GigaDevice Semiconductor Inc.

Arm® Cortex®- M3/M4/M33 32-bit MCU

应用笔记

AN027

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1. 简介

ISP（在系统可编程）协议是可编程设备可以编程写入用户代码，而不需要从电路板上取下来，已经编程的器件也可以用 ISP 方式擦除或再编程。常用的 ISP 协议是基于 USART、USB、I2C 等。本文介绍的方法基于串口 ISP 协议。

由于使用 ISP 上位机升级程序需要借助电脑，在实际生产过程中会带来不便。因此实现了一种嵌入式 ISP 主机用于对目标 MCU 的程序进行升级。嵌入式主机根据 ISP 协议通过串口与 BootLoader 进行通信，从而实现对目标 MCU 程序的升级。

注意：具体协议可参考 ISP 串口协议说明。

2. 硬件连接

将 GD32F303ZET6 作为嵌入式主机，GD32F407VGT6 为目标 MCU，本文介绍嵌入式主机如何通过串口 ISP 对目标 MCU 进行程序升级。

GD32F4xx 系列芯片提供了三种引导源，可以通过 BOOT0 和 BOOT1 引脚来进行选择，详细说明见*表 2-1. 引导模式*。该两个引脚的电平状态会在复位后的第四个 CK_SYS（系统时钟）的上升沿进行锁存。用户可自行选择所需要的引导源，通过设置上电复位和系统复位后的 BOOT0 和 BOOT1 的引脚电平。一旦这两个引脚电平被采样，它们可以被释放并用于其他用途。

表 2-1. 引导模式

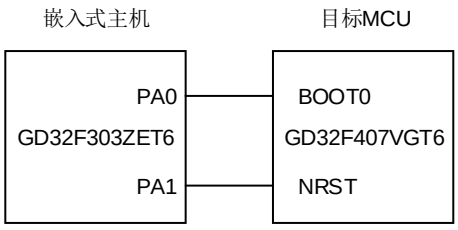
引导源选择	启动模式选择引脚	
	BOOT1	BOOT0
主 FLASH 存储器	x	0
系统存储器	0	1
片上 SRAM	1	1

将嵌入式主机 BOOT1 接地，并选两个 GPIO 引脚分别用于控制目标板 BOOT0 及 NRST 引脚电平。BOOT0 及 NRST 引脚电平不同时功能如*表 2-2. BOOT0 及 NRST 引脚功能*所示。例如 PA0 控制 BOOT0，PA1 控制 NRST，如*图 2-1. 硬件连接*所示。

表 2-2. BOOT0 及 NRST 引脚功能

功能	引脚电平	说明
BOOT0	高	从 BootLoader 启动
	低	从 flash 启动
NRST	高	无影响
	低	复位

图 2-1. 硬件连接



3. 串口升级程序

3.1. 串口初始化

串口初始化如*表 3-1. 串口初始化*所示。

表 3-1. 串口初始化

```
/*!
    \brief        configure COM port
    \param[in]    com: COM on the board
      \arg          EVAL_COM1: COM1 on the board
      \arg          EVAL_COM2: COM2 on the board
    \param[out] none
    \retval       none
*/
void gd_eval_com_init(uint32_t com)
{
    uint32_t com_id = 0U;
    if(EVAL_COM1 == com){
        com_id = 0U;
    }else if(EVAL_COM2 == com){
        com_id = 1U;
    }
    /* enable GPIO clock */
    rcu_periph_clock_enable(COM_GPIO_CLK[com_id]);
    /* enable USART clock */
    rcu_periph_clock_enable(COM_CLK[com_id]);
    /* connect port to USARTx_Tx */
    gpio_init(COM_GPIO_PORT[com_id],    GPIO_MODE_AF_PP,    GPIO_OSPEED_50MHZ,
COM_TX_PIN[com_id]);
    /* connect port to USARTx_Rx */
    gpio_init(COM_GPIO_PORT[com_id], GPIO_MODE_IN_FLOATING, GPIO_OSPEED_50MHZ,
COM_RX_PIN[com_id]);
    /* USART configure */
    usart_deinit(com);
    usart_parity_config(com, USART_PM_EVEN);
    usart_word_length_set(com, USART_WL_9BIT);
    usart_baudrate_set(com, 57600U);
    usart_receive_config(com, USART_RECEIVE_ENABLE);
    usart_transmit_config(com, USART_TRANSMIT_ENABLE);
    usart_enable(com);
}
```

```
/* USART interrupt configuration */
nvic_irq_enable(USART0_IRQn, 0, 0);
/* enable the USART RBNE interrupt */
usart_interrupt_enable(USART0, USART_INT_RBNE);
```

3.2. 控制引脚配置

将 GD32F303ZET6 开发板的 PA0 和 PA1 分别连接 GD32F407VGT6 开发板的 BOOT0 和 NRST 引脚。

PA0 和 PA1 引脚配置如*表 3-2. PA0 和 PA1 引脚配置*所示。

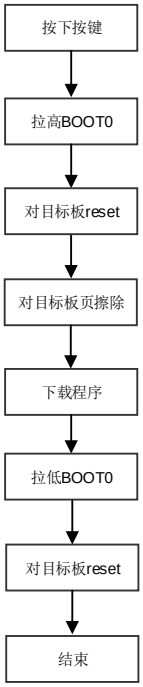
表 3-2. PA0 和 PA1 引脚配置

```
/* enable the clock */
rcu_periph_clock_enable(RCU_GPIOA);
/* configure BOOT0_CTL port */
gpio_init(GPIOA, GPIO_MODE_OUT_PP, GPIO_OSPEED_50MHZ, GPIO_PIN_0);
gpio_bit_reset(GPIOA, GPIO_PIN_0);
/* configure NRST_CTL port */
gpio_init(GPIOA, GPIO_MODE_OUT_PP, GPIO_OSPEED_50MHZ, GPIO_PIN_1);
gpio_bit_set(GPIOA, GPIO_PIN_1);
```

3.3. 升级程序

待下载 bin2 在下载之前存储到嵌入式主机 0x08004000 地址处，格式为 bin2=bin 文件大小（4 字节）+bin1 文件。可根据需要将 bin 文件存储在其他位置，bin 格式也可以自由设置。嵌入式主机对目标 MCU 进行程序升级流程图如*图 3-1. 主程序流程图*所示。

图 3-1. 主程序流程图



具体操作步骤如下：

1、 将目标 MCU 的 BOOT0 拉高。

表 3-3. BOOT0 拉高

```
void boot0_high(void)
{
    gpio_bit_set(GPIOA, GPIO_PIN_0);
    /* pull up the target reset pin */
    gpio_bit_reset(GPIOA, GPIO_PIN_1);
    gpio_bit_set(GPIOA, GPIO_PIN_1);
    /* wait for the target to reset */
    delay_1ms(300);
}
```

2、 发送握手命令，当嵌入式主机收到 0x79，说明握手成功。

表 3-4. 握手命令

```
ErrStatus usart_handshake(void)
{
    uint16_t count = 0;
    while(count++<10){
        usart_data_transmit(USART0, 0x7F);
        while(RESET == usart_flag_get(USART0, USART_FLAG_TC));
        while((ERROR == ack_flag) && (timeout--)){
        }
        if(0 != timeout){
```

```
                ack_flag = ERROR;
                return SUCCESS;
            }
        }
        return ERROR;
}
```

3、 发送页擦除命令。

首先根据 GD32F4xx flash 结构以及 bin 文件的大小索引需要擦除的扇区。

表 3-5. 获取需要擦除的页数

```
static uint32_t f4_get_sector_number(uint32_t bin_size)
{
    uint32_t sector_size[32] = {16, 16, 16, 16, 64, 128, 128, 128, 128, 128, 128, 128,
                                16, 16, 16, 16, 64, 128, 128, 128, 128, 128, 128, 128,
                                256, 256, 256, 256, 256, 256, 256};
    uint32_t i,j;
    uint32_t sector_number = 0;
    uint32_t sector_address;
    sector_address = 0x08000000 + bin_size;
    for(i=0; i<31; i++){
        uint32_t start_address = 0x08000000;
        uint32_t end_address = 0x08000000;
        for(j=0; j<=i; j++){
            start_address += sector_size[j] * 1024;
            end_address += sector_size[j] * 1024;
        }
        start_address -= sector_size[i] * 1024;
        end_address -= 1;
        if(sector_address>=start_address && sector_address<=end_address){
            sector_number = i;
            break;
        }
    }
    return sector_number;
}
```

执行页擦除命令。

表 3-6. 擦除命令

```
ErrStatus usart_send_erase_command(void)
{
    uint32_t bin_size;
    uint16_t sector_number = 0;
    uint32_t i, temp;
```

```
    /* extend erase command */
    buffer_cmd[0] = 0x44;
    buffer_cmd[1] = 0xFF - buffer_cmd[0];
    /* get the bin size */
    bin_size = *(uint32_t *)(0x8004000);
    bin_size = bin_size;
    sector_number = f4_get_sector_number(bin_size);

    usart_buffer_send(buffer_cmd, 2);
    if(SUCCESS != wait_ack()){
        return ERROR;
    }

    buffer_cmd[0] = (sector_number>>8) & 0xff;
    buffer_cmd[1] = sector_number & 0xff;

    for(i=0; i<sector_number+1; i++){
        temp = 2+2*i;
        buffer_cmd[temp] = (i>>8) & 0xff;
        buffer_cmd[temp+1] = i & 0xff;
    }

    buffer_cmd[temp+2] = data_xor(buffer_cmd, temp+2);
    usart_buffer_send(buffer_cmd, temp+3);

    if(SUCCESS != wait_ack()){
        return ERROR;
    }
    return SUCCESS;
}
```

4、 发送编程命令。

bin 文件小于等于 252 字节：

表 3-7. 编程命令（小于等于 252 字节）

```
/*!
    \brief        send the program command
    \param[in]    pro_addr: the address of the target to be programmed
    \param[in]    bin_addr: the address where stored the bin file
    \param[in]    pro_size: the size to be programmed
    \param[out] none
    \retval       ErrStatus
*/
ErrStatus usart_send_program_command(uint32_t pro_addr, uint32_t bin_addr, uint32_t pro_size)
```

```
{
    uint8_t i;

    buffer_cmd[0] = USART_CMD_PROGRAM;
    buffer_cmd[1] = 0xFF - buffer_cmd[0];

    usart_buffer_send(buffer_cmd, 2);

    if(SUCCESS != wait_ack()){
        return ERROR;
    }
    buffer_cmd[0] = (uint8_t)((pro_addr >> 24) & 0xff);
    buffer_cmd[1] = (uint8_t)((pro_addr >> 16) & 0xff);
    buffer_cmd[2] = (uint8_t)((pro_addr >> 8) & 0xff);
    buffer_cmd[3] = (uint8_t)(pro_addr & 0xff);
    buffer_cmd[4] = data_xor(buffer_cmd, 4);

    usart_buffer_send(buffer_cmd, 5);
    if(SUCCESS != wait_ack()){
        return ERROR;
    }
    memset(buffer_cmd, 0, sizeof(buffer_cmd));
    buffer_cmd[0] = pro_size-1;
    for(i=0; i<pro_size; i=i+4){
        *((uint32_t *)&buffer_cmd[1+i]) = *(uint32_t *)(bin_addr+4+i);
    }
    buffer_cmd[pro_size + 1] = data_xor(buffer_cmd, pro_size + 1);

    usart_buffer_send(buffer_cmd, pro_size + 2);
    if(SUCCESS != wait_ack()){
        return ERROR;
    }
    memset(buffer_cmd, 0, sizeof(buffer_cmd));
    return SUCCESS;
}
```

由于 BootLoader 存储空间有限，当 bin 文件大于 252 字节时，需要对 bin 文件进行拆包。

表 3-8. 编程命令（大于 252 字节）

```
/*!
    \brief          send the program command
    \param[in]    pro_addr: the address of the target to be programmed
    \param[in]    bin_addr: the address where stored the bin file
    \param[out] none
```

```
    \retval       ErrStatus
*/
ErrStatus usart_program_bin(uint32_t pro_addr, uint32_t bin_addr)
{
    uint32_t bin_size;
    uint32_t i;
    uint32_t pack_num, pack_size, res_size;
    /* 4 bytes aligned */
    pack_size = 252;

    bin_size = (*(uint32_t *)(bin_addr));
    pack_num = bin_size/pack_size;
    res_size = bin_size % pack_size;
    /* Unpacking the bin and then program to the flash of the target MCU */
    for(i=0; i<pack_num; i++){
        usart_send_program_command(pro_addr + i*pack_size, bin_addr + i*pack_size,
pack_size);
    }
    if(0 != res_size){
        usart_send_program_command(pro_addr + pack_num*pack_size, bin_addr +
pack_num*pack_size, res_size);
    }
    return SUCCESS;
}
```

5、 将目标 MCU 的 BOOT0 拉低，并对其进行复位。

表 3-9. BOOT0 拉低

```
void boot0_low(void)
{
    gpio_bit_reset(GPIOA, GPIO_PIN_0);
    /* pull down the target reset pin */
    gpio_bit_reset(GPIOA, GPIO_PIN_1);
    gpio_bit_set(GPIOA, GPIO_PIN_1);
    /* wait for the target to reset */
    delay_1ms(300);
}
```

至此，GD32F407VGT6 中程序已经可以正常运行。

4. 版本历史

表 4-1. 版本历史

版本号.	说明	日期
1.0	首次发布	2021 年 12 月 14 日

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