.

Fixed

- eRPC: Fix misra erpc c, GitHub PR #158.
- eRPC: Allow conditional compilation of message_loggers and pre_post_action.
- eRPC: (D)SPI slave transports updated to avoid busy loops in rtos environments.
- erpcgen: Re-implement EnumMember::hasValue(), GitHub PR #159.
- erpcgen: Fixing several misra issues in shim code, erpcgen and unit tests updated, GitHub PR #156.
- erpcgen: Fix bison file, GitHub PR #156.

1.8.0

Added

- eRPC: Support win32 thread, GitHub PR #108.
- eRPC: Add mbed support for malloc() and free(), GitHub PR #92.
- eRPC: Introduced pre and post callbacks for eRPC call, GitHub PR #131.
- eRPC: Introduced new USB CDC transport.
- eRPC: Introduced new Linux spidev-based transport.
- eRPC: Added formatting extension for VSC, GitHub PR #134.
- erpcgen: Introduce ustring type for unsigned char and force cast to char*, GitHub PR #125.

Fixed

- eRPC: Update makefile.
- eRPC: Fixed warnings and error with using MessageLoggers, GitHub PR #127.
- eRPC: Extend error msg for python server service handle function, GitHub PR #132.
- eRPC: Update CMSIS UART transport layer to avoid busy loops in rtos environments, introduce semaphores.
- eRPC: SPI transport update to allow usage without handshaking GPIO.
- eRPC: Native _WIN32 erpc serial transport and threading.
- eRPC: Arbitrator deadlock fix, TCP transport updated, TCP setup functions introduced, GitHub PR #121.
- eRPC: Update of matrix_multiply.py example: Add –serial and –baud argument, GitHub PR #137.
- eRPC: Update of .clang-format, GitHub PR #140.
- eRPC: Update of erpc_framed_transport.cpp: return error if received message has zero length, GitHub PR #141.
- eRPC, erpcgen: Fixed error messages produced by -Wall -Wextra -Wshadow -pedantic-errors compiler flags, GitHub PR #136, #139.
- eRPC, erpcgen: Core re-formatted using Clang version 10.
- erpcgen: Enable deallocation in server shim code when callback/function pointer used as out parameter in IDL.
- erpcgen: Removed '$' character from generated symbol name in '_$union' suffix, GitHub PR #103.

- erpcgen: Resolved mismatch between C++ and Python for callback index type, GitHub PR #111.
- erpcgen: Python generator improvements, GitHub PR #100, #118.
- erpcgen: Fixed error messages produced by -Wall -Wextra -Wshadow -pedantic-errors compiler flags, GitHub PR #136.

1.7.4

Added

- eRPC: Support MU transport unit testing.
- eRPC: Adding mbed os support.

Fixed

- eRPC: Unit test code updated to handle service add and remove operations.
- eRPC: Several MISRA issues in rpmsg-based transports addressed.
- eRPC: Fixed Linux/TCP acceptance tests in release target.
- eRPC: Minor documentation updates, code formatting.
- erpcgen: Whitespace removed from C common header template.

1.7.3

Fixed

- eRPC: Improved the test_callbacks logic to be more understandable and to allow requested callback execution on the server side.
- eRPC: TransportArbitrator::prepareClientReceive modified to avoid incorrect return value type.
- eRPC: The ClientManager and the ArbitratedClientManager updated to avoid performing client requests when the previous serialization phase fails.
- erpcgen: Generate the shim code for destroy of statically allocated services.

1.7.2

Added

- eRPC: Add missing doxygen comments for transports.

Fixed

- eRPC: Improved support of const types.
- eRPC: Fixed Mac build.
- eRPC: Fixed serializing python list.
- eRPC: Documentation update.

1.7.1

Fixed

- eRPC: Fixed semaphore in static message buffer factory.
- erpcgen: Fixed MU received error flag.
- erpcgen: Fixed tcp transport.

1.7.0

Added

- eRPC: List names are based on their types. Names are more deterministic.
- eRPC: Service objects are as a default created as global static objects.
- eRPC: Added missing doxygen comments.
- eRPC: Added support for 64bit numbers.
- eRPC: Added support of program language specific annotations.

Fixed

- eRPC: Improved code size of generated code.
- eRPC: Generating crc value is optional.
- eRPC: Fixed CMSIS Uart driver. Removed dependency on KSDK.
- eRPC: Forbid users use reserved words.
- eRPC: Removed outByref for function parameters.
- eRPC: Optimized code style of callback functions.

1.6.0

Added

- eRPC: Added @nullable support for scalar types.

Fixed

- eRPC: Improved code size of generated code.
- eRPC: Improved eRPC nested calls.
- eRPC: Improved eRPC list length variable serialization.

1.5.0

Added

- eRPC: Added support for unions type non-wrapped by structure.
- eRPC: Added callbacks support.
- eRPC: Added support @external annotation for functions.
- eRPC: Added support @name annotation.
- eRPC: Added Messaging Unit transport layer.
- eRPC: Added RPMSG Lite RTOS TTY transport layer.
- eRPC: Added version verification and IDL version verification between eRPC code and eRPC generated shim code.
- eRPC: Added support of shared memory pointer.
- eRPC: Added annotation to forbid generating const keyword for function parameters.
- eRPC: Added python matrix multiply example.
- eRPC: Added nested call support.
- eRPC: Added struct member “byref” option support.
- eRPC: Added support of forward declarations of structures
- eRPC: Added Python RPMsg Multiendpoint kernel module support
- eRPC: Added eRPC sniffer tool

1.4.0

Added

- eRPC: New RPMsg-Lite Zero Copy (RPMsgZC) transport layer.

Fixed

- eRPC: win_flex_bison.zip for windows updated.
- eRPC: Use one codec (instead of inCodec outCodec).

[1.3.0]

Added

- eRPC: New annotation types introduced (@length, @max_length, ...).
- eRPC: Support for running both erpc client and erpc server on one side.
- eRPC: New transport layers for (LP)UART, (D)SPI.
- eRPC: Error handling support.

[1.2.0]

Added

- eRPC source directory organization changed.
- Many eRPC improvements.

[1.1.0]

Added

- Multicore SDK 1.1.0 ported to KSDK 2.0.0.

[1.0.0]

Added

- Initial Release

1.5 Multimedia

1.5.1 Audio Voice

Audio Voice Components

MCUXpresso SDK : audio-voice-components

Overview This repository is for MCUXpresso SDK audio-voice-components middleware delivery and it contains the components officially provided in NXP MCUXpresso SDK. This repository is part of the MCUXpresso SDK overall delivery which is composed of several sub-repositories/projects. Navigate to the top/parent repository (mcuxsdk-manifests) for the complete delivery of MCUXpresso SDK.

Documentation Overall details can be reviewed here: MCUXpresso SDK Online Documentation

Visit Audio Voice Components - Documentation to review details on the contents in this sub-repo.

Setup Instructions on how to install the MCUXpresso SDK provided from GitHub via west manifest Getting Started with SDK - Detailed Installation Instructions

Contribution Contributions are not currently accepted. Guidelines to contribute will be posted in the future.

Overview This repository allows users to add additional functionality to the Maestro Audio framework. This structure is designed for integration with Maestro and is not intended for standalone use. For information on the use of individual components, please refer to the Maestro programmer's guide.

This repository acts as Zephyr module, to be able to use these libraries in Zephyr build system.

Content

- *asrc* - Libraries and public files of Asynchronous Sample Rate Converter, version 1.0.0
- *ssrc* - Libraries and public files of Synchronous Sample Rate Converter, version 1.0.0
- *opus* - Source files of Opus decoder and encoder, version 1.3.1
- *opusfile* - Source files for Opus streams in the Ogg container, version 0.12
- *ogg* - Source files of Ogg container, version 1.3.5
- *decoders* - Libraries and public files of following audio decoders:
  - *aac* - AAC decoder, version 1.0.0
  - *flac* - FLAC decoder, version 1.0.0
  - *mp3* - MP3 decoder, version 1.0.0
  - *wav* - WAV decoder, version 1.0.0
- zephyr/ - Files allowing usage of the libraries in Zephyr build

Following table contains information about libraries and source files availability:

Asynchronous Sample Rate Converter The Asynchronous Sample Rate Converter (ASRC) software module compensates the drift between two mono audio signals. This is not a frequency converter and so the nominal signal frequency is the same before and after the ASRC. More details about ASRC are available in the User Guide, which is located in asrc\doc\.

Synchronous Sample Rate Converter The Synchronous Sample Rate Converter (SSRC) software module converts an audio signal (mono or stereo) with a certain sampling frequency to an audio signal with another sampling frequency. More details about SSRC are available in the *User Guide*.

Opus For Opus decoder and encoder documentation please see following link: opus.

Opus File The Opus File provides a API for decoding and basic manipulation of Opus streams in Ogg container and depends on *Opus* and *Ogg* libraries. For Opus File documentation please see following link: opusfile.

Ogg Container For Ogg container documentation please see following link: ogg.

Decoders Each decoder contains libraries for supported processor and toolchain (see table above), corresponding Public API file and documentation folder.

AAC For decoder features please see *aacdec*, for API Usage please see *aacd_ug*.

FLAC For decoder features please see *flacdec*, for API Usage please see *flacd_ug*.

MP3 For decoder features please see *mp3dec*, for API Usage please see *mp3d_ug*.

WAV For decoder features please see *wavdec*, for API Usage please see *wavd_ug*.

Zephyr build To add library into the Zephyr build, add CONFIG_NXP_AUDIO_VOICE_COMPONENTS_* for specific libraries into your prj.conf. For all configuration options, see zephyr/Kconfig.

List of supported libraries in Zephyr:

- Decoders:
  - AAC
  - FLAC
  - MP3
  - FLAC
  - OPUS
- Encoders
  - OPUS

AAC decoder

AAC decoder features

- The AAC decoder implementation supports the following:
- Supported profile : AAC-LC
- Sampling rate : 8 kHz, 11.025 kHz, 12 kHz, 16 kHz, 22.05 kHz, 24 kHz, 32 kHz, 44.1 kHz, 48 kHz
- Channel : stereo and mono
- Bits per samples : 16 bit
- Container format : (MPEG-2 Style)AAC transport format - ADTS and ADIF.

Specification and reference

Performance

Memory information The memory usage of the decoder in bytes is:

- Code/flash = 26332 + 19264 = 45596
- Data/RAM = 26832

Section	Size
.text	26332
.ro & .const	19264
.bss	26832

CPU usage

- CPU core clock in MHz: 20.97.

Track type	Duration of track in second	Frame size in bytes	Performance MIPS of codec (in MHz)
48 kHz, stereo	38 s	4096	12.2 MHz

API Usage of AAC Decoder

Overview

- This section describes the integration steps to call AAC decoder APIs by the application code. During each step, the used data structures and functions are explained. All CCI public APIs are defined in aac_cci.h header file. This file is located at \decoders\aac.

Configuration

Build Options AAC Decoder library is built with the following defined/enabled macros.

- There is no macro or define used to build the AAC decoder.

Buffer Allocation

- The AAC decoder does not perform dynamic memory allocation. The application calls the function AACDecoderGetMemorySize() to get the decoder memory requirements. This function must be called before all other decoder functions are invoked.
- The application first gets the required memory size for the decoder, then allocates memory for the decoder structures. Structures contain Main Decoder parameters and decoder information parameters.
- This function populates the required memory for the decoder and returns the required memory size in bytes.

Initialization

- AACDecoderInit() function must be called before decode API. This API allocates the memory to decoder main structure and also initializes the decoder main structure parameters.
- It also registers the call back functions to the decoder, which is used by the decoder to read or seek the input stream.

Decoding

- AACDecoderDecode() function is main decoding API of the decoder. This API decodes the encoded input stream and fills the PCM output samples into decoder output PCM buffer.
- This API gives the information about the number of samples produced by the decoder and also provides the pointer to the decoder output PCM samples buffer.

Seeking

- AACDecoderSeek() function calculates the actual frame boundary align offset from the unalign seek offset and returns the actual seek offset. It also resets the decoder internal states and variables.

Callback Usage All the callback functions are assigned to the respective pointers before the codec initialization is called. Callback APIs are described below.

Read Callback API AAC Decoder read call back API reads the bytes from the input stream and fills them into decoder internal bit stream buffer. It returns the number of bytes read from the input stream.

Seek Callback API This call back API is for the seek operation.

Get File Position Callback API This call back API gives the current file position.

FLAC decoder

FLAC decoder features

- The FLAC decoder implementation support the following:
- Sampling rate: 8 kHz, 11.05 kHz, 12 kHz, 16 kHz, 22.05 kHz, 32 kHz, 44.1 kHz, and 48 kHz.
- Channel : stereo and mono
- Bits per samples : 16 bits

Specification and reference

Official website

- FLAC lossless audio codec is at https://xiph.org/flac.

Inbound licensing

- For licensing information please refer to FLAC's official website: https://xiph.org/flac/license.html.

Performance

Memory information The memory usage of the decoder in bytes is:

- Code/flash = 15744 + 2080 = 17824
- Data/RAM = 27936

Section	Size
.text	15744
.ro & .const	2080
.bss	27936

CPU usage

- Output frame size: 16384 bytes.
- CPU core clock in MHz: 20.97.

Track type	Duration of track in second	Performance MIPS of codec (in MHz)
48 kHz, stereo	76 s	30.7 MHz
32 kHz, stereo	76 s	20.3 MHz
8 kHz, stereo	37 s	5.34 MHz

Following test cases are performed:

- Audio format listening test
- Audio quality test

For all above test cases, test tracks are played through the end without any distortion, glitching, hanging, or crashing.

API Usage of FLAC Decoder

Overview

- This section describes the integration steps to call FLAC decoder APIs by the application code. During each step the used data structures and functions are explained. All cci public APIs are defined in flac_cci.h header file. This file is located at \decoders\flac\include.

Configuration

Build Options

- SUPPORT_16_BITS_ONLY :- This macro is used to enable 16bits per sample flac decoder.
- *ASM* :- This macro is used to enable ARM assembly macros for 24bits per sample flac decoder.

Buffer Allocation

- The FLAC decoder does not perform dynamic memory allocation. The application calls the function FLACDecoderGetMemorySize() to get the decoder memory requirements. This function must be called before all other decoder functions are invoked.
- The application first gets the required memory size for the decoder and then allocates memory for the decoder structures. Structures contain Main Decoder parameters and decoder information parameters.
- This function populates the required memory for the decoder and returns the required memory size in bytes.

Initialization

- FLACDecoderInit() function must be called before decode API. This API allocates the memory to decoder main structure and also initializes the decoder main structure parameters.
- It also registers the call back functions to the decoder, which will be used by decoder to read or to seek the input stream.

Decoding

- FLACDecoderDecode() function is main decoding API of the decoder. This API decodes the encoded input stream and fills the PCM output samples into decoder output PCM buffer.
- This API gives the information about the number of samples produced by the decoder and also provides the pointer to the decoder output PCM samples buffer.

Seeking

- FLACDecoderSeek() function calculates the actual frame boundary align offset from the unalign seek offset and returns the actual seek offset. It also resets the decoder internal states and variables.

Callback Usage All the callback functions will be assigned to the respective pointers before the codec initialization is called. Callback APIs are described below.

Read Callback API FLAC Decoder read call back API reads the bytes from the input stream and fills them into decoder internal bit stream buffer. It returns the number of bytes read from the input stream.

Seek Callback API This call back API is for the seek operation.

Get File Position Callback API This call back API gives the current file position.

MP3 decoder

MP3 decoder features

- MP3 decoder supports mpeg-1, mpeg-2, mpeg-2.5.
- All MP3 features supported , including joint stereo, mid-side stereo, intensity stereo, and dual channel.
- Supported sampling rate: 8 kHz, 11.025 kHz, 12 kHz, 16 kHz, 22.05 kHz, 24 kHz, 32 kHz, 44.1 kHz and 48 kHz.
- Supported channel: stereo and mono
- Supported bits per samples: 16 bit
- Supported bit rate: 8, 16, 24, 32, 40, 48, 56, 64, 80, 96, 112, 128, 144, 160, 176, 192, 224, 256, 320, 384, 416, and 448.

Performance

Memory information The memory usage of the decoder (data obtained from IAR compiler) in bytes is:

- Code/flash = 26884 + 18372 = 45256
- RAM = 16200

Section	Size
.text	26884
.ro & .const	18372
.bss	16200

CPU usage The performance of the decoder was measured using the real hardware platform (RT1060).

- CPU core clock in MHz: 600.

Track type	Duration of track in second	Frame size in bytes	Performance MIPS of codec (in MHz)
320 Kbps, 44.1 kHz, stereo	358 s	2304	~24 MHz
192 Kbps, 48 kHz, stereo	10 s	2304	~18 MHz

API Usage of MP3 Decoder

Overview

- This section describes the integration steps to call MP3 decoder APIs by the application code. During each step the used data structures and functions are explained. All cci public APIs are defined in mp3_cci.h header file. This file is located at $\backslash$decoders$\backslash$mp3.

Configuration

Build Options MP3 Decoder library is built with the following defined/enabled macros.

- There is no macro or define used to build the MP3 decoder.

Buffer Allocation

- The MP3 decoder does not perform dynamic memory allocation. The application calls the function MP3DecoderGetMemorySize() to get the decoder memory requirements. This function must be called before all other decoder functions are invoked.
- The application first gets the required memory size for the decoder and then allocates memory for the decoder structures. Structures contain Main Decoder parameters and decoder information parameters.
- This function populates the required memory for the decoder and returns the required memory size in bytes.

Initialization

- MP3DecoderInit() function must be called before decode API. This API allocates the memory to decoder main structure and also initializes the decoder main structure parameters.
- It also registers the call back functions to the decoder, which will be used by decoder to read or to seek the input stream.

Decoding

- MP3DecoderDecode() function is main decoding API of the decoder. This API decodes the encoded input stream and fills the PCM output samples into decoder output PCM buffer.
- This API gives the information about the number of samples produced by the decoder and also provides the pointer to the decoder output PCM samples buffer.

Seeking

- MP3DecoderSeek() function calculates the actual frame boundary align offset from the un-align seek offset and returns the actual seek offset. It also resets the decoder internal states and variables.

Callback Usage All the callback functions will be assigned to the respective pointers before the codec initialization is called. Callback APIs are described below.

Read Callback API MP3 Decoder read call back API reads the bytes from the input stream and fills them into decoder internal bit stream buffer. It returns the number of bytes read from the input stream.

Seek Callback API This call back API is for the seek operation.

Get File Position Callback API This call back API gives the current file position.

WAV decoder

WAV decoder features

- The WAV decoder implementation support the following:
- Sampling rate: 8 kHz, 11.025kHz, 16 kHz, 22.05 kHz, 32 kHz, 44.1 kHz, and 48 kHz.
- Channel: stereo and mono
- PCM format with 8/16/24 bits per sample.

Performance

Memory information The memory usage of the decoder in bytes is:

- Code/flash = 6260 + 342 = 6602
- Data/RAM = 16 + 20696 = 20712

Section	Size
.text	6260
.ro & .const	342
.bss	20696
.data	16

CPU usage The performance of the decoder was measured using the decoder standalone unit test.

- CPU core clock in MHz: 20.97 MHz.

Track type	Duration of track in second	Frame size in bytes	Performance MIPS of codec (in MHz)
48 kHz, stereo, PCM	12 s	4096	9.68 MHz

Following test cases were performed:

- Audio format listening test
- Audio quality test

For all above test cases, test tracks are played through the end without any distortion, glitching, hanging, or crashing.

API Usage of WAV Decoder

Overview

- This section describes the integration steps to call MP3 decoder APIs by the application code. During each step the used data structures and functions are explained. All cci public APIs are defined in wav_cci.h header file. This file is located at \decoders\wav.

Configuration

Build Options WAV Decoder library is built with the following defined/enabled macros.

- There is no macro or define used to build the WAV decoder.

Buffer Allocation

- The WAV decoder does not perform dynamic memory allocation. The application calls the function WAVDecoderGetMemorySize() to get the decoder memory requirements. This function must be called before all other decoder functions are invoked.
- The application first gets the required memory size for the decoder and then allocates memory for the decoder structures. Structures contain Main Decoder parameters and decoder information parameters.
- This function populates the required memory for the decoder and returns the required memory size in bytes.

Initialization

- WAVDecoderInit() function must be called before decode API. This API allocates the memory to decoder main structure and also initializes the decoder main structure parameters.
- It also registers the call back functions to the decoder, which will be used by decoder to read or to seek the input stream.

Decoding

- WAVDecoderDecode() function is main decoding API of the decoder. This API decodes the encoded input stream and fills the PCM output samples into decoder output PCM buffer.
- This API gives the information about the number of samples produced by the decoder and also provides the pointer to the decoder output PCM samples buffer.

Seeking

- WAVDecoderSeek() function calculates the actual frame boundary align offset from the unalign seek offset and returns the actual seek offset. It also resets the decoder internal states and variables.

Callback Usage All the callback functions will be assigned to the respective pointers before the codec initialization is called. Callback APIs are described below.

Read Callback API WAV Decoder read call back API reads the bytes from the input stream and fills them into decoder internal bit stream buffer. It returns the number of bytes read from the input stream.

Seek Callback API This call back API is for the seek operation.

Get File Position Callback API This call back API gives the current file position.

Synchronous Sample Rate Converter

Introduction The Synchronous Sample Rate Converter (SSRC) software module converts a mono or stereo audio signal with a certain sampling frequency to an audio signal with a different sampling frequency. The sample rate converter works synchronously, meaning that input and output sampling rates are exactly known for a mutual clock reference.

To accomplish a professional sampling conversion quality and minimal system footprint, the SRC SW module contains highly optimized components.

The SSRC module supports the following features.

- Multiple instances of the sample rate converter can run at the same time.
- Supported sampling frequencies: 32 kHz, 44.1 kHz, and 48 kHz plus the halves and the quarters of these three sample rates. The input and output sample rates are freely selectable out of the supported sampling rates
- Selectable Mono/Stereo Input/Output.
- Selectable quality level: high quality/ very high quality.

Acronyms *Table 1* lists the acronyms used in this document.

Acror	Description
Fs	Sampling Frequency
Fs-LOW	Lowest sample rate used for the conversion **Note:** Input sample rate for up sampling and the output sample rate for down sampling
FsIN	Input sample rate
FsOU	Output sample rate
MIPS	Million Instructions Per Second
SSRC	Synchronous sample rate converter
THD+	Total Harmonic Distortion plus Noise **Note:** The THD+N is defined as the total power of the unwanted signal divided by the power of the wanted signal. The wanted signal is defined as a full scale, 1 kHz sine wave.

Parent topic:*Introduction*

Performance figures The Total Harmonic Distortion Plus Noise (THD+N) of the converted signals is below - 76 (high-quality mode) and - 85 (very high-quality mode) for signal frequencies below 0.45*FsLOW (=90 % of the Nyquist range of the lowest sample clock)

Table 1 and *Table 2* give the THD+N performance (FsIN on the vertical axis and FsOUT on the horizontal axis) for the two supported quality levels. The numbers in the tables give the worst-case THD+N measured for signal frequencies below 0.45*FsLOW. For each conversion ratio, 100 THD+N measurements were executed with signal frequencies linearly spread over the complete Nyquist range.

FsIN/ FsOUT	8000	11025	12000	16000	22050	24000	32000	44100	48000
8000	-92.1	-79.7	-80.1	-80.1	-79.6	-80.2	-79.4	-79.1	-79.2
11025	-79	-92.9	-80	-79.9	-80.2	-79.8	-79.9	-79.5	-78.9
12000	-79	-79.2	-92.7	-80.1	-79.8	-80.3	-79.8	-79.8	-79.5
16000	-81.7	-78.8	-80.2	-93	-78.3	-77.7	-78.3	-78.3	-77.9
22050	-77.5	-81.8	-78.2	-79	-93	-79.9	-79.8	-80.3	-79.9
24000	-77.4	-77.9	-81.2	-79.1	-79.2	-92.5	-80.1	-79.8	-79.9
32000	-81	-77.5	-78.9	-81.2	-78.7	-80.1	-92.9	-79.7	-79.2
44100	-79.1	-81.2	-76.7	-77.8	-82	-78.2	-79.1	-93	-79.7
48000	-78.7	-78.8	-81.1	-77.6	-77.9	-81.8	-79.1	-79.3	-93

FsIN/ FsOUT	8000	11025	12000	16000	22050	24000	32000	44100	48000
8000	-92.1	-86.6	-88.6	-91.5	-86.4	-89	-89.7	-89.3	-89.3
11025	-89.1	-92.9	-86.3	-86.3	-91.6	-86.3	-86.5	-89.7	-89.3
12000	-91.4	-88.4	-92.7	-89.6	-86.6	-91.5	-86.8	-86.6	-89.7
16000	-93.1	-88.4	-90.4	-93	-86.6	-88.8	-91.5	-86.5	-89.4
22050	-90.7	-93.5	-89.7	-89.3	-93	-86.5	-86.3	-91.5	-86.6
24000	-93.8	-90.5	-93.5	-91.7	-88.4	-92.5	-89.7	-86.6	-91.5
32000	-93.8	-91	-91.2	-93.3	-88.4	-90.5	-92.9	-86.7	-89
44100	-93.7	-93.6	-91.5	-90.6	-93.8	-89.8	-89.3	-93	-86.5
48000	-94.1	-92.6	-94	-94	-90.1	-93.7	-91.8	-88.4	-93

Parent topic:*Introduction*

Resource usage This section lists the memory and processing requirements for the SSRC module.

Memory requirements The following are the memory requirements for the SSRC module.

Memory item	Size in bytes
Instance memory (persistent)	548
Scratch memory (non-persistent)	15.536 *1*
Program memory for Arm9E and XScale	14k
Program memory for Arm7	15k

Parent topic: Resource usage

1 Worst case number for I/O buffers of 40 ms. If smaller I/O buffers are used, this number is smaller. The required scratch memory is roughly equal to 2 times the buffer size on the highest sample rate.

Processing requirements The following tables give the MIPS performance of the SSRC module. The cycles are measured with zero wait state memory and for I/O buffers of 40 ms.

Note: The user processing 32-bit processing must refer to the very high-quality MIPS results.

On Arm7 and Arm9

FsIN / FsOUT	8000	11025	12000	16000	22050	24000	32000	44100	48000
8000	0.13	4.77	5.17	1.84	6.75	7.33	3.55	9.1	9.89
11025	5.42	0.18	5.58	6.84	2.53	7.75	9.71	4.89	10.31
12000	5.85	6.39	0.2	7.01	8.97	2.76	9.89	12.94	5.32
16000	1.69	7.74	7.99	0.26	9.54	10.33	3.68	13.5	14.65
22050	7.2	2.33	10.09	10.83	0.36	11.17	13.67	5.07	15.49
24000	7.79	8.33	2.53	11.7	12.78	0.39	14.03	17.94	5.51
32000	3.12	10.32	10.58	3.38	15.48	15.98	0.52	19.08	20.66
44100	9.96	4.3	13.65	14.4	4.65	20.18	21.67	0.72	22.34
48000	10.8	11.34	4.68	15.58	16.67	5.06	23.4	25.56	0.78

FsIN / FsOUT	8000	11025	12000	16000	22050	24000	32000	44100	48000
8000	0.07	7.71	8.24	2.28	10.5	11.28	4.41	13.44	14.48
11025	8.19	0.1	8.96	11.04	3.14	12	15.09	6.08	15.2
12000	8.76	9.52	0.1	11.3	14.48	3.41	15.36	20.07	6.61
16000	2.14	11.73	12.01	0.14	15.41	16.48	4.55	21	22.56
22050	10.78	2.94	15.39	16.38	0.19	17.92	22.08	6.27	24
24000	11.57	12.34	3.2	17.51	19.04	0.21	22.61	28.97	6.83
32000	4.19	15.48	15.77	4.27	23.46	24.01	0.28	30.83	32.96
44100	14.78	5.77	20.56	21.56	5.89	30.77	32.75	0.38	35.83
48000	15.92	16.7	6.28	23.15	24.69	6.41	35.02	38.08	0.42

FsIN / FsOUT	8000	11025	12000	16000	22050	24000	32000	44100	48000
8000	0.13	13.61	14.52	4.43	19.03	20.43	8.8	25.06	26.99
11025	14.85	0.18	15.91	19.47	6.1	21.82	27.35	12.13	28.38
12000	15.84	17.36	0.2	19.97	25.4	6.64	27.85	36.26	13.21
16000	4.25	21.24	21.79	0.26	27.22	29.03	8.86	38.07	40.85
22050	20.02	5.85	27.72	29.7	0.36	31.81	38.94	12.2	43.63
24000	21.45	22.98	6.37	31.68	34.71	0.39	39.94	50.8	13.28
32000	8.39	28.74	29.29	8.5	42.48	43.58	0.52	54.43	58.07
44100	28.11	11.57	38.05	40.03	11.71	55.43	59.4	0.72	63.62
48000	30.19	31.71	12.59	42.9	45.96	12.74	63.36	69.42	0.78

Parent topic: Processing requirements

On Arm9e and XScale

FsIN / FsOUT	8000	11025	12000	16000	22050	24000	32000	44100	48000
8000	0.03	1.14	1.25	0.54	1.95	2.14	1.04	3.85	4.23
11025	1.31	0.05	1.36	1.62	0.75	2.23	2.78	1.44	4.38
12000	1.43	1.57	0.05	1.68	2.13	0.82	2.84	3.72	1.57
16000	0.5	1.86	1.93	0.07	2.27	2.5	1.09	3.9	4.29
22050	2.19	0.69	2.42	2.61	0.1	2.72	3.24	1.5	4.46
24000	2.4	2.52	0.75	2.86	3.15	0.1	3.35	4.25	1.63
32000	0.92	3.12	3.18	1.01	3.72	3.86	0.14	4.55	4.99
44100	4.28	1.27	4.15	4.37	1.39	4.83	5.23	0.19	5.43
48000	4.7	4.9	1.39	4.8	5.03	1.51	5.72	6.3	0.21

FsIN / FsOUT	8000	11025	12000	16000	22050	24000	32000	44100	48000
8000	0.06	1.87	2.02	1.07	3.09	3.36	2.07	6.09	6.63
11025	2.27	0.09	2.25	2.66	1.47	3.56	4.4	2.85	7.01
12000	2.45	2.76	0.09	2.75	3.43	1.6	4.5	5.83	3.1
16000	0.99	3.23	3.36	0.13	3.73	4.05	2.14	6.17	6.72
22050	3.69	1.36	4.14	4.55	0.17	4.51	5.31	2.95	7.13
24000	4.01	4.28	1.48	4.9	5.51	0.19	5.51	6.85	3.21
32000	1.83	5.26	5.39	1.98	6.46	6.71	0.25	7.47	8.09
44100	7.22	2.52	6.94	7.38	2.72	8.27	9.1	0.35	9.02
48000	7.85	8.33	2.74	8.02	8.57	2.97	9.81	11.03	0.38

FsIN / FsOUT	8000	11025	12000	16000	22050	24000	32000	44100	48000
8000	0.03	1.21	1.33	0.61	2.08	2.29	1.17	4.1	4.51
11025	1.47	0.05	1.44	1.72	0.84	2.38	2.97	1.61	4.66
12000	1.62	1.76	0.05	1.78	2.26	0.91	3.03	3.98	1.75
16000	0.55	2.1	2.17	0.07	2.42	2.65	1.22	4.16	4.57
22050	2.49	0.76	2.73	2.95	0.1	2.88	3.45	1.68	4.75
24000	2.75	2.86	0.83	3.23	3.52	0.1	3.56	4.53	1.83
32000	1	3.56	3.63	1.11	4.2	4.34	0.14	4.84	5.3
44100	4.86	1.38	4.74	4.98	1.53	5.46	5.89	0.19	5.75
48000	5.38	5.55	1.5	5.5	5.71	1.66	6.47	7.05	0.21

FsIN / FsOUT	8000	11025	12000	16000	22050	24000	32000	44100	48000
8000	0.06	2.11	2.29	1.2	3.55	3.86	2.31	6.99	7.61
11025	2.62	0.09	2.52	3.01	1.66	4.07	5.07	3.19	8
12000	2.85	3.15	0.09	3.11	3.9	1.81	5.17	6.75	3.47
16000	1.09	3.73	3.85	0.13	4.22	4.57	2.41	7.1	7.72
22050	4.32	1.5	4.79	5.23	0.17	5.05	6.02	3.32	8.15
24000	4.74	4.99	1.64	5.69	6.3	0.19	6.22	7.8	3.61
32000	1.98	6.18	6.3	2.18	7.45	7.71	0.25	8.44	9.14
44100	8.43	2.72	8.18	8.64	3.01	9.59	10.47	0.35	10.1
48000	9.26	9.66	2.97	9.49	9.97	3.27	11.39	12.59	0.38

Parent topic: Processing requirements

On Cortex-A8 for worst case of 48000 Hz to 44100 Hz

Mode	MIPs
Mono at High Quality	3.13
Stereo at High Quality	3.61
Mono at Very High Quality	4.13
Stereo at Very High Quality	6.52

Parent topic: Processing requirements

Parent topic: Resource usage

Parent topic:*Introduction*

Application programmers interface (API)

This section describes the application programming interface (API) libraries of the SSRC module.

Type definitions

This section describes the type definitions of the SSRC module.

Types for allocation of instance and scratch memory

The instance memory is the memory that contains the state of one instance of the SSRC module. Multiple instances of the SSRC module can exist, each with it is own instance memory. S memory is the memory that is only used temporarily by the process function of the SSRC module. This memory can be used as scratch memory by any other function running in the same thread as the SSRC module. Different threads cannot share the scratch memories.

The application must allocate both the instance and the scratch memory. The SSRC module does not allocate memory.

There is a data type available for both the instance and the scratch memory, namely SSRC_Instance_t and SSRC_Scratch_t. The instance type is defined as structures of the correct size in the SSRC header file. Both the instance and the scratch memory must be 4 bytes aligned.

Parent topic: Type definitions

LVM_Fs_en

Definition:

```
typedef enum
{
    LVM_FS_8000     = 0,
    LVM_FS_11025    = 1,
```

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```
    LVM_FS_12000   = 2,
    LVM_FS_16000   = 3,
    LVM_FS_22050   = 4,
    LVM_FS_24000   = 5,
    LVM_FS_32000   = 6,
    LVM_FS_44100   = 7,
    LVM_FS_48000   = 8
} LVM_Fs_en;
```

Description:

Used to pass the input and the output sample rate to the SSRC.

Parent topic: Type definitions

LVM_Format_en Definition:

```
typedef enum
{
    LVM_STEREO          = 0,
    LVM_MONOINSTEREO    = 1,
    LVM_MONO            = 2
} LVM_Format_en;
```

Description:

The LVM_Format_en enumerated type is used to set the value of the SSRC data format.

The SSRC supports input data in two formats Mono and Stereo. For an input buffer of NumSamples = N (meaning N sample pairs for Stereo and MonoInStereo or N samples for Mono), the format of data in the buffer is as listed in *Table 1*:

Sample Number	Stereo	MonoInStereo	Mono
0	Left(0)	Mono(0)	Mono(0)
1	Right(0)	Mono(0)	Mono(1)
2	Left(1)	Mono(1)	Mono(2)
3	Right(1)	Mono(1)	Mono(3)
4	Left(2)	Mono(2)	Mono(4)
“	“	“	“
“	“	“	“
N-2	Left(N/2-1)	Mono(N/2-1)	Mono(N-2)
N-1	Right(N/2-1)	Mono(N/2-1)	Mono(N-1)
N	Left(N/2)	Mono(N/2)	Not Used
N+1	Right(N/2)	Mono(N/2)	Not Used
N+2	Left(N/2+1)	Mono(N/2+1)	Not Used
N+3	Right(N/2+1)	Mono(N/2+1)	Not Used
“	“	“	Not Used
“	“	“	Not Used
2*N-2	Left(N-1)	Mono(N-1)	Not Used

Parent topic: Type definitions

SSRC_Quality_en Definition:

```
typedef enum
{
    SSRC_QUALITY_HIGH           = 0,
```

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```
    SSRC_QUALITY_VERY_HIGH      = 1,
    SSRC_QUALITY_DUMMY          = LVM_MAXENUM
} SSRC_Quality_en;
```

Description:

Used to select the quality level of the SSRC. For details, see Performance figures. Selecting the highest-quality level, comes with a cost in the SSRC processing requirements. Therefore, it should only be done for critical applications.

Parent topic: Type definitions

Instance parameters Definition:

```
typedef struct
{
    SSRC_Quality_en     Quality;
    LVM_Fs_en           SSRC_Fs_In;
    LVM_Fs_en           SSRC_Fs_Out;
    LVM_Format_en       SSRC_NrOfChannels;
    short               NrSamplesIn;
    short               NrSamplesOut;
} SSRC_Params_t;
```

Description:

Used to pass the SSRC instance parameters to the SSRC module. It is a structure that contains the members for input sample rate, output sample rate, the number of channels, and the number of samples on the input and output audio stream.

Parent topic: Type definitions

Nr of samples mode Definition:

```
typedef enum
{
    SSRC_NR_SAMPLES_DEFAULT     = 0,
    SSRC_NR_SAMPLES_MIN         = 1,
    SSRC_NR_SAMPLES_DUMMY       = LVM_MAXENUM
} SSRC_NR_SAMPLES_MODE_en;
```

Description:

The SSRC_NR_SAMPLES_MODE_en enumerated type specifies the two different modes that can be used to retrieve the number of samples using the SSRC_GetNrSamples function.

Parent topic: Type definitions

Function return status Definition:

```
typedef enum
{
    SSRC_OK                     = 0,
    SSRC_INVALID_FS             = 1,
    SSRC_INVALID_NR_CHANNELS    = 2,
    SSRC_NULL_POINTER           = 3,
    SSRC_WRONG_NR_SAMPLES       = 4,
    SSRC_ALLINGMENT_ERROR       = 5,
```

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```
    SSRC_INVALID_MODE          = 6,
    SSRC_INVALID_VALUE         = 7,
    SSRC_ALLINGMENT_ERROR      = 8,
    LVXXX_RETURNSTATUS_DUMMY = LVM_MAXENUM
} SSRC_ReturnStatus_en;
```

Description:

The SSRC_ReturnStatus_en enumerated type specifies the different error codes returned by the API functions. For the exact meaning, see the individual function descriptions.

Parent topic: Type definitions

Parent topic:*Application programmers interface (API)*

Functions This section lists all the API functions of the SSRC module and explains their parameters.

SSRC_GetNrSamples **Prototype:**

```
SSRC_ReturnStatus_en SSRC_GetNrSamples
  (SSRC_NR_SAMPLES_MODE_en  Mode,
   SSRC_Params_t*           pSSRC_Params );
```

Description:

This function retrieves the number of samples or sample pairs for stereo used as an input and as an output of the SSRC module.

Nam	Type	Description
Mod	SSRC_N	There are two modes: - SSRC_NR_SAMPLES_DEFAULT: In this mode, the function returns the number of samples for 40 ms blocks - SSRC_NR_SAMPLES_MIN: the function returns the minimal number of samples supported for this conversion ratio. The SSRC_Init function accepts each integer multiple of this ratio. Formula: blocksize (ms) = 1/gcd(Fs_In,Fs_Out)
pSSI	SSRC_Pa	Pointer to the instance parameters. The application fills in the values of the input sample rate, the output sample rate, and the number of channels. Based on this input, the SSRC_GetNrSamples fills in the values for the number of samples for the input and the output audio stream.

Returns:

SSRC_OK	When the function call succeeds.
SSRC_INVALID_FS	When the requested input or output sampling rates are invalid.
SSRC_INVALID_NR_CHANN	When the channel format is not equal to LVM_MONO or LVM_STEREO.
SSRC_NULL_POINTER	When pSSRC_Params is a NULL pointer.
SSRC_INVALID_MODE	When mode is not a valid setting.

Note: The SSRC_GetNrSamples function returns the values from the following tables. Instead of calling the SSRC_GetNrSamples function, use the values from these tables directly.

Sample rate	Nr of samples
8000	320
11025	441
12000	480
16000	640
22050	882
24000	960
32000	1280
44100	1764
48000	1920

In/Out	8000	11025	12000	16000	22050	24000	32000	44100	48000
8000	11	320441	23	12	160441	13	14	80441	16
11025	441320	11	147160	441640	12	147320	4411280	14	147640
12000	32	160147	11	34	80147	12	38	40147	14
16000	21	640441	43	11	320441	23	12	160441	13
22050	441160	21	14780	441320	11	147160	441640	12	147320
24000	31	320147	21	32	160147	11	34	80147	12
32000	41	1280441	83	21	640441	43	11	320441	23
44100	44180	41	14740	441160	21	14780	441320	11	147160
48000	61	640147	41	31	320147	21	32	160147	11

Parent topic: Functions

SSRC_GetScratchSize **Prototype:**

```
SSRC_ReturnStatus_en SSRC_GetScratchSize
  (SSRC_Params_t*     pSSRC_Params,
   LVM_INT32*         pScratchSize );
```

Description:

This function retrieves the scratch size for a given conversion ratio and for given buffer sizes at the input and at the output.

Name	Type	Description
pSSRC_Par	SSRC_Param	Pointer to the instance parameters. All members should have a valid value.
pScratch-Size	LVM_INT32*	Pointer to the scratch size. The SSRC_GetScratchSize function fills in the correct value (in bytes).

|

Returns:

SSRC_OK	When the function call succeeds.
SSRC_INVALID_FS	When the requested input or output sampling rates are invalid.
SSRC_INVALID_NR_CHANN	When the channel format is not equal to LVM_MONO or LVM_STEREO.
SSRC_NULL_POINTER	When pSSRC_Params or pScratchSize is a NULL pointer.
SSRC_WRONG_NR_SAMPLI	When the number of samples on the input or on the output are incorrect.

Parent topic: Functions

SSRC_Init **Prototype:**

```
SSRC_ReturnStatus_en SSRC_Init
  (SSRC_Instance_t* pSSRC_Instance,
   SSRC_Scratch_t*  pSSRC_Scratch,
   SSRC_Params_t*   pSSRC_Params,
   LVM_INT16**      ppInputInScratch,
   LVM_INT16**      ppOutputInScratch);
```

Description:

The SSRC_Init function initializes an instance of the SSRC module.

Name	Type	Description
pSSRC_	SSRC_	Pointer to the instance of the SSRC. This application must allocate the memory before calling the SSRC_Init function.
pSSRC_	SSRC_	Pointer to the scratch memory. The pointer is saved inside the instance and is used by the SSRC_Process function. The application must allocate the scratch memory before calling the SSRC_Init function.
pSSRC_	SSRC_	Pointer to the instance parameters.
ppInputInScratch	LVM_I	The SSRC module can be called with the input samples located in scratch. This pointer points to a location that holds the pointer to the location in the scratch memory that can be used to store the input samples. For example, to save memory.
ppOutputInScratch	LVM_I	The SSRC module can store the output samples in the scratch memory. This pointer points to a location that holds the pointer to the location in the scratch memory that can be used to store the output samples. For example, to save memory.

Returns:

SSRC_OK	When the function call succeeds.
SSRC_INVALID_FS	When the requested input or output sampling rates are invalid.
SSRC_INVALID_NR_CHANN	When the channel format is not equal to LVM_MONO or LVM_STEREO.
SSRC_NULL_POINTER	When pSSRC_Params or pScratchSize is a NULL pointer.
SSRC_WRONG_NR_SAMPLI	When the number of samples on the input or on the output are incorrect.
SSRC_ALIGNMENT_ERROR	When the instance memory or the scratch memory is not 4 bytes aligned.

Parent topic: Functions

SSRC_SetGains **Prototype:**

```
SSRC_ReturnStatus_en SSRC_SetGains
  (SSRC_Instance_t* pSSRC_Instance,
   LVM_Mode_en      bHeadroomGainEnabled,
   LVM_Mode_en      bOutputGainEnabled,
   LVM_INT16        OutputGain);
```

Description:

This function sets headroom gain and the post gain of the SSRC. The SSRC_SetGains function is an optional function that should be used only in rare cases. Preferably, use the default settings.

Name	Type	Description
pSSRC	SSRC	Pointer to the instance of the SSRC.
bHeadroomGainEnabled	LVM_	Parameter to enable or disable the headroom gain of the SSRC. The default value is LVM_MODE_ON. LVM_MODE_OFF can be used if it can be guaranteed that the input level is below - 6 in all cases (the default headroom is -6 dB).
bOutputGainEnabled	LVM_	Parameter to enable or disable the output gain. The default value is LVM_MODE_ON.
OutputGain	LVM_	The value of the output gain. The output gain is a linear gain value. 0x7FFF is equal to +6 dB and 0x0000 corresponds to -inf dB. By default, a 3 dB gain is applied (OutputGain = 23197), resulting in an overall gain of -3 dB (-6 dB headroom +3 dB output gain). Unit Q format Data Range Default value Linear gain Q1.14 [0;32767] 23197

Returns:

SSRC_OK	When the function call succeeds
SSRC_NULL_POINT	When pSSRC_Instance is a NULL pointer
SSRC_INVALID_MO	Wrong value used for the bHeadroomGainEnabled or the OutputGainEnabled parameters.
SSRC_INVALID_VAI	When OutputGain is out of the range [0;32767].

Parent topic: Functions

SSRC_Process **Prototype:**

```
SSRC_ReturnStatus_en SSRC_Process
  (SSRC_Instance_t* pSSRC_Instance,
   LVM_INT16*       pSSRC_AudioIn,
   LVM_INT16*       pSSRC_AudioOut);
```

Description:

Process function for the SSRC module. The function takes pointers as input and output audio buffers.

The sample format used for the input and output buffers is 16-bit little-endian. Stereo buffers are interleaved (L1, R1, L2, R2, and so on), mono buffers are deinterleaved (L1, L2, and so on).

Name	Type	Description
pSSRC_Instance	SSRC_Instance_t*	Pointer to the instance of the SSRC.
pSSRC_AudioIn	LVM_INT16*	Pointer to the input samples.
pSSRC_AudioOut	LVM_INT16*	Pointer to the output samples.

Returns:

SSRC_OK	When the function call succeeds.
SSRC_NULL_POINTEI	When one of pSSRC_Instance, pSSRC_AudioIn, or pSSRC_AudioOut is NULL.

Parent topic: Functions

SSRC_Process_D32 **Prototype:**

```
SSRC_ReturnStatus_en SSRC_Process_D32
  (SSRC_Instance_t* pSSRC_Instance,
   LVM_INT32*       pSSRC_AudioIn,
   LVM_INT32*       pSSRC_AudioOut);
```

Description:

Process function for the SSRC module. The function takes pointers as input and output audio buffers.

The sample format used for the input and output buffers is 32-bit little-endian. Stereo buffers are interleaved (L1, R1, L2, R2, and so on), mono buffers are deinterleaved (L1, L2, and so on).

Name	Type	Description
pSSRC_Instance	SSRC_Instance_t*	Pointer to the instance of the SSRC.
pSSRC_AudioIn	LVM_INT32*	Pointer to the input samples.
pSSRC_AudioOut	LVM_INT32*	Pointer to the output samples.

Returns:

|SSRC_OK|When the function call succeeds.| |SSRC_NULL_POINTER|When one of pSSRC_Instance, pSSRC_AudioIn, or pSSRC_AudioOut is NULL.|

Parent topic: Functions

Parent topic:*Application programmers interface (API)*

Dynamic function usage This chapter explains how and when the SSRC functions are or can be used.

Define the number of samples to be used on input and output Call the function SSRC_GetNrSamples. Each integer multiple of the returned number of samples can be used.

Parent topic: Dynamic function usage

Allocate scratch memory To calculate the required size of the scratch memory, call the SSRC_GetScratchSize function. Allocate memory for the returned size.

Parent topic: Dynamic function usage

Initialize the SSRC instance Call the SSRC_Init function.

Parent topic: Dynamic function usage

Process samples The SSRC_Process function can now be called any number of times.

Parent topic: Dynamic function usage

Destroy the SSRC instance When the processing is completed, the allocated memory for the instance and the scratch can be freed.

Parent topic: Dynamic function usage

Parent topic:*Application programmers interface (API)*

Reentrancy None of the SSRC functions are re-entrant.

Parent topic:*Application programmers interface (API)*

Additional user information This section provides information on the Attenuation of the signal and Notes on integration.

Attenuation of the signal When a fully saturated or clipped input is applied to an SRC module, the aliases after the sample rate conversion, although sufficiently suppressed, can still result in a clipped output. To prevent clipped output, the output of the SSRC module is by default attenuated with 3 dB. Although not advised, this gain value can be changed using the SSRC_SetGains function.

Parent topic:*Additional user information*

Notes on integration Although the sample rate converter module works with audio signals on different sampling rates, it is a synchronous module. The module takes a block of input samples, consumes the input completely, and produces a full buffer with output samples. As a result, the SSRC only accepts a limited number of input and output block sizes. To flush last, incomplete, block of an audio stream, the block is padded with zeros until it is full before the SSRC processes it.

Parent topic:*Additional user information*

Example application The source code of the example application can be found in the .\EX_APP\APP_FileIO\SRC directory of the release package. The .\EX_APP\APP_FileIO\MAKE directory contains a make file that can be used to build the example application. When building the application, an executable is generated in the .\EX_APP\APP_FileIO\EXE directory.

The example application takes as command-line input parameters:

1. The path toward the input PCM file. It assumes raw 16 bit signed little-endian put. Stereo input samples should be interleaved (L1, L2 R1, R2,...), mono samples should be deinterleaved (L1, L2, and so on).
2. The path toward the output PCM file.
3. The input sample rate.
4. The output sample rate.
5. The channel format (mono or stereo).

Integration test A correct integration of the SSRC module can be verified in two ways.

- Bit accurate test
- THD+N measurement

Bit accurate test The TestFiles directory of the release package contains a test input (sampled at 44,100 Hz) and several expected output files (sample rates from 8000 Hz to 48,000 Hz). If the same test input file is applied to the SRC after integration in the target platform, the output is bit accurate with the expected output file that matches the output-sample rate

Parent topic:*Integration test*

THD+N measurement Produce a swept sine and feed it through the SSRC module. Do a THD+N measurement on the obtained output signal. The THD+N of the converted signals should be below - 77 in the interval [0 - 0.45] FsLOW.

Parent topic:*Integration test*

Maestro Audio Framework

MCUXpresso SDK : Maestro

Overview This repository is for MCUXpresso SDK maestro middleware delivery and it contains the components officially provided in NXP MCUXpresso SDK. This repository is part of the MCUXpresso SDK overall delivery which is composed of several sub-repositories/projects. Navigate to the top/parent repository (mcuxsdk-manifests) for the complete delivery of MCUXpresso SDK.

Documentation Overall details can be reviewed here: MCUXpresso SDK Online Documentation

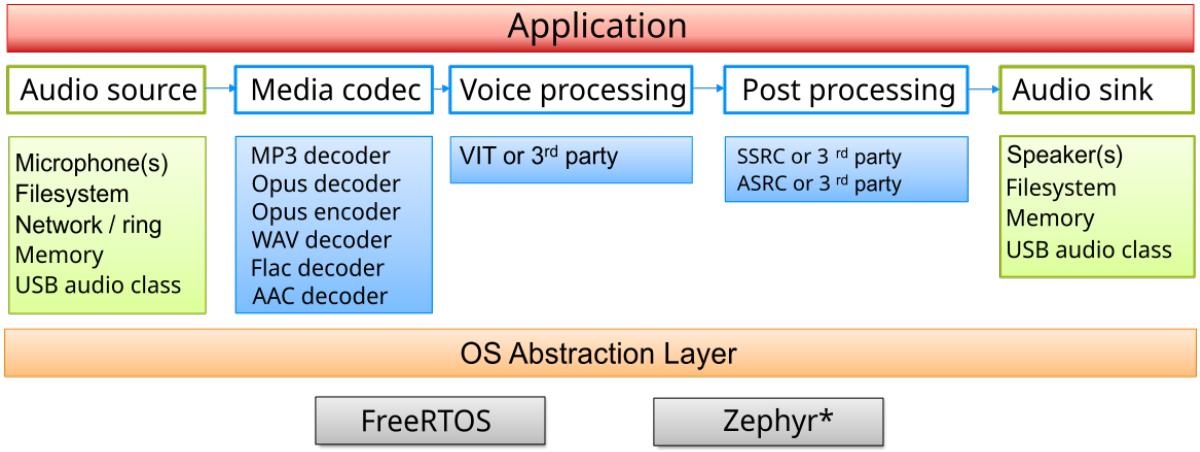
Visit Maestro - Documentation to review details on the contents in this sub-repo.

Setup Instructions on how to install the MCUXpresso SDK provided from GitHub via west manifest Getting Started with SDK - Detailed Installation Instructions

Contribution We welcome and encourage the community to submit patches directly to the Maestro project placed on github. Contributing can be managed via pull-requests.

Introduction Maestro audio framework intends to enable chaining of basic audio processing blocks, called *elements*. These blocks then form stream processing objects, called *pipeline*. This pipeline can be used for multiple audio processing use cases.

The processing blocks can include (but are not limited to) different audio sources (for example file or microphone), decoders or encoders, filters or effects, and audio sinks. Framework overview is depicted in the following picture:



*not all elements and libraries are supported in Zephyr port. For more information, see *Maestro on Zephyr*

The Maestro audio framework is an open-source component developed by NXP Semiconductors and released under the BSD-compatible license. It is running on RTOS (Zephyr or FreeRTOS), abstracted by OSA layer.

For detailed description of the audio Maestro framework, please refer to the *programmer's guide*.

To see what is new, see *changelog*.

Maestro on Zephyr Getting started guide and further information for Maestro on Zephyr may be found *here*.

Maestro on FreeRTOS Maestro on FreeRTOS is supported in NXP's SDK. To get started, see mcuxsdk doc.

Supported examples The current version of the Maestro audio framework supports several optional *features*, some of which are used in these examples:

- *maestro_playback*
- *maestro_record*
- *maestro_usb_mic*
- *maestro_usb_speaker*

The examples can be found in the **audio_examples** folder of the desired board. The demo applications are based on FreeRTOS and use multiple tasks to form the application functionality.

Example applications overview To set up the audio framework properly, it is necessary to create a streamer with streamer_create API. It is also essential to set up the desired hardware peripherals using the functions described in streamer_pcm.h. The Maestro example projects consist of several files regarding the audio framework. The initial file is main.c with code to create multiple tasks. For features including SD card (in the maestro_playback examples, reading a file from SD card is supported and in maestro_record writing to SD card is currently supported) the APP_SDCARD_Task is created. The command prompt and connected functionalities are handled by APP_Shell_Task.

One of the most important parts of the configuration is the streamer_pcm.c where the initialization of the hardware peripherals, input and output buffer management can be found. For further information please see also streamer_pcm.h

In the Maestro USB examples (maestro_usb_mic and maestro_usb_speaker), the USB configuration is located in the usb_device_descriptor.c, audio_microphone.c and audio_speaker.c files. For further information please see also usb_device_descriptor.h, audio_microphone.h and audio_speaker.h.

In order to be able to get the messages from the audio framework, it is necessary to create a thread for receiving the messages from the streamer, which is usually called a Message Task. The message thread is placed in the app_streamer.c file, reads the streamer message queue, and reacts to the following messages:

- STREAM_MSG_ERROR - stops the streamer and exits the message thread
- STREAM_MSG_EOS - stops the streamer and exits the message thread
- STREAM_MSG_UPDATE_DURATION - prints info about the stream duration
- STREAM_MSG_UPDATE_POSITION - prints info about current stream position
- STREAM_MSG_CLOSE_TASK - exits the message thread

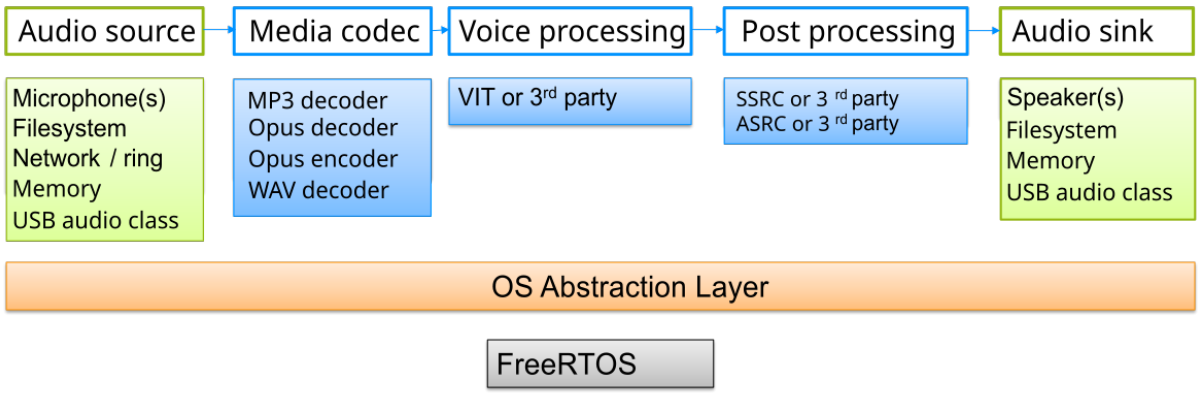
File structure

Folder	Description
src	Maestro audio framework sources
src/inc	Maestro include files
src/core	Maestro core sources
src/cci	Common decoder interface sources
src/cei	Common encoder interface sources
src/elements	Maestro elements sources
src/devices	External audio devices implementation (audio source & audio sink elements)
src/utils	Helper utilities utilized by Maestro
docs	Generated documentation
doxygen	Documentation sources
components	Glue for audio libraries, so they can be used in elements
tests	Maestro tests
zephyr/	Zephyr related files
zephyr/samples/	Zephyr samples
zephyr/tests/	Zephyr tests
zephyr/audioTracks/	Audio tracks for testing
zephyr/wrappers/	Zephyr NXP SDK Wrappers
zephyr/doc/	Zephyr documentation configuration for Sphinx
zephyr/scripts/	Zephyr helper scripts, mostly for testing

Maestro Audio Framework Programmer's Guide

Introduction Maestro audio framework provides instruments for playback and capture of different audio streams. In order to do that the framework uses API for creating various audio and voice pipelines with the support of media and track information. This document describes the framework in its detail, and the usage of API for pipeline creation using different elements. The framework needs an operating system in order to create different tasks for audio processing and communication with the application.

Architecture overview A high-level block diagram of the streamer used in Maestro is shown below. An element is the most important class of objects in the streamer (see streamer_element.c). A chain of elements will be created and linked together when a *pipeline* is created. Data flows through this chain of elements in form of data buffers. An element has one specific function, which can be the reading of data from a file, decoding of this data, or outputting this data to a sink device. By chaining together several such elements, a pipeline is created that can do a specific task, for example, the playback.



Pipeline

The pipeline is created within the streamer_create API using the streamer_create_pipeline call. In the example applications provided in the MCUXpresso SDK the pipeline is created in the app_streamer.c file. In order to create a pipeline user needs to provide a PipelineElements structure consisting of array of element indexes ElementIndex and the number of elements in the pipeline. Then the pipeline is built automatically and user can specify the properties of the elements using the streamer_set_property API. All the element properties can be found in the streamer_element_properties.h file.

The streamer can handle up to two pipelines within a single task. The first pipeline with index 0 can be created using the streamer_create function as described above. Then the streamer_create_pipeline function should be used to create the second pipeline (pipeline with index 1). Both pipelines are processed sequentially, so after the first pipeline is processed, the second pipeline is processed.

After the pipeline is sucessfully created, all elements and entire pipeline are in STATE_NULL state. A user can start the streamer by setting the pipeline state to STATE_PLAYING using the streamer_set_state function. The pipeline can also be paused or stopped using the same function. Use the STATE_PAUSED to pause and use STATE_NULL to stop. The function changes the state of each element that is in the pipeline in turn, and after all the elements have obtained the desired state, the state of entire pipeline is changed.

Elements The current version of the Maestro framework supports several types of elements (StreamElementType). In each pipeline should be used one source element (elements with the _SRC suffix) and one sink element (elements with the _SINK suffix). A decoder, encoder or audio_proc element can be connected between these two elements. The audio_proc element can be used more than once within the same pipeline.

Each element type (StreamElementType) has several functions that are determined by a unique element index (ElementIndex). These indexes are used to create a pipeline, and each element index can only be used once in the same pipeline. The type_lookup_table shows which StreamElementType supports which ElementIndex.

Each element index (ElementIndex) has its own properties and a list of these properties can be found in the streamer_element_properties.h file. These properties are divided into groups and each group is identified by a property mask (e.g. for speaker it is PROP_SPEAKER_MASK). Then the property_lookup_table in the streamer_msg.c file determines which property group relates to which element index (ElementIndex). When an element is created and added to the pipeline, its properties are set to their defalut values. Default values can be seen in the initialization function of a particular element. The initialization functions are specified in the element_list array in the streamer_element.c file (e.g. for the audio_proc element it is the audio_proc_init_element function). The user can get the value of the property using the streamer_get_property function or change its value using the streamer_set_property function.

The source code of the elements can be found in the middleware\audio_voice\maestro\src\elements\ folder.

Add a new element type The user can add a new element type (StreamElementType) to the Maestro audio framework. For this, the following steps need to be done.

- Add a new element type to the StreamElementType enum type in the streamer_api.h.
- Create a new *.c and *.h files for the new element type in the middleware\audio_voice\maestro\src\elements\ folder. All necessary structures and functions (functions for src pads, sink pads and element itself) needs to be defined in these files. Inspiration can be found in other elements.
- Link the initialization function to the element type in the element_list array in the streamer_element.c file. To do this, a new definition that enables the element needs to be created (e.g. there is a STREAMER_ENABLE_AUDIO_PROC definition for the audio_proc element).

- Associate the newly created element type with an element index (ElementIndex) by adding a new pair to the type_lookup_table in the streamer.c file.
- If the user wants to use the newly created element in an application, the definiton that enables the element must be defined at the project level.

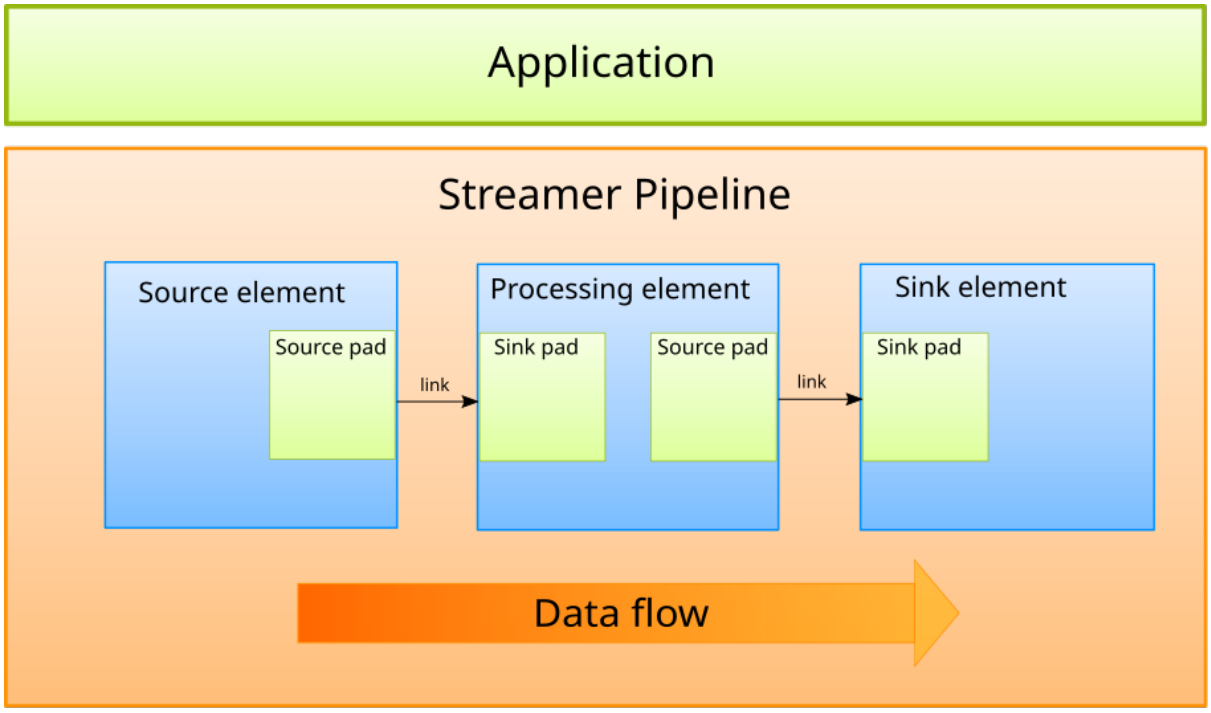
Mostly the user doesn't need to create a new element type, but just create an element index.

Add a new element index To create a new element index in the Maestro audio framework, follow these steps:

- Add a new element index to the ElementIndex enum type in the streamer_api.h.
- Create the required properties for the newly created element index in the streamer_element_properties.h file.
- Associate the newly created property group with newly created element index by adding a new pair to the property_lookup_table in the streamer_msg.c file.
- Associate the newly created element index with an element type (StreamElementType) by adding a new pair to the type_lookup_table in the streamer.c file.
- Add support for the created properties to functions of the associated element type. These functions are defined in files that correspond to a particular element type. The files are located in the middleware\audio_voice\maestro\src\elements\ folder.

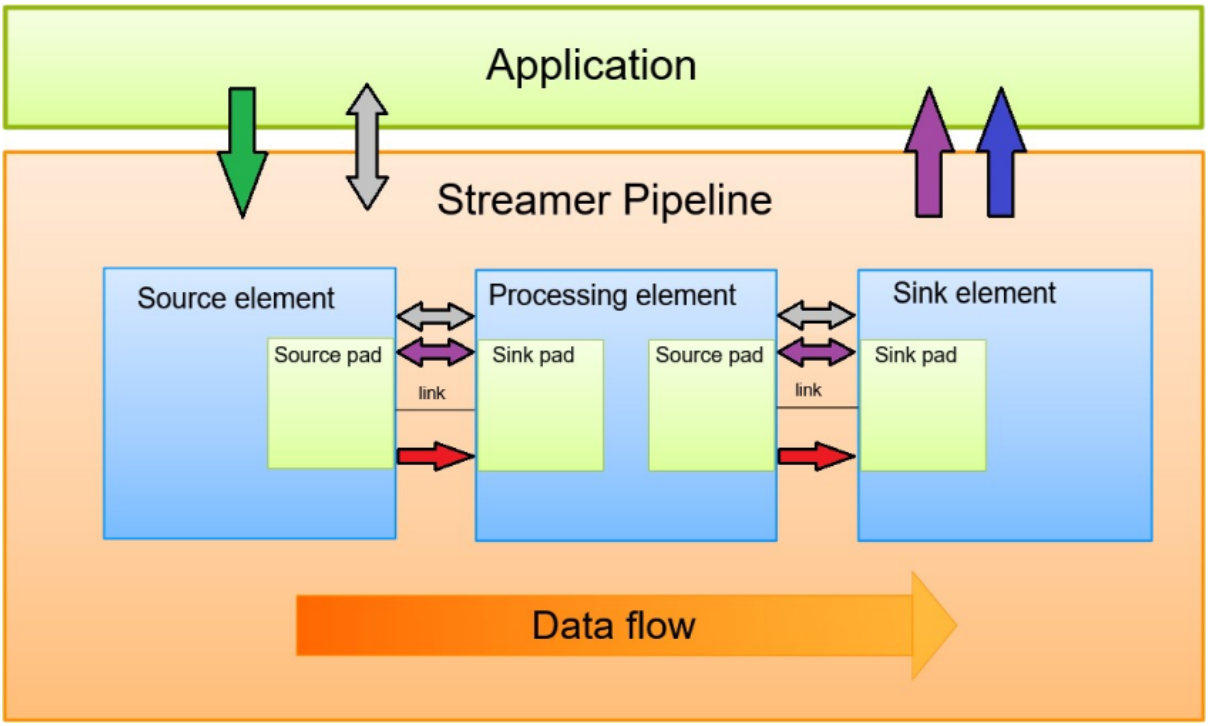
It is important to know that each element type (StreamElementType) can be associated with more than one element index (ElementIndex), but each element index (ElementIndex) can be associated with only one element type (StreamElementType).

Pads Pads are elements' inputs and outputs. A pad can be viewed as a "plug" or "port" on an element where links may be made with other elements, and through which data can flow to or from those elements. Data flows out of an element through a source pad, and elements accept incoming data through a sink pad. Source and sink elements have only source and sink pads, respectively. For detailed information about pads, please see the API reference from pad.c.



Internal communication The streamer (the core of the framework) provides several mechanisms for communication and data exchange between the application, a pipeline, and pipeline elements:

- Buffers are objects for passing streaming data between elements in the pipeline. Buffers always travel from sources to sinks (downstream).
- Messages are objects sent from the application to the streamer task to construct, configure, and control a streamer pipeline.
- Callbacks are used to transmit information such as errors, tags, state changes, etc. from the pipeline and elements to the application.
- Events are objects sent between elements. Events can travel upstream and downstream. Events may also be sent to the application
- Queries allow applications to request information such as duration or current playback position from the pipeline. Elements can also use queries to request information from their peer elements (such as the file size or duration). They can be used both ways within a pipeline, but upstream queries are more common



Decoders and encoders Maestro framework uses a common codec interface for decoding purposes and a common encoder interface for encoding. Those interfaces encapsulate the usage of specific codecs. Reference codecs are available in audio-voice-components repository which should be in \middleware\audio_voice\components\ folder.

Common codec interface The Common Codec Interface is the intended interface for all used **decoders**. The framework will integrate a CCI decoder element into the streamer to interface with all decoders.

Using the CCI to interface with Metadata

- cci_extract_meta_data must be called before any other Codec Interface APIs. This API extracts the metadata information of the codec and fills this information in the

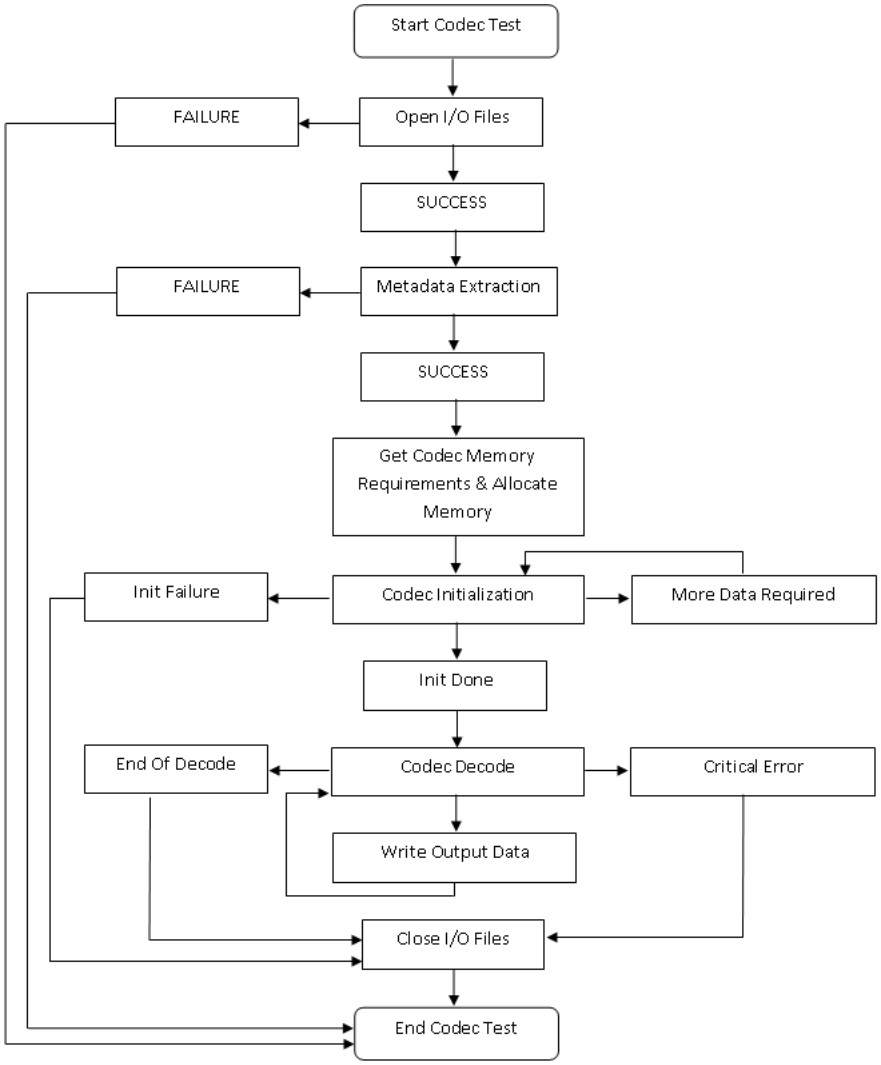
file_meta_data_t structure. The file_meta_data_t structure must be allocated by the application.

- This function first extracts the input file extension and based on that it calls the specific codec's metadata extraction function. If it finds an invalid extension or unsupported extension then it returns with META_DATA_FILE_NOT_SUPPORTED code for any unsupported file format.
- If this API finds the valid metadata then it returns with META_DATA_FOUND code. If this API does not find any metadata information then it returns with META_DATA_NOT_FOUND code. It also returns with META_DATA_FILE_NOT_SUPPORTED code for any unsupported file format.

Using the CCI to interface with Decoders

- codec_get_mem_info gets the memory requirement based on the specific decoder stream type. It returns the size in bytes of the specific codec. The user of the decoders must allocate memory of this size and this memory is used by the initialization API. The user or application must pass this allocated memory pointer to the init API.
- codec_init must be called before the codec's decode API. This API calls the codec-specific initialization function based on the codec stream type. This API allocates the memory to the codec main structure and also initializes the codec main structure parameters. It also registers the call back functions to the codec which will be used by the codec to read or seek the input stream.
- codec_decode is the main decoding API of the codec. This API calls the codec-specific decoding function based on the codec stream type. This API decodes the input raw stream and fills the PCM output samples into codec output PCM buffer. This API gives the information about the number of samples produced by the codec and also gives the pointer of the codec output PCM samples buffer.
- codec_get_pcm_samples must be called after the codec's decode API. This API calls the codec specific Get PCM Sample API based on the codec stream type. This API gets the PCM samples from the codec in constant block size and fills them into the output PCM buffer. It returns the number of samples get from the codec and also gives the pointer of the output PCM buffer.
- codec_reset calls the codec specific reset API base on stream type and resets the codec.
- codec_seek accepts the seek bytes offset converted from the time by application. This API calls the decoder's internal seek API to calculate the actual seek offset which frame boundary aligns. This API returns the actual seek offset.

The basic sequence to use a decoder with the CCI is shown below:



Adding new decoders to the CCI This section explains how to integrate a new decoder in the Common Codec Interface. The CCI assumes the decoder library to be used is in the \middleware\audio_voice\audiocomponents\decoders*decoder*\libs\ folder of the maestro framework. The CCI is just a wrapper around a specific implementation. The decoder is expected to be extended as needed to meet the APIs described above.

- Register Decoder Top level APIs in Common Codec Interface
  - Place the decoder lib in libs folder.
  - Add prototypes of the decoder top level APIs in codec_interface.h file (located at maestro\src\cci\inc\ folder).
  - In codec_interface.c file (located at maestro\src\cci\src\), add top level Decoder APIs in decoder function table.
  - Pseudo code for this is as described below.

```
const codec_interface_function_table_t g_codec_function_table[STREAM_TYPE_COUNT] = {
#ifdef VORBIS_CODEC
    {
        &VORBISDecoderGetMemorySize,
        &VORBISDecoderInit,
        &VORBISDecoderDecode,
        NULL,
```

(continues on next page)

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```
        NULL,
        &VORBISDecoderSeek,
        &VORBISDecoderGetIOFrameSize,
    },
#else
    {
        NULL,
        NULL,
        NULL,
        NULL,
        NULL,
        NULL,
        NULL,
    }
#endif
};
```

- Enable or Disable Decoder
  - Define VORBIS_CODEC macro in audio_cfg.h file.
  - Comment this macro if you want to disable VORBIS Decoder otherwise keep it defined in order to enable the decoder.
- Add Extract Metadata API for the decoder
  - Add extract metadata API source file for the decoder at streamer/cci/metadata/src/vorbis folder.
  - Add this code in extract metadata lib project space.
  - Build the extract metadata lib and copy that lib to libs folder.
  - Add the desired stream type into ccidec_extract_meta_data API (in codecextractmetadata.c file) to call VORBIS Decoder extract metadata API.
- Add stream type of the new decoder in the stream type enum audio_stream_type_t in codec_interface_public_api.h
  - Stream type of the decoder in stream type enum and decoder APIs in decoder function table must be in the same sequence.

Common encoder interface Please see the following section about the *cei*.

Maestro performance

Memory information The memory usage of the framework components using reference codecs (data obtained from GNU ARM compiler) in bytes is:

text	data	bss	component
48790	2752	4	aac decoder
4348	16400	212	asrc
15512	0	4	flac decoder
76462	16	5013	maestro
34211	0	4	mp3 decoder
211974	0	0	opus
65446	0	4	ssrc
5850	16	12	wav decoder

Maestro framework uses dynamic allocation of audio buffers. The total amount of memory allocated for the pipeline depends on the following parameters:

- Number of elements in the pipeline
- Element types
- Audio stream properties
  - Sampling rate
  - Bit width
  - Channel number
  - Frame size

CPU usage The performance of the pipeline was measured using the real hardware platform (RT1060).

- CPU core clock in MHz: 600.

Pipeline type	Performance MIPS of pipeline (in MHz)
audio source -> audio sink	~10.26 MHz
audio source -> file sink	~9.84 MHz
file source (8-channel PCM) -> audio sink	~16.5 MHz

For performance details about the supported codecs please see audio-voice-components repository documentation.

CEI encoder The Maestro streamer contains an element adapting an extensible set of audio encoders in the form of functions conforming to the CEI (Common Encoder Interface). This element enables the user to choose and configure a suitable encoder at runtime.

Header files CEI itself and the CEI encoders are using following header files, in which you may be interested:

- cei.h - contains types used by the element itself and an encoder implementing the CEI
- cei_enctypes.h - contains a list of possible encoders and types used for interfacing with a CEI encoder
- cei_table.h - contains a table of functions implementing integrated CEI encoders

Instantiating the element This element's index is ELEMENT_ENCODER_INDEX and its type is TYPE_ELEMENT_ENCODER, as defined in streamer_api.h. It has one source pad (data input) and one sink pad (data output). It is initialized like any other element, meaning that it is instantiated and inserted into the pipeline using the create_element, add_element_pipeline and link_elements functions. Inversely, for destroying the element, the unlink_elements, remove_element_pipeline and destroy_element are used. This element alone does not depend on any additional software layers other than these required by the Maestro streamer itself, so no pre-initialization before this element instantiation is necessary.

Element properties Use Maestro streamer property API (streamer_set_property and streamer_get_property) for setting or getting these. The constants are defined in streamer_element_properties.h.

- PROP_ENCODER_CHUNK_SIZE

  - **Synopsis:** Determines the length of a chunk pulled from the sibling of the source pad and essentially influences the size of allocated buffers. If the actual amount of data pulled is smaller, the rest is zero-filled.
  - **Type:** unsigned 32-bit integer
  - **Default value:** 1920
  - **Constraints:**
    * Must be bigger than zero, otherwise STREAM_ERR_INVALID_ARGS is returned.
    * Cannot be changed if the actual encoder has been created. If done so, STREAM_ERR_ELEMENT_BAD_STATUS is returned.

- PROP_ENCODER_TYPE
  - **Synopsis:** Determines the exact encoder (CEI implementation) to be used.
  - **Type:** CeiEncoderType (cei_enctypes.h)
  - **Default value:** CEIENC_LAST
  - **Constraints:**
    * Must not be equal to CEIENC_LAST, otherwise STREAM_ERR_INVALID_ARGS will be returned.
    * Selected encoder must be implemented, otherwise STREAM_ERR_INVALID_ARGS will be returned.
    * Cannot be changed if the actual encoder has been created. If done so, STREAM_ERR_ELEMENT_BAD_STATUS will be returned.
  - **Behaviour influenced:** The encoder element process function will return FLOW_ERROR if this property isn't set.

- PROP_ENCODER_CONFIG
  - **Synopsis:** Determines encoder-specific configuration (application, bitrate, ...).
  - **Type:** Pointer to the encoder-specific configuration structure.
  - **Default value:** Determined by the encoder.
  - **Constraints**:
    * The encoder has to be configurable. If it is not, STREAM_ERR_ERR_GENERAL will be returned on any access.
    * The structure has to conform to the encoder requirements. If the encoder returns an error code, STREAM_ERR_GENERAL will be returned.

- PROP_ENCODER_BITSTREAMINFO
  - **Synopsis:** Specifies information about the incoming bitstream (sample rate, sample depth, ...).
  - **Type:** Pointer to CeiBitstreamInfo (cei_enctypes.h).
  - **Default value:**

```
(CeiBitstreamInfo) {
    .sample_rate = 0,
    .num_channels = 0,
    .endian = AF_LITTLE_ENDIAN,
    .sign = TRUE,
    .sample_size = 0,
    .interleaved = TRUE
}
```

- **Constraints:**
  - Cannot be changed if the actual encoder has been created. If done so, STREAM_ERR_ELEMENT_BAD_STATUS will be returned.
  - As of now, only bitstreams containing 16-bit interleaved (if 2 or more channels will be encoded) samples are supported. If anything else was set to the sample_size and interleaved members, STREAM_ERR_INVALID_ARGS will be returned.
- **Behaviour influenced:**
  - Given the characteristics of some elements available, different packets of data (header and payload, referred to as "chunk" above) may be pulled by this element. Each packet can contain a different header, which may or may not contain useful information about the bitstream. If a packet with the AudioPacketHeader (todofile.h) is pulled at first and any other iteration of the streamer pipeline, the bitstream parameters configured by this property are implicitly available and are not expected to be specified by the user. Other packet header types (such as RawPacketHeader) don't contain any bitstream parameters and require the user to specify the parameters manually using this property. Failure to do so will result in the element's process function returning FLOW_ERROR. Same situation will occur if a packet with the AudioPacketHeader is received and its contents differ from the already acquired bitstream parameters.
  - As of now, CEI is defined to work with 16-bit signed little-endian (s16le) samples, which are interleaved if the bitstream contains more than one channels. This element handles endianness and unsigned to signed conversion.

CEI definition - implementing your own encoder The CEI defines following function pointer types:

- CeiFnGetMemorySize: Returns number of bytes required for encoder state for a given number of channels.
- CeiFnEncoderInit: Initialize an encoder for a given sample rate and channel count.
- CeiFnEncoderGetConfig: Copy current or default configuration to a given structure pointer.
- CeiFnEncoderSetConfig: Configure the encoder from a given structure pointer.
- CeiFnEncode: Encode a given buffer to a given output buffer.

Detailed descriptions of function behaviour, parameters and expected return values are available as docblocks in the cei.h file.

Each encoder is implemented as a set of pointers pointing to functions conforming to these types, grouped in the CeiEncoderFunctions structure. Specifying the CeiEncoderGetConfig fnGetConfig and CeiFnEncoderSetConfig fnSetConfig members is optional, as an encoder does not have to be configurable. If so desired, specify NULL. Implementation of the remaining functions is mandatory, however. If at least one of these functions isn't implemented and NULL is specified instead, the encoder will be considered as not implemented.

To register an implemented encoder with the element, add a new entry to the CeiEncoderType enum and add the CeiEncoderFunctions struct value to the table CeiEncoderFunctions ceiEncTable[] located in the cei_table.h header file. Note and match the order of items in that table, as a CeiEncoderType value is used as an index. Same goes for the size_t ceiEncConfigSizeTable[]. If configuration is not applicable, specify 0 at the appropriate index. If configuration is applicable, describe the configuration structure in the cei_enctypes.h header file and add its size to that table.

Maestro playback example

Table of content

Overview The Maestro playback example demonstrates audio processing on the ARM cortex core utilizing the Maestro Audio Framework library.

The application is controlled by commands from a shell interface using serial console and the audio files are read from the SD card.

Depending on target platform or development board there are different modes and features of the demo supported.

- **Standard** - The mode demonstrates playback of encoded files from an SD card with up to 2 channels, up to 48 kHz sample rate and up to 16 bit width. This mode is enabled by default.
- **Multi-channel** - The mode demonstrates playback of raw PCM files from an SD card with 2 or 8 channels, 96kHz sample rate and 32 bit width. The decoders and synchronous sample rate converter are not supported in this mode. The Multi-channel mode is only supported on selected platforms, see the table below. The *Example configuration* section contains information on how to enable it.

As shown in the table below, the application is supported on several development boards and each development board may have certain limitations, some development boards may also require hardware modifications or allow to use of an audio expansion board. Therefore, please check the supported features and *Hardware modifications* or *Example configuration* sections before running the demo.

Limitations:

- Note:
  - *LPCXPresso55s69* - MCUXpresso IDE project default debug console is semihost
- Decoder:
  - **AAC:**
    - The reference decoder is supported only in the MCUXpresso IDE and ARMGCC.
  - **FLAC:**
    - *LPCXpresso55s69* - When playing FLAC audio files with too small frame size (block size), the audio output may be distorted because the board is not fast enough.
  - **OPUS:**
    - *LPCXpresso55s69* - The decoder is disabled due to insufficient memory may be distorted because the board is not fast enough.
- Sample rate converter:
  - **SSRC:**

        * *LPCXpresso55s69* - When a memory allocation ERROR occurs, it is necessary to disable the SSRC element due to insufficient memory.

Known issues:

- Decoder:
  - **MP3:**
    * The reference decoder has issues with some of the files. One of the channels can be sometimes distorted or missing parts of the signal.
  - **OPUS:**
    * The decoder doesn't support all the combinations of frame sizes and sample rates. The application might crash when playing an unspupported file.

More information about supported features can be found on the *Supported features* page.

Hardware requirements

- Desired development board
- Micro USB cable
- Headphones with 3.5 mm stereo jack
- SD card with supported audio files
- Personal computer
- Optional:
  - Audio expansion board AUD-EXP-42448 (REV B)

Hardware modifications Some development boards need some hardware modifications to run the application. If the development board is not listed here, its default setting is required.

- *EVKB-MIMXRT1170:*
  1. Please remove below resistors if on board wifi chip is not DNP:
     - R228, R229, R232, R234
  2. Please make sure R136 is weld for GPIO card detect.

Preparation

1. Connect a micro USB cable between the PC host and the debug USB port on the development board.
2. Open a serial terminal with the following settings:
   - 115200 baud rate
   - 8 data bits
   - No parity
   - One stop bit
   - No flow control
3. Download the program to the target board.
4. Insert the headphones into the Line-Out connector (headphone jack) on the development board.

5. Either press the reset button on your development board or launch the debugger in your IDE to begin running the demo.

Running the demo When the example runs successfully, you should see similar output on the serial terminal as below:

```
**********************************
Maestro audio playback demo start
**********************************

[APP_Main_Task] started

Copyright 2022 NXP
[APP_SDCARD_Task] start
[APP_Shell_Task] start

>> [APP_SDCARD_Task] SD card drive mounted
```

Type help to see the command list. Similar description will be displayed on serial console (*If multi-channel playback mode is enabled, the description is slightly different*):

```
>> help

"help": List all the registered commands

"exit": Exit program

"version": Display component versions

"file": Perform audio file decode and playback

 USAGE: file [stop|pause|volume|seek|play|list|info]
   stop              Stops actual playback.
   pause             Pause actual track or resume if already paused.
   volume <volume>   Set volume. The volume can be set from 0 to 100.
   seek <seek_time>  Seek currently paused track. Seek time is absolute time in milliseconds.
   play <filename>   Select audio track to play.
   list              List audio files available on mounted SD card.
   info              Prints playback info.
```

Details of commands can be found *here*.

Example configuration The example can be configured by user. Before configuration, please check the *table* to see if the feature is supported on the development board.

- **Enable Multi-channel mode:**
  - Add the MULTICHANNEL_EXAMPLE symbol to preprocessor defines on project level.
  - Connect AUD-EXP-42448 (see the point below).
- **Connect AUD-EXP-42448:**
  - *EVKC-MIMXRT1060:*
    1. Disconnect the power supply for safety reasons.
    2. Insert AUD-EXP-42448 into J19 to be able to use the CS42448 codec for multichannel output.
    3. Uninstall J99.
    4. Set the DEMO_CODEC_WM8962 macro to 0 in the app_definitions.h file

5. Set the DEMO_CODEC_CS42448 macro to 1 in the app_definitions.h file.

Functionality The file play <filename> command calls the STREAMER_file_Create or STREAMER_PCM_Create function from the app_streamer.c file depending on the selected mode.

- When the *Standard* mode is enabled, the command calls the STREAMER_file_Create function that creates a pipeline with the following elements:
  - ELEMENT_FILE_SRC_INDEX
  - ELEMENT_DECODER_INDEX
  - ELEMENT_SRC_INDEX (If SSRC_PROC is defined)
  - ELEMENT_SPEAKER_INDEX
- When the *Multi-channel* mode is enabled, the command calls STREAMER_PCM_Create function, which creates a pipeline with the following elements:
  - ELEMENT_FILE_SRC_INDEX (PCM format only)
  - ELEMENT_SPEAKER_INDEX
  - *Note:*
    * If the input file is an 8 channel PCM file, output to all 8 channels is available. The properties of the PCM file are set in the app_streamer.c file using file source properties sent to the streamer:
      · PROP_FILESRC_SET_SAMPLE_RATE - default value is 96000 [Hz]
      · PROP_FILESRC_SET_NUM_CHANNELS - default value is 8
      · PROP_FILESRC_SET_BIT_WIDTH - default value is 32

Playback itself can be started with the STREAMER_Start function.

Each of the elements has several properties that can be accessed using the streamer_get_property or streamer_set_property function. These properties allow a user to change the values of the appropriate elements. The list of properties can be found in streamer_element_properties.h. See the example of setting property value in the following piece of code from the app_streamer.c file:

```
ELEMENT_PROPERTY_T prop;

EXT_PROCESS_DESC_T ssrc_proc = {SSRC_Proc_Init, SSRC_Proc_Execute, SSRC_Proc_Deinit,␣
↪&get_app_data()->proc_args};

prop.prop = PROP_SRC_PROC_FUNCPTR;
prop.val  = (uintptr_t)&ssrc_proc;

if (streamer_set_property(streamer, 0, prop, true) != 0)
{
    return -1;
}

prop.prop = PROP_AUDIOSINK_SET_VOLUME;
prop.val  = volume;
streamer_set_property(streamer, 0, prop, true);
```

Some of the predefined values can be found in the streamer_api.h.

States The application can be in 3 different states:

- Idle

- Running
- Paused

In each state, each command can have a different behavior. For more information, see *Commands in detail* section.

Commands in detail The applicatin is controlled by commands from the shell interface and the available commands for the selected mode can be displayed using the `help` command. Commands are processed in the `cmd.c` file.

- *help, version*
- *file stop*
- *file pause*
- *file volume <volume>*
- *file seek <seek_time>*
- *file play <filename>*
- *file list*
- *file info*

Legend for diagrams:

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    A((State)):::state
    B{Condition}:::condition
    C[Error message]:::error
    D[Process function]:::function
```

help, version

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    A((Idle)):::state --> D[Write help or version]:::function
    B((Running)):::state --> D
    C((Paused)):::state --> D
    D-->E((No state
    change)):::state
```

file stop

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D
```

```
B((Idle)):::state --> B
C((Running)):::state -->E((Idle)):::state
D((Paused)):::state -->E
```

file pause

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    B((Idle)):::state --> B
    C((Running)):::state -->E((Paused)):::state
    D((Paused)):::state -->F((Running)):::state
```

file volume <volume>

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    B((Idle)):::state --> M[Error: Play a track first]:::error
    C((Running)):::state --> G{Volume
    parameter
    empty?}:::condition
    D((Paused)):::state --> G
    G -- Yes -->H[Error: Enter volume parameter]:::error
    G -- No -->I{Volume
    in range?}:::condition
    I -- No -->J[Error: invalid value]:::error
    I -- Yes -->K[Set volume]:::function
    J --> L((No state
    change)):::state
    K --> L
    H--> L
```

file seek <seek_time>

The seek argument is only supported in the Standard mode.

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    B((Idle)):::state --> E[Error: First select
    an audio track to play]:::error
    E-->B
    C((Running)):::state --> F[Error: First
    pause the track]:::error
    F --> C
    D((Paused)):::state --> G{Seek
    parameter
    empty?}:::condition
    G --No --> H{AAC file?}:::condition
```

```
G --Yes --> I[Error: Enter
a seek time value]:::error
I-->N((Paused)):::state;
H --Yes -->J[Error: The AAC decoder
does not support
the seek command]:::error
J-->N
H --No -->K{Seek
parameter
positive?}:::condition
K --No -->L[Error: The seek
time must be
a positive value]:::error
L-->N
K --Yes -->M[Seek the file]:::function
M-->N
```

file play <filename>

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    C((Running)):::state --> Z[Error: First stop
    current track]:::error
    D((Paused)):::state --> Z
    B((Idle)):::state --> E{SD Card
    inserted?}:::condition
    E -- No -->F[Error: Insert SD
    card]:::error
    E -- Yes -->G{File
    name
    empty?}:::condition
    G -- Yes -->H[Error: Enter
    file name]:::error
    G -- No -->I{File exists?}:::condition
    I -- No -->O[Error: File
    doesn't exist]:::error
    I -- Yes -->J{Supported
    format?}:::condition
    J -- Yes -->K[Play the track]:::function
    J -- No -->L[Error: Unsupported
    file]:::error
    K -->M((Running)):::state
    L --> W((No state
    change)):::state
    O --> W
    H --> W
    F --> W
    Z --> W
```

file list

```
flowchart TD
    classDef function fill:#69CA00
```

```
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    B((Idle)):::state --> G{SD Card
    inserted?}:::condition
    C((Running)):::state --> G
    D((Paused)):::state --> G
    G -- Yes -->H[List supported files]:::function
    G -- No -->I[Error: Insert SD card]:::error
    I --> J((No state
    change)):::state
    H --> J
```

file info

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    B((Idle)):::state -->E[Write file info]:::function
    C((Running)):::state -->E
    D((Paused)):::state -->E
    E --> F((No state
        change)):::state
```

Processing Time Typical streamer pipeline execution times and their individual elements for the EVKC-MIMXRT1060 development board are presented in the following tables. The time spent on output buffers is not included in the traversal measurements. However, file reading time is accounted for. In the case of the WAV codec, the audio file was accessed in every pipeline run. Therefore, during each run, the file was read from the SD card. However, for the MP3 codec, where data must be processed in complete MP3 frames, the file was not read in every run. Instead, it was read periodically only when the codec buffer did not contain a complete frame of data.

For further details, please refer to the *Processing Time* document.

WAV	streamer	file_src	codec	SSRC_proc	speaker
48kHz	1.1 ms	850 µs	150 µs	70 µs	40 µs
44kHz	1.75 ms	850 µs	180 µs	670 µs	40 µs

MP3	streamer	file_src	codec	SSRC_proc	speaker
48 kHz with file read	2.9 ms	2.3 µs	450 µs	60 µs	50 µs
48 kHz without file read	0.5 ms	x	400 µs	40 µs	40 µs
44 kHz with file read	3.2 ms	2.3 µs	440 µs	400 µs	50 µs
44 kHz without file read	0.9 ms	x	440 µs	390 µs	40 µs

Maestro record example

Table of content

Overview The Maestro record example demonstrates audio processing on the ARM cortex core utilizing the Maestro Audio Framework library.

The application is controlled by commands from a shell interface using serial console.

Depending on target platform or development board there are different modes and features of the demo supported.

- **Loopback** - The application demonstrates a loopback from the microphone to the speaker without any audio processing. Mono, stereo or multichannel mode can be used, depending on the hardware, see *table* below.
- **File recording** - The application takes audio samples from the microphone inputs and stores them to an SD card as an PCM file. The PCM file has following parameters:
  - Mono and stereo : 2 channels, 16kHz, 16bit width
  - Multi-channel (AUD-EXP-42448): 6 channels, 16kHz, 32bit width
- **Voice control** - The application takes audio samples from the microphone input and uses the VIT library to recognize wake words and voice commands. If a wake word or a voice command is recognized, the application write it to the serial terminal.
- **Encoding** - The application takes PCM samples from memory and sends them to the Opus encoder. The encoded data is stored in memory and compared to a reference. The result of the comparison is finally written into the serial terminal.

As shown in the table below, the application is supported on several development boards, and each development board may have certain limitations, some development boards may also require hardware modifications or allow to use of an audio expansion board. Therefore, please check the supported features and *Hardware modifications* or *Example configuration* sections before running the demo.

Limitations:

- Note:
  - *LPCXPresso55s69* - MCUXpresso IDE project default debug console is semihost
- Addition labraries
  - **VIT:**
    - The VIT is supported only in the MCUXpresso IDE and ARMGCC.
    - *LPCXpresso55s69* - The VIT is disabled by default due to insufficient memory. To enable it, see the *Example configuration* section.

        * *EVK-MCXN5XX* - Some VIT models can't fit into memory. In order to free some space it is necessary to disable SD card handling and opus encoder. To disable it, see the *Example configuration* section.

- Encoder
  - **OPUS:**
    * *LPCXpresso55s69* - The encoder is not supported due to insufficient memory.
- The File recording mode is not supported on *RW612BGA* development board due to missing SD card slot.

Known issues:

- *EVKB-MIMXRT1170* - After several tens of runs (the number of runs is not deterministic), the development board restarts because a power-up sequence is detected on the RESET pin (due to a voltage drop).

More information about supported features can be found on the *Supported features* page.

Hardware requirements

- Desired development board
- Micro USB cable
- Headphones with 3.5 mm stereo jack
- Personal computer
- Optional:
  - SD card for file output
  - Audio expansion board AUD-EXP-42448 (REV B)
- *LPCXpresso55s69:*
  - Source of sound with 3.5 mm stereo jack connector

Hardware modifications Some development boards need some hardware modifications to run the application. If the development board is not listed here, its default setting is required.

- *EVKB-MIMXRT1170:*
  1. Please remove below resistors if on board wifi chip is not DNP:
     - R228, R229, R232, R234
  2. Please make sure R136 is weld for GPIO card detect.
- *EVK-MCXN5XX:*
  - Short: JP7 2-3, JP8 2-3, JP10 2-3, JP11 2-3
- *RW612BGA:*
  - Connect: JP50; Disconnect JP9, JP11

Preparation

1. Connect a micro USB cable between the PC host and the debug USB port on the development board
2. Open a serial terminal with the following settings:
   - 115200 baud rate

- 8 data bits
- No parity
- One stop bit
- No flow control

3. Download the program to the target board.
4. Insert the headphones into the Line-Out connector (headphone jack) on the development board.
5. *LPCXpresso55s69:*
   - Insert source of sound to audio Line-In connector (headphone jack) on the development board.
6. Either press the reset button on your development board or launch the debugger in your IDE to begin running the demo.

Running the demo When the example runs successfully, you should see similar output on the serial terminal as below:

```
******************************
Maestro audio record demo start
******************************

Copyright 2022 NXP
[APP_SDCARD_Task] start
[APP_Shell_Task] start

>> [APP_SDCARD_Task] SD card drive mounted
```

Type help to see the command list. Similar description will be displayed on serial console:

```
>> help

"help": List all the registered commands

"exit": Exit program

"version": Display component versions

"record_mic": Record MIC audio and perform one (or more) of following actions:
- playback on codec
- perform voice recognition (VIT)
- store samples to a file.

USAGE: record_mic [audio|file|<file_name>|vit] 20 [<language>]
The number defines length of recording in seconds.

Please see the project defined symbols for the languages supported.
Then specify one of: en/cn/de/es/fr/it/ja/ko/pt/tr as the language parameter.
For voice recognition say supported WakeWord and in 3s frame supported command.
Please note that this VIT demo is near-field and uses 1 on-board microphone.

NOTES: This command returns to shell after the recording is finished.
       To store samples to a file, the "file" option can be used to create a file
       with a predefined name, or any file name (without whitespaces) can be specified
       instead of the "file" option.

"opus_encode": Initializes the streamer with the Opus memory-to-memory pipeline and
encodes a hardcoded buffer.
```

Details of commands can be found *here*.

Example configuration The example can be configured by user. There are several options how to configure the example settings, depending on the environment. For configuration using west and Kconfig, please follow the instructions here. Before configuration, please check the *table* to see if the feature is supported on the development board.

- **Connect AUD-EXP-42448:**
  - *EVKC-MIMXRT1060:*
    1. Disconnect the power supply for safety reasons.
    2. Insert AUD-EXP-42448 into J19 to be able to use the CS42448 codec for multichannel output.
    3. Uninstall J99.
    4. Set the DEMO_CODEC_WM8962 macro to 0 in the app_definitions.h file
    5. Set the DEMO_CODEC_CS42448 macro to 1 in the app_definitions.h file.
  - *Note:*
    * The audio stream is as follows:
      - Stereo INPUT 1 (J12) -> LINE 1&2 OUTPUT (J6)
      - Stereo INPUT 2 (J15) -> LINE 3&4 OUTPUT (J7)
      - MIC1 & MIC2 (P1, P2) -> LINE 5&6 OUTPUT (J8)
      - Insert the headphones into the different line outputs to hear the inputs.
      - To use the Stereo INPUT 1, 2, connect an audio source LINE IN jack.
- **Enable VIT:**
  - *LPCXpresso55s69 and MCX-N5XX:*
    * In MCUXPresso IDE (SDK package):
      1. Remove SD_ENABLED and STREAMER_ENABLE_FILE_SINK symbols from preprocessor defines on project level.
      2. Add VIT_PROC symbol to preprocessor defines on project level:
         - (Project -> Properties -> C/C++ Build -> Settings -> MCU C Compiler -> Preprocessor)
    * In armgcc in SDK package:
      1. Remove SD_ENABLED and STREAMER_ENABLE_FILE_SINK symbols from preprocessor defines in flags.cmake file.
      2. Remove OPUS_ENCODE=1 and STREAMER_ENABLE_ENCODER preprocessor defines in flags.cmake file.
      3. Add VIT_PROC symbol to preprocessor defines in flags.cmake file.
      4. Remove sdmmc_config.c,.h files from CMakeLists.txt file.
    * In Kconfig:
      1. Disable File sink MCUX_COMPONENT_middleware.audio_voice.maestro.element.file_sink.enable
      2. Make sure SD card support is disabled MCUX_COMPONENT_middleware.sdmmc.sd and MCUX_COMPONENT_middleware.sdmmc.host.usdhc
      3. Make sure sdmmc_config files (.c, .h) is excluded from project build

        - remove mcux_add_source function that adds the sources in reconfig.cmake in maestro_record/cm33_core0 folder
    4. Disable fatfs MCUX_COMPONENT_middleware.fatfs and MCUX_COMPONENT_middleware.fatfs.sd
    5. Disable file utils MCUX_COMPONENT_middleware.audio_voice.maestro.file_utils.enable
    6. Make sure Opus encoder is disabled MCUX_COMPONENT_middleware.audio_voice.maestro.element.encoder.opus.enable
    7. Make sure VIT_PROC symbol is defined
        - remove mcux_remove_macro function that removes the VIT_PROC preprocessor definition in reconfig.cmake in maestro_record folder
    8. Make sure VIT processing is enabled MCUX_PRJSEG_middleware.audio_voice.components.vit

- **VIT model generation:**
  - For custom VIT model generation (defining own wake words and voice commands) please use https://vit.nxp.com/
- **Disable SD card handling:**
  - In MCUXPresso IDE:
    - Remove SD_ENABLED and STREAMER_ENABLE_FILE_SINK symbols from preprocessor defines on project level:
      - (Project -> Properties -> C/C++ Build -> Settings -> MCU C Compiler -> Preprocessor)
  - In armgcc in SDK package:
    - Remove SD_ENABLED and STREAMER_ENABLE_FILE_SINK symbols from preprocessor defines in flags.cmake file.
  - In Kconfig:
    1. Disable File sink MCUX_COMPONENT_middleware.audio_voice.maestro.element.file_sink.enable
    2. Make sure SD card support is disabled MCUX_COMPONENT_middleware.sdmmc.sd

Functionality The record_mic or opus_encode command calls the STREAMER_mic_Create or STREAMER_opusmem2mem_Create function from the app_streamer.c file depending on the selected mode.

- When the *Loopback* mode is selected, the command calls the STREAMER_mic_Create function that creates a pipeline with the following elements:
  - ELEMENT_MICROPHONE_INDEX
  - ELEMENT_SPEAKER_INDEX
- When the *File recording* mode is selected, the command calls the STREAMER_mic_Create function that creates a pipeline with the following elements: - ELEMENT_MICROPHONE_INDEX - ELEMENT_FILE_SINK_INDEX
- When the *Voice control* mode is selected, the command calls the STREAMER_mic_Create function that creates a pipeline with the following elements: - ELEMENT_MICROPHONE_INDEX - ELEMENT_VIT_INDEX

- When the Encoding mode is selected, the command calls the STREAMER_opusmem2mem_Create function that creates a pipeline with the following elements: - ELEMENT_MEM_SRC_INDEX - ELEMENT_ENCODER_INDEX - ELEMENT_MEM_SINK_INDEX

Recording itself can be started with the STREAMER_Start function.

Each of the elements has several properties that can be accessed using the streamer_get_property or streamer_set_property function. These properties allow a user to change the values of the appropriate elements. The list of properties can be found in streamer_element_properties.h. See the example of setting property value in the following piece of code from the app_streamer.c file:

```
ELEMENT_PROPERTY_T prop;

prop.prop = PROP_MICROPHONE_SET_NUM_CHANNELS;
prop.val  = DEMO_MIC_CHANNEL_NUM;
streamer_set_property(handle->streamer, 0, prop, true);

prop.prop = PROP_MICROPHONE_SET_BITS_PER_SAMPLE;
prop.val  = DEMO_AUDIO_BIT_WIDTH;
streamer_set_property(handle->streamer, 0, prop, true);

prop.prop = PROP_MICROPHONE_SET_FRAME_MS;
prop.val  = DEMO_MIC_FRAME_SIZE;
streamer_set_property(handle->streamer, 0, prop, true);

prop.prop = PROP_MICROPHONE_SET_SAMPLE_RATE;
prop.val  = DEMO_AUDIO_SAMPLE_RATE;
streamer_set_property(handle->streamer, 0, prop, true);
```

Some of the predefined values can be found in the streamer_api.h.

States The application can be in 2 different states:

- Idle
- Running

Commands in detail

- *help, version*
- *record_mic audio <time>*
- *record_mic file <time>*
- *record_mic <file_name> <time>*
- *record_mic vit <time> <language>*
- *opus_encode*

Legend for diagrams:

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    A((State)):::state
    B{Condition}:::condition
    C[Error message]:::error
    D[Process function]:::function
```

help, version

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    A((Idle)):::state --> C[Write help or version]:::function
    B((Running)):::state --> C
    C --> E((No state
    change)):::state
```

record_mic audio <time>

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    B((Idle)):::state --> D{time
    > 0 ?}:::condition
    D -- Yes --> F[recording]:::function
    D -- No --> E[Error: Record length
    must be greater than 0]:::error
    E --> B
    F --> C((Running)):::state
    C -->G{time
    expired?}:::condition
    G -- No --> C
    G -- Yes --> B
```

record_mic file <time>/record_mic <file_name> <time>

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    B((Idle)):::state --> C{time
    > 0 ?}:::condition
    C -- Yes --> D{SD card
    inserted?}:::condition
    C -- No --> E[Error: Record length
    must be greater than 0]:::error
    E --> B
    D -- Yes --> G{Custom
    file name?}:::condition
    G -- Yes --> H[Create custom
    file name]:::function
    G -- No --> I[Create default
    file name]:::function
    H --> J[Recording]:::function
    I --> J
    J --> K((Running)):::state
```

```
K -->L{time
expired?}:::condition
L -- No --> K
L -- Yes --> B
D -- No --> F[Error: Insert SD
card first]:::error
F --> B
```

record_mic vit <time> <language>

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    B((Idle)):::state --> C{time
    > 0 ?}:::condition
    C -- Yes --> E{Selected
    language?}:::condition
    C -- No --> D[Error: Record length
    must be greater than 0]:::error
    D --> B
    E -- Yes --> G{Supported
    language?}:::condition
    E -- No --> F[Error: Language
    not selected]:::error
    F -->B
    G -- Yes -->I[Recording with
    voice recognition]:::function
    G -- No -->H[Error: Language not supported]:::error
    H --> B
    I --> J((Running)):::state
    J -->K{time
    expired?}:::condition
    K -- No --> J
    K -- Yes --> B
```

opus_encode

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    B((Idle)):::state -->C[Encode file]:::function
    C -->D[Check result]:::function
    D -->B
```

Processing Time Typical execution times of the streamer pipeline for the EVKC-MIMXRT1060 development board are detailed in the following table. The duration spent on output buffers and reading from the microphone is excluded from traversal measurements. Three measured

pipelines were considered. The first involves a loopback from microphone to speaker, supporting both mono and stereo configurations. The second pipeline is a mono voice control setup, comprising microphone and VIT blocks. The final pipeline is a stereo voice control setup, integrating microphone and VIT blocks.

For further details of execution times on individual elements, please refer to the *Processing Time* document.

	streamer
microphone -> speaker 1 channel	40 µs
microphone -> speaker 2 channels	115 µs
microphone -> VIT	7.4 ms

Maestro USB microphone example

Table of content

Overview The Maestro USB microphone example demonstrates audio processing on the ARM cortex core utilizing the Maestro Audio Framework library.

The application is controlled by commands from a shell interface using serial console.

The development board will be enumerated as a USB audio class 2.0 device on the USB host. The application takes audio samples from the microphone inputs and sends them to the USB host via the USB bus. User will see the volume levels obtained from the USB host but this is only an example application. To leverage the volume values, the demo has to be modified.

As shown in the table below, the application is supported on several development boards, and each development board may have certain limitations, some development boards may also require hardware modifications or allow to use of an audio expansion board. Therefore, please check the supported features and *Hardware modifications* or *Example configuration* sections before running the demo.

Limitations:

- *Note:*
  1. When connected to MacBook, change the PCM format from (0x02,0x00,) to (0x01,0x00,) in the g_config_descriptor[CONFIG_DESC_SIZE] in the usb_descriptor.c file. Otherwise, it can't be enumerated and noise is present when recording with the QuickTime player because the sampling frequency and bit resolution do not match.

2. When device functionality is changed, please uninstall the previous PC driver to make sure the device with changed functionality can run normally.
3. If you're having audio problems on Windows 10 for recorder, please disable signal enhancement as the following if it is enabled and have a try again.

Known issues:

- No known issues.

More information about supported features can be found on the *Supported features* page.

Hardware requirements

- Desired development board
- 2x Micro USB cable
- Personal Computer
- *LPCXpresso55s69:*
  - Source of sound with 3.5 mm stereo jack connector

Hardware modifications Some development boards need some hardware modifications to run the application. If the development board is not listed here, its default setting is required.

Preparation

1. Connect the first micro USB cable between the PC host and the debug USB port on the development board
2. Open a serial terminal with the following settings:
   - 115200 baud rate
   - 8 data bits
   - No parity
   - One stop bit
   - No flow control
3. Download the program to the target board.
4. *LPCXpresso55s69:*
   - Insert source of sound to Audio Line-In connector (headphone jack) on the development board.
5. Connect the second micro USB cable between the PC host and the USB port on the development board.
6. Either press the reset button on your development board or launch the debugger in your IDE to begin running the demo.

Running the demo When the example runs successfully, you should see similar output on the serial terminal as below:

```
**********************************************
Maestro audio USB microphone solutions demo start
**********************************************

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```

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```
[APP_Shell_Task] start

>> usb_mic -1

Starting maestro usb microphone application
The application will run until the board restarts
[STREAMER] Message Task started
Starting recording
[STREAMER] start usb microphone
Set Cur Volume : 1f00
```

Type help to see the command list. Similar description will be displayed on serial console:

```
>> help

"help": List all the registered commands

"exit": Exit program

"version": Display component versions

"usb_mic":  Record MIC audio and playback to the USB port as an audio 2.0
        microphone device.

  USAGE: usb_mic <seconds>
    <seconds>  Time in seconds how long the application should run.
            When you enter a negative number the application will
            run until the board restarts.
  EXAMPLE:   The application will run for 20 seconds: usb_mic 20
```

Details of commands can be found *here*.

Example configuration The example only supports one mode and do not support any additional libraries, so the example can't be configured by user.

Functionality The usb_mic command calls the STREAMER_mic_Create function from the app_streamer.cfile that creates pipeline with the following elements: - ELEMENT_MICROPHONE_INDEX - ELEMENT_USB_SINK_INDEX

Recording itself can be started with the STREAMER_Start function.

Each of the elements has several properties that can be accessed using the streamer_get_property or streamer_set_property function. These properties allow a user to change the values of the appropriate elements. The list of properties can be found in streamer_element_properties.h. See the example of setting property value in the following piece of code from the app_streamer.c file:

```
ELEMENT_PROPERTY_T prop;

prop.prop = PROP_MICROPHONE_SET_SAMPLE_RATE;
prop.val  = AUDIO_SAMPLING_RATE;

streamer_set_property(handle->streamer, 0, prop, true);

prop.prop = PROP_MICROPHONE_SET_NUM_CHANNELS;
prop.val  = 1;

streamer_set_property(handle->streamer, 0, prop, true);

prop.prop = PROP_MICROPHONE_SET_FRAME_MS;
```

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```
    prop.val  = 1;

    streamer_set_property(handle->streamer, 0, prop, true);
```

Some of the predefined values can be found in the streamer_api.h.

States The application can be in 2 different states:

- Idle
- Running

Commands in detail

- *help, version*
- *usb_mic <seconds>*

Legend for diagrams:

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    A((State)):::state
    B{Condition}:::condition
    C[Error message]:::error
    D[Process function]:::function
```

help, version

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    A((Idle)):::state --> C[Write help or version]:::function
    B((Running)):::state --> C
    C --> E((No state
    change)):::state
```

usb_mic <seconds>

```
flowchart TD
    classDef function fill:#c6d22c
    classDef condition fill:#7cb2de
    classDef state fill:#fcb415
    classDef error fill:#FF999C

    B((Idle)):::state -->C{seconds
    == 0?}:::condition
    C -- No --> E{seconds
    < 0?}:::condition
    C -- Yes --> D[Error: Incorrect
```

command parameter]:::error
D -->B
E -- Yes --> G[recording]:::function
G --> H((Running)):::state
H --> H
E -- No --> F[recording]:::function
F --> I((Running)):::state
I --> J{seconds
expired?}:::condition
J -- No -->I
J -- Yes --> B

Maestro USB speaker example

Table of content

Overview The Maestro USB speaker example demonstrates audio processing on the ARM cortex core utilizing the Maestro Audio Framework library.

The application is controlled by commands from a shell interface using serial console.

The development board will be enumerated as a USB audio class 2.0 device on the USB host. The application takes audio samples from the USB host and sends them to the audio Line-Out port. User will see the volume levels obtained from the USB host but this is only an example application. To leverage the volume values, the demo has to be modified.

Depending on target platform or development board there are different modes and features of the demo supported.

- **Standard** - The mode demonstrates playback with up to 2 channels, up to 48 kHz sample rate and up to 16 bit width. This mode is enabled by default.
- **Multi-Channel** - In this mode the device is enumerated as a UAC 5.1. This mode is disabled by default. See the *Example configuration* section to see how to enable the mode.
  - When playing an 5.1 audio file, the example sends only the front-left and front-right channels to the audio Line-Out port (the other channels are ignored), since this example only supports on-board codecs with stereo audio output.

As shown in the table below, the application is supported on several development boards, and each development board may have certain limitations, some development boards may also require hardware modifications or allow to use of an audio expansion board. Therefore, please check the supported features and *Hardware modifications* or *Example configuration* sections before running the demo.

Limitations:

- *Note:*
  - If the USB device audio speaker example uses an ISO IN feedback endpoint, please attach the device to a host like PC which supports feedback function. Otherwise, there might be attachment issue or other problems.

Known issues:

- No known issues.

More information about supported features can be found on the *Supported features* page.

Hardware requirements

- Desired development board
- 2x Micro USB cable
- Personal Computer
- Headphones with 3.5 mm stereo jack

Hardware modifications Some development boards need some hardware modifications to run the application. If the development board is not listed here, its default setting is required.

Preparation

1. Connect the first micro USB cable between the PC host and the debug USB port on the development board
2. Open a serial terminal with the following settings:
   - 115200 baud rate
   - 8 data bits
   - No parity
   - One stop bit
   - No flow control
3. Download the program to the target board.
4. Connect the second micro USB cable between the PC host and the USB port on the development board.
5. Insert the headphones into Line-Out connector (headphone jack) on the development board.
6. Either press the reset button on your development board or launch the debugger in your IDE to begin running the demo.

Running the demo When the example runs successfully, you should see similar output on the serial terminal as below:

```
*********************************************
Maestro audio USB speaker solutions demo start
*********************************************

Copyright 2022 NXP
[APP_Shell_Task] start

>> usb_speaker -1
```

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```
Starting maestro usb speaker application
The application will run until the board restarts
[STREAMER] Message Task started
Starting playing
[STREAMER] start usb speaker
Set Cur Volume : fbd5
```

Type help to see the command list. Similar description will be displayed on serial console:

```
>> help

"help": List all the registered commands

"exit": Exit program

"version": Display component versions

"usb_speaker": Play data from the USB port as an audio 2.0
               speaker device.

 USAGE:      usb_speaker <seconds>
  <seconds>  Time in seconds how long the application should run.
             When you enter a negative number the application will
             run until the board restarts.
  EXAMPLE:   The application will run for 20 seconds: usb_speaker 20
```

Details of commands can be found *here*.

Example configuration The example can be configured by user. Before configuration, please check the *table* to see if the feature is supported on the development board.

- **Enable Multi-channel mode:**
  - The feature can be enabled by set the USB_AUDIO_CHANNEL5_1 macro to 1U in the usb_device_descriptor.h file.
  - *Note:* When device functionality is changed, such as UAC 5.1, please uninstall the previous PC driver to make sure the device with changed functionality can run normally.

Functionality The Usb_speaker command calls the STREAMER_speaker_Create function from the app_streamer.cfile that creates pipeline with the following elements: - ELEMENT_USB_SRC_INDEX - ELEMENT_SPEAKER_INDEX

Playback itself can be started with the STREAMER_Start function.

Each of the elements has several properties that can be accessed using the streamer_get_property or streamer_set_property function. These properties allow a user to change the values of the appropriate elements. The list of properties can be found in streamer_element_properties.h. See the example of setting property value in the following piece of code from the app_streamer.c file:

```
ELEMENT_PROPERTY_T prop;

prop.prop = PROP_USB_SRC_SET_SAMPLE_RATE;
prop.val  = AUDIO_SAMPLING_RATE;

streamer_set_property(handle->streamer, 0, prop, true);

prop.prop = PROP_USB_SRC_SET_NUM_CHANNELS;
prop.val  = 2;
```

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```
    streamer_set_property(handle->streamer, 0, prop, true);

    prop.prop = PROP_USB_SRC_SET_FRAME_MS;
    prop.val  = 1;

    streamer_set_property(handle->streamer, 0, prop, true);
```

Some of the predefined values can be found in the streamer_api.h.

States The application can be in 2 different states:

- Idle
- Running

Commands in detail

- *help, version*
- *usb_speaker <seconds>*

Legend for diagrams:

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    A((State)):::state
    B{Condition}:::condition
    C[Error message]:::error
    D[Process function]:::function
```

help, version

```
flowchart TD
    classDef function fill:#69CA00
    classDef condition fill:#0EAFE0
    classDef state fill:#F9B500
    classDef error fill:#F54D4D

    A((Idle)):::state --> C[Write help or version]:::function
    B((Running)):::state --> C
    C --> E((No state
    change)):::state
```

usb_speaker <seconds>

```
flowchart TD
    classDef function fill:#c6d22c
    classDef condition fill:#7cb2de
    classDef state fill:#fcb415
    classDef error fill:#FF999C

    B((Idle)):::state -->C{Duration
    == 0?}:::condition
```

C -- No --> E{Duration
< 0?}:::condition
C -- Yes --> D[Error: Incorrect
command parameter]:::error
D -->B
E -- Yes --> G[playing]:::function
G --> H((Running)):::state
H --> H
E -- No --> F[playing]:::function
F --> I((Running)):::state
I --> J{Duration
expired?}:::condition
J -- No -->I
J -- Yes --> B

Supported features The current version of the audio framework supports several optional features. These can be limited to some MCU cores or development boards variants. More information about support can be found on the specific example page:

- *maestro_playback*
- *maestro_record*
- *maestro_usb_mic*
- *maestro_usb_speaker*

Some features are delivered as prebuilt library and the binaries can be found in the \middleware\audio_voice\components*component*\libs folder. The source code of some features can be found in the \middleware\audio_voice\maestro\src folder.

Decoders Supported decoders and its options are:

Decoder	Sample rates [kHz]	Number of channels	Bit depth
AAC	8, 11.025, 12, 16, 22.05, 24, 32, 44.1, 48	1, 2 (mono/stereo)	16
FLAC	8, 11.025, 12, 16, 22.05, 32, 44.1, 48	1, 2 (mono/stereo)	16
MP3	8, 11.025, 12, 16, 22.05, 24, 32, 44.1, 48	1, 2 (mono/stereo)	16
OPUS	8, 16, 24, 48	1, 2 (mono/stereo)	16
WAV	8, 11.025, 16, 22.05, 32, 44.1, 48	1, 2 (mono/stereo)	8, 16, 24

For more details about the reference decoders please see audio-voice-components repository documentation \middleware\audio_voice\components\.

Encoders

- **OPUS encoder** - The current verion of the audio framework only supports a OPUS encoder. For more details about the encoder please see the following link.

Sample rate converters

- **SSRC** - Synchronous sample rate converter. More details about SSRC are available in the User Guide, which is located in middleware\audio_voice\components\ssrc\doc\.
- **ASRC** - Asynchronous sample rate converter is not used in our examples, but it is part of the maestro middleware and can be enabled. To enable ASRC, the maestro_framework_asrc and CMSIS_DSP_Library_Source components must be added to the project. Furthermore, it is necessary to switch from Redlib to Newlib (semihost) library and add a platform definition

to the project (e.g. for RT1170: PLATFORM_RT1170_CORTEXM7). Supported platforms can be found in the PL_platformTypes.h file. More details about ASRC are available in the User Guide, which is located in middleware\audio_voice\components\asrc\doc\.

Additional libraries

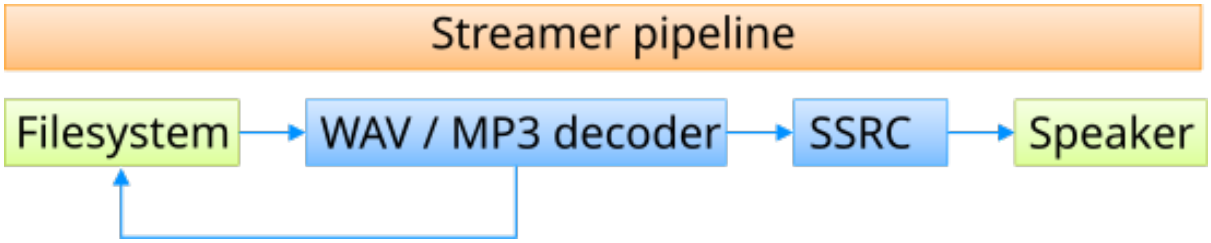
- **VIT** - Voice Intelligent Technology (VIT) Wake Word and Voice Command Engines provide free, ready to use voice UI enablement for developers. It enables customer-defined wake words and commands using free online tools. More details about VIT are available in the VIT package, which is located in middleware\audio_voice\components\vit\{platform}\Doc\(depending on the platform) or via following link.

Processing Time

Table of content

The individual time measurements were conducted using a logic analyzer by monitoring changes in the GPIO port levels on the EVKC-MIMXRT1060 development board. These measurements were executed for each individual pipeline run, capturing the timing at each corresponding element, and, when relevant, the interconnections between these elements.

Maestro playback example For the Maestro playback example the following reference audio file was used: test_48khz_16bit_2ch.wav. In this example, the pipeline depicted in the diagram was considered. Media codecs WAV and MP3 were taken into account. To compare the times spent on the SSRC block, sampling rates for both codecs were selected: 44.1 kHz and 48 kHz.



The measurement of streamer pipeline run started at the beginning of streamer_process_pipelines(): streamer.c and ended in the function streamer_pcm_write(): streamer_pcm.c just before the output buffer.

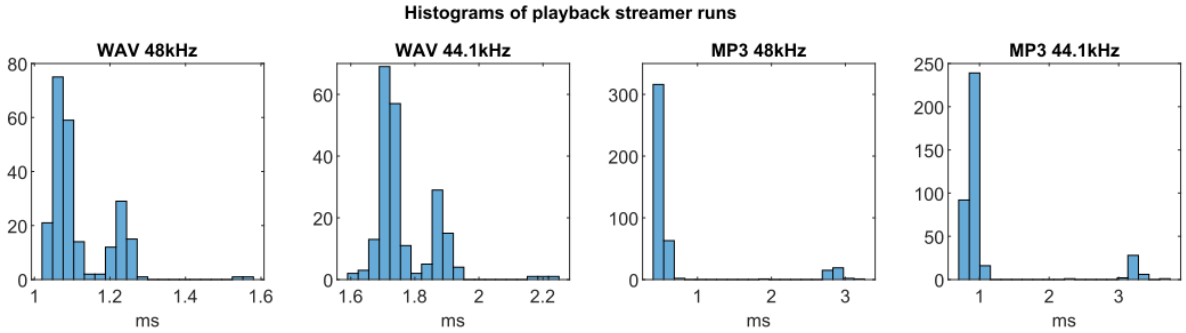
In the scenario involving the WAV codec, the audio file was accessed in every iteration of the streamer pipeline. Meaning, during each run, the file was read directly from the SD card. However, in the case of the MP3 codec, where data processing necessitates complete MP3 frames, the file wasn't read during every run. Rather, it was accessed periodically, triggered when the codec buffer lacked a complete MP3 frame of data. The total time spent on codec processing varies significantly depending on the type and implementation of the codec. For certain types of codecs, like FLAC, there may be multiple file accesses during a single pipeline run. The provided values are specific to the reference implementation. For details about the codecs please see see audio-voice-components documentation middleware\audio_voice\components\.

The duration of the streamer pipeline illustrates that with a sampling frequency of 48 kHz, there is no resampling occurring at the SSRC element. Consequently, the overall pipeline time is lower than in the case of 44.1 kHz audio, where resampling takes place.

To enhance comprehension of the system's behavior, histograms of the pipeline run times and its elements are included. The greater time variance with the MP3 codec is precisely due to

the absence of file reads in every run. In clusters with shorter times, there are no file accesses, while in clusters with longer times, file reads occur. This indicates that the majority of runs do not involve file access.

	WAV 48 kHz	WAV 44 kHz	MP3 48 kHz file read	MP3 48 kHz w/o file read	MP3 44 kHz file read	MP3 44 kHz w/o file read
mean	1.11 ms	1.76 ms	2.87 ms	0.51 ms	3.22 ms	0.89 ms
min	1.03 ms	1.60 ms	2.74 ms	0.41 ms	2.33 ms	0.74 ms
max	1.29 ms	2.23 ms	3.24 ms	1.83 ms	3.73 ms	1.12 ms



Time on each element In the tables and histograms below, the timings for individual elements and their connections are provided. Given that the file reading function was invoked during the codec's operation, the tables for individual elements display the total time on the codec element, the time on the codec element before the file read, and the time on the codec element after the file read. The individual blocks in the tables are as follows:

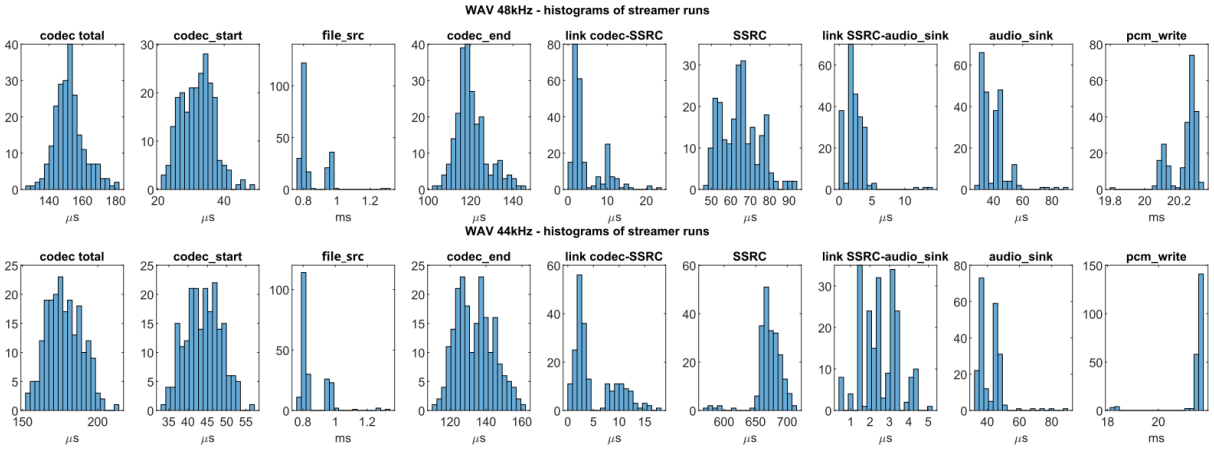
- **streamer** - total time of one pipeline run without time on output buffers
- **codec start** - time on decoder before file read
- **codec end** - time on decoder after file read
- **codec total** - codec_start+codec_end
- **file_src** - file reading time
- **SSRC_proc** - time on SSRC element
- **audio_sink** - time on audio sink without ouput buffers
- **pcm_write** - time on output buffers
- **link** - time on element links

The start times of the time intervals for individual blocks and their respective links were measured by altering the GPIO pin level in the following functions:

- **streamer** - streamer_process_pipelines():streamer.c
- **codec** - decoder_sink_pad_process_handler():decoder_pads.c
- **file_src** - filesrc_read():file_src_rtos.c
- **SSRC_proc** - SSRC_Proc_Execute():ssrc_proc.c
- **audio_sink** - audiosink_sink_pad_chain_handler():audio_sink.c
- **pcm_write** - streamer_pcm_write():streamer_pcm.c
- **link** - pad_push():pad.c

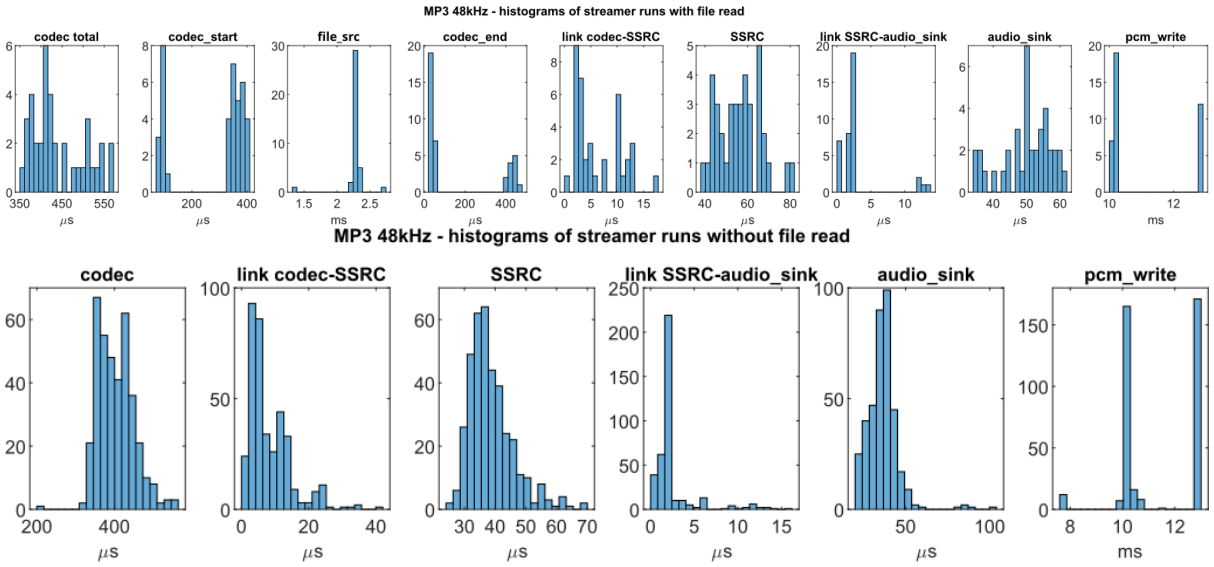
WAV 48kHz	strean	codec total	codec start	file_sr	codec end	link codec-SSRC	SSRC_p	link SSRC-audio_sink	au-dio_sin	pcm_write
mean	1.119 ms	152 µs	31 µs	0.843 ms	120 µs	5 µs	64 µs	2 µs	40 µs	20.228 ms
min	1.026 ms	125 µs	21 µs	0.773 ms	104 µs	<1 µs	47 µs	<1 µs	30 µs	19.805 ms
max	1.290 ms	193 µs	49 µs	1.311 ms	144 µs	23 µs	93 µs	14 µs	91 µs	20.324 ms

WAV 44kHz	strean	codec total	codec start	file_sr	codec end	link codec-SSRC	SSRC_p	link SSRC-audio_sink	au-dio_sin	pcm_write
mean	1.765 ms	178 µs	44 µs	0.853 ms	134 µs	5 µs	671 µs	3 µs	42 µs	21.472 ms
min	1.604 ms	145 µs	33 µs	0.770 ms	112 µs	<1 µs	574 µs	<1 µs	33 µs	18.163 ms
max	2.233 ms	218 µs	57 µs	1.335 ms	161 µs	18 µs	715 µs	5 µs	89 µs	21.746 ms



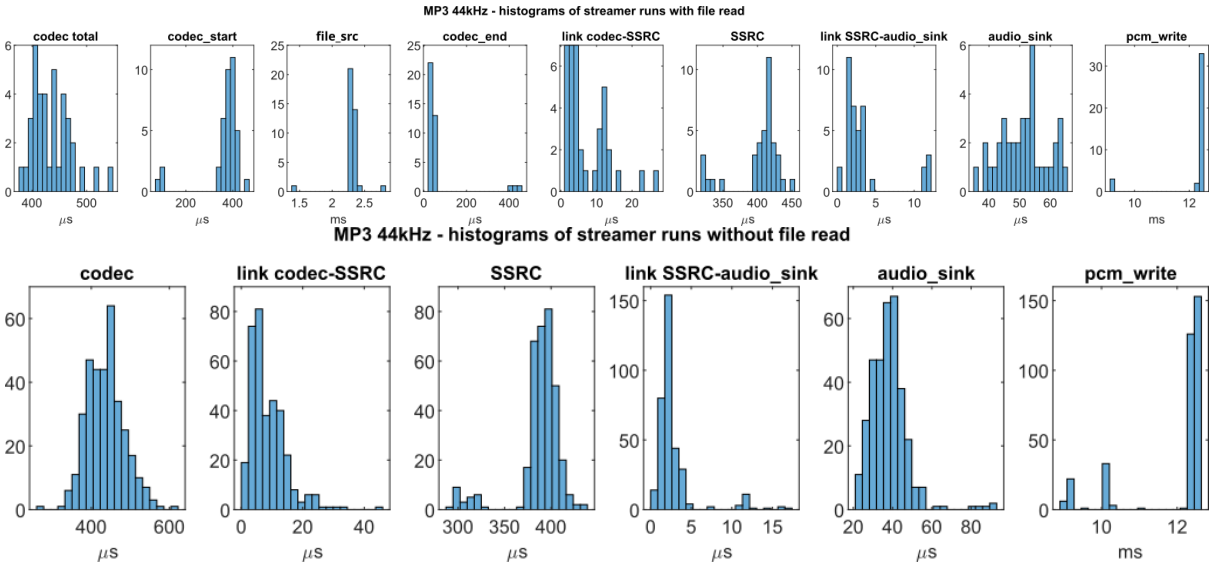
MP3 48 kHz w/ file read	strear	codec total	codec start	file_sr	codec end	link codec-SSRC	SSRC_|	link SSRC-audio_sink	au-dio_sir	pcm_write
mean	2.871 ms	441 µs	279 µs	2.271 ms	162 µs	6 µs	56 µs	3 µs	50 µs	11.019 ms
min	2.739 ms	353 µs	74 µs	1.353 ms	26 µs	<1 µs	40 µs	<1 µs	34 µs	10.091 ms
max	3.244 ms	570 µs	409 µs	2.728 ms	467 µs	18 µs	80 µs	14 µs	62 µs	12.910 ms

MP3 48 kHz w/o file read	strear	codec total	codec start	file_s	codec end	link codec-SSRC	SSRC_	link SSRC-audio_sink	au-dio_sir	pcm_write
mean	0.508 ms	403 µs	x	x	x	8 µs	39 µs	3 µs	36 µs	11.326 ms
min	0.407 ms	208 µs	x	x	x	<1 µs	25 µs	<1 µs	21 µs	7.715 ms
max	1.834 ms	563 µs	x	x	x	41 µs	69 µs	16 µs	104 µs	12.941 ms

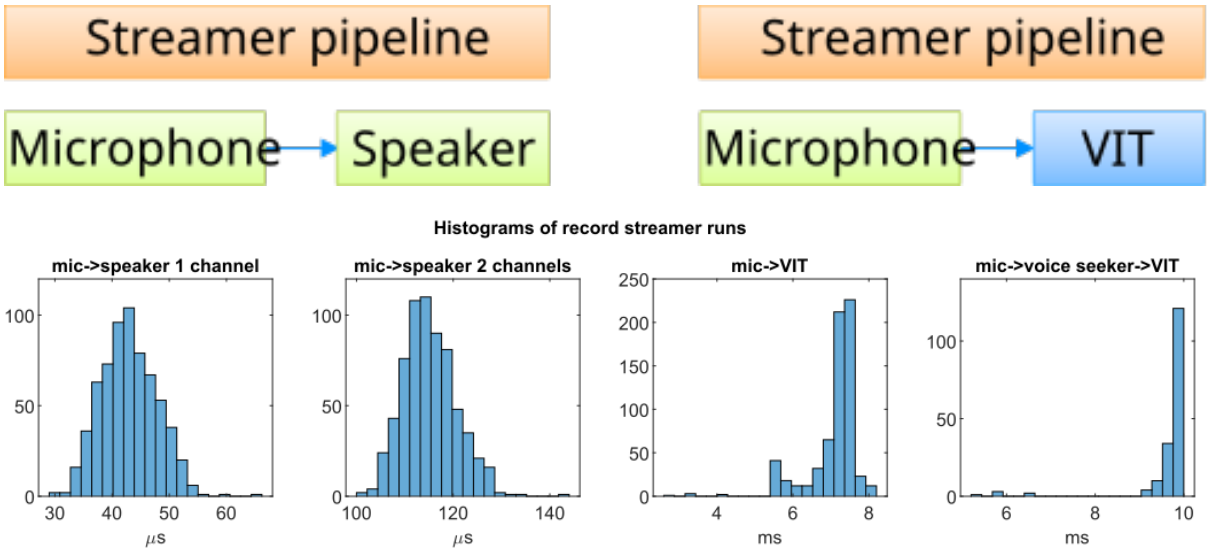


MP3 44 kHz w/ file read	strear	codec total	codec start	file_sr	codec end	link codec-SSRC	SSRC_	link SSRC-audio_sink	au-dio_sir	pcm_write
mean	3.217 ms	436 µs	367 µs	2.300 ms	66 µs	7 µs	403 µs	3 µs	51 µs	12.188 ms
min	2.329 ms	383 µs	73 µs	1.411 ms	26 µs	2 µs	318 µs	<1 µs	35 µs	9.119 ms
max	3.726 ms	547 µs	464 µs	2.801 ms	441 µs	27 µs	454 µs	12 µs	65 µs	12.529 ms

MP3 44 kHz w/o file read	strear	codec total	codec start	file_s	codec end	link codec-SSRC	SSRC_	link SSRC-audio_sink	au-dio_sir	pcm_write
mean	0.891 ms	437 µs	x	x	x	9 µs	388 µs	3 µs	38 µs	11.934 ms
min	0.738 ms	268 µs	x	x	x	<1 µs	290 µs	<1 µs	22 µs	8.964 ms
max	1.115 ms	620 µs	x	x	x	45 µs	438 µs	17 µs	92 µs	12.624 ms



Maestro record example Typical execution times of the streamer pipeline and its individual elements for the EVKC-MIMXRT1060 development board are detailed in the following tables. The duration spent on output buffers and reading from the microphone is excluded from traversal measurements. Three measured pipelines are depicted in the figure below. The first involves a loopback from microphone to speaker, supporting both mono and stereo configurations. The second pipeline is a mono voice control setup, comprising microphone and VIT blocks. The final pipeline is a stereo voice control setup, integrating microphone and VIT blocks. The measurement of streamer pipeline run started at the beginning of streamer_process_pipelines():streamer.c and ended in the function streamer_pcm_write(): streamer_pcm.c just before the output buffer.



The individual blocks in the tables are as follows:

- **streamer** - total time of one pipeline run without time on output buffers and without time reading from the microphone
- **audio_src_start** - time on audio src before reading from the microphone
- **audio_src_end** - time on audio src after reading from the microphone
- **pcm_read** - reading from the microphone
- **vit** - time on VIT element
- **audio_sink** - time on audio sink without ouput buffers

- **pcm_write** - time on output buffers
- **link** - time on element links

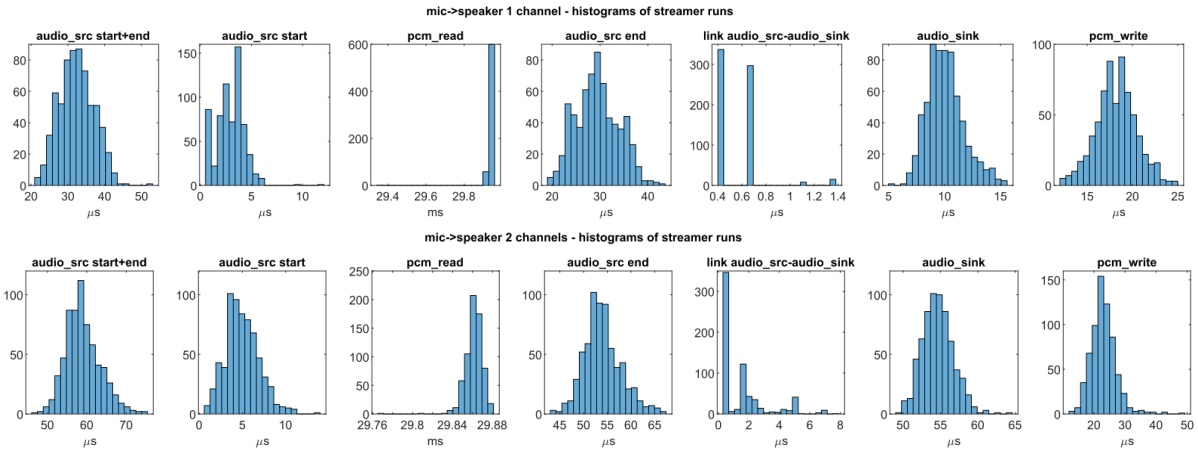
The start times of the time intervals for individual blocks and their respective links were measured by altering the GPIO pin level in the following functions:

- **streamer** - streamer_process_pipelines():streamer.c
- **audio_src** - audiosrc_src_process():audio_src.c
- **pcm_read** - streamer_pcm_read():streamer_pcm.c
- **vit** - vitsink_sink_pad_chain_handler():vit_sink.c
- **audio_sink** - audiosink_sink_pad_chain_handler():audio_sink.c
- **pcm_write** - streamer_pcm_write():streamer_pcm.c
- **link** - pad_push():pad.c

Pipeline Microphone -> Speaker

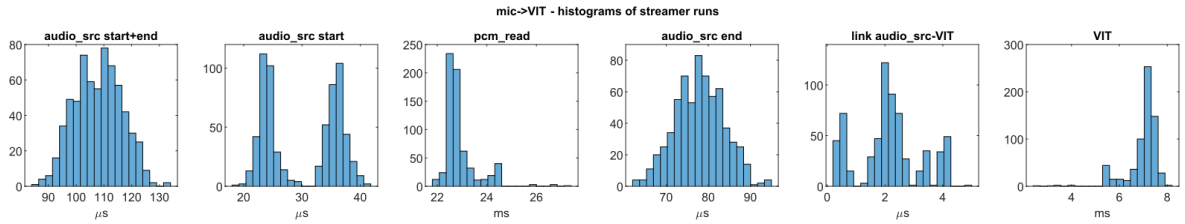
microphone -> speaker mono	stream	audio_src_sta	pcm_re	audio_src_er	link audio_src-audio_sink	audio_sink	pcm_write
mean	43 µs	3 µs	29.938 ms	29 µs	<1 µs	10 µs	18 µs
min	26 µs	<1 µs	29.350 ms	19 µs	<1 µs	5 µs	12 µs
max	72 µs	12 µs	29.957 ms	44 µs	1 µs	15 µs	25 µs

microphone -> speaker stereo	stream	audio_src_sta	pcm_re	audio_src_er	link audio_src-audio_sink	audio_sink	pcm_write
mean	115 µs	5 µs	29.861 ms	54 µs	2 µs	55 µs	23 µs
min	94 µs	<1 µs	29.768 ms	43 µs	<1 µs	50 µs	12 µs
max	154 µs	14 µs	29.880 ms	67 µs	8 µs	65 µs	49 µs



Pipeline Microphone -> VIT

microphone -> VIT	streamer	audio_src_start	pcm_read	audio_src_end	link audio_src-vit	vit
mean	7.380 ms	30 µs	22.624 ms	78 µs	2 µs	7.261 ms
min	2.641 ms	10 µs	2.2265 ms	58 µs	<1 µs	2.559 ms
max	7.780 ms	42 µs	2.7341 ms	94 µs	5 µs	7.624 ms



Maestro on Zephyr

- Based on and tested with Zephyr version, given by tag v4.0.0
- Tested with Zephyr SDK version 16.4
- To see the pre-built documentation, see: README.html. Also see the *documentation section*.

Maestro sample for recording data from microphone to RAM

Description This sample records data from microphone (alias `dmic0` in devicetree) and stores them to a buffer in RAM.

Currently one PDM channel with fixed 16 kHz sample rate and 16 bit sample width is supported.

For configuration options, see Kconfig and prj.conf.

User Input/Output

- Input:

  None.

- Output:

  UART Output:

  - `Demo result: OK` if everything went OK
  - `Demo result: FAIL` otherwise

Supported platforms Currently tested for:

- RD_RW612_BGA.

Maestro voice detection sample using VIT

Description Records data from microphone (alias dmic0 in devicetree) and detects voice commands from selected language model. Detected commands are printed via UART.

Language model may be changed via Kconfig using CONFIG_MAESTRO_EXAMPLE_VIT_LANGUAGE selection. For other configuration options, see example's Kconfig and prj.conf.

This project requires an NXP board supported by the VIT library.

The example has to be modified if a new board needs to be added. Please create an issue in that case.

User Input/Output

- Input:

  None.

- Output:

  UART Output:

  - List of voice commands the model can detect (printed immediately after start)
  - <Specific voice command> if voice command was detected
  - Demo result: FAIL otherwise

Dependencies

- VIT library: https://www.nxp.com/design/design-center/software/embedded-software/voice-intelligent-technology-wake-word-and-voice-command-engines:VOICE-INTELLIGENT-TECHNOLOGY

Supported platforms Currently tested for:

- RD_RW612_BGA.

Maestro decoder sample

Description Tests and demonstrates decoder functionality in Maestro pipeline.

Supported decoders:

- MP3
- WAV
- AAC
- FLAC
- OPUS with OGG envelop
- (RAW OPUS - TBD)

Data Input:

- Prepared encoded audio data (part of Maestro repository, folder zephyr/audioTracks)
- Prepared decoded audio data (RAW PCM format, part of Maestro repository, folder zephyr/audioTracks)

Function:

1. Loads encoded data into source buffer stored in RAM

2. Decodes audio data using selected decoder and stores data in RAM
3. Compares prepared data with decoded data to check if its the same
4. Prints Demo result: OK or Demo result: FAIL via UART

User Input/Output

- Input:

  None

- Output:

  UART Output

  - Demo result: OK if everything went OK
  - Demo result: FAIL otherwise

Dependencies

- Audio voice component library (pulled in by Maestro's west), containing Decoder libraries

Configuration

- See prj.conf for user input sections
  - Selecting decoder may be done by enabling CONFIG_MAESTRO_EXAMPLE_DECODER_SELECTED in prj.conf file. When no decoder is selected, default one (WAV) is used instead.
  - System settings should be modified (stack size, heap size) based on selected decoder and system capabilities/requirements in prj.conf.
- For other configuration options, see example's Kconfig and prj.conf.

Supported platforms Currently tested for:

- RD_RW612_BGA - Working decoders: FLAC, WAV, OPUS OGG

Maestro encoder sample

Description Tests and demonstrates encoder functionality in Maestro pipeline.

Supported encoders:

- OPUS with OGG envelop - TBD
- RAW OPUS - TBD

Input:

- Prepared decoded audio data (RAW PCM format, part of Maestro repository)
- Prepared encoded audio data (part of Maestro repository)

Function:

1. Loads RAW data into source buffer stored in RAM
2. Encodes audio data using selected encoder and stores data in RAM
3. Compares prepared data with decoded data if same
4. Prints Demo result: OK or Demo result: FAIL via UART

Dependencies

- Audio voice component library (pulled in by Maestro's west), containing Encoder libraries

User Input/Output Input:

- None

Output:

- UART Output
  - Demo result: OK if everything went OK
  - Demo result: FAIL otherwise

Configuration

- See prj.conf for user input sections
  - Selecting encoder may be done by enabling CONFIG_MAESTRO_EXAMPLE_ENCODER_SELECTED in prj.conf file. When no encoder is selected, default one (OPUS) is used instead.
  - System settings should be modified (stack size, heap size) based on selected encoder and system capabilities/requirements in prj.conf file.
- For other configuration options, see example's Kconfig and prj.conf.

Supported platforms Currently tested for:

- RD_RW612_BGA - Working encoders: None.

Maestro mem2mem sample

Description Tests basic memory to memory pipeline.

Function:

1. Moves generated data with fixed size of 256B from memory source to memory sink.
2. Compares copied data to check if they're the same.
3. Returns Demo result: OK or Demo result: FAIL via UART.

Maestro environment setup Follow these steps to set up a Maestro development environment on your machine.

1. If you haven't already, please follow this guide to set up a Zephyr development environment and its dependencies first:
   - Cmake
   - Python
   - Devicetree compiler
   - West
   - Zephyr SDK bundle
2. Get Maestro. You can pick either of the options listed below. If you need help deciding which option is the best fit for your needs, please see the *FAQ*.
   - Freestanding Maestro - This option pulls in only Maestro's necessary dependencies.

     Run:

     ```
     1. west init -m <maestro repository url> --mr <revision> --mf west-freestanding.yml
     ↪<foldername>
     2. cd <foldername>
     3. west update
     ```

   - Maestro as a Zephyr module

     To include Maestro into Zephyr, update Zephyr's west.yml file:

     ```
     projects:
     name: maestro
     url: <maestro repository url>
     revision: <revision with Zephyr support>
     path: modules/audio/maestro
     import: west.yml
     ```

     Then run west update maestro command.

Build and run Maestro example These steps will guide you through building and running Maestro samples. You can use either the command line utilizing Zephyr's powerful west tool or you can use VS Code's GUI. Detailed steps for both options are listed below.

Using command line See Zephyr's Building, Flashing and Debugging guide if you aren't familiar with it yet.

1. To **build** a project, run:

   ```
   west build -b <board> -d <output build directory> <path to example> -p
   ```

   For example, this compiles VIT example for rd_rw612_bga board:

   ```
   1. cd maestro/zephyr
   2. west build -b rd_rw612_bga -d build samples/vit -p
   ```

2. To **run** a project, run:

   ```
   west flash -d <directory>
   ```

   e.g.:

```
west flash -d build
```

3. To **debug** a project, run:

```
west debug -d <directory>
```

e.g.:

```
west debug -d build
```

Using MCUXpresso for VS Code For this you have to have NXP's MCUXpresso for VS Code extension installed.

1. Import your topdir as a repository to MCUXPresso for VS Code:
   - Open the MCUXpresso Extension. In the *Quickstart Panel* click *Import Repository*.
   - In the displayed menu click *LOCAL* tab and select the folder location of your *topdir*.
   - Click *Import*.
   - The repository is successfully added to the *Installed Repositories* view once the import is successful.
2. To import any project from the imported repository:
   - In the *Quickstart Panel* click *Import Example from Repository*.
   - For **Repository** select *your imported* repository.
   - For **Zephyr SDK** the installed Zephyr SDK is selected automatically. If not, select one.
   - For **Board** select your board (*make sure* you've selected the *correct* revision).
   - For **Template** select the folder path to your project.
   - Click the *Create* button.
3. Build the project by clicking the *Build Selected* icon (displayed on hover) in the extension's *Projects* view. After the build, the debug console window displays the memory usage (or compiler errors if any).
4. Debug the project by clicking the *Debug* (play) icon (displayed on hover) in the extension's *Projects* view.
5. The execution will pause. To continue execution click *Continue* on the debug options.
6. In the *SERIAL MONITOR* tab of your console panel, the application prints the Zephyr boot banner during startup and then prints the test results.

Folder structure

```
maestro/
    ...
    zephyr/              All Zephyr related files
      samples/           Sample examples
      tests/             Tests
      audioTracks/       Audio tracks for testing
      doc/               Documentation configuration for Sphinx
      wrappers/          NXP SDK Wrappers
      scripts/           Helper scripts, mostly for testing
      module.yml         Defines module name, Cmake and Kconfig locations
      CMakeList.txt      Defines module's build process
      Kconfig            Defines module's configuration
      osa/               Deprecated. OSA port for Zephyr
      ...
```

Supported elements and libraries Here is the list of all features currently supported in Maestro on Zephyr. Our goal is to support all features in Maestro on Zephyr that are already supported in Maestro on NXP's SDK and to extend them further.

Supported elements:

- Memory source
- Memory sink
- Audio source
- Audio sink
- Process sink
- Decoder
- Encoder

Supported decoders:

- WAV
- MP3
- FLAC
- OPUS OGG
- AAC

Supported encoders:

- OPUS RAW

Supported libraries:

- VIT

Examples support All included examples use UART as output. Examples are located in `zephyr/tests` and `zephyr/samples` directories.

List of included examples:

- *Maestro sample for recording data from microphone to RAM*
- *Maestro voice detection sample using VIT*
- *Maestro encoder sample*
- *Maestro decoder sample*
- *Maestro mem2mem sample*

Examples support for specific boards:

Example	RDRW612BGA	LPCx-presso55s69	MIMXRT1060EVKE	MIMXRT1170EVKB
Record	YES	TO BE TESTED	TO BE TESTED	TO BE TESTED
VIT	YES	TO BE TESTED	TO BE TESTED	TO BE TESTED
Encoder	In progress: OPUS RAW	TO BE TESTED	TO BE TESTED	TO BE TESTED
Decoder	YES - WAV, FLAC, OPUS OGG	TO BE TESTED	TO BE TESTED	TO BE TESTED
Mem2mem	YES	TO BE TESTED	TO BE TESTED	TO BE TESTED

Creating your own example There are two ways to create your own example - you can either one of the included examples as a reference or you can create your own example from scratch by hand.

When creating your own example from scratch, set CONFIG_MAESTRO_AUDIO_FRAMEWORK=y in your prj.conf file. Then you can start enabling specific elements by setting CONFIG_MAESTRO_ELEMENT_<NAME>_ENABLE=y.

However, the recommended way to edit config options is to open gui-config (or menuconfig) by calling west build -t guiconfig. Then you can use the graphical interface to interactively turn on/off the features you need.

Documentation Please note, Maestro documentation is under reconstruction. It is currently mixing several tools and formats.

To see the pre-generated Maestro Zephyr documentation, see zephyr/doc/doc/README.html

To generate the Zephyr documentation, go under zephyr/doc folder and execute make html. Sphinx version sphinx-build 8.1.3 must be installed. Open doc/doc/html/README.hml afterwards.

To see Maestro core documentation, go to the Maestro top directory and see README.md.

FAQ

1. Should I choose the freestanding version of Maestro or should integrate it into my west instead?
   - Freestanding version of Maestro pulls in all the dependencies it needs including Zephyr itself.
   - Integrating it as a module is easier if you already have your Zephyr environment set up.

Maestro Audio Framework changelog

2.0.2

- Removed VoiceSeeker support

2.0.1

- Fixed filesrc buffer alignment

2.0.0 (newest)

- Added Zephyr port, see *Zephyr README*.
  - Possible to use standalone version, pulling its own Zephyr and dependencies
  - Possible to import it as a module in your Zephyr project
- Changed build system - newly uses Kconfig and Cmake
- Supports NXP MCUXSDK (previously 2.x)
- Changed folder structure and names to improve readability (description may be found in *README*)
- Removed audio libraries and placed into audio-voice-components repository
- Added libraries are pulled into the build via Kconfig and Cmake

- Changed Maestro library core - minor changes

1.8.0

- New platforms support: MCX-N5XX-EVK, FRDMMCXN236 and RD-RW612-BGA
- Fixed compilation warnings
- Documentation improvements and updates
  - Added section with processing time information
  - Added application state diagrams
- Various updates and fixes

1.7.0

- Removed EAP support for future SDK releases
- Created new API for audio_sink and audio_src to support USB source, sink
- ASRC library integrated
- License changed to BSD 3-Clause
- Improved pipeline creation API
- Fixed compilation warnings in Opus
- Various other improvements and bug fixes

1.6.0

- Up to 2 parallel pipelines supported
- Synchronous Sample Rate Converter support Added
- Various improvements and bug fixes

1.5.0

- Enabled switching from 2 to 4 channel output during processing
- PadReturn type has been replaced by FlowReturn
- Support of AAC, WAV, FLAC decoders
- Renamed eap element to audio_proc element
- Added audio_proc to VIT pipeline to support VoiceSeeker
- Minor bug fixes

1.4.0

- Use Opusfile lib for Ogg Opus decoder
- Refactor code, fix issues found in unit tests
- Various bug fixes

1.3.0

- Make Maestro framework open source (except mp3 and wav decoder)
- Refactor code, remove unused parts, add comments

1.2.0

- Unified buffering in audio source, audio sink
- Various improvements and bug fixes

1.0_rev0

- Initial version of framework with support for Cortex-M7 platforms

Chapter 2

RTOS

2.1 FreeRTOS

2.1.1 FreeRTOS kernel

Open source RTOS kernel for small devices.

FreeRTOS kernel for MCUXpresso SDK Readme

FreeRTOS kernel for MCUXpresso SDK ChangeLog

FreeRTOS kernel Readme

2.1.2 FreeRTOS drivers

This is set of NXP provided FreeRTOS reentrant bus drivers.

2.1.3 backoffalgorithm

Algorithm for calculating exponential backoff with jitter for network retry attempts.

Readme

2.1.4 corehttp

C language HTTP client library designed for embedded platforms.

2.1.5 corejson

JSON parser.

Readme

2.1.6 coremqtt

MQTT publish/subscribe messaging library.

2.1.7 corepkcs11

PKCS #11 key management library.

Readme

2.1.8 freertos-plus-tcp

Open source RTOS FreeRTOS Plus TCP.

Readme