Memory
Self-diagnosis Program
Application Note

Outlines

This application note describes the self-diagnosis program for the memories.
The self-diagnosis program in this document is the library which is used to check the read from and write to the memory.
This library supports the sample program with the peripheral driver of TXZ series enclosed, and should be used after it is overwritten to the sample program.

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1. Preface

This application note describes the self-diagnosis program for the memories.
This library code should be used after it is added (overwritten) to the published sample program.

The explanation of this document uses the TMPM4K Group (1).
When the program is applied to a product, some appropriate modification may be necessary depending on the specifications of the product.

This sample program has been developed and evaluated under the conditions in the operation confirmation environment in “Self-diagnosis Program Application Note – Basic Setting”, and by using the TMPM4K4A 1.0.0 sample program and the reference manual released in February in 2019.

2. Outline of Self-diagnosis Test Library

This self-diagnosis test library has been checked on the evaluation board.

The following self-test function is supported.

Name	Description
RAM test	The checker patterns, 0x55555555 and 0xAAAAAAAA, are written to an address in the memory, respectively, and it is checked that the read data of the address is correct. This test is done to each address in a specified memory region (18 KB maximum).
FLASH test	The CRC32 value is calculated for the read data of a specified address region to check that the programmed values in the Flash memory are read correctly (128 KB maximum). This calculated CRC32 value is compared with the CRC32 value which was acquired at the program build. (This test is executed in IAR Embedded Workbench only.)
CRC calculation test	The CRC32 value of a specified memory region is calculated by the CRC calculation hardware (CRC-B).

2.1. Self-diagnosis Sample Project

In the “Project\Examples\Safety” folder, the following sample project for the self-diagnosis library is placed.

Project name	Operation	Utilized self-diagnosis library function
MEMORY_Sample	RAM test and Flash memory test are executed. The result is shown with the LED lighting.	safety_RAM() safety_FLASH()

3. Details of Self-diagnosis Test Library

This section describes the details of the self-diagnosis test library function.
This sample program is a self-diagnosis program for the memories.
The following setting is an example when a product in the TMPM4K group (1) is used.

The source code (.c file) of the self-diagnosis library is in the “Libraries\Safety\src” folder, and the header file (.h file) is in the “Libraries\Safety\inc” folder.

3.1. RAM Test

The checker patterns, 0x55555555 and 0xAAAAAAAA, are written to an address in the RAM, and it is checked that the read data of the address is correct.
This test is done to each address in a specified memory region (18 KB maximum).

When an error is detected, the address of the error is written to the result memory buffer.

After the test, the value of each memory address returns the value before the test, but the value when the test fails is undefined.

If the tested memory area includes a region modified by an interrupt process (a stack region or a region of the variables modified by the interrupt process), unexpected modification may occur.

In such a case, it is recommended that the test region be divided into a non-modified region and a modified one. The modified region should be tested with disabling the interrupt.

The “safety_RAM” function does not use any interrupts.

Source file: safety_ram.c
Header file: safety_ram.h
Used library: txz_gpio.c/.h

Function name	
bool safety_RAM(uint32_t start, uint32_t length, uint32_t *result_word)	
Input parameter	
uint32_t start	Test start RAM address. Rounded to 4-multiple number.
uint32_t length	Test region (Byte unit). Rounded to 4-multiple number.
Output parameter	
uint32_t *result_word	Memory buffer which stores the result. The address where an error is detected is written. (When no errors are detected, no writes are done.)
Return value	
bool	Test result (true: success, false: failure)

* If the return value cannot be confirmed for several seconds, it is supposed the test is not executed correctly. The process for the test failure should be done.
When, however, the terminal I/O output display is used, it takes several seconds to complete the display. The judgment of the test failure should be done by checking the display.

3.2. Flash Memory Test

The CRC32 value is calculated for the read data of a specified address region to check that the programmed values in the Flash memory are read correctly.

This function does not check the test region, but any region in the Flash memory can be specified.
The region should be specified correctly in the test program.

This library function does not use any interrupts.

Source file: safety_flash.c
Header file: safety_flash.h
Used library: txz_gpio.c/.h

Function name	
bool safety_FLASH(uint32_t start, uint32_t length, uint32_t crc32_value)	
Input parameter	
uint32_t start	Test start Flash memory address. The value can be set in units of 1 Byte.
uint32_t length	Test region (Byte) The value can be set in units of 1 Byte.
uint32_t crc32_value	The CRC32 value for the test region which has been calculated.
Output parameter	
None.	-
Return value	
bool	Test result (true: success, false: failure)

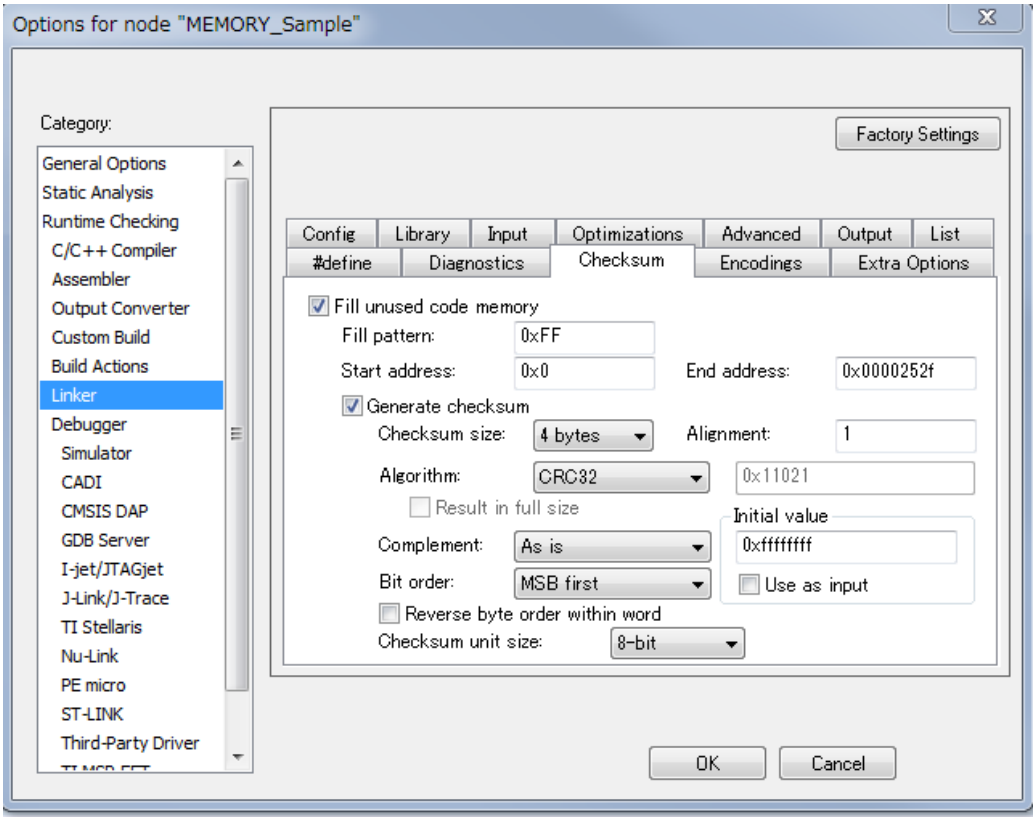
* If the return value cannot be confirmed for several seconds, it is supposed the test is not executed correctly. The process for the test failure should be done.
When, however, the terminal I/O output display is used, it takes several seconds to complete the display. The judgment of the test failure should be done by checking the display.

<In the case of IAR Embedded Workbench>

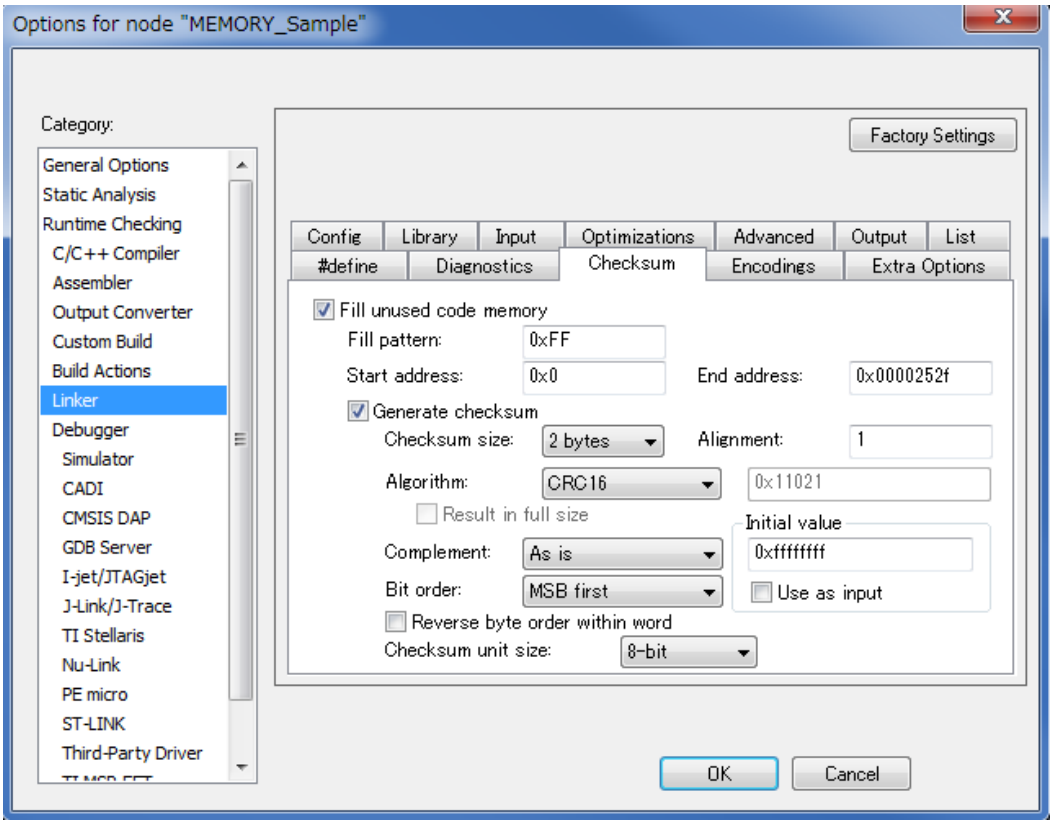
In order to use this function, the CRC32 value for a specified region of the Flash memory should be calculated in advance. The linker option of the IAR Embedded Workbench can be used for the calculation with the following setting.
(For the CRC16 value, the same setting is used.)

(As an example, the MEMORY_Sample project is used.)
1. Referring to “Modification of Linker Setting File for CRC32/CRC16 Calculation”, the linker setting file should be modified.
2. In the option setting of the target project, the setting in the following figure should be done in the “Checksum” tab in the “Linker” option.

In the case of CRC32:



In the case of CRC16:



Of these, "start address" and "end address" change for each project.
Generally, the start address is set to the first address of the Flash memory (0x0 for TMPM4K4A). And the end address is set to the last address of the Flash memory. It is, however, necessary to exclude the region which stores CRC32 and CRC16 values. So the addresses of the region should be known somehow.

3. The end address should be set to an arbitrary one (0x1000, and others), and the build should be done.
4. The address of the "__checksum" variable should be checked in the MAP file.

The section of "Modification of Linker Setting File for CRC32/CRC16 Calculation" describes how to check.
MEMORY_Sample.map (example of CRC32 (extract))

```
.rodata              const      0x000024a8     0x0  zero_init3.o [5]
.rodata              const      0x000024a8     0x0  packbits_init_single.o [5]
Initializer bytes    const      0x000024a8    0x85  <for P2-1>
CHECKSUM                        0x00002530     0x4  <Block>
  .checksum          const      0x00002530     0x4  Place holder __checksum
                                - 0x00002534  0x2390
```

The above example shows that "__checksum" variable which stores the checksum result of the Linker calculation is assigned to 0x2530. ".icf" setting of the linker is modified so that "__checksum" is placed to the last address of ReadOnly memory in the Flash memory in 1. step.
So the end address of the checked region should be the previous address of 0x2530, that is, 0x252F in the Flash memory.

5. The "checksum" tab in the Linker setting should be opened again. "End address" should be set to 0x252F, and the build should be done again. Then, the region of the checksum calculation and its value are shown as the message at the build.

6. Now the preparation has been done. Using the following variables in the program, the Flash memory region and the values of the CRC32 and the CRC16 can be utilized.

```
// use IAR Linker defined symbol "__checksum"
extern uint32_t __checksum;

// use IAR Linker defined symbol "__checksum_begin", "__checksum_end"
// following symbols are defined as assembler LABEL
extern uint8_t __checksum_begin;          // FLASH start
extern uint8_t __checksum_end;            // FLASH end except __checksum

// in IAR we can use Linker Symbol so use it
#define FLASH_TEST_START            (uint32_t)(&__checksum_begin)
#define FLASH_TEST_SIZE             (&__checksum_end - &__checksum_begin + 1)
#define FLASH_TEST_CRC32VALUE     (__checksum)

(snip)

      result = safety_FLASH(FLASH_TEST_START, FLASH_TEST_SIZE,
FLASH_TEST_CRC32VALUE);
```

In order to the DEBUGMSG is enabled in this MEMORY_Sample, the library implementation is set to “semi-hosting” for “general options/library configurations and library low level interface implementation”, set “stdout/stderr” to “via semi-hosting”, and the NDEBUG should be removed in “C/C++ compile/Preprocessor Defined symbols”. Then the build should be done. The terminal I/O displays as follows.

```
RAM (Non Stack): SUCCESS.
RAM (Stack): SUCCESS.
__checksum_begin=0x00000000, __checksum_end=0x0000252f, __checksum=0x3037947f
get_CRC32: start=0x00000000, length=0x00002530
safety_FLASH: value=0x3037947f, provided=0x3037947f
FLASH: SUCCESS. CRC=0x3037947f
Finish!.
```

3.3. Setting for CRC Calculation Test

The Flash memory test uses the CRC calculation function (CRC-B) to calculate the CRC32 and the CRC16 values of a specified memory region. Referring to this program code, the CRC calculation can be done using the CRC-B.
(Refer to “Libraries\Safety\src\safety_flash.c”.)

The following modification is necessary to operate the CRC32 calculation or the CRC16 calculation.

From Libraries\Safety\inc\ safety_flash.h;

<In the case of CRC32>

```
#define CRC32        0
#define CRC16        1
#define CRC          CRC32
```

<In the case of CRC16>

```
#define CRC32        0
#define CRC16        1
#define CRC          CRC16
```

4. Modification of Linker Setting File for CRC32/CRC16 Calculation

The MEMORY_Sample project uses the CRC32-B circuit to calculate the CRC32 and CRC16 values of a Flash memory address region. The calculated value is compared with the CRC32 and CRC 16 values in the binary file which is generated by the compiler to check if the values are identical or not, respectively. The CRC values of the Flash memory region should be calculated in advance using the linker function.
In order to do that, the common linker setting file TMPM4K4FYAUG.icf (Note1) for TMPM4K4A should be modified as follows.
TMPM4K4FYAUG.icf is the linker setting file which only the IAR Embedded Workbench can be used.
The linker setting file cannot be used in Arm® Keil®.

<In the case of IAR Embedded Workbench>

Description before modification

```
place in ROM_region        { readonly };
```

↓

Description after modification

```
define block CHECKSUM with alignment = 4 { ro section .checksum };
place in ROM_region { ro, last block CHECKSUM };
```

A modified linker setting file, TMPM4K4FYAUG_checksum.icf, is prepared in the Libraries\Safety folder.

This modification places the __checksum variable which stores the CRC32 value of the memory region set automatically by the linker to the end of the Readonly data. (When the linker option to generate the checksum is not set and __checksum variable is not used, this modification of the linker setting file affects nothing.)

The location of the __checksum variable can be checked using .map file which is generated at the build of the project.
In the case of MEMORY_Sample, .map file is generated in
Project\Examples\Safety\MEMORY_Sample\Debug\List.

Example of MEMORY_Sample.map (extract)

```
.text                ro code  0x00002450    0x38  packbits_init_single.o [5]
.iar.init_table      const    0x00002488    0x20  - Linker created -
.rodata              const    0x000024a8     0x0  zero_init3.o [5]
.rodata              const    0x000024a8     0x0  packbits_init_single.o [5]
Initializer bytes    const    0x000024a8    0x85  <for P2-1>
CHECKSUM                      0x00002530     0x4  <Block>
  .checksum          const    0x00002530     0x4  Place holder __checksum
                            - 0x00002534  0x2390
```

In the above example, the address 0x2530 is assigned to the __checksum variable.

Note1:Stored in C:\Program Files (x86)\IAR Systems\Embedded Workbench 8.0\arm\config\linker\Toshiba folder.

5. List of Used Drivers

This test library uses the driver and the code in the project of the TMPM4KxA_v1.0.0 version.

CMSIS library

Category	Source file name
Start-up	startup_TMPM4K4A.s
System (Clock setting and others)	system_TMPM4KxA.c

Periph_driver

Category	Source file name
GPIO	txz_gpio.c

In the Project examples

Category	Source file name
BSP (Evaluation board support)	bsp.c
LED output	bsp_led.c

6. Reference Document

For development, refer to the following documents.

- Datasheet of each product
- Reference Manual
- Self-diagnosis Program Application Note - Basic Setting
- ARM® Cortex®-M4 Processor technical Reference Manual
- ARMv7-M Architecture Reference Manual

7. Revision History

Revision	Date	Description
1.0	2019-08-27	First release

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