

Application Note

N32G031 Series Security Startup Application Note

Introduction

Security plays an increasingly important role in the field of electronic applications. In electronic design, the level of component safety requirements is increasing, and electronic equipment manufacturers are incorporating many new technology solutions into new component designs. Software technologies are emerging to improve security. Standards for hardware and software security requirements are also under continuous development.

This document describes how the project in N32G031 MCU to perform the requirements of IEC60730 software safety related operations and related application code content.

This document applies to the N32G031 series products of National Technologies.

All Rights Reserved

Content

Content.....	2
1. This section describes the IEC60730 Class B software standard	1
2. Test point process description	2
2.1 Check the flow at startup	3
2.1.1 CPU startup detection	4
2.1.2 Detection when watchdog starts	5
2.1.3 FLASH startup detection	6
2.1.4 RAM startup detection	10
2.1.5 Clock startup detection	11
2.1.6 Control flow startup detection	13
2.2 Run time inspection process	13
2.2.1 CPU runtime detection.....	13
2.2.2 Stack boundary runtime overflow detection	14
2.2.3 System clock running detection	15
2.2.4 FLASH runtime detection.....	16
2.2.5 Watchdog running detection	17
2.2.6 Local RAM runtime self-check	17
3. Key points of software library migration	20
4. Version history.....	21
5. Legal Notice	22

1. This section describes the IEC60730 Class B software standard

To ensure the safety of electrical appliances, risk control measures during software operation need to be evaluated.

IEC60730, issued by the International Electrotechnical Commission, introduces the requirements for the evaluation of software for household appliances. In Appendix H(H.2.21), software is classified as follows:

Category A software: the software only realizes the functions of the product and does not involve the security control of the product. Software for room thermostats, lighting controls...

Category B software: software designed to prevent unsafe operation of electronic devices. For example, the washing machine software with automatic door lock control, the induction cooker software with overheating control...

Category C software: software designed to avoid certain specific hazards. Such as automatic burner control and hot break of closed water heater (mainly for some explosive equipment)

The specific evaluation requirements of class B software include components to be tested and related faults and test schemes, which are sorted out in the following table (refer to IEC60730 Table H.11.12.7) :

Components to be detected		Fault/error	Fault classification	Nations with library	Test Solution Overview
1.CPU	1.1 register	Hysteresis (Stuck at)	MCU related	Y	Write relevant registers and check
	1.3 Program counter	Hysteresis (Stuck at)	MCU related	Y	When the PC runs fly, start the watchdog reset
2.Interruption		No interrupts or interrupts too frequently	Application of the relevant	N	Count the number of interrupts
3. The clock		Wrong frequency	MCU related	Y	Use HSI to measure HSE clock frequency
4. Memory	4.1 Non-volatile memory	All single bit errors	MCU related	Y	FLASH CRC integrity check
	4.2 Volatile memory	DC fault	MCU related	Y	1. SRAM March C test 2. Stack overflow detection
	4.3 Addressing (related to non-volatile and volatile memory)	Hysteresis (Stuck at)	MCU related	Y	FLASH/SRAM tests are included
5. Internal data path	5.1 data	Hysteresis (Stuck at)	MCU related	N	Only for MCU using external memory, monolithic MCU is not required
	5.2 addressing	Wrong address	MCU related	N	

External communication	6.1 data	The Hamming distance is 3	Application of the relevant	N	Add verification in data transfer
	6.2 addressing	Wrong address	Application of the relevant	N	
	6.3 sequential	Wrong timing	Application of the relevant	N	Count the number of communication events
7. Input and output	7.1 digital I/O	Error defined in H27	Application of the relevant	N	None
	7.2 Analog input and output	Error defined in H27	Application of the relevant	N	None

2. Test point process description

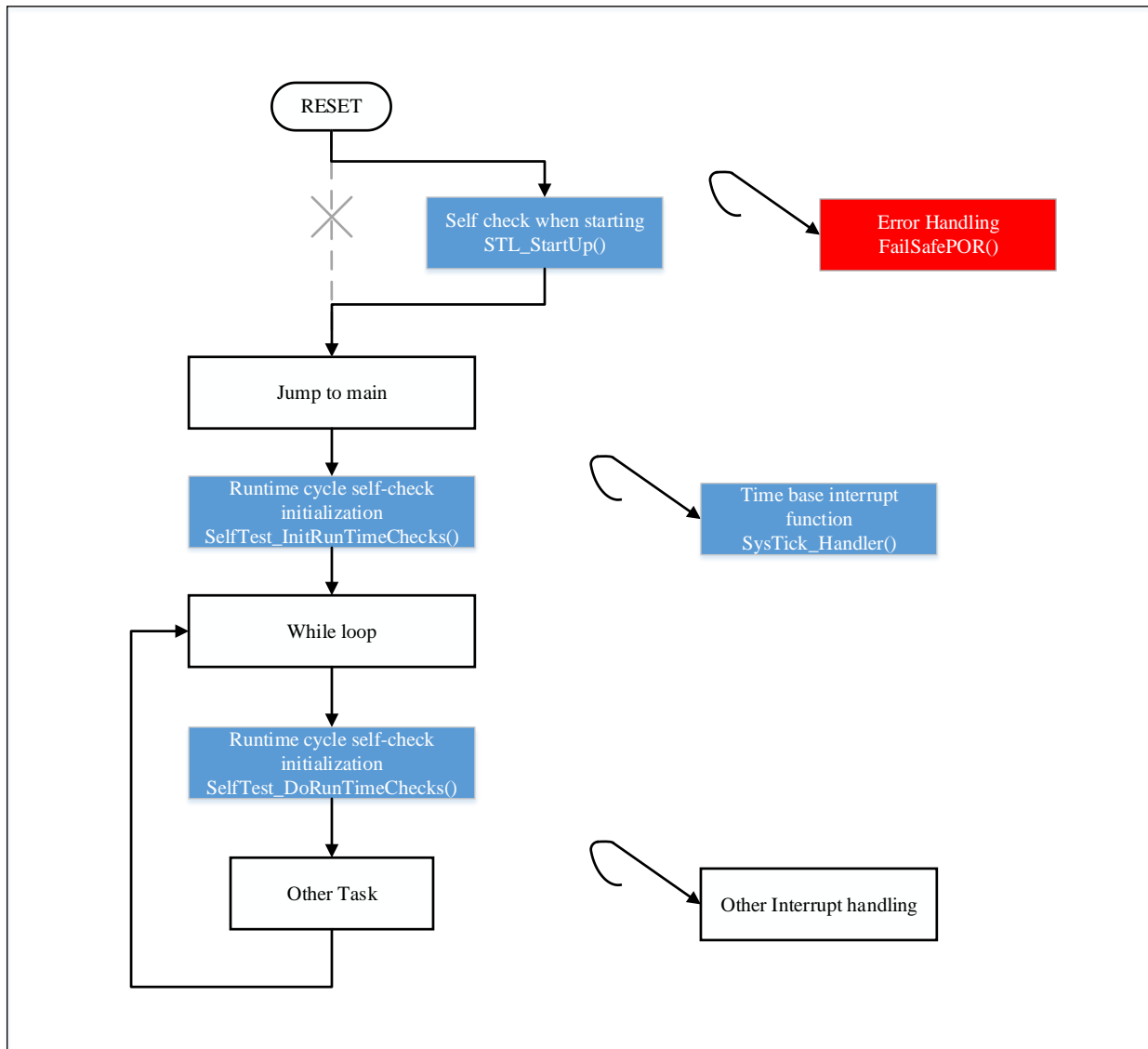
Class B software package program inspection content is divided into two main parts: self-check at startup and periodic self-check at runtime. Self-test at startup includes:

- CPU detection
- Watchdog detection
- Flash integrity detection
- RAM function detection
- System clock Detection
- Control flow detection

Periodic self-check at runtime:

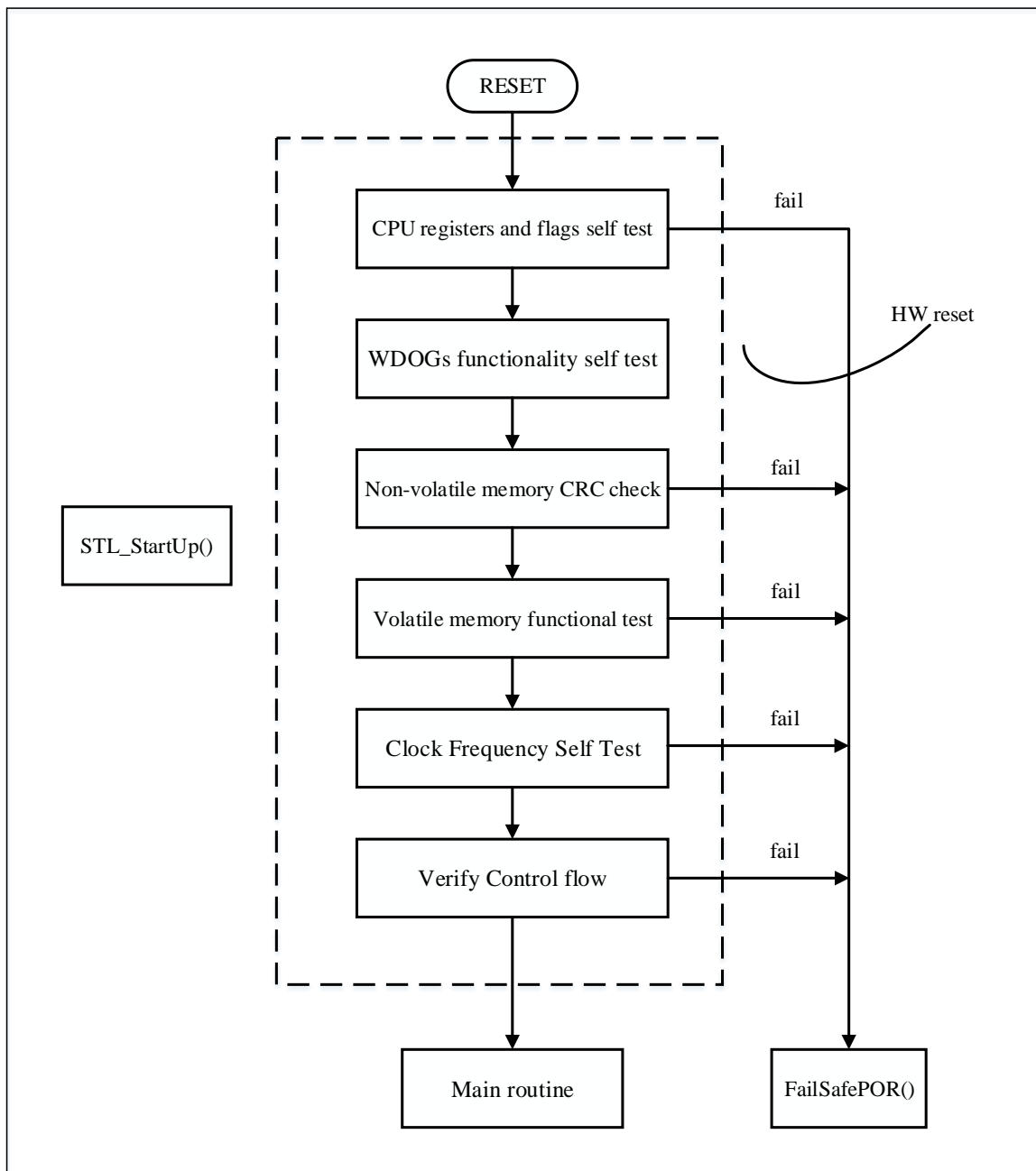
- Local CPU kernel register detection
- Stack boundary overflow detection
- System clock running detection
- Flash CRC segmentation detection
- Watchdog detection
- Local RAM self-check (in interrupt service routines)

The overall flow diagram is as follows:



2.1 Check the flow at startup

Before the chip enters main function from startup, the startup detection is carried out first, and the startup file is modified to execute this part of the code. After the detection process is over, the `__iar_program_start` function is called to jump back to main function. The following is a flow diagram for performing a bootstrap self-check:



2.1.1 CPU startup detection

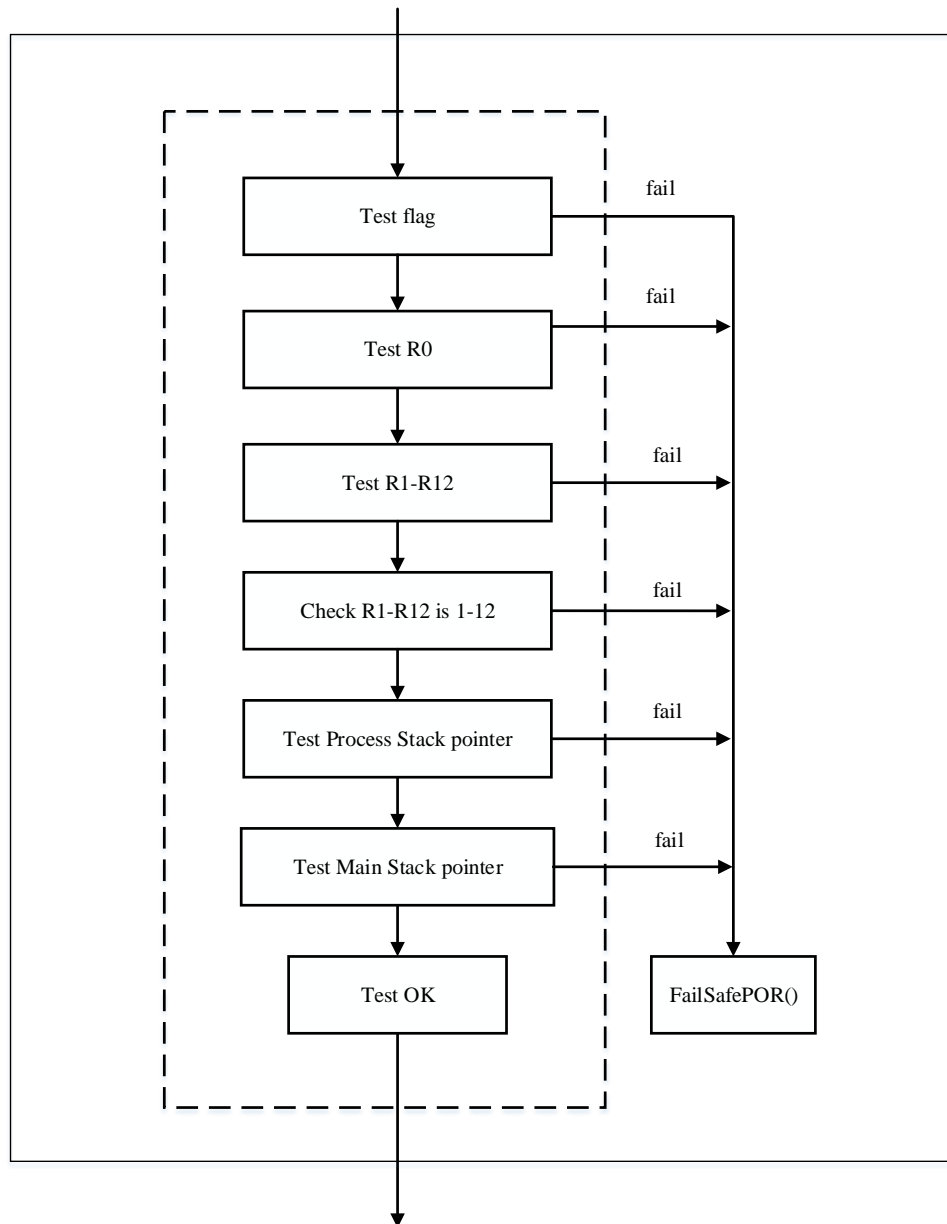
CPU self-check mainly checks whether the kernel flags, registers and so on are correct. If an error occurs, FailSafePOR () is called.

CPU self-check at startup and runtime will be carried out, at startup, R0~R12, PSP, MSP register and Z(zero), N(negative), C(carry), V(overflow) flag bit function test will be a self-check; When run, periodic self-check, only detect registers R1~R12.

Register detection is implemented as follows: write 0xAAAAAAAA and 0x55555555 to the register respectively, and then compare whether the read value is the written value. Write 1 after R1 is tested, write 2 after R2 is tested, and so on.

The specific implementation method of flag bit detection is as follows: set the flag position

bits respectively. If the flag bit is checked incorrectly, the fault function will be entered. The detection flow diagram is as follows:

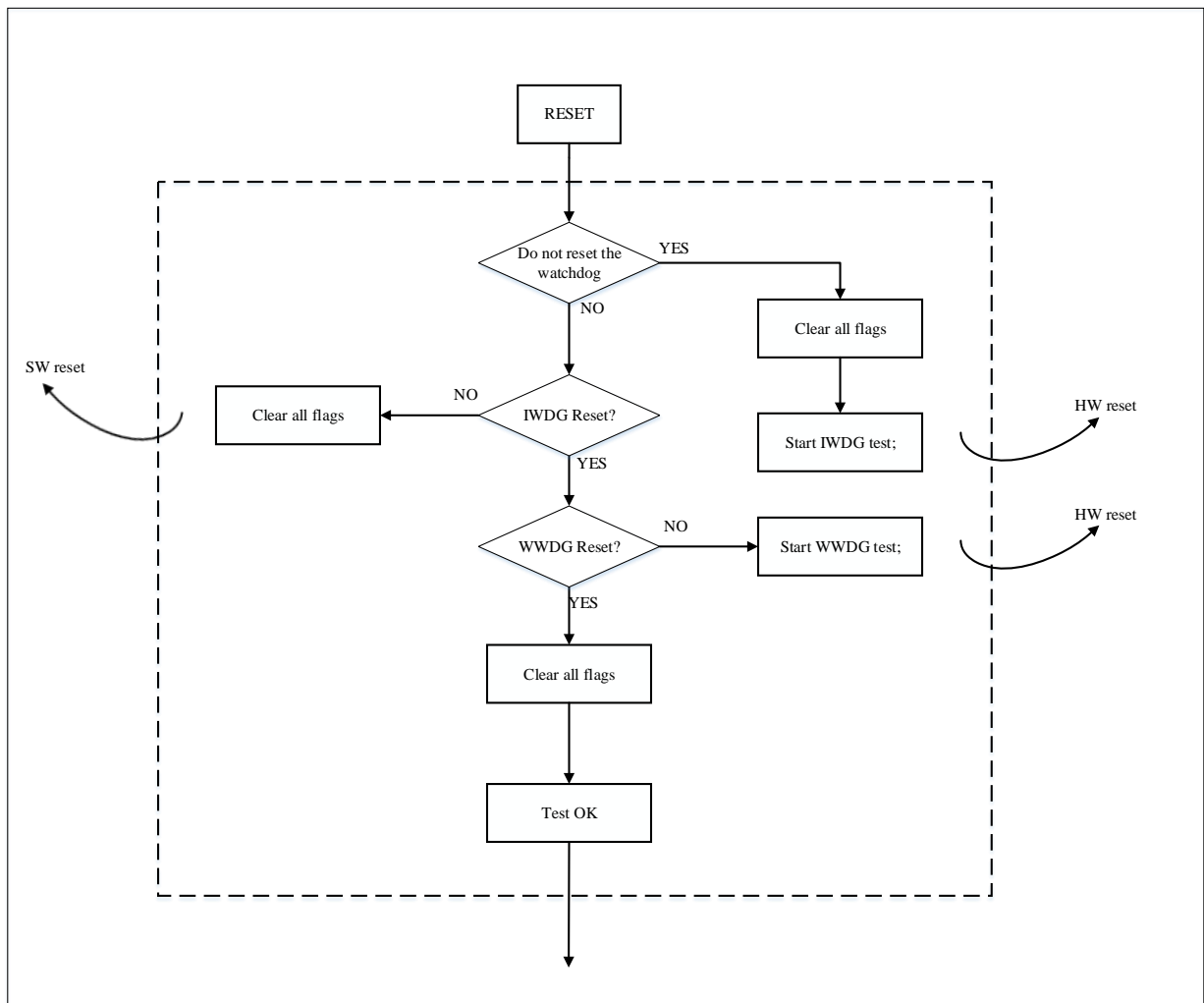


2.1.2 Detection when watchdog starts

Test to verify that independent watchdog and window watchdog can be reset correctly to ensure that runfly can be reset in time to prevent jam when the program is running.

After the initial reset, clear all reset status register flag bits, start the IWDG test, reset the chip, and judge whether it is the IWDG reset flag bit; if it is set, start the WWDG test to reset the chip, if the WWDG reset flag bit is set, the watchdog test passes, clear all flags.

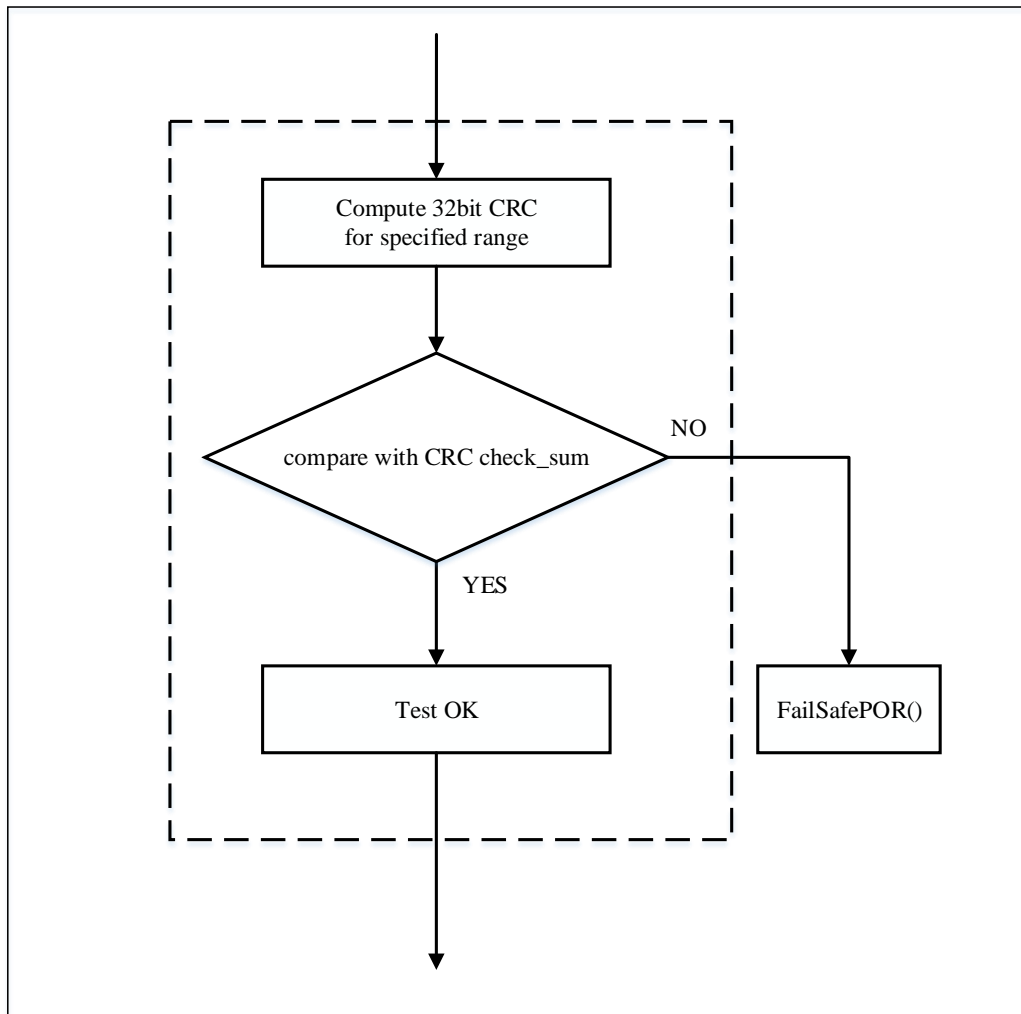
The flow diagram is as follows:



2.1.3 FLASH startup detection

FLASH self-check is a program that calculates FLASH data with CRC algorithm and compares the result value with the CRC value calculated during compilation and stored in the specified location of FLASH to confirm the integrity of FLASH.

The flow diagram is as follows:



The FLASH range of CRC calculation is configured according to the actual situation of the whole program, and the method is different in KEIL and IAR.

IAR configuration:

The CRC calculation is supported in the IAR configuration options. Just configure the parameters, and the compiled file will automatically add the CRC check_sum value to the selected FLASH calculation range:

Category:

- General Options
- Static Analysis
- Runtime Checking
- C/C++ Compiler
- Assembler
- Output Converter
- Custom Build
- Build Actions
- Linker**
- Debugger
- Simulator
- Angel
- CADI
- CMSIS DAP
- GDB Server
- IAR ROM-monitor
- I-jet/JTAGjet
- J-Link/J-Trace
- TI Stellaris
- Macraigor
- PE micro
- RDI
- ST-LINK
- Third-Party Driver

Factory Settings

Output List #define Diagnostics Checksum Extra Options

☒ Fill unused code memory

Fill pattern: 0xFF

Start address: 0x08000000 End address: 0x0800C7FF

☒ Generate checksum

Checksum size: 4 bytes Alignment: 1

Algorithm: CRC32 0x4c11db7

☐ Result in full size

Complement: As is

Bit order: MSB first

☒ Reverse byte order within word

Checksum unit size: 8-bit

Initial value: 0xffffffff

☐ Use as input

OK Cancel

The range of calculating CRC in the program is configured according to the .icf file, which can be modified according to the needs. Add 4 to the above configuration:

```

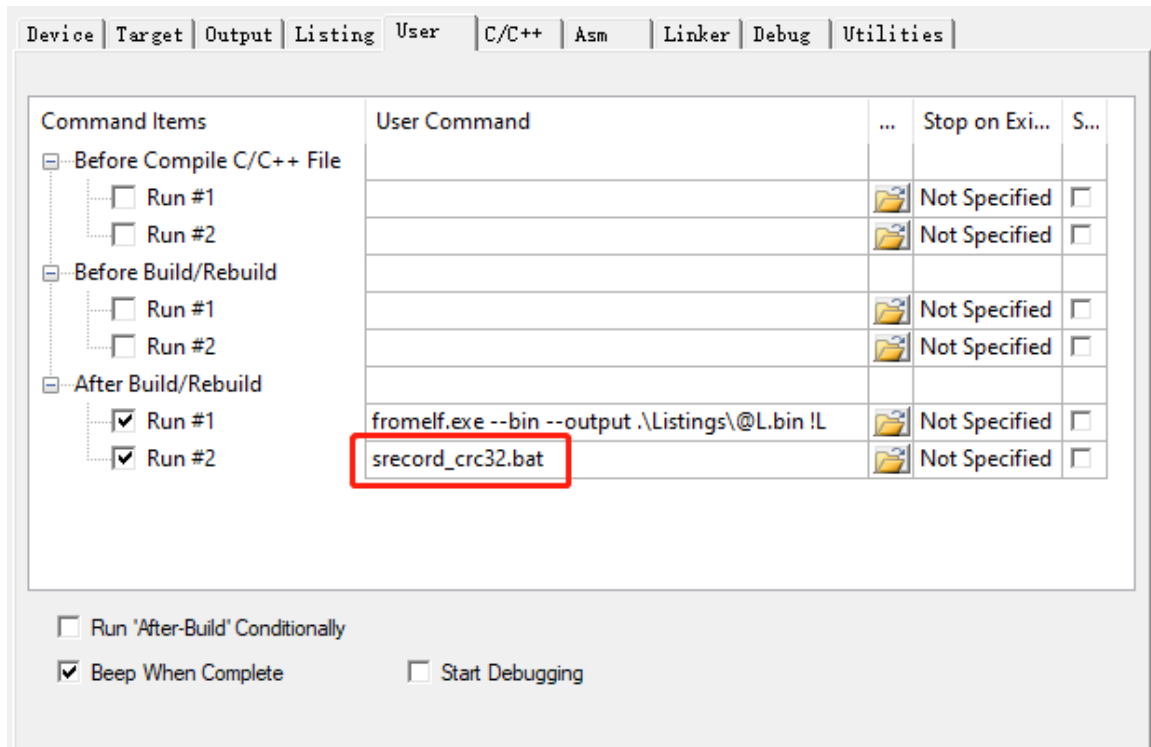
N32G031x8.icf
1  /*###ICF### Section handled by ICF editor, don't touch! ****/
2  /*-Editor annotation file-*/
3  /* IcfEditorFile="$TOOLKIT_DIR$\config\ide\IcfEditor\cortex_vl_0.xml" */
4  /*-Specials-*/
5  define symbol __ICFEDIT_intvec_start__ = 0x08000000;
6  /*-Memory Regions-*/
7  define symbol __ICFEDIT_region_ROM_start__ = 0x08000000;
8  define symbol __ICFEDIT_region_ROM_end__ = 0x0800C803; /* max 0x0800:
9  define symbol __ICFEDIT_region_RAM_start__ = 0x20000100;
10 define symbol __ICFEDIT_region_RAM_end__ = 0x20001FFF;
11

```

Keil configuration:

The configuration of Keil is more complicated. ARM officially recommends using the third-party software SRecord for ROM Self-Test in MDK-ARM.

According to the project configuration, after the compilation is completed, the script file srecord_crc32.bat will be called. Through the srec_cat.exe software, the data in the N32G031_SelfTest.hex file generated by Keil will be calculated by CRC, and the CRC check result will be generated. Add to the specified location to get a new N32G031_SelfTest_CRC.hex file:



Open the .bat file with Notepad or other tools, and modify the following according to the actual application:

```

1  \SREC\srec_cat .\Objects\N32G031_SelfTest.hex -intel -crop 0x08000000 0x0800FF00 -fill 0x00 0x08000000 0x0800FF00 ^
2  -crc32-l 0x0800FF00 -o .\Objects\N32G031_SelfTest_CRC.hex -intel
3

```

file name before calculation calculation range fill in blank with 0
 CRC result file name after calculation

The range of calculating CRC in the program is configured according to the n32g0xx_STLparam.h file, which can be modified according to requirements, which is consistent with the above configuration:

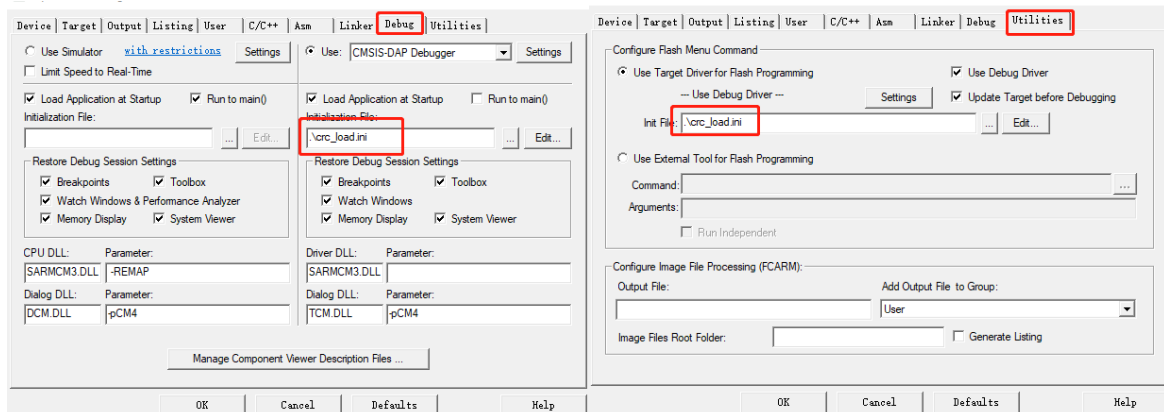
```

n32g0xx_STLparam.h
238 #ifdef __CC_ARM /* KEIL Compiler */
239
240 /* This is the KEIL compiler entry point, usually executed right after reset */
241 extern void __main( void );
242
243 /* Constants necessary for Flash CRC calculation (ROM_SIZE in byte) */
244 /* byte-aligned addresses */
245 #define ROM_START ((uint32_t *)0x08000000uL)
246 #define ROM_END ((uint32_t *)0x0800FF00uL) /* Modify according to needs */
247 #define ROM_SIZE ((uint32_t)ROM_END - (uint32_t)ROM_START)

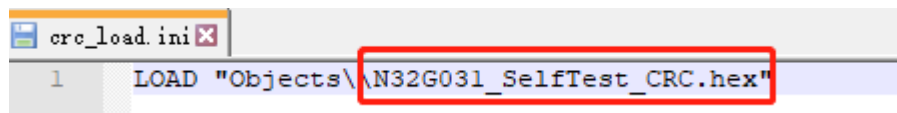
```

Therefore, the final generated N32G031_SelfTest_CRC.hex file needs to be used whether it is downloading or debugging, so the .ini file needs to be added to the Keil configuration option

to download the new .hex file. The configuration is as follows:



It should be noted that the .ini file should also modify the content file name configuration according to the actual application:



2.1.4 RAM startup detection

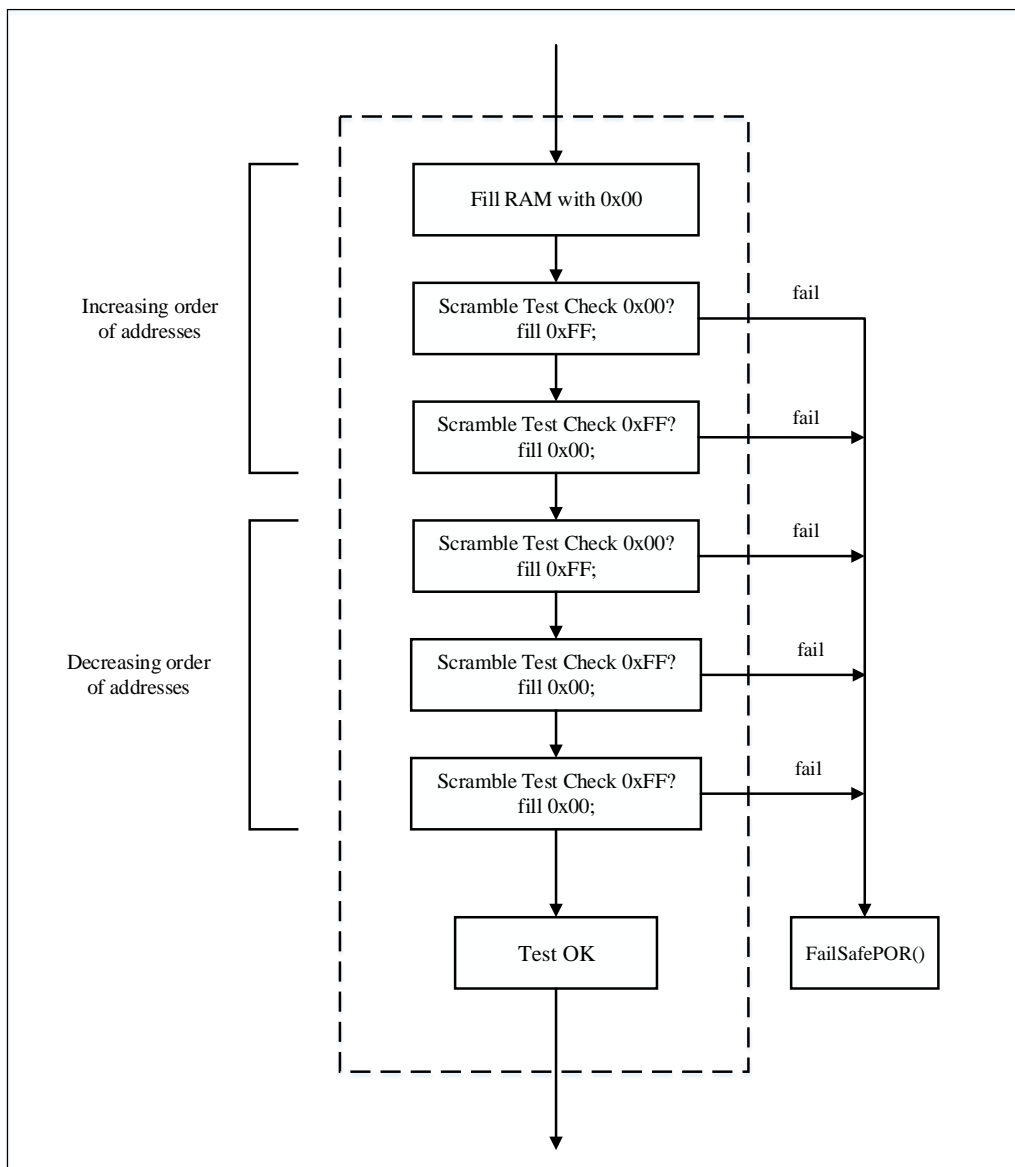
SRAM detection detects errors not only in the data region, but also in its internal address and data path.

SRAM self-check uses The Mar-C algorithm, which is an algorithm used for SRAM testing of embedded chips as part of security certification. All ranges of SRAM are detected at startup.

First, the whole SRAM is cleared, and then 1 bit by bit, each set one bit, test whether the bit is 1, if it is, continue, if not, an error is reported; After all are set, clear 0 bit by bit. After clearing a bit, test whether the bit is cleared to 0 or not. If it is, it is correct, otherwise, an error is reported. Until the test of the entire RAM space is completed.

The test time is 6 cycles, and the whole RAM is checked and filled word by word alternately with the values 0x00 and 0xFF. The first 3 cycles are executed according to increasing address, and the last 3 cycles are executed according to decreasing address.

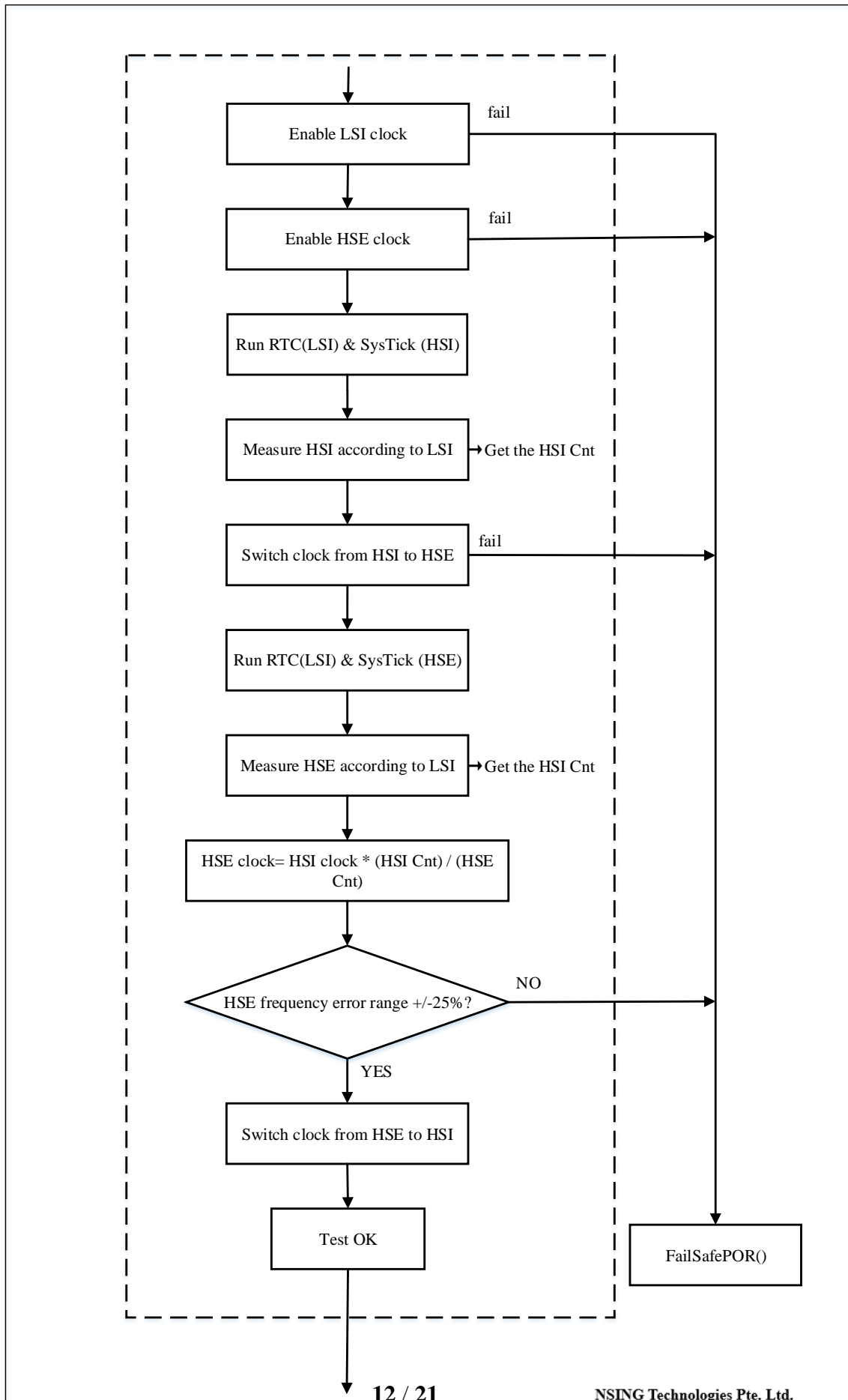
The whole RAM detection algorithm process is shown in the figure below:



2.1.5 Clock startup detection

The test principle is as follows:

1. Start the external high-speed clock source (HSE).
2. Before the test starts, the system clock source is set to HSI by default. Then, initialize RTC(LSI clock source) and SysTick (system clock source). When the SysTick count is decremented from the reload value to 0. Record the current RTC count to get the HSI Cnt.
3. Set the system clock source to HSE and initialize RTC(LSI) and SysTick (system clock source) to obtain HSE Cnt in the same manner.
4. Take HSI clock frequency as the standard, calculate HSE frequency according to the following flow chart formula, and compare the frequency value with the expected range value: if it exceeds $\pm 25\%$, the test fails. After the test, switch to the system clock source HSI. The expected range can be adjusted by users according to actual applications. Macros are defined as HSE_LimitHigh() and HSE_LimitLow().



2.1.6 Control flow startup detection

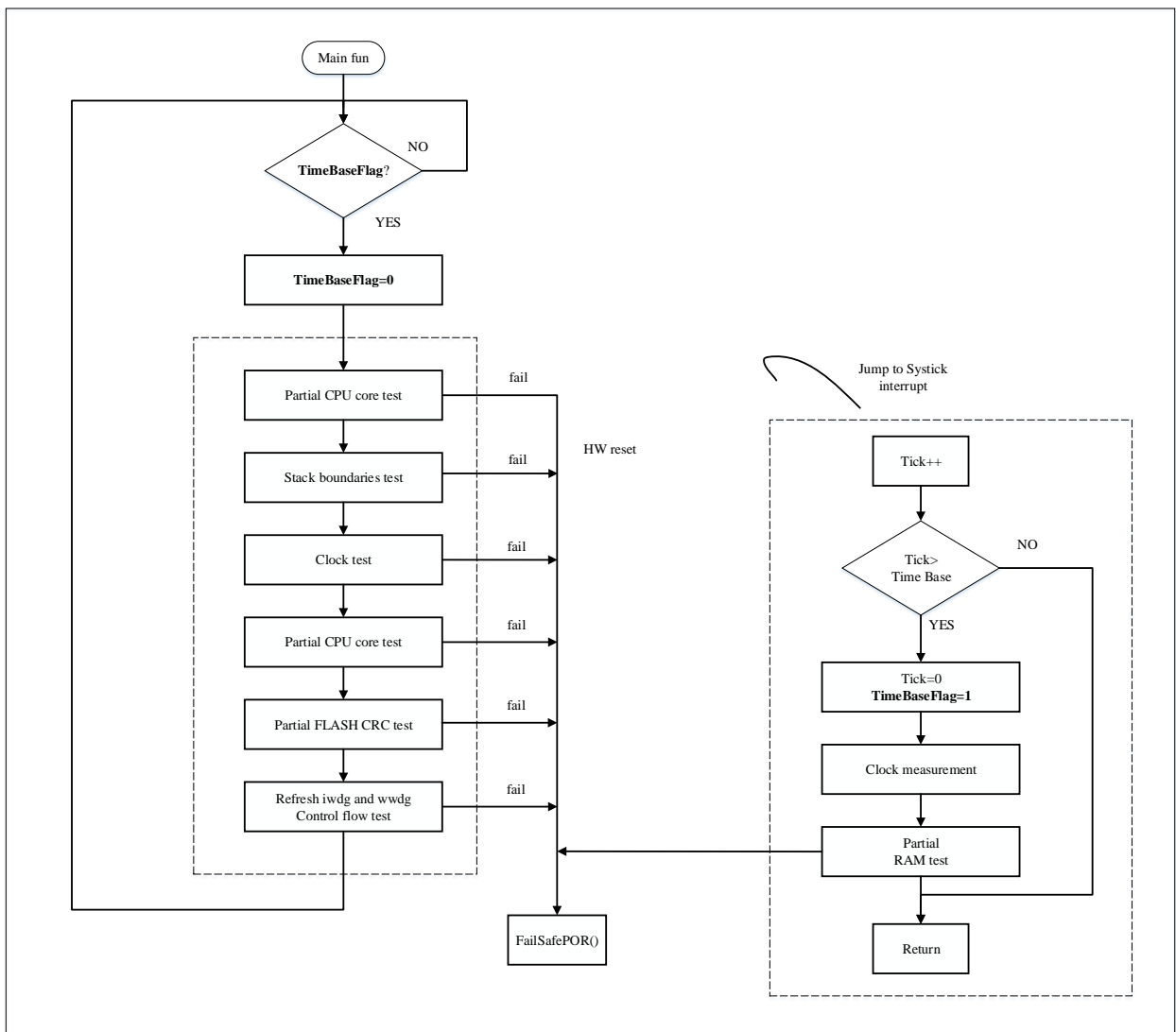
The self-check part of the startup ends with the control flow detection pointer program.

Initialize the variables CtrlFlowCnt to 0, CtrlFlowCntInv to 0xFFFFFFFF. In each test step, CtrlFlowCnt adds a fixed value, CtrlFlowCntInv subtracting the same fixed value. At the end of the start self-check, judge whether the sum of the two values is still 0xFFFFFFFF.

2.2 Run time inspection process

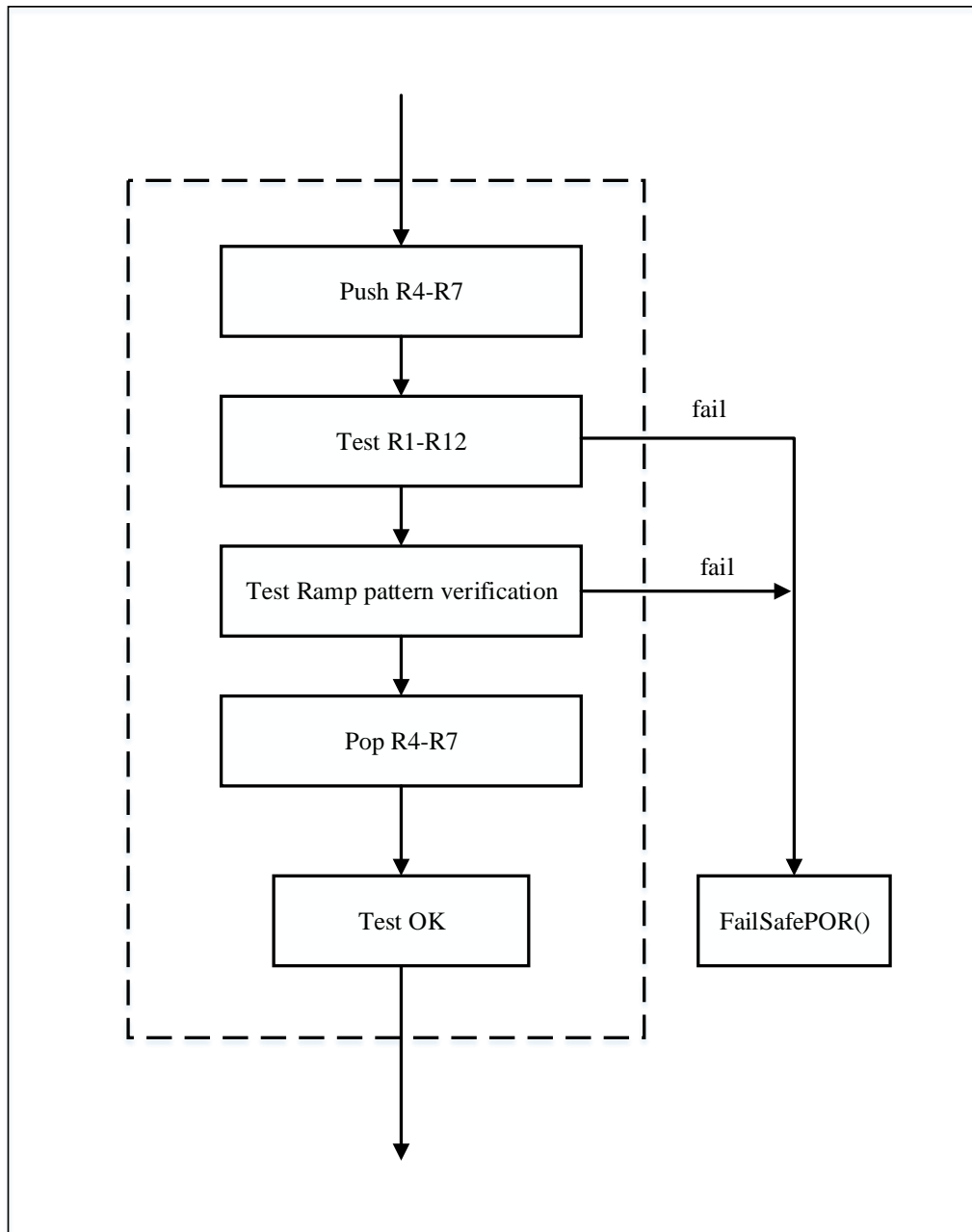
If the startup self-check passes successfully, the run-time periodic self-check must be initialized before entering the main loop.

The runtime checks periodically based on SysTick. The run-time periodic detection process is as follows:



2.2.1 CPU runtime detection

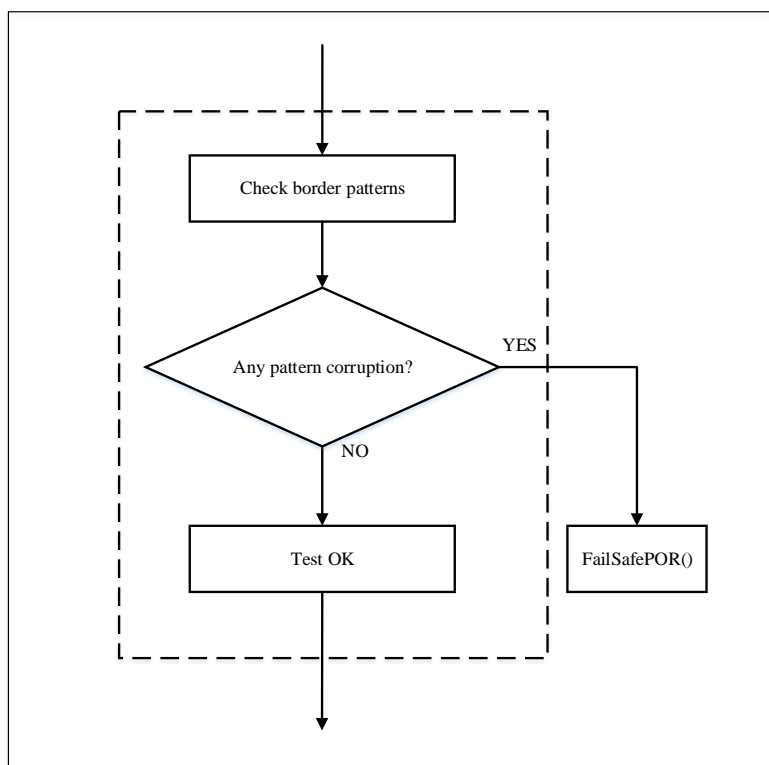
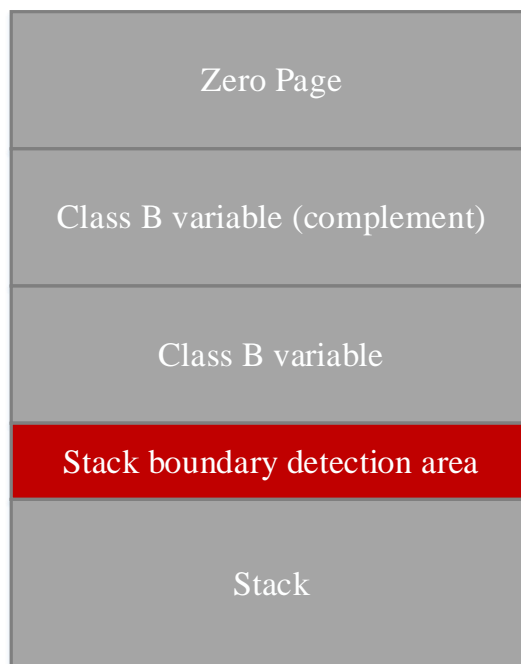
The CPU runtime periodic self-check is similar to the self-check at startup, except that the kernel flags and stack Pointers are not detected.



2.2.2 Stack boundary runtime overflow detection

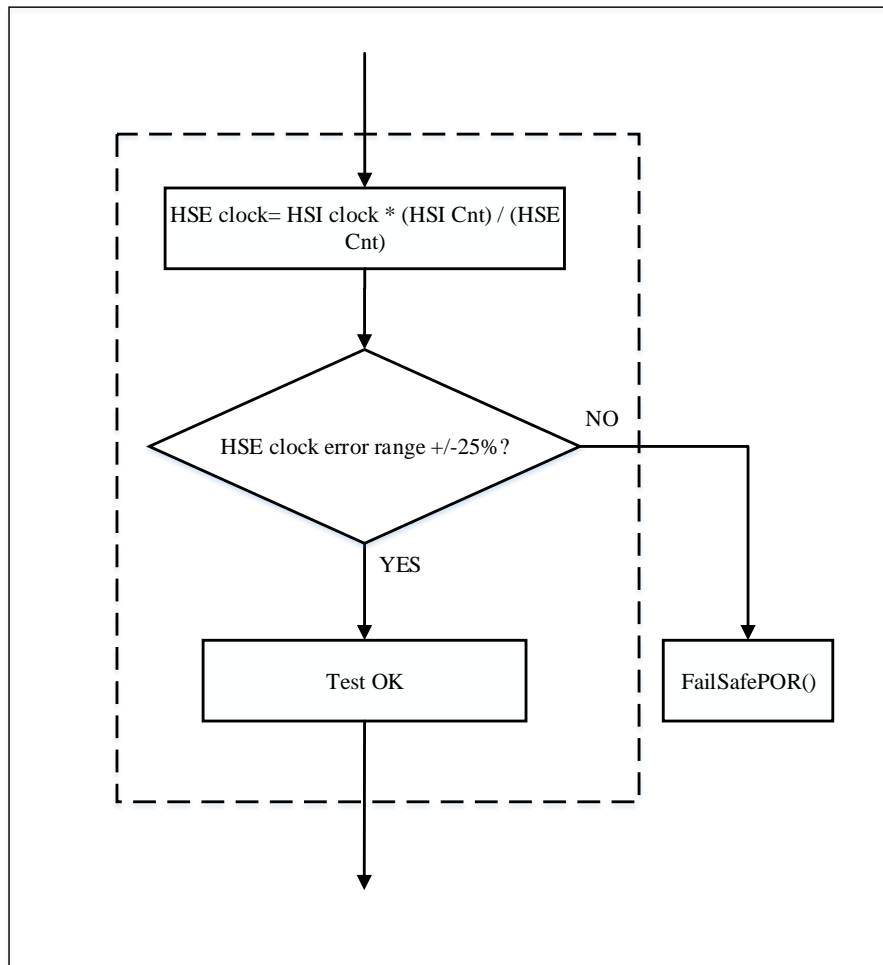
This test detects stack overflow by determining the data integrity of pattern array in the boundary detection area. If the original pattern data is corrupted, the test fails and a fail-safe program is invoked.

The lower address closely following the stack area is defined as the stack boundary detection area. This area can be configured differently depending on the device. The user must define enough areas for the stack and ensure that pattern is placed correctly.



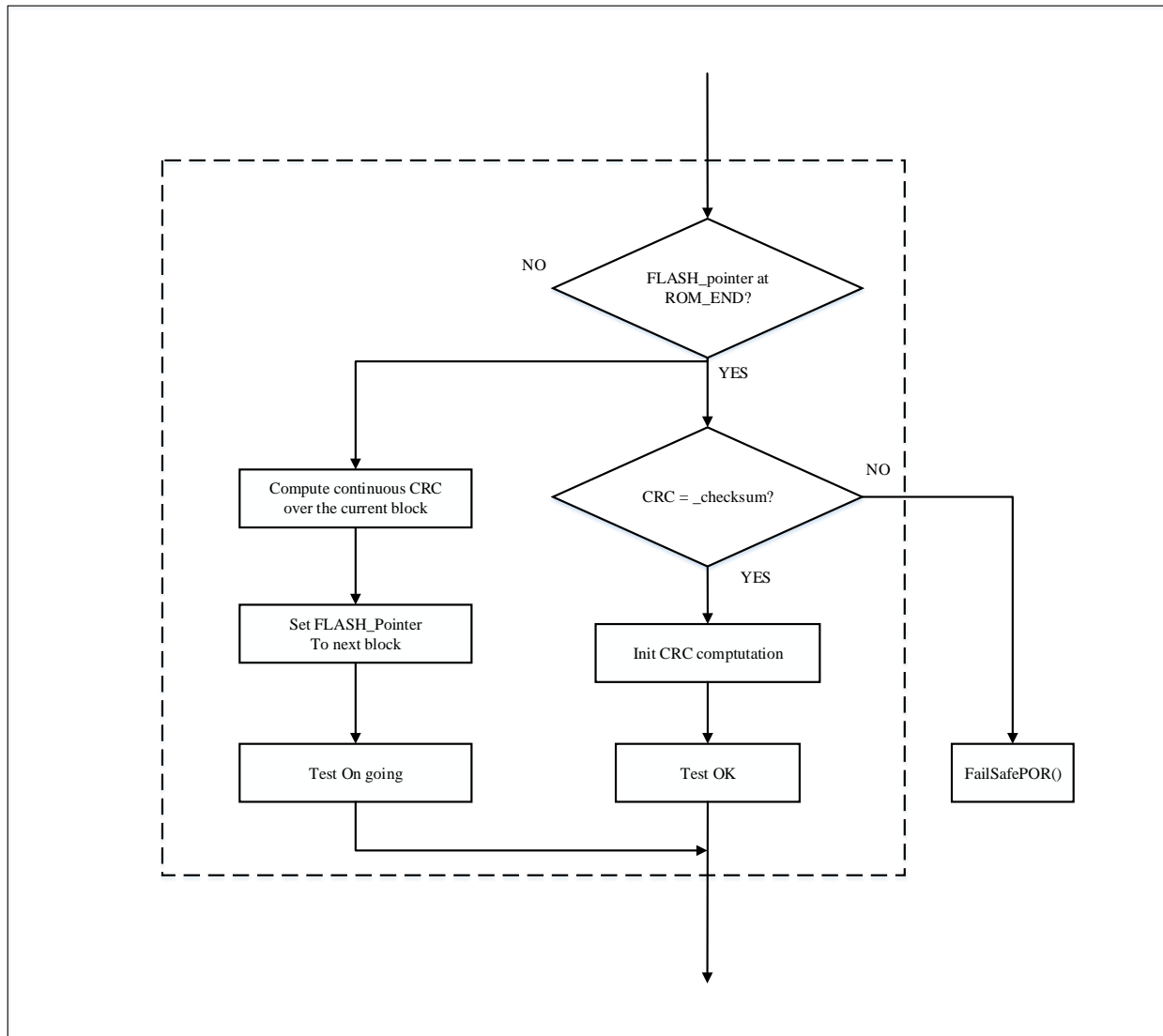
2.2.3 System clock running detection

The detection of system clock during runtime is similar to that during startup. HSE frequency is calculated through HSI Cnt and HSE Cnt, and the process is as follows:



2.2.4 FLASH runtime detection

The Flash CRC self-check is performed during the runtime. Because the detection range varies with the time required, you can configure segmented CRC calculation based on the size of the user application. When the CRC values are calculated to the last range, the CRC values are compared.



2.2.5 Watchdog running detection

During runtime, dogs need to be fed regularly to ensure the normal operation of the system. The watchdog dog feeding part is placed at the end of STL_DoRunTimeChecks().

2.2.6 Local RAM runtime self-check

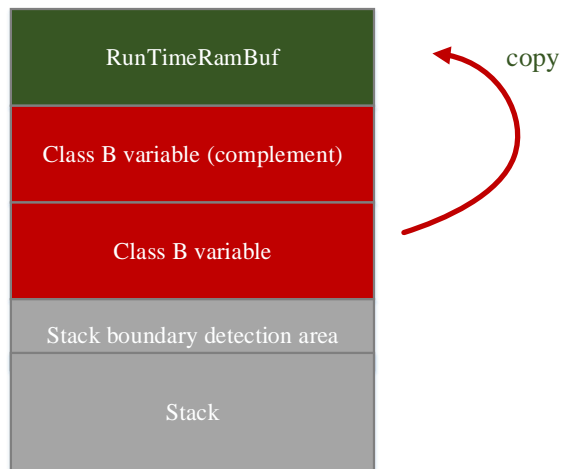
The RAM self-check at run time is done in the SysTick interrupt function. The test covers only the portion of memory allocated to the class B variable.

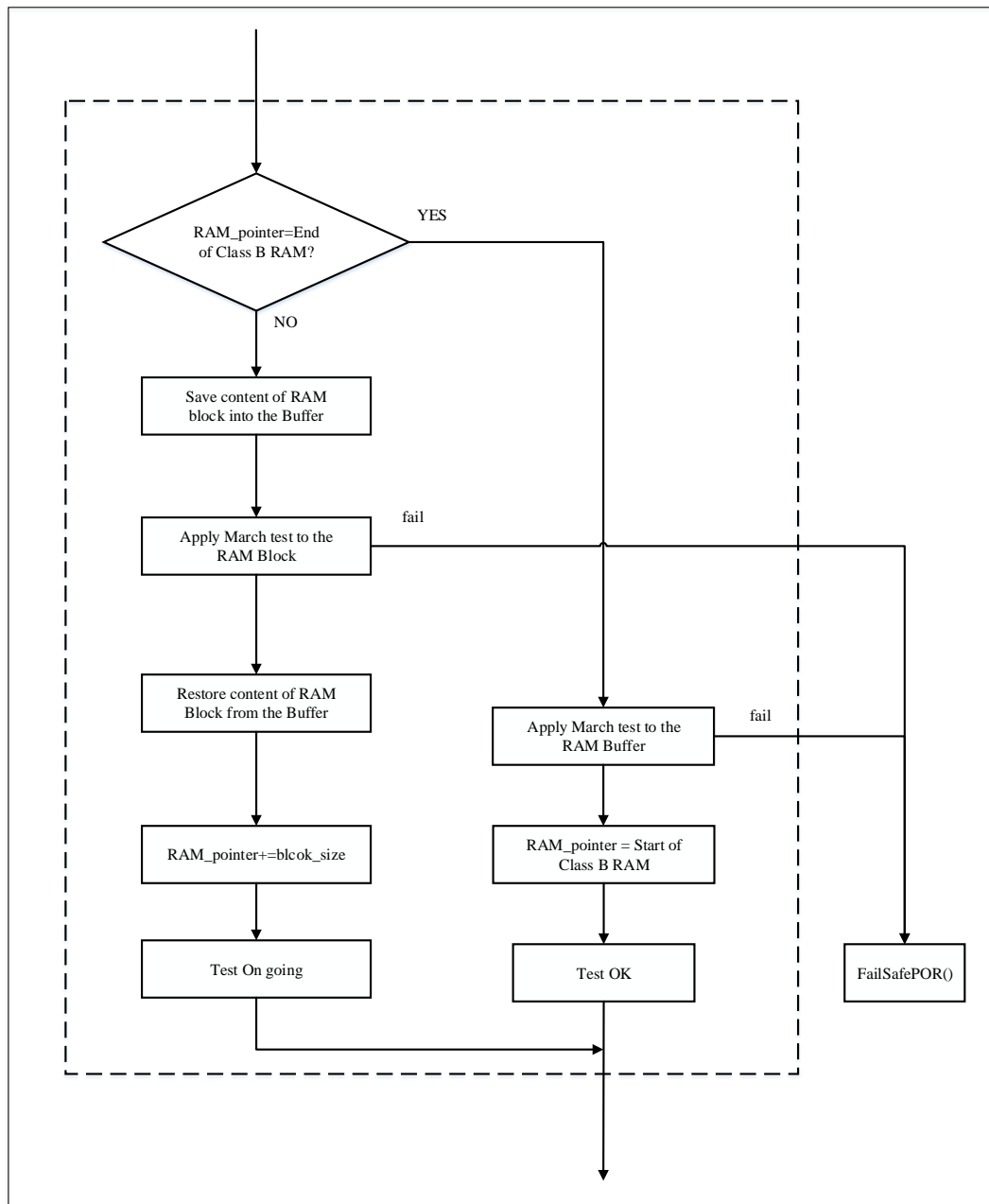
According to the area divided by the class B variable, every 6 bytes is a block. Before the March-C test, save the block data in the RunTimeRamBuf, and then put the RunTimeRamBuf back to the original area of the class B after the test is completed. Until all tests in the class B area are completed.

After the class B zone test is complete, the RunTimeRamBuf zone is march-c tested. After the test is complete, the pointer is restored to the class B start address for the next test.

Note: During RAM check, global interrupts are temporarily disabled and re-enabled afterward. Therefore, users must ensure their application code does not conflict with RAM check. For example, I2C modules should confirm data transmission/reception completion before

initiating RAM check.





3. Key points of software library migration

- Before executing the user program, execute the STL_StartUp function (to start the self-check);
- Set WWDG and IWDG to prevent them from being reset when the program is running properly;
- Set up RAM and FLASH detection range at startup and runtime;
 - The range of CRC checksum, and the location where the checksum is stored in the Flash
 - The range of storage addresses for ClassB variables
 - Location of stack boundary detection area
- Troubleshoot detected faults.
- Add user-related fault detection content based on specific applications;
- Define the frequency of program runtime self-check according to the specific application;
- After the chip is reset, the STL_StartUp function must be called for startup self-check before initialization.
- Call STL_InitRunTimeChecks() before entering the main loop, and call STL_DoRunTimeChecks() in the main loop;
- Users can release Verbose comments to enter diagnostic mode and output text information through the Tx(PA9) pin of USART1.

Set the serial port to 115200Bits/s, no parity, 8-bit data, and 1 stop bit.

4. Version history

Version	Date	Note
V1.0	2021-11-06	1. Create a document
V1.1	2022-05-18	1. Document content proofreading, formatting adjustment
V1.2	2022-09-07	1. Chapter 2.1.3 adds keil project configuration instructions
V1.3	2025-09-26	1. Section 2.2.6: Key Considerations for RAM Detection

5. Legal Notice

This document is the exclusive property of NSING TECHNOLOGIES PTE. LTD. (Hereinafter referred to as NSING). This document, and the product of NSING described herein (Hereinafter referred to as the Product) are owned by NSING under the laws and treaties of Republic of Singapore and other applicable jurisdictions worldwide. The intellectual properties of the product belong to NSING Technologies Inc. and NSING Technologies Inc. does not grant any third party any license under its patents, copyrights, trademarks, or other intellectual property rights. Names and brands of third party may be mentioned or referred thereto (if any) for identification purposes only. NSING reserves the right to make changes, corrections, enhancements, modifications, and improvements to this document at any time without notice. Please contact NSING and obtain the latest version of this document before placing orders. Although NSING has attempted to provide accurate and reliable information, NSING assumes no responsibility for the accuracy and reliability of this document. It is the responsibility of the user of this document to properly design, program, and test the functionality and safety of any application made of this information and any resulting product. In no event shall NSING be liable for any direct, indirect, incidental, special, exemplary, or consequential damages arising in any way out of the use of this document or the Product. NSING Products are neither intended nor warranted for usage in systems or equipment, any malfunction or failure of which may cause loss of human life, bodily injury or severe property damage. Such applications are deemed, Insecure Usage'. Insecure usage includes, but is not limited to: equipment for surgical implementation, atomic energy control instruments, airplane or spaceship instruments, all types of safety devices, and other applications intended to supporter sustain life. All Insecure Usage shall be made at user's risk. User shall indemnify NSING and hold NSING harmless from and against all claims, costs, damages, and other liabilities, arising from or related to any customer's Insecure Usage Any express or implied warranty with regard to this document or the Product, including, but not limited to. The warranties of merchantability, fitness for a particular purpose and non-infringement are disclaimed to the fullest extent permitted by law. Unless otherwise explicitly permitted by NSING, anyone may not use, duplicate, modify, transcribe or otherwise distribute this document for any purposes, in whole or in part.