GigaDevice Semiconductor Inc.

Arm® Cortex®- M3/M4/M23/M33 32-bit MCU

应用笔记

AN043

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1. 介绍

Flash作为一种非易失性存储器，在微控制器系统中起着不可或缺的作用，其性能的好坏将影响整个系统的运行效率。其性能主要反映在对flash的操作时间上，包括全片擦除、页擦除、字编程时间。

该应用笔记提供了两种对flash操作时间测量的方法。

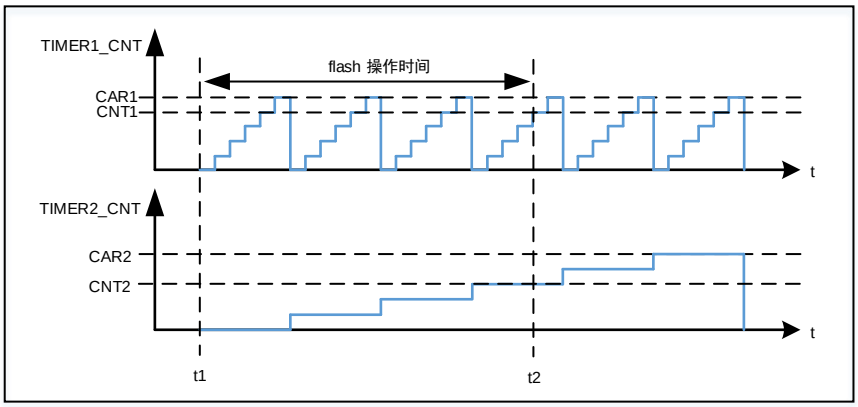
2. Flash 操作时间测量方法

2.1. 定时器计数法

定时器计数法采用 MCU 内部定时器计数，并利用计数值计算对 flash 的操作时间。该方法通过在进行 flash 操作之前清除定时器计数值并启动计数，在 flash 操作完成之后读取计数器值并关闭计数。为了提高测量精度，我们将系统运行在最高主频 64MHz，并将定时器时钟分频成 8MHz，即定时器计数周期为 0.125us。由于 L23x 定时器为 16 位定时器，则单个定时器最大只能测量 65536*0.125us = 8.192ms，为了提高测量时间范围，可采用定时器级联的方法。将其中一个定时器更新事件脉冲作为另一个定时器的时钟源，这样可以在保证最大精度的同时，将测量时间扩大为 65536*8.192ms=536.870912s。如*图 2-1. 定时器测量 flash 操作时间的方法*所示，flash 操作时间 tf：

$$tf = t2\text{-}t1 = (CNT1 + (CAR1 * CNT2)) * 0.125us \quad (2\text{-}1)$$

图 2-1. 定时器测量 flash 操作时间的方法

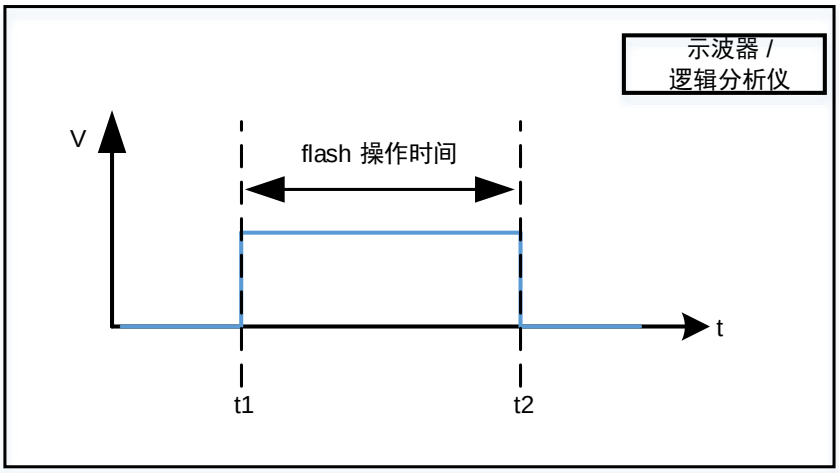


2.2. I/O 电平翻转法

采用 MCU 外部引脚输出高低电平，并使用示波器/逻辑分析仪测量该脉冲时间。

该方法通过在进行 flash 操作之前，将普通 IO 口设置为高电平；在 flash 操作完成之后，将普通 IO 口设置为低电平。通过示波器/逻辑分析仪测量测量正脉冲时间。如*图 2-2. IO 口测量 flash 操作时间的方法*所示，flash 操作时间为 tf = t2-t1。

图 2-2. IO 口测量 flash 操作时间的方法

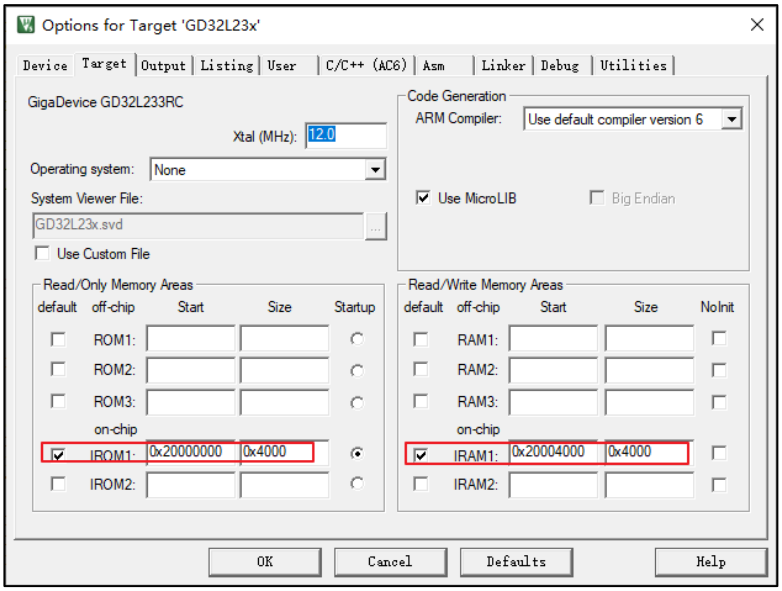

示波器 /
逻辑分析仪
V
flash 操作时间
t
t1
t2

3. Flash 操作时间测量具体实现

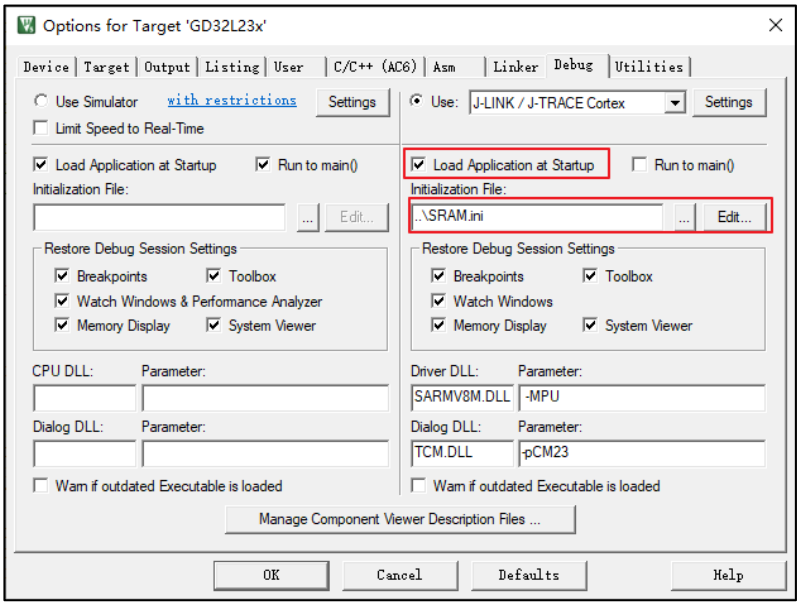
3.1. SRAM 中启动配置

为测量 flash 特性，需要把测量程序放在 sram 中运行。在 sram 中启动调试配置步骤如下：

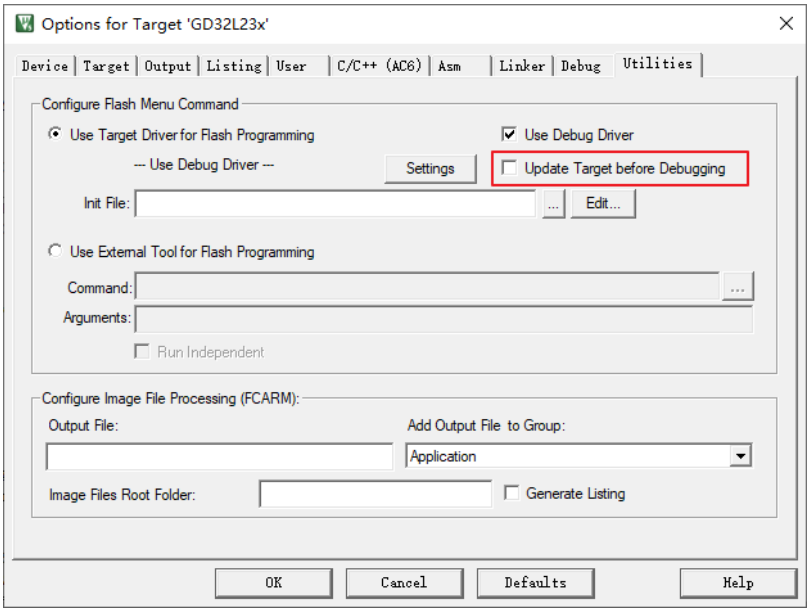
1. 根据实际 sram 空间，配置分散加载区域



2. 添加从 SRAM 中启动的初始化文件



3. 配置 Utilities 选项



4. SRAM.ini 初始化文件

```
FUNC void Setup (void) {
/* Setup Stack Pointer */
SP = _RDWORD(0x20000000);
/* Setup Program Counter */
PC = _RDWORD(0x20000004);
/* Setup Vector Table Offset Register */
_WDWORD(0xE000ED08, 0x20000000);
}
/* Download, Project.axf, the same with your project name */
LOAD Project.axf INCREMENTAL
/* Setup for Running */
```

3.2. 软件实现

通过宏的方式，可以使用定时器方法和 I/O 电平翻转方法分别对 flash 的全片擦除、页擦除、字编程时间进行测量。具体代码实现如下：

1. TIMER 配置

```
void timer_config(void)
{
    timer_parameter_struct timer_initpara;

    rcu_periph_clock_enable(RCU_TIMER);
    rcu_periph_clock_enable(RCU_TIMER2);

    timer_deinit(TIMER_USE);
    /* TIMER1 configuration */
```

```
    timer_initpara.prescaler         = TIMER_PRESCALER;
    timer_initpara.alignedmode       = TIMER_COUNTER_EDGE;
    timer_initpara.counterdirection  = TIMER_COUNTER_UP;
    timer_initpara.period            =65535;
    timer_initpara.clockdivision     = TIMER_CKDIV_DIV1;
    timer_init(TIMER_USE, &timer_initpara);

    /* auto-reload preload enable */
    timer_auto_reload_shadow_enable(TIMER_USE);
    /* configure TIMER1 master slave mode */
    timer_master_slave_mode_config(TIMER_USE, TIMER_MASTER_SLAVE_MODE_ENABLE);
    timer_master_output_trigger_source_select(TIMER_USE, TIMER_TRI_OUT_SRC_UPDATE);

    timer_deinit(TIMER2);
    /* TIMER2 configuration */
    timer_initpara.prescaler         = 0;
    timer_initpara.alignedmode       = TIMER_COUNTER_EDGE;
    timer_initpara.counterdirection  = TIMER_COUNTER_UP;
    timer_initpara.period            = 65535;
    timer_initpara.clockdivision     = TIMER_CKDIV_DIV1;
    timer_init(TIMER2, &timer_initpara);

    timer_auto_reload_shadow_enable(TIMER2);
    /* slave mode selection: TIMER2 */
    timer_slave_mode_select(TIMER2, TIMER_SLAVE_MODE_EXTERNAL0);
    timer_input_trigger_source_select(TIMER2, TIMER_SMCFG_TRGSEL_ITI0);
}
```

2. 主程序代码

```
/* macro definition */
#define GD32L233RC
#define TEST_MASS_ERASE              1
#define TESE_PAGE_ERASE              1
#define TEST_WORD_PROGRAMME          1
#define TIMER_CNT_MESURE_METHOD      1

#define TIMER_PRESCALER              (8 - 1)
#define TIMER_USE                    TIMER1
#define RCU_TIMER                    RCU_TIMER1
#define PROGRAMME_DATA               0xaa55aa55
#define ADDRESS_TO_PROGRAMME         0x08000000
#define PAGE_TO_ERASE1               0x08000000

#define MEASURE_NUMS                 1
```

```
#define AVERAGE_VALUE_POSITION    (MEASURE_NUMS)

#if defined(GD32L233RC)
#define PAGE_SIZE1_WORD                 ((4*1024)/4)
#define FLASH_SIZE_WORD                 ((256*1024) /4)
#endif
#define    USART_COM          USART1
/* flash operation time struct definition */
typedef struct {
    uint32_t word_programme[MEASURE_NUMS+1];
    uint32_t page_erase[MEASURE_NUMS+1];
    uint32_t mass_erase[MEASURE_NUMS+1];
}flash_operation_time_struct;

flash_operation_time_struct    flash_operation_time;

int main(void)
{
    uint16_t measure_counts = 0;
    /* gpio, timer, usart configuration */
    rcu_periph_clock_enable(RCU_GPIOC);
    gpio_mode_set(GPIOC, GPIO_MODE_OUTPUT, GPIO_PUPD_NONE,GPIO_PIN_0);
    gpio_output_options_set(GPIOC, GPIO_OTYPE_PP, GPIO_OSPEED_50MHZ, GPIO_PIN_0);
    gpio_bit_reset(GPIOC, GPIO_PIN_0);
    gd_eval_com_init(USART_COM);
    timer_config();

    fmc_unlock();
    /* mass erase measure */
#if TEST_MASS_ERASE
    do{
      {
          uint32_t i =0;
          /* mass erase, then programme full flash with PROGRAMME_DATA */
          fmc_mass_erase();
          for(i = 0; i < FLASH_SIZE_WORD; i++){
              fmc_word_program((ADDRESS_TO_PROGRAME + (i * 4)),
PROGRAME_DATA);
          }
      }
#if TIMER_CNT_MESURE_METHOD
        /* clear timer count and enable timer */
        timer_disable(TIMER_USE);
```

```
            timer_disable(TIMER2);
            TIMER_CNT(TIMER_USE) = 0;
            TIMER_CNT(TIMER2) = 0;
            timer_enable(TIMER_USE);
            timer_enable(TIMER2);
#else
            /* set gpio pin to high level */
            gpio_bit_set(GPIOC, GPIO_PIN_0);
#endif
            /* start mass erase */
            fmc_mass_erase();
#if TIMER_CNT_MESURE_METHOD
            /* get the mass erase time */
            flash_operation_time.mass_erase[measure_counts] = TIMER_CNT(TIMER_USE) +
65536*TIMER_CNT(TIMER2);
#else
            /* set gpio pin to low level */
            gpio_bit_reset(GPIOC, GPIO_PIN_0);
#endif
      }while(++measure_counts < MEASURE_NUMS);
#if TIMER_CNT_MESURE_METHOD
      /* get the average mass erase time */
      {
            uint32_t temp =0;
            for(measure_counts =0; measure_counts < MEASURE_NUMS; measure_counts++)
            {
                  temp += flash_operation_time.mass_erase[measure_counts];
            }
            flash_operation_time.mass_erase[AVERAGE_VALUE_POSITION] = temp /
MEASURE_NUMS;
      }
#endif
#endif
      /* page erase measure */
#if TESE_PAGE_ERASE
measure_counts = 0;
do{
          {
                uint32_t i =0;
                /* page erase, then programme this page with PROGRAMME_DATA */
                fmc_page_erase(PAGE_TO_ERASE1);
                for(i = 0; i < 512; i++){
                      fmc_word_program((ADDRESS_TO_PROGRAME + (i * 4)),
```

```
PROGRAME_DATA);
                }
            }
#if TIMER_CNT_MESURE_METHOD
            /* clear timer count and enable timer */
            timer_disable(TIMER_USE);
            timer_disable(TIMER2);
            TIMER_CNT(TIMER_USE) = 0;
            TIMER_CNT(TIMER2) = 0;
            timer_enable(TIMER_USE);
            timer_enable(TIMER2);
#else
            /* set gpio pin to high level */
            gpio_bit_set(GPIOC, GPIO_PIN_0);
#endif
            /* start page erase */
            fmc_page_erase(PAGE_TO_ERASE1);
#if TIMER_CNT_MESURE_METHOD
            /* get the page erase time */
            flash_operation_time.page_erase[measure_counts] = TIMER_CNT(TIMER_USE) +
65536*TIMER_CNT(TIMER2);
#else
            /* set gpio pin to low level */
            gpio_bit_reset(GPIOC, GPIO_PIN_0);
#endif
    }while(++measure_counts < MEASURE_NUMS);
#if TIMER_CNT_MESURE_METHOD
    /* get the average page erase time */
    {
        uint32_t temp =0;
        for(measure_counts =0; measure_counts < MEASURE_NUMS; measure_counts++)
        {
            temp += flash_operation_time.page_erase[measure_counts];
        }
        flash_operation_time.page_erase[AVERAGE_VALUE_POSITION] = temp /
MEASURE_NUMS;
    }
#endif
#endif
    /* word programme measure */
#if TEST_WORD_PROGRAMME
measure_counts = 0;
do{
```

```
        fmc_page_erase(PAGE_TO_ERASE1);
#if TIMER_CNT_MESURE_METHOD
        /* clear timer count and enable timer */
        timer_disable(TIMER_USE);
        timer_disable(TIMER2);
        TIMER_CNT(TIMER_USE) = 0;
        TIMER_CNT(TIMER2) = 0;
        timer_enable(TIMER_USE);
        timer_enable(TIMER2);
#else
        /* set gpio pin to high level */
        gpio_bit_set(GPIOC, GPIO_PIN_0);
#endif
        /* start word programme */
        fmc_word_program(ADDRESS_TO_PROGRAMME +(4*measure_counts) ,
PROGRAMME_DATA);
#if TIMER_CNT_MESURE_METHOD
        /* get the word programme time */
        flash_operation_time.word_programme[measure_counts] = TIMER_CNT(TIMER_USE)+
65536*TIMER_CNT(TIMER2);
#else
        /* set gpio pin to low level */
        gpio_bit_reset(GPIOC, GPIO_PIN_0);
#endif
    }while(++measure_counts < MEASURE_NUMS);
#if TIMER_CNT_MESURE_METHOD
    /* get the average word programme time */
    {
        uint32_t temp =0;
        for(measure_counts =0; measure_counts < MEASURE_NUMS; measure_counts++)
        {
            temp += flash_operation_time.word_programme[measure_counts];
        }
        flash_operation_time.word_programme[AVERAGE_VALUE_POSITION] = temp /
MEASURE_NUMS;
    }
#endif
#endif

#if TIMER_CNT_MESURE_METHOD
    /* print flash operation time by usart */
    printf("word programme time:%.2f(us)\r\npage erase time:%.2f (us)\r\nmass erase time:%.2f
(us)\r\n",
```

```
                flash_operation_time.word_programme[AVERAGE_VALUE_POSITION]*0.125, \
                flash_operation_time.page_erase[AVERAGE_VALUE_POSITION]*0.125, \
                flash_operation_time.mass_erase[AVERAGE_VALUE_POSITION]*0.125);
#endif
/* infinite loop */
    while(1){

    }
}
```

4. 测试结果

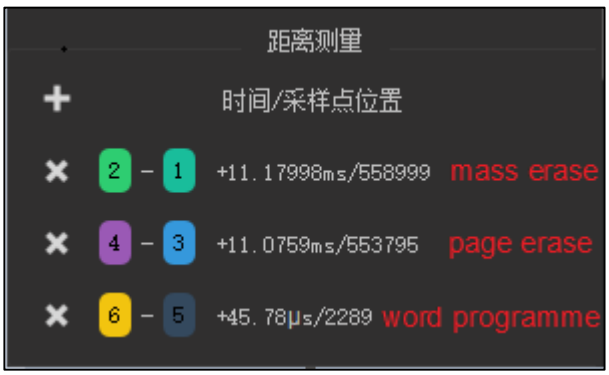
打开宏 TEST_MASS_ERASE、TESE_PAGE_ERASE、TEST_WORD_PROGRAMME、TIMER_CNT_MESURE_METHOD。编译工程，点击调试按钮，点击全速运行。*图 4-1.串口输出 flash 操作时间*结果如下。

图 4-1.串口输出 flash 操作时间

```
word programe time:46.00(us)
page erase time:11072.63(us)
mass erase time:11176.75(us)
```

打开宏 TEST_MASS_ERASE、TESE_PAGE_ERASE、TEST_WORD_PROGRAMME，关闭宏 TIMER_CNT_MESURE_METHOD。编译工程，点击调试按钮，点击全速运行。*图 4-2. 逻辑分析仪输出 flash 操作时间*结果如下。

图 4-2. 逻辑分析仪输出 flash 操作时间



5. 版本历史

表 5-1. 版本历史

版本号.	说明	日期
1.0	首次发布	2021 年 11 月 8 日

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