NXP Semiconductors
Application Note

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KEA Bootloader

Contents

1 Introduction

This application note describes the architecture and usage of the KEA bootloader within the KEA MCUs.

This bootloader supports SPI (Serial Peripheral Interface) and UART (Universal Asynchronous Receiver/Transmitter) as communication interfaces and can be easily modified to support other kinds of communication interfaces.

2 Architecture description

The bootloader is organized in three layers:

- Bootloader - is in charge of starting the user application and polling for incoming data
- Communication handling / Memory handling – is in charge of processing the received data and handling the writes to non-volatile memory
- Microcontroller drivers – is in charge of handling all the low-level communication with the actual peripherals available on the microcontroller.

The following image showcases a diagram of the architecture of the bootloader:

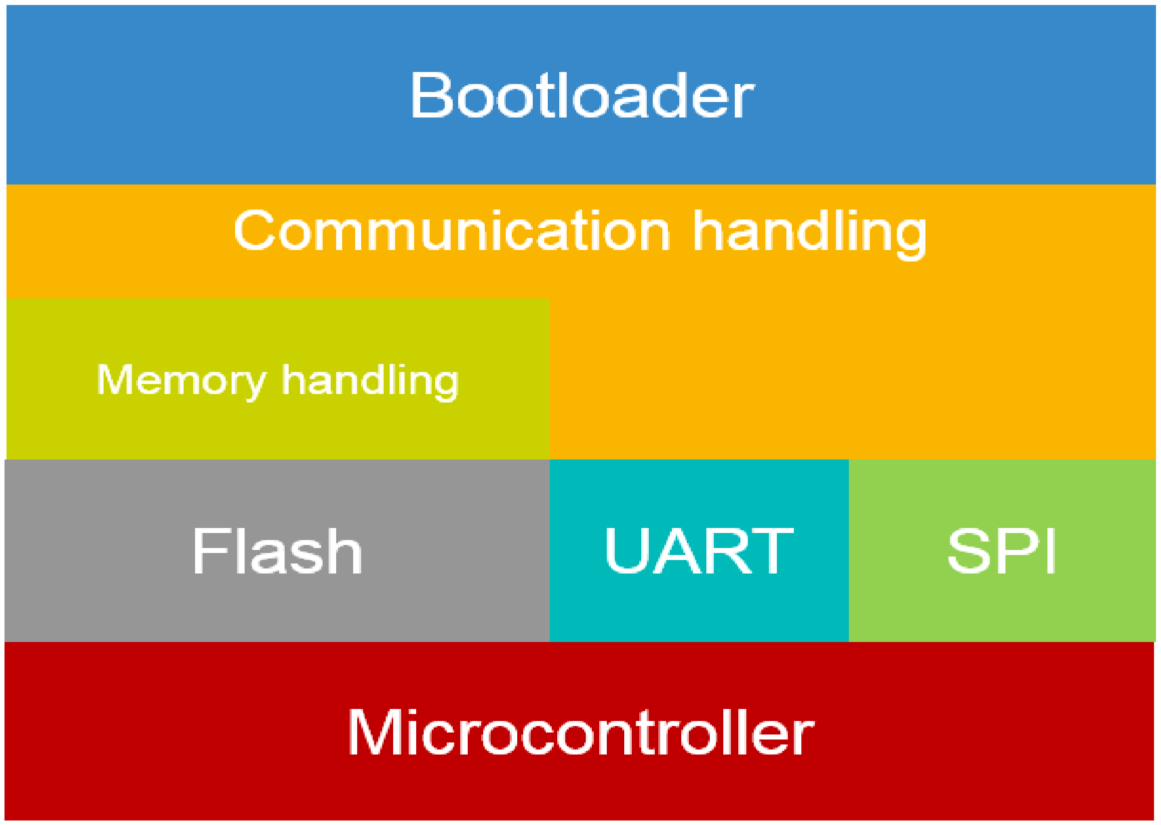


Figure 1. Bootloader Architecture

The bootloader is placed in the first 4 kB of flash memory. The current footprint of the bootloader is 3.25 kB the remaining .75 kB is reserved for future usage. This initial 4kB of memory is write protected from any attempt to overwrite the boot loader from the user application will be blocked by this protection mechanism (for more details regarding this protection mechanism please refer to the device reference manual chapter 18.3.6 Protection).

The remaining 124 kB available on the device are intended to be used by the user application. The following diagram showcases the memory layout that the bootloader has and the application must follow:

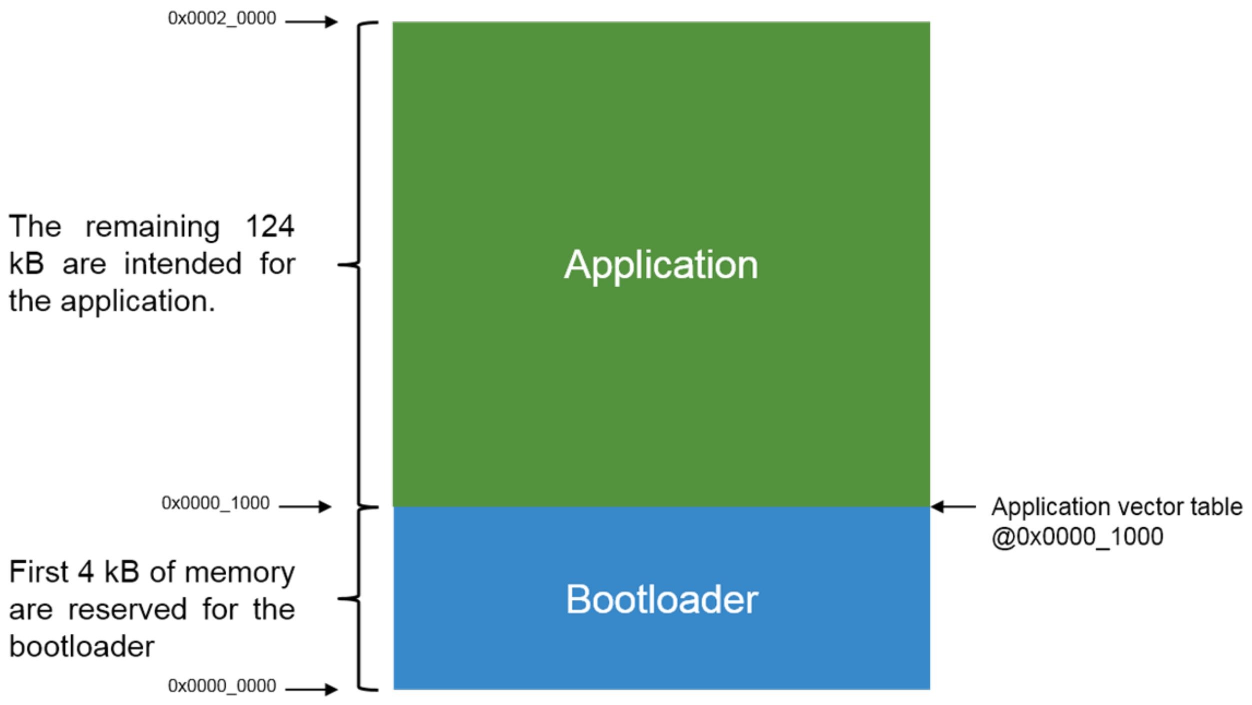

0x0002_0000
The remaining 124 kB are intended for the application.
Application
0x0000_1000
Application vector table @0x0000_1000
First 4 kB of memory are reserved for the bootloader
Bootloader
0x0000_0000

Figure 2. Memory layout

As displayed in the above figure, the bootloader expects the application vector table to be located at the end of the first 4 kB of flash (i.e. 0x1000), this is required since the application stack pointer and entry point are taken from this vector table.

2.1 Bootloader workflow overview

The bootloader workflow can be observed in the figure below:

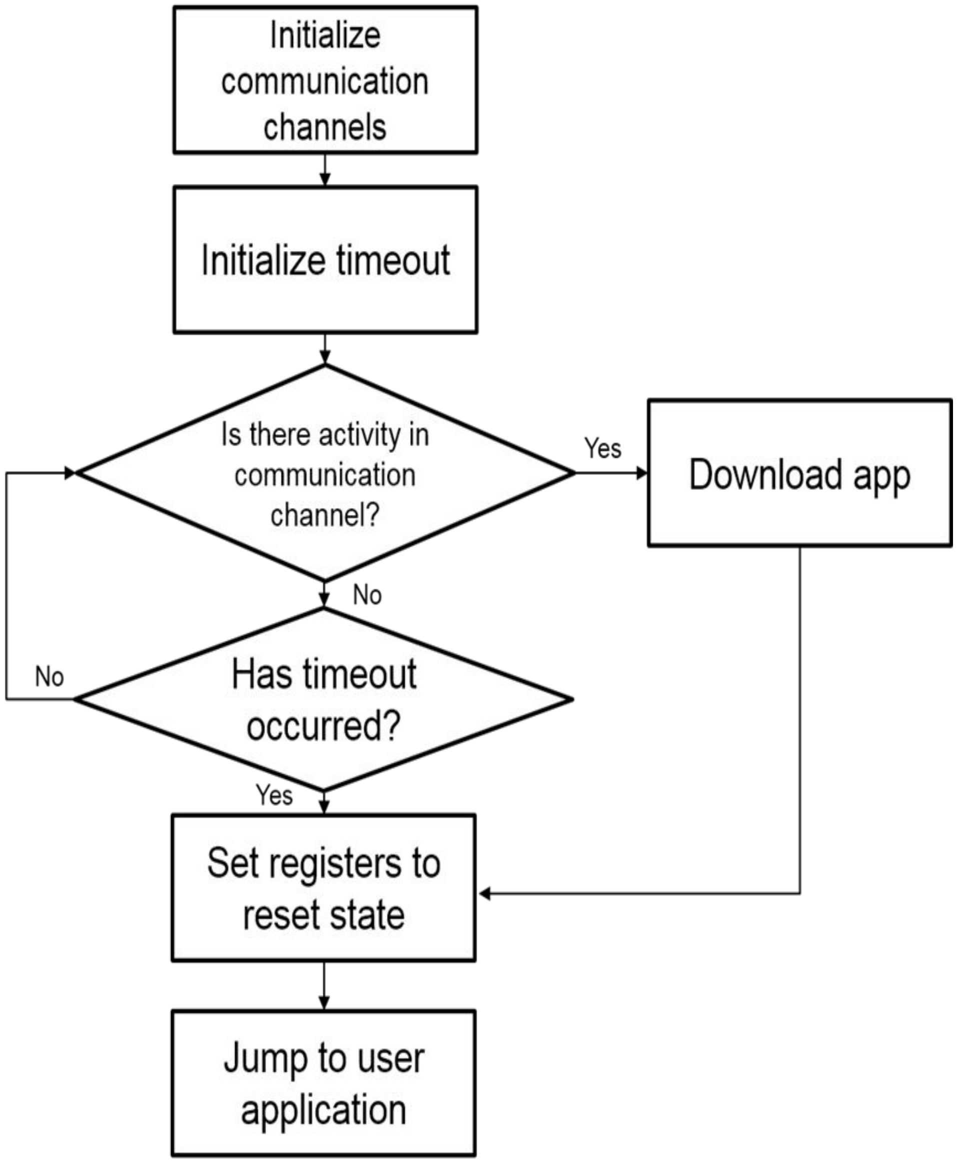

Initialize communication channels
Initialize timeout
Is there activity in communication channel?
Yes
Download app
No
No
Has timeout occurred?
Yes
Set registers to reset state
Jump to user application

Figure 3. Bootloader workflow

The first step is to initialize the available communication channels, in this instance only UART and SPI are available, but if another communication channel is required its initialization routine should be called here.

To select the communication channel to be used simply modify ‘sources/drivers/inc/comm.h’ in line 11 to select the communication interface to use. Setting the preprocessor directive to 0 disables the communication interface and setting it to 1 enables it.

```
/* Define communication
        interfaces to use, 0-> Disable 1-> Enable */
```

```
#define UART_COMM          1
```

```
#define SPI_COMM           0
```

Both interfaces can be enabled to work simultaneously, but since the bootloader is optimized for size, the bootloader's linker file would have to be modified to accommodate the generated code. Therefore it is recommended to use only one kind of communication at a time. If both interfaces are needed, the first one to detect activity in the bus will be used to download the application, in case both interfaces detect activity at the same time UART communication has a higher priority and will be used instead of SPI.

By default the bootloader is set to work with UART communication only.

The second step is to initialize the timeout mechanism. After reset, the microcontroller will poll the selected communication channel, if no activity was detected during the time allowed by the timeout mechanism the device will attempt to execute the last application loaded, if the device did not received an application it would get stuck in a loop. In order to attempt the download of an application another reset is required.

The timeout value is configurable and it is set by default to five seconds. Only one second multiples can be selected, in order to change the timeout value simply set the desired value in 'sources/drivers/inc/timeout.h' line 14.

```
/* Define timeout value, the
        base is 1s */
```

```
#define TIMEOUT_VAL        5
```

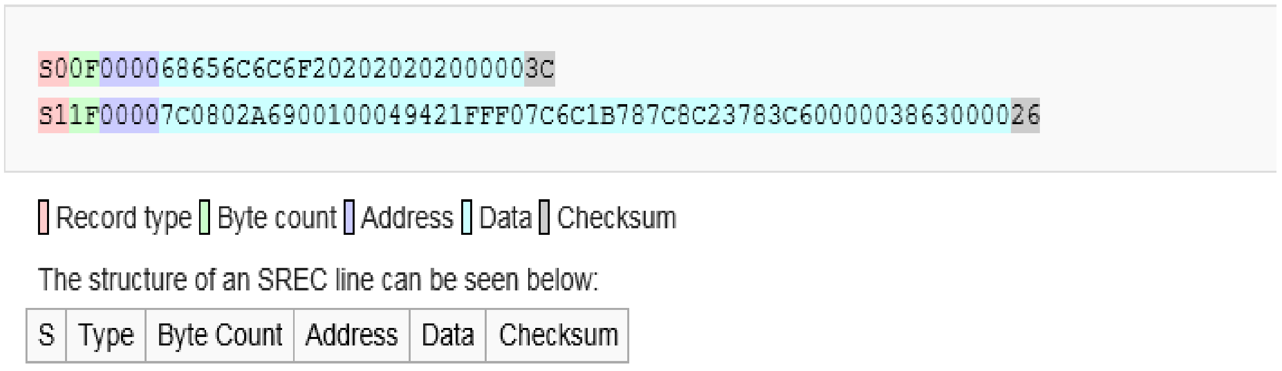
Once the timeout mechanism has been initialized the device starts polling for activity in the communication channel for the time allotted by the timeout value. If activity is detected in the communication channel, the bootloader starts downloading the application via the selected communication channel (e.g. UART or SPI).

If a timeout occurs or an application is flashed to the device, the bootloader disables and set all the registers that are modified to its reset state. This step is required to ensure that, the application starts executing on an environment close to out of reset state.

Once the registers have been set to its reset state the device attempts to jump to the user application residing on 0x1000 address.

2.2 Communication handling overview

The first step carried out by the communication handling routine is to obtain an SREC 'phrase' through the selected channel. A phrase is simply a line of the SREC file. Two lines (phrase) of an SREC file can be found below:



```
S00F000068656C6C6F202020202000003C
S11F00007C0802A6900100049421FFF07C6C1B787C8C23783C6000003863000026
```

🟥 Record type 🟩 Byte count 🟪 Address 🟦 Data ⬜ Checksum

The structure of an SREC line can be seen below:

S	Type	Byte Count	Address	Data	Checksum

Figure 4. SREC phrase structure

The first two characters are sent in ASCII format, 'S' and SREC type (e.g. '0', '1'…'9'), the remaining data is converted to its hexadecimal representation and sent (instead of sending '0' and 'F' 0x0F is sent). For a detailed description of an SREC format please refer to the following webpage: https://en.wikipedia.org/wiki/SREC_(file_format)

The phrase is received and stored in the following structure:

```
typedefunion
```

```
{
uint8_t Byte [MAX_PHSIZE_BP];              /* Byte level access to the
        Phrase */
```

```
struct
{
```

```
char PhraseType ;      /* Type of received record (e.g. S0, S1, S5, S9...) */              uint8_t
PhraseSize ;  /* Phrase size (address + data +
        checksum) */
/* Address, depending on
        the type of record it might vary */
        uint8_t PhraseAddress [MAX_ADDRESS_BP]__attribute__ ((aligned (32)));
/* Maximum 32 data bytes */
uint8_t PhraseData [MAX_DATA_BP]__attribute__ ((aligned (32)));
uint8_t PhraseCRC ;    /* Checksum of size + address + data */
```

```
} F ;
```

```
} BootPhraseStruct ;
```

This structure holds all the information provided by the SREC phrase, such as record type, byte count, address, data and cyclic redundancy check (CRC).

Once the structure has been populated it is checked to verify that it contains a valid record type (i.e. within ‘0’ and ‘9’), its size is within the SREC maximum and also the CRC is computed with the received data and compared with the CRC that was received. If any of these conditions are not met, i.e. invalid record type, invalid record size or CRC does not match, an ERR_CRC (0x41) signal is sent back to the device that is sending the data. If everything is received without issues the received data is processed and an ERR_OK (0x45) signal is sent as an acknowledge.

If the type of record received carries the data to write to the microcontroller (either ‘1’, ‘2’ or ‘3’) then the data is processed and written by the memory handling layer.

This process is repeated until the termination record is received (either ‘7’, ‘8’ or ‘9’), once this record is received the communication handling routine ends and returns to the bootloader.

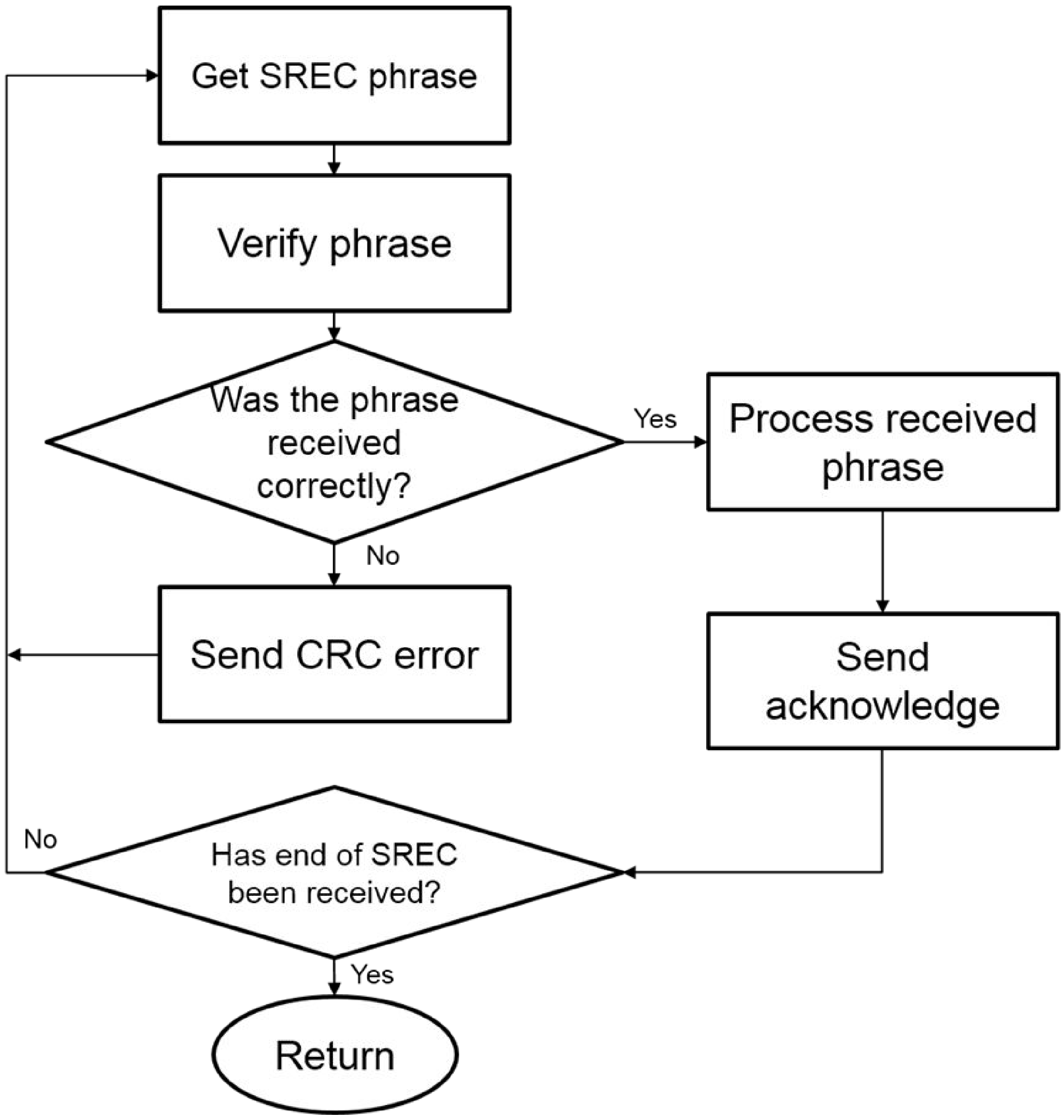


Figure 5. Communication handling workflow

3 Building compatible applications

The application should start at 0x1000 (4 kB) of flash and its vector table should be placed at this address.

An easy and quick way to compile an application compatible with this bootloader is to simply add an offset of 4 kB to the memory section of the linker file, some examples on two IDEs are shown below.

On KDS:

MEMORY

```
{
m_interrupts            (RX)    : ORIGIN = 0x00001000,
      LENGTH = 0x00000100

          m_flash_config         (RX)    : ORIGIN = 0x00001400, LENGTH =
        0x00000010

          m_text                  (RX)
        : ORIGIN = 0x00001410, LENGTH = 0x0001DBF0

          m_data
          (RW)    : ORIGIN = 0x1FFFF000, LENGTH =
        0x00004000
}
```

On S32DS:

MEMORY

```
{
FLASH_1           (RX)    : ORIGIN = 0x00001000, LENGTH = 0x00000100

          FLASH_CONFIG      (RX)    : ORIGIN = 0x00001400, LENGTH = 0x00000010
FLASH_2           (RX)          : ORIGIN =        0x00001410, LENGTH = 0x0001DBF0
SRAM              (RW)    : ORIGIN = 0x1FFFF000, LENGTH = 0x00004000
}
```

The best way to adapt an application to work with the bootloader is to eliminate the flash_config memory section of the linker file (Project_Settings/Linker_Files/SKEAZ128xxx4_flash.ld) as well as the actual configuration in the startup file (Project_Settings/Startup_Code/startup_SKEAZ1284.S line 100), there is a sample application attached within this AN package. Also Appendix B on page 20 features an example linker file for both S32DS and KDS.

As long as the vector table is located at 0x1000 (4 kB) and the application memory space does not overlap with the bootloader's (0x00 – 0x1000) the bootloader is capable of flashing and running the application.

4 Using the bootloader

The bootloader expects the image to load in SREC format, for instructions on how to generate an SREC file on KDS and S32DS please refer to Appendix A on page 11. Precompiled example SREC files are available within this AN package, these examples work on both the TRK-KEA128 and FRDM-KEAZ128 boards.

NOTE

Some IDE's place the name of the project in the first SREC phrase (S0), this could cause issues with the bootloader whenever the project name exceeds 27 characters. The maximum data per phrase is 32 bytes, but the IDE appends the string ':srec' to the project name, hence the 27 characters as maximum allowed.

The bootloader supports two different communication channels:

- UART
- SPI

If the UART interface (default) is selected then the bootloader interface can be used directly with the board, otherwise a UART to SPI translator board is required (source code included in AN package).

4.1 SPI interface

To use the SPI interface a UART to SPI bridge must be used, this has been implemented on the UART2SPI project, simply load this project on the board that will work as a converter and connect the signals as follow:

Table 1. SPI connections

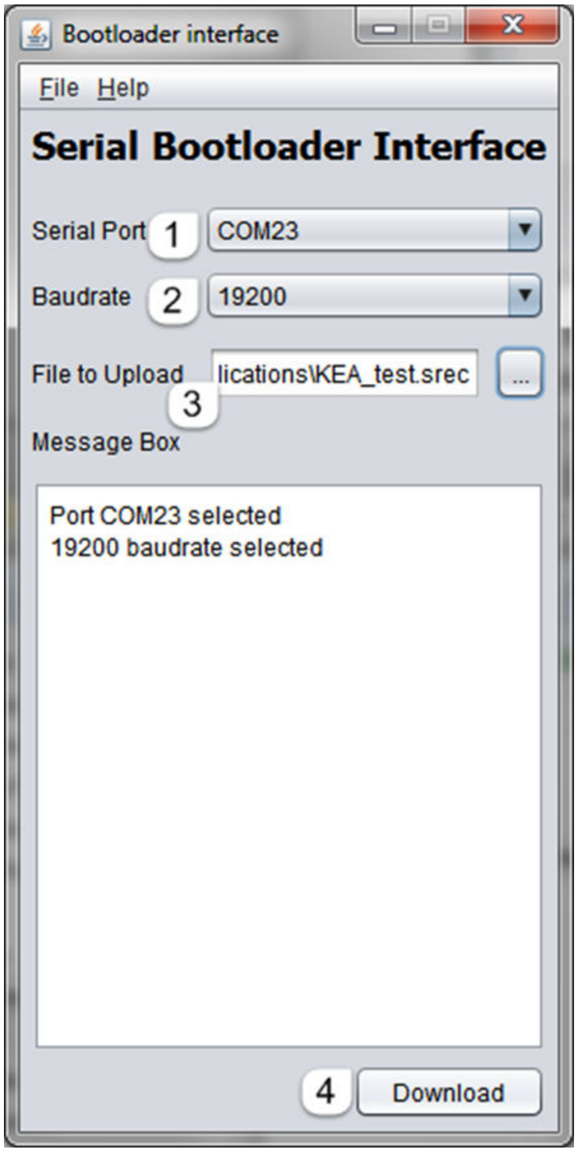
Bridge (Master)	**Target (Slave)**
PTG4 (SCL)	PTD0 (SCL)
PTG5 (MOSI)	PTD1 (MOSI)
PTG6 (MISO)	PTD2 (MISO)
PTG7 (PCS)	PTD3 (PCS)

Once connected simply follow the steps described on the UART interface section (select the bridge's UART port instead of the target).

4.2 UART interface

While using the UART interface simply open the java application located in 'Java interface/' and follow these steps:

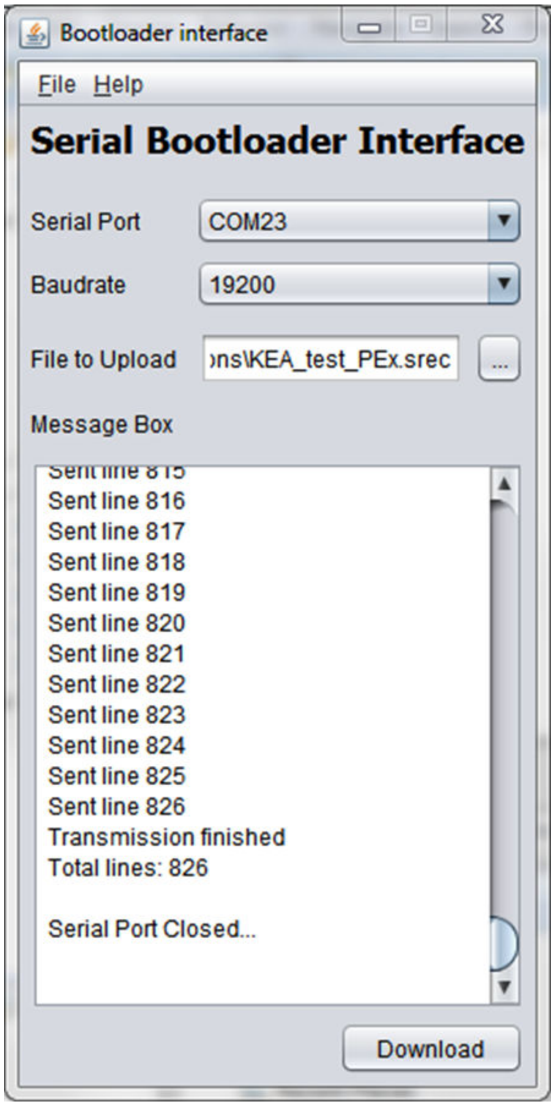
1. Select communication port.
2. Select baudrate, the default baudrate is 19200.
3. Select SREC file to send.
4. Click download, and the SREC file will be sent line after line.



COM23
19200
lications\KEA_test.srec

```
Port COM23 selected
19200 baudrate selected
```

Once the whole SREC file has been sent the java interface will close the port and the application should start execution on the target board.



Serial Bootloader Interface

Serial Port COM23

Baudrate 19200

File to Upload ›ns\KEA_test_PEx.srec

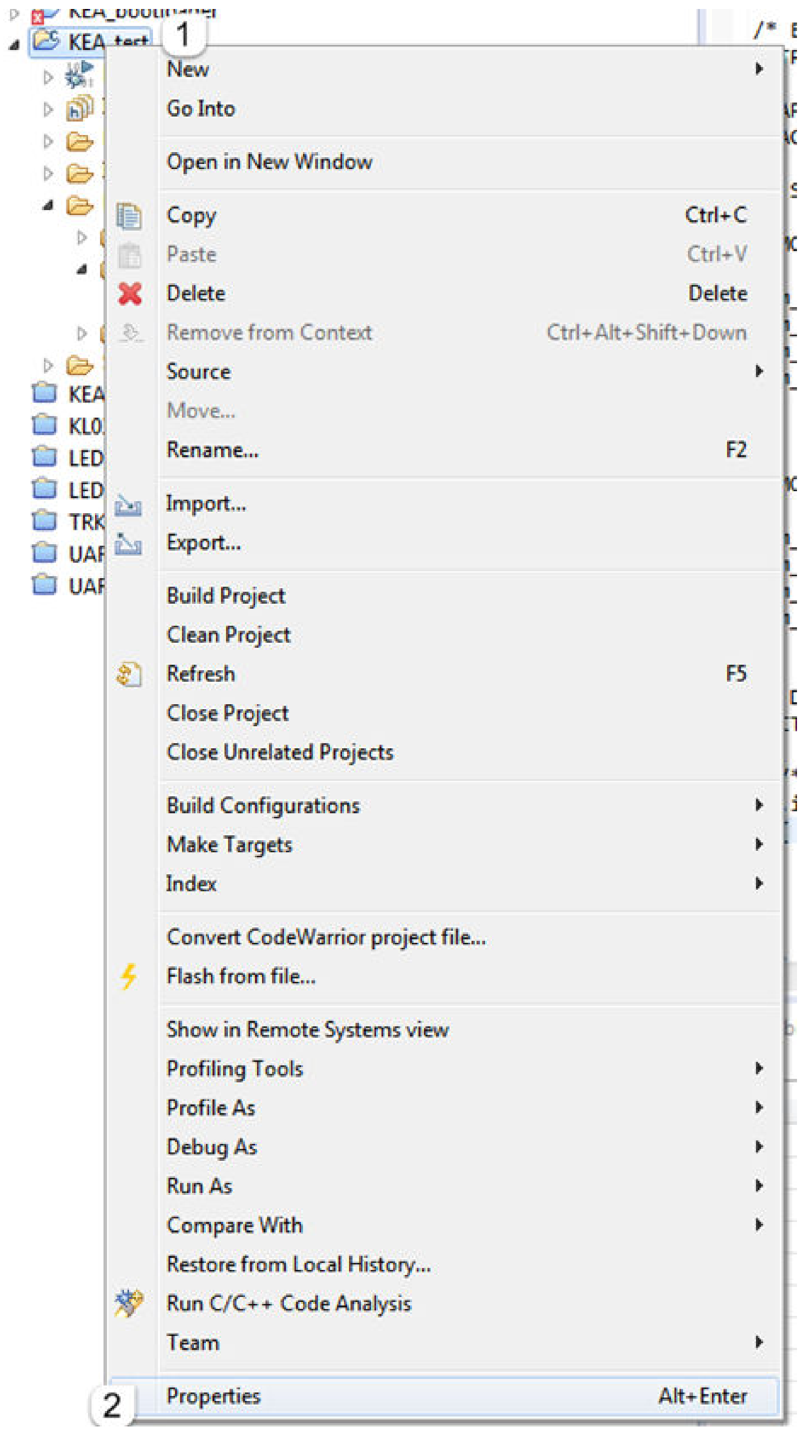
Message Box

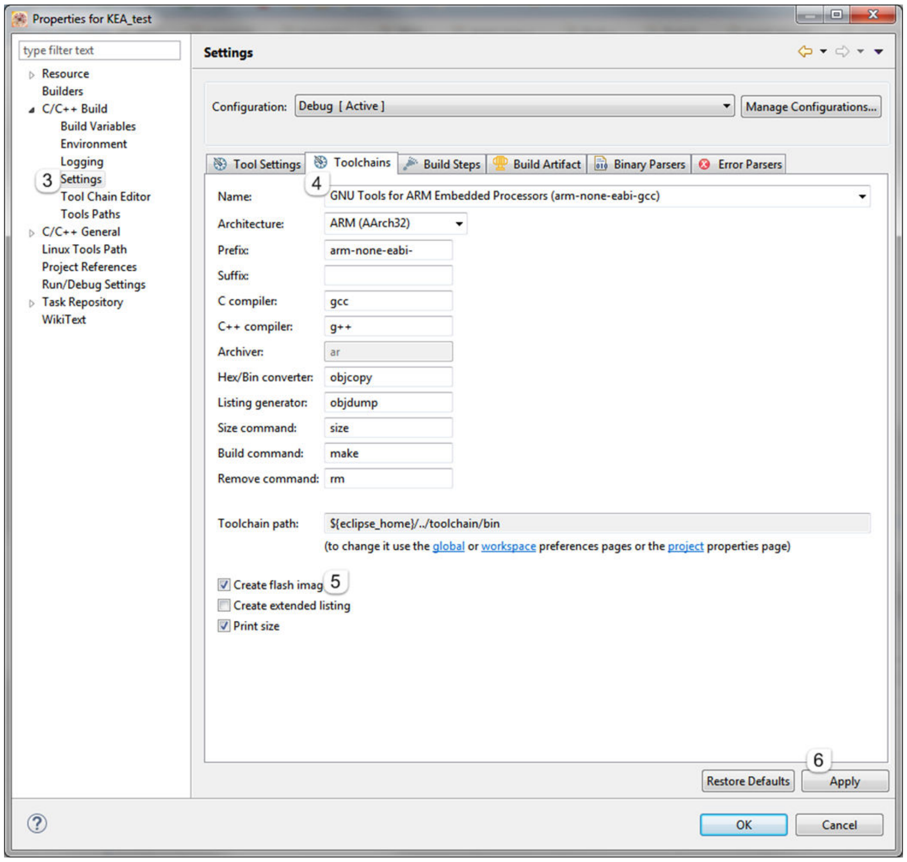
```
Sent line 815
Sent line 816
Sent line 817
Sent line 818
Sent line 819
Sent line 820
Sent line 821
Sent line 822
Sent line 823
Sent line 824
Sent line 825
Sent line 826
Transmission finished
Total lines: 826

Serial Port Closed...
```

A Appendix A

A.1 On KDS

On KDS:


KEA_bootloader
KEA_test
1
New
Go Into
Open in New Window
Copy Ctrl+C
Paste Ctrl+V
Delete Delete
Remove from Context Ctrl+Alt+Shift+Down
Source
Move...
Rename... F2
Import...
Export...
Build Project
Clean Project
Refresh F5
Close Project
Close Unrelated Projects
Build Configurations
Make Targets
Index
Convert CodeWarrior project file...
Flash from file...
Show in Remote Systems view
Profiling Tools
Profile As
Debug As
Run As
Compare With
Restore from Local History...
Run C/C++ Code Analysis
Team
Properties Alt+Enter
2



Configuration: Debug [Active]

Name: GNU Tools for ARM Embedded Processors (arm-none-eabi-gcc)

Architecture: ARM (AArch32)

Prefix: arm-none-eabi-

Suffix:

C compiler: gcc

C++ compiler: g++

Archiver: ar

Hex/Bin converter: objcopy

Listing generator: objdump

Size command: size

Build command: make

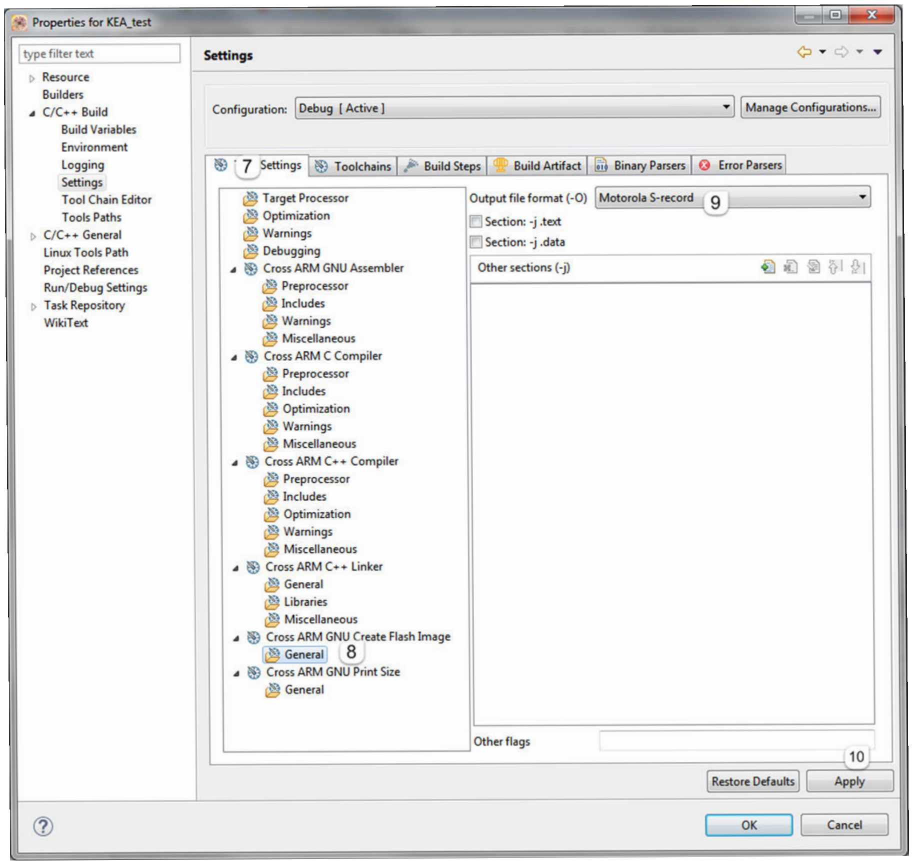
Remove command: rm

Toolchain path: ${eclipse_home}/../toolchain/bin

(to change it use the global or workspace preferences pages or the project properties page)

- [✓] Create flash image
- [ ] Create extended listing
- [✓] Print size

On KDS



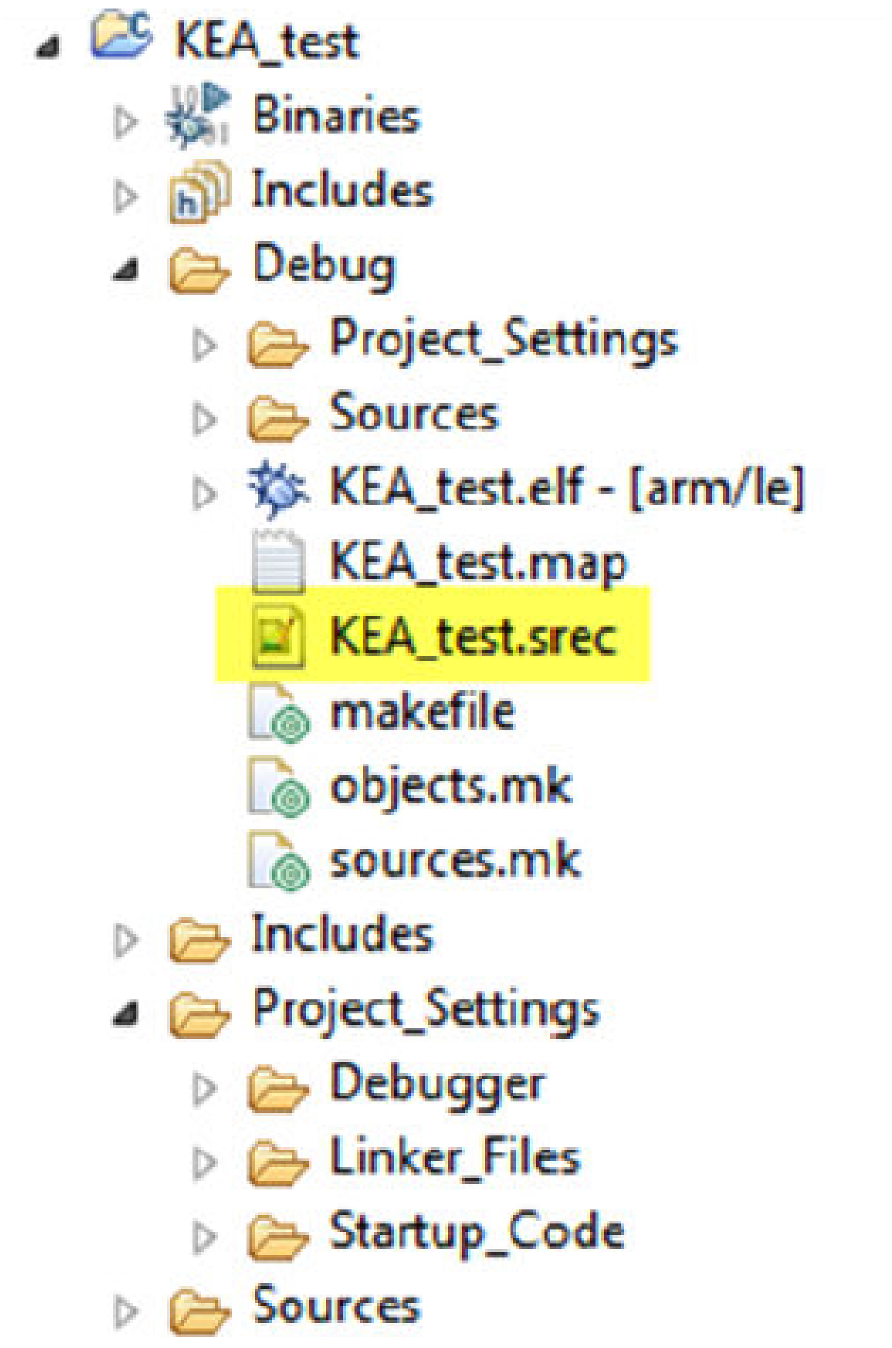
Configuration: Debug [Active]

Output file format (-O): Motorola S-record

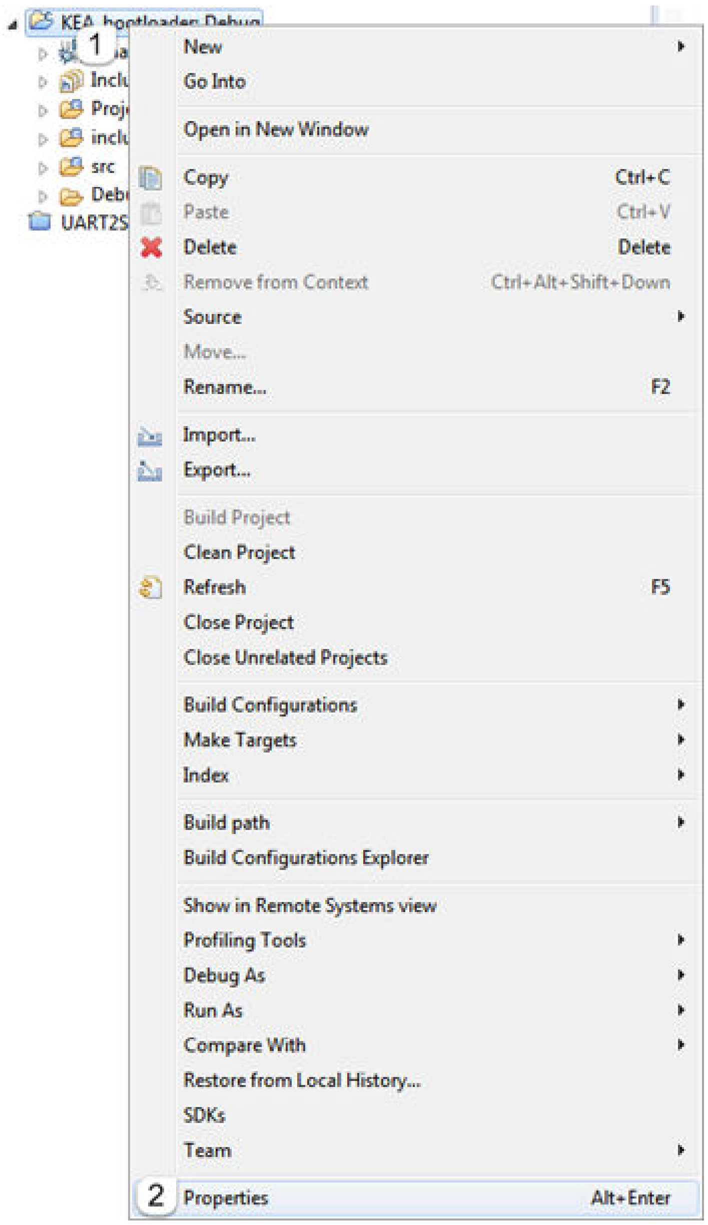
Section: -j .text [ ]

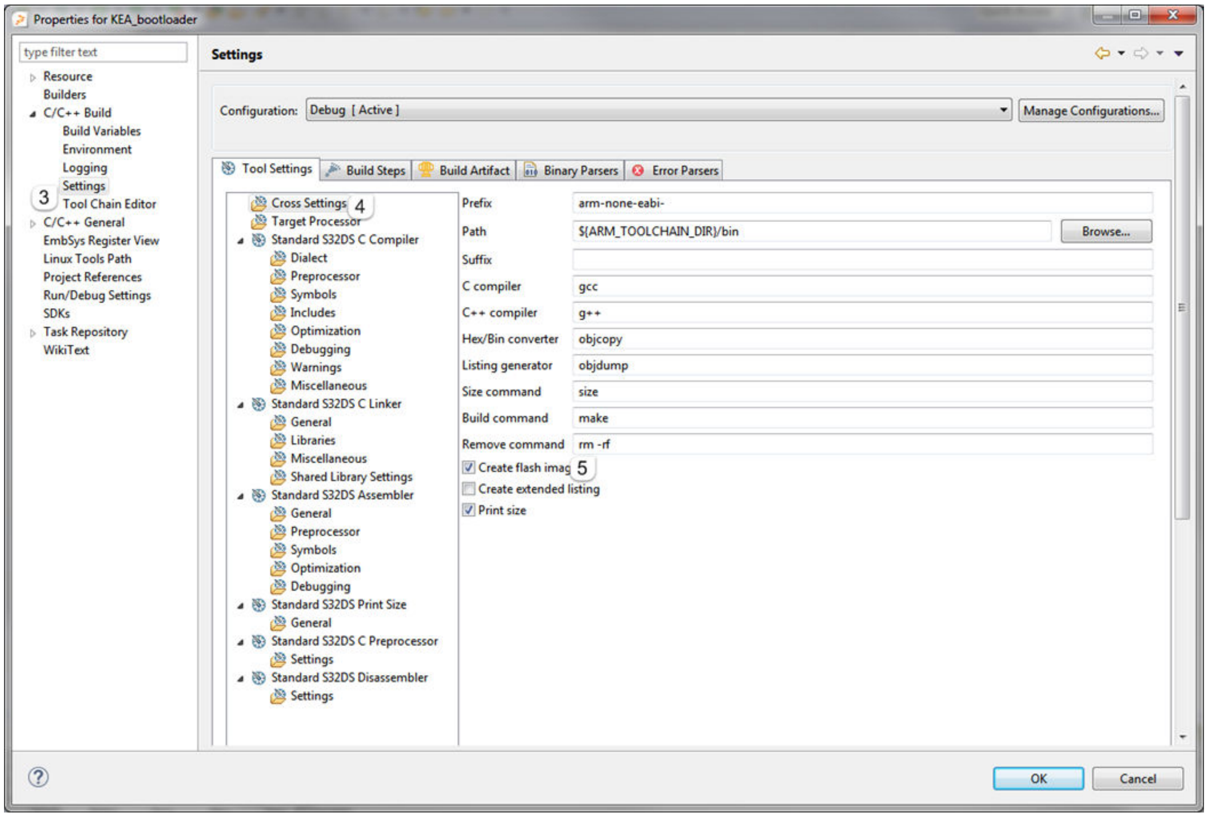
Section: -j .data [ ]

Other flags:


KEA_test
Binaries
Includes
Debug
Project_Settings
Sources
KEA_test.elf - [arm/le]
KEA_test.map
KEA_test.srec
makefile
objects.mk
sources.mk
Includes
Project_Settings
Debugger
Linker_Files
Startup_Code
Sources

A.2 S32DS

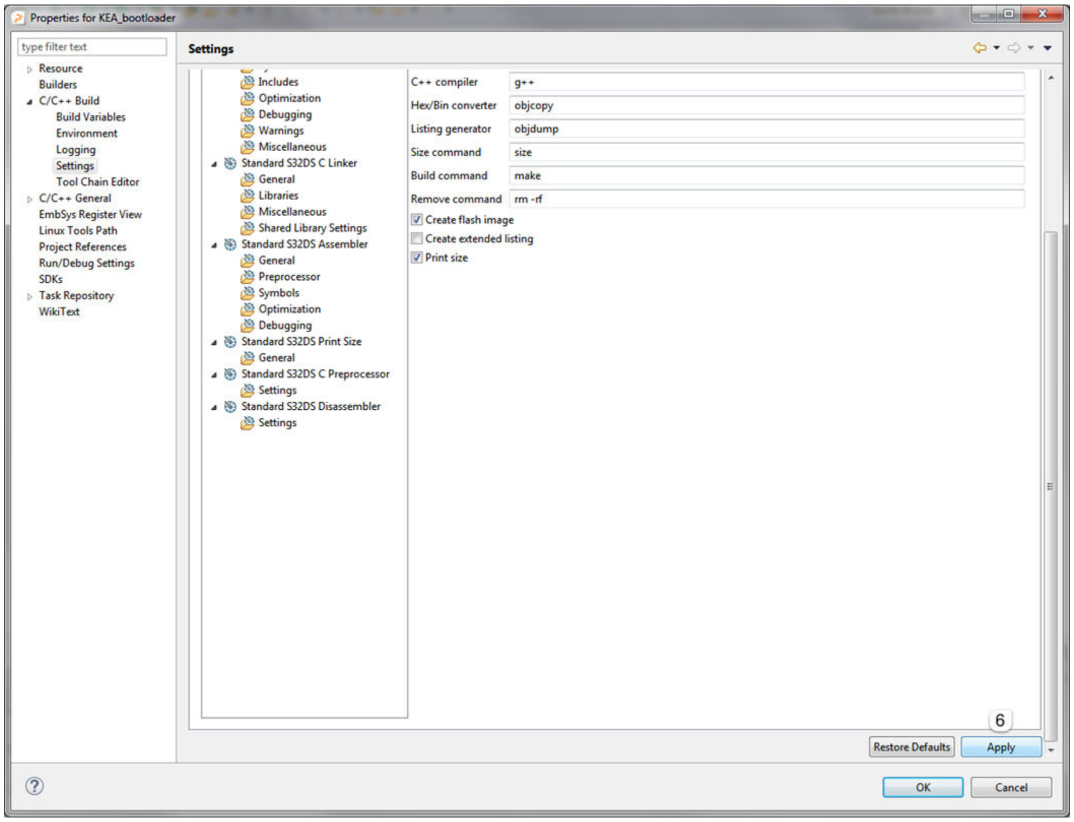

KEA_bootloader: Debug
1
Inclu
Proj
inclu
src
Debu
UART2S
New
Go Into
Open in New Window
Copy Ctrl+C
Paste Ctrl+V
Delete Delete
Remove from Context Ctrl+Alt+Shift+Down
Source
Move...
Rename... F2
Import...
Export...
Build Project
Clean Project
Refresh F5
Close Project
Close Unrelated Projects
Build Configurations
Make Targets
Index
Build path
Build Configurations Explorer
Show in Remote Systems view
Profiling Tools
Debug As
Run As
Compare With
Restore from Local History...
SDKs
Team
2
Properties Alt+Enter



Configuration: Debug [Active]

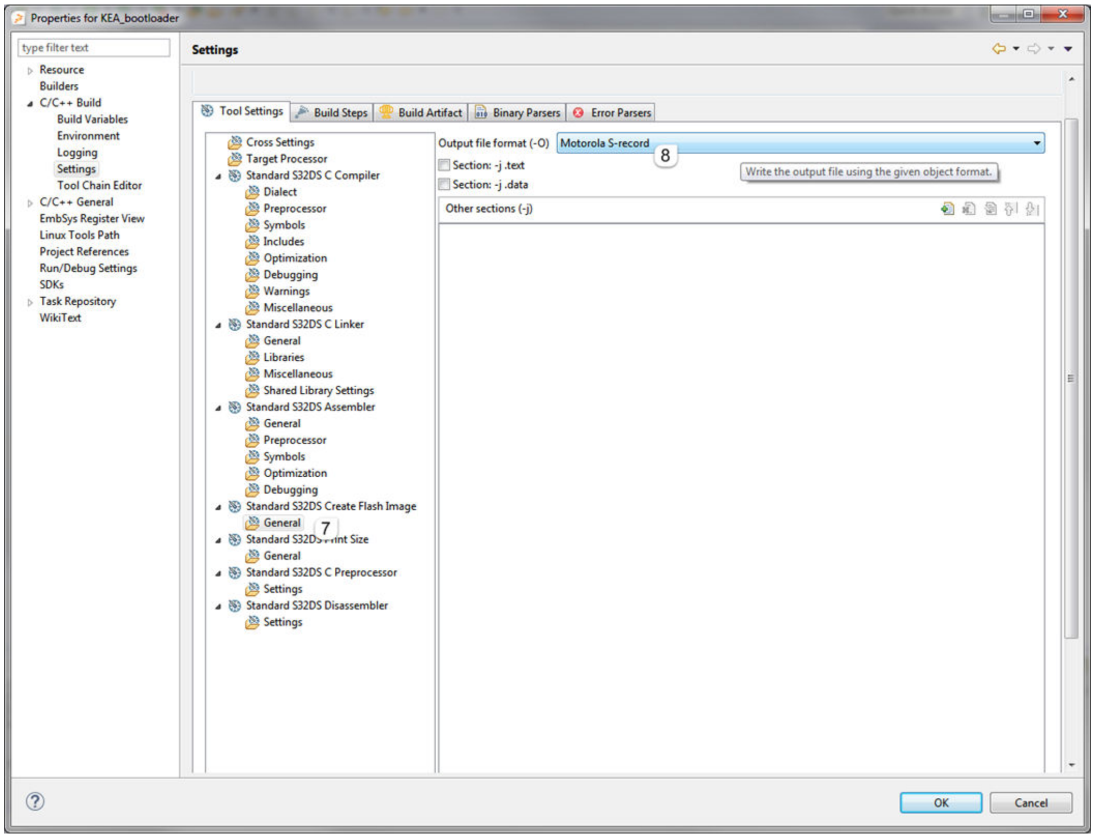
Prefix	arm-none-eabi-
Path	${ARM_TOOLCHAIN_DIR}/bin
Suffix	
C compiler	gcc
C++ compiler	g++
Hex/Bin converter	objcopy
Listing generator	objdump
Size command	size
Build command	make
Remove command	rm -rf

- [✓] Create flash imag
- [ ] Create extended listing
- [✓] Print size

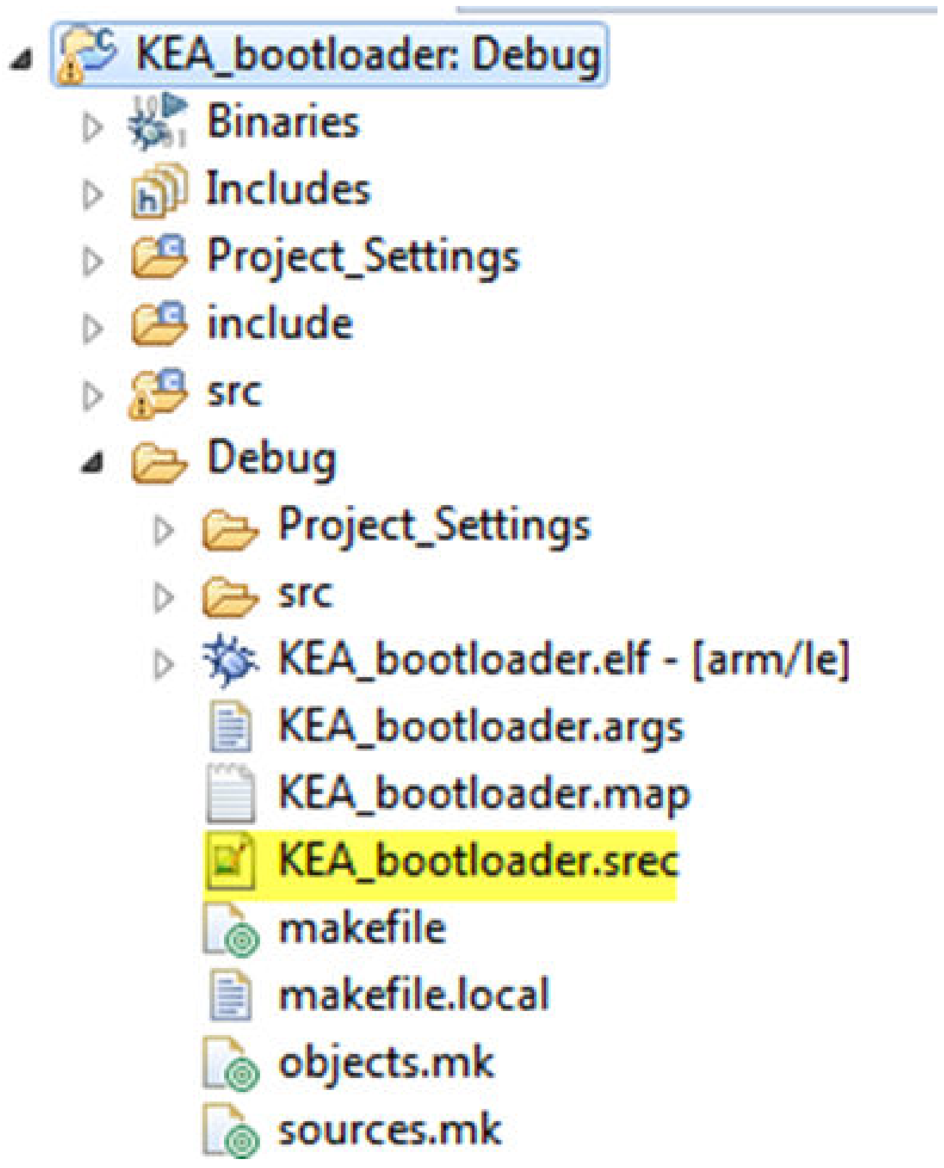


C++ compiler: g++
Hex/Bin converter: objcopy
Listing generator: objdump
Size command: size
Build command: make
Remove command: rm -rf

[✓] Create flash image
[ ] Create extended listing
[✓] Print size



Output file format (-O): Motorola S-record
Section: -j .text
Section: -j .data
Write the output file using the given object format.



B Appendix B

B.1 Linker file on KDS

```
/* Linker file for GNU C Compiler*/

/* Entry Point */
ENTRY(Reset_Handler)
HEAP_SIZE = DEFINED(__heap_size__)   ? __heap_size__   : 0x00000400;
STACK_SIZE = DEFINED(__stack_size__) ? __stack_size__ : 0x00000400;
```

```
/* Specify the memory areas */
MEMORY
{
m_interrupts          (RX)   : ORIGIN = 0x00001000, LENGTH = 0x00000100
m_text                (RX)   : ORIGIN = 0x00001100, LENGTH = 0x0001EF00
m_data                (RW)   : ORIGIN = 0x1FFFF000, LENGTH = 0x00004000
}

/* Define output sections */
SECTIONS
{
/* The startup code goes first into internal flash */
.interrupts :
{
 __VECTOR_TABLE = .;
  . = ALIGN(4);
KEEP(*(.isr_vector))     /* Startup code */
. = ALIGN(4);
} > m_interrupts

/* The program code and other data goes into internal flash */
.text :
 {
. = ALIGN(4);
*(.text)                 /* .text sections (code) */
*(.text*)                 /* .text* sections (code) */
*(.rodata)               /* .rodata sections (constants, strings, etc.)*/
*(.rodata*)              /* .rodata* sections (constants, strings, etc.) */
*(.glue_7)               /* glue arm to thumb code */
*(.glue_7t)              /* glue thumb to arm code */
*(.eh_frame)
 KEEP (*(.init))
KEEP (*(.fini))
. = ALIGN(4);
} > m_text

.ARM.extab :
 {
*(.ARM.extab* .gnu.linkonce.armextab.*)
} > m_text

.ARM :
{
__exidx_start = .;
*(.ARM.exidx*)
__exidx_end = .;
} > m_text

.ctors :
 {
__CTOR_LIST__ = .;
/* gcc uses crtbegin.o to find the start of
the constructors, so we make sure it is
first.  Because this is a wildcard,it
doesn't matter if the user does not
actually link against crtbegin.o; the
linker won't look for a file to match a
wildcard.  The wildcard also means that it
doesn't matter which directory crtbegin.o
is in.  */
KEEP (*crtbegin.o(.ctors))
KEEP (*crtbegin?.o(.ctors))
/* We don't want to include the .ctor section from
from the crtend.o file until after the sorted ctors.
The .ctor section from the crtend file contains the
end of ctors marker and it must be last */
KEEP (*(EXCLUDE_FILE(*crtend?.o *crtend.o) .ctors))
KEEP (*(SORT(.ctors.*)))
KEEP (*(.ctors))
__CTOR_END__ = .;
  } > m_text

.dtors :
{
__DTOR_LIST__ = .;
KEEP (*crtbegin.o(.dtors))
KEEP (*crtbegin?.o(.dtors))
KEEP (*(EXCLUDE_FILE(*crtend?.o *crtend.o) .dtors))
KEEP (*(SORT(.dtors.*)))
KEEP (*(.dtors))
__DTOR_END__ = .;
} > m_text

.preinit_array :
{
PROVIDE_HIDDEN (__preinit_array_start = .);
KEEP (*(.preinit_array*))
PROVIDE_HIDDEN (__preinit_array_end = .);
  } > m_text
.init_array :
 {
PROVIDE_HIDDEN (__init_array_start = .);
KEEP (*(SORT(.init_array.*)))
KEEP (*(.init_array*))
PROVIDE_HIDDEN (__init_array_end = .);
} > m_text

.fini_array :
 {
PROVIDE_HIDDEN (__fini_array_start = .);
KEEP (*(SORT(.fini_array.*)))
KEEP (*(.fini_array*))
PROVIDE_HIDDEN (__fini_array_end = .);
} > m_text

__etext = .;    /* define a global symbol at end of code */
__DATA_ROM = .; /* Symbol is used by startup for data initialization */

/* reserve MTB memory at the beginning of m_data */
.mtb : /* MTB buffer address as defined by the hardware */

. = ALIGN(8);
_mtb_start = .;
KEEP(*(.mtb_buf)) /* need to KEEP Micro Trace Buffer as not referenced by application
*/
= ALIGN(8);
mtb_end = .;
  } > m_data
```

```
.data : AT(__DATA_ROM)
{
. = ALIGN(4);
__DATA_RAM = .;
__data_start__ = .;      /* create a global symbol at data start */
*(.data)                 /* .data sections */
*(.data*)                /* .data* sections */
KEEP(*(.jcr*))
. = ALIGN(4);
__data_end__ = .;        /* define a global symbol at data end */
  } > m_data

/* Symbol is used by startup for data initialization */
__DATA_END = __DATA_ROM + (__data_end__ - __data_start__);

/* Uninitialized data section */
.bss :
 {
/* This is used by the startup in order to initialize the .bss section */
. = ALIGN(4);
__START_BSS = .;
__bss_start__ = .;
*(.bss)
*(.bss*)
*(COMMON)
. = ALIGN(4);
__bss_end__ = .;
__END_BSS = .;
} > m_data

.heap :
{
. = ALIGN(8);
__end__ = .;
PROVIDE(end = .);
__HeapBase = .;    .
+= HEAP_SIZE;
__HeapLimit = .;
} > m_data
.stack :
{
. = ALIGN(8);
. += STACK_SIZE;
} > m_data

__StackTop    = .;
__StackLimit = __StackTop - STACK_SIZE;
PROVIDE(__stack = __StackTop);

.ARM.attributes 0 : { *(.ARM.attributes) }
}
```

B.2 Linker file on S32DS

```
/* Linker file for GNU C Compiler */
/* Entry Point */
ENTRY(Reset_Handler)

/*
To use "new" operator with EWL in C++ project the following symbol shall be defined
*/
/*EXTERN(_ZN10__cxxabiv119__terminate_handlerE)*/
/* Highest address of the user mode stack */
_estack = 0x20003000;     /* end of SRAM */
__SP_INIT = _estack;
HEAP_SIZE  = DEFINED(__heap_size__)   ? __heap_size__   :0x00000500;
STACK_SIZE = DEFINED(__stack_size__) ? __stack_size__ : 0x00000400;
/* Specify the memory areas*/
MEMORY
{
FLASH_1           (RX)   : ORIGIN = 0x00001000, LENGTH = 0x0001F000
SRAM              (RW)   : ORIGIN = 0x1FFFF000, LENGTH = 0x00004000
/* Define output sections*/
SECTIONS
{
/* The startup code goes first into internal flash */
.interrupts :
{
__VECTOR_TABLE = .;
. = ALIGN(4);
KEEP(*(.isr_vector))      /* Startup code */
. = ALIGN(4);
} > FLASH_1

/* The program code and other data goes into internal flash */
.text :
{
. = ALIGN(4);
*(.text)                 /* .text sections (code) */
*(.text*)                /* .text* sections (code) */
*(.rodata)               /* .rodata sections (constants, strings, etc.) */
*(.rodata*)              /* .rodata* sections (constants, strings, etc.) */
*(.glue_7)               /* glue arm to thumb code */
*(.glue_7t)              /* glue thumb to arm code */
*(.eh_frame)
KEEP (*(.init))
KEEP (*(.fini))
. = ALIGN(4);
} > FLASH_1

.ARM.extab :
{
*(.ARM.extab* .gnu.linkonce.armextab.*)
} > FLASH_1

.ARM :
{
__exidx_start = .;
*(.ARM.exidx*)
__exidx_end = .;
} > FLASH_1  .ctors :
{    __CTOR_LIST__ = .;
/* gcc uses crtbegin.o to find the start of
the constructors, so we make sure it is
first.   Because this is a wildcard, it
```

```
doesn't matter if the user does not
actually link against crtbegin.o; the
linker won't look for a file to match a
wildcard.   The wildcard also means that it
doesn't matter which directory crtbegin.o
is in.   */
KEEP (*crtbegin.o(.ctors))
KEEP (*crtbegin?.o(.ctors))
/* We don't want to include the .ctor section from
from the crtend.o file until after the sorted ctors.
The .ctor section from the crtend file contains the
end of ctors marker and it must be last */
KEEP (*(EXCLUDE_FILE(*crtend?.o*crtend.o) .ctors))
KEEP (*(SORT(.ctors.*)))
KEEP (*(.ctors))
__CTOR_END__ = .;
} > FLASH_1

.dtors :
{
__DTOR_LIST__ = .;
KEEP (*crtbegin.o(.dtors))
KEEP (*crtbegin?.o(.dtors))
KEEP (*(EXCLUDE_FILE(*crtend?.o *crtend.o) .dtors))
KEEP (*(SORT(.dtors.*)))
KEEP (*(.dtors))
__DTOR_END__ = .;
} > FLASH_1

.preinit_array :
{
PROVIDE_HIDDEN  (__preinit_array_start = .);
KEEP (*(.preinit_array*))
PROVIDE_HIDDEN (__preinit_array_end = .);
} > FLASH_1

.init_array :
{
PROVIDE_HIDDEN
(__init_array_start = .);
KEEP (*(SORT(.init_array.*)))
KEEP (*(.init_array*))
PROVIDE_HIDDEN (__init_array_end = .);
} > FLASH_1

.fini_array :
{
PROVIDE_HIDDEN (__fini_array_start = .);
KEEP(*(SORT(.fini_array.*)))
KEEP (*(.fini_array*))
PROVIDE_HIDDEN (__fini_array_end = .);
} > FLASH_1

__etext = .;      /* define a global symbol at end of code */
__DATA_ROM = .;  /* Symbol is used by startup for data initialization */

/* reserve MTB memory at the beginning of SRAM */
.mtb :  /* MTB buffer address as defined by the hardware */
{
. = ALIGN(8);
```

```
_mtb_start = .;
KEEP(*(.mtb_buf))  /* need to KEEP Micro Trace Buffer as not referenced by application */
. = ALIGN(8);
_mtb_end = .;
} > SRAM

.data : AT(__DATA_ROM)
{
. = ALIGN(4);
__DATA_RAM = .;
__data_start__ = .;      /* create a global symbol at data start */
_sdata = .;         /* create a global symbol at data start */
*(.data)                 /* .data sections */
*(.data*)                /* .data* sections */
KEEP(*(.jcr*))
. = ALIGN(4);
__data_end__ = .;         /* define a global symbol at data end */
 _edata = .;        /* define a global symbol at data end */
} > SRAM

/* Symbol is used by startup for data initialization */
__DATA_END = __DATA_ROM + (__data_end__ - __data_start__);
___data_size = _edata - _sdata;

/*Uninitialized data section */
.bss :
{
/* This is used by the startup in order to initialize the .bss section */
. = ALIGN(4);
__START_BSS = .;
__bss_start__ = .;
*(.bss)
*(.bss*)
*(COMMON)
. = ALIGN(4);
__bss_end__ = .;
__END_BSS = .;
} > SRAM

_romp_at = __DATA_ROM + SIZEOF(.data);
.romp : AT(_romp_at)
{
       __S_romp = _romp_at;
LONG(__DATA_ROM);
LONG(_sdata);
LONG(___data_size);
LONG(0);
LONG(0);
LONG(0);
} > SRAM

.heap :
{
. = ALIGN(8);
__end__ = .;
_end = .;
PROVIDE(end = .);
__HeapBase = .;
. += HEAP_SIZE;
__HeapLimit = .;
```

```
} > SRAM

.stack :
{
. = ALIGN(8);
. += STACK_SIZE;
} > SRAM

__StackTop    = .;
__StackLimit = __StackTop - STACK_SIZE;
PROVIDE(__stack = __StackTop);
.ARM.attributes 0 : { *(.ARM.attributes) }
}
```