SPC1168 I2C 使用指南

概述

I2C 总线用于连接微控制器及其外围设备，具有接口线少、控制简单、通信速率较高等优点，广泛应用于微控制器、LCD 驱动器、触摸屏、存储器、键盘等接口。

注意：	本文档主要以 SPC1168 为例进行介绍。

目录

图片列表

版本历史

版本	日期	作者	状态	变更
A/0	2023-06-15	CanChai	Outdated	首次发布。
C/0	2024-03-26	Jiali Zhou	Released	修改排版格式。

术语或缩写

术语或缩写	描述
/	/

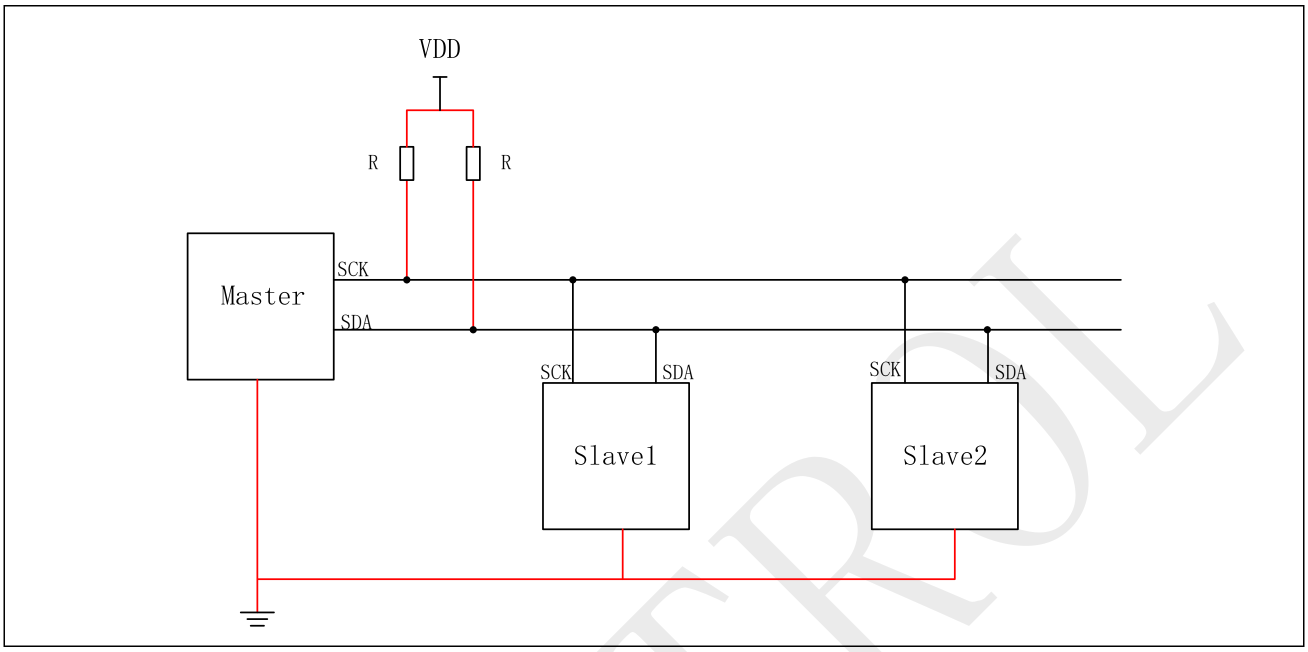
1 I2C 特性

SPC1168 内建一个 I2C 单元，其 I2C 单元有以下特点：

- 支持三种速度模式（标准速度模式 100kb/s、快速模式 400kb/s、高速模式 2Mb/s）；
- 时钟同步；
- 内建宽度 32byte 深度 16 的发送和接收 FIFO；
- 支持 7 位和 10 位地址寻址；
- 支持 7 位和 10 位地址模式下的混合格式传输；

2 I2C 使用注意事项

图 2-1：I2C 连接示意图



I2C 接口采用开漏输出的方式输出，导致无法输出高电平，因此必须上拉电阻实现输出高电平的能力如图 2-1 所示。如果上拉了电阻，但在实际应用当中发现时钟的频率低于理论的时钟频率以及时钟的上升比较迟缓时，可以通过减小上拉电阻来提高驱动能力，适当改善时钟波形来提高频率。但上拉电阻并不是越小越好，对于上拉电阻的选择也是有一定的范围。可以产品实际情况计算出可以上拉电阻的最小值 R_{min} 和最大值 R_{max}。

根据 Spintrol 对应产品数据手册 I2C 的 IO 特性，I2C 的引脚的达到最小高电平阈值为 V_{DVDD5} - 0.5V，达到最大低电平的阈值为 0.5V，某时刻电压的计算表达式可以表示为：

$$V_t = V_{DVDD5}\left(1 - e^{-\frac{t}{RC}}\right)$$

其中 t 为自上电开始至达到 V_t 所需的时间，RC 是时间常数。以 V_{DVDD5}=5V 为例（以实际测量为准）计算到达最大低电平阈值时间 t_1 和到达最小高电平阈值时间 t_2。

到达最大低电平阈值时间 t_1 为：

$$V_{t_1} = 0.5 = V_{DVDD5}\left(1 - e^{-\frac{t_1}{RC}}\right)$$

则

$$t_1 = 0.1053605 * RC$$

到达最小高电平阈值时间 t_2 为：

$$V_{t_2} = V_{DVDD5} - 0.5 = V_{DVDD5}\left(1 - e^{-\frac{t_2}{RC}}\right)$$

则

$$t_2 = 2.3025850 * RC$$

由V_{t_1}到达V_{t_2}时间T为：

$$T = t_2 - t_1 = 2.1972245 * RC$$

由于 IIC 设计指标规定了 SCL/SDA 上升时间 t_r 最大值，预估总线电容 C_b。标准模式 t_r 时间为 1000ns，快速模式 t_r 时间为 300ns，快速 plus 模式 t_r 时间为 120ns。标准模式 C_b 电容为 400pF，快速模式 C_b 电容为 400pF，快速模式 plus C_b 电容为 550pF。

所以可以由以上表达式推算出 R_{max} 为：

$$R_{max} = \frac{t_r}{2.1972245 * C_b}$$

且 IIC 设计指标规定上拉电阻最小值可表示为：

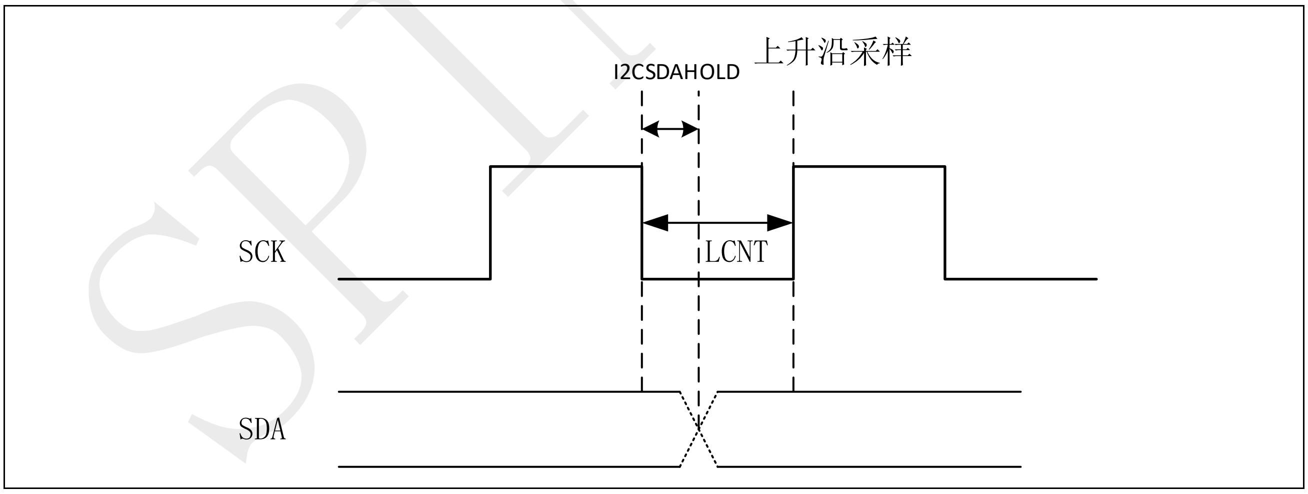
$$R_{min} = \frac{V_{DVDD5} - V_{OL}}{I_{OL}}$$

其中 V_{OL} 为最大低电平阈值 0.5，I_{OL} 为引脚的额定最小电流（根据设置引脚的输出强度不同而不同，当 STRENGTH 为 1 时，最小电流为 26.1mA）。

需要注意的是，I2C 在通信的过程不仅与上拉电阻的选择有关，还与 I2C 的通信的距离有关。I2C 总线适用于短距离通信，一般通信距离在 20cm 左右才能保证 I2C 的信号质量。为确保主从设备通信的信号质量，两设备之间需要共地用来确保两设备一致的基准电平，否则在通信过程中容易产生毛刺干扰通信数据。

在 Spintrol 的 I2C 控制器中提供了 I2CSDAHOLD 寄存器配置，当 I2C 设备进行发送时，可以通过设置 I2CSDAHOLD 的值调节数据发送的时间；当 I2C 设备进行接收时，设置 I2CSDAHOLD 时间无效。根据 IIC 设计指标，在标准模式下 I2CSDAHOLD 时间不得低于 50us，快速模式下 I2CSDAHOLD 时间不得低于 0.6us，高速模式下 I2CSDAHOLD 时间不得低于 160ns，I2CSDAHOLD 时间不得超过实际 I2C 时钟的 LCNT 低电平时间，如图 2-2 所示。

图 2-2：I2CSDAHOLD 数据保持时间配置



3 I2C 实例

I2C 总线传输具有三种传输模式：Bulk 传输模式、Poll 传输模式、中断传输模式，数据传输格式如图 3-1 所示。

START 信号：时钟为高电平时数据线由高变低。

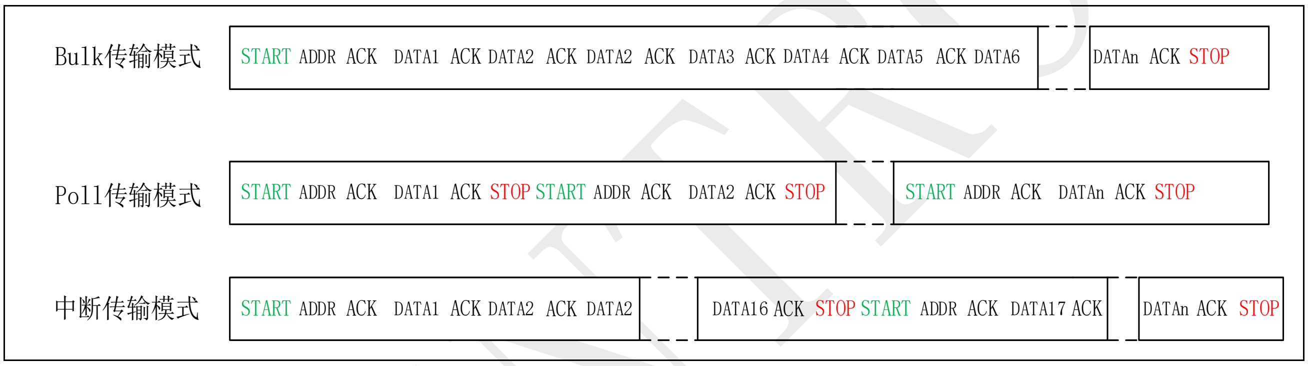
STOP 信号：时钟为高电平时数据线有低变高。

Bulk 传输模式：所有数据一次性传输，只发一次 START 信号、STOP 信号、从设备地址。

Poll 传输模式：每发一个数据，会发一次 START 信号、STOP 信号、从设备地址。

中断传输模式：每发发送 FIFO 深度的数据，会发送一次 START 信号、STOP 信号、从设备地址。

图 3-1：三种模式数据传输格式


Bulk传输模式
START ADDR ACK DATA1 ACK DATA2 ACK DATA2 ACK DATA3 ACK DATA4 ACK DATA5 ACK DATA6
DATAn ACK STOP
Poll传输模式
START ADDR ACK DATA1 ACK STOP START ADDR ACK DATA2 ACK STOP
START ADDR ACK DATAn ACK STOP
中断传输模式
START ADDR ACK DATA1 ACK DATA2 ACK DATA2
DATA16 ACK STOP START ADDR ACK DATA17 ACK
DATAn ACK STOP

3.1 Bulk 传输模式

3.1.1 主机发送与接收

本示例中演示 I2C 作为主机使用 Bulk 传输模式进行发送数据和接收数据。当示例的 MASTER_TRANSMIT 宏为 1 时进行发送数据，当 MASTER_TRANSMIT 宏为 0 时进行接收数据，其配置流程如下：

- 初始化系统时钟，UART 调试口以及初始化 I2C 的 GPIO；
- 调用 I2C_EnableStopDetectInt()函数使能探测 STOP 信号中断，通过判断是否进入中断来判断通信是否完成；
- 调用 I2C_MasterInit()函数初始化 I2C 为 master 设备，并初始化速度为 400K；
- 调用 I2C_MasterBulkWrite()或者 I2C_MasterBulkRead()函数进行发送或者接收数据；

Bulk 传输（主机发送与接收）

```
/* I2C GPIO Config*/
#define             SDA_GPIO                GPIO_38
#define             SCL_GPIO                GPIO_39
#define             SDA_GPIO_FUNC            GPIO38_I2C_SDA
#define             SCL_GPIO_FUNC            GPIO39_I2C_SCL

#define             DEBUG_INFO               1             /* the controlling flag of
printf info*/
#define             MASTER_TRANSMIT           1             /* 1: master transmit 0:
master receive */

#define             T_BUFFER_SIZE            128
#define             I2C_SPEED               400000
#define             I2C_Slave_ADDR           0x9            /* IIC Slave ADDR */

uint32_t            gu32BuffSize             = T_BUFFER_SIZE;
uint8_t             gau8TxBuf[T_BUFFER_SIZE];
uint8_t             gau8RxBuf[T_BUFFER_SIZE];
uint32_t            gu32_cnt_i2c_stop_isr;
ErrorStatus          estatus;

static ErrorStatus Check_Receive_Data(void)
{
    int i;
    uint8_t u8Data = 0;

    /*To check the datum sent and received are the same*/
    for(i = 0; i < gu32BuffSize; i++)
    {
        if (gau8RxBuf[i] != u8Data)
        {
            printf("[Error]@%4d: TX(0x%02X) != RX(0x%02X)\n", __LINE__, u8Data,
gau8RxBuf[i] );

            return ERROR;
        }
        else
        {
            printf("%3d: TX(0x%02X) == RX(0x%02X)\n", i, u8Data, gau8RxBuf[i] );
        }

        u8Data++;
    }

    return SUCCESS;
}

void Master_Bulk_TxRX_data(void)
{
    int i;
    uint8_t u8Data = 0;
    uint32_t u32IsrCnt = 0;                 /* Interrupt Check variable */

    if (MASTER_TRANSMIT)
    {
        /* Generate random datum to transmit */
        for (i = 0; i < gu32BuffSize; i++)
        {
            gau8TxBuf[i] = u8Data++;

            printf("gau8TxBuf[%d] = 0x%x\n", i, gau8TxBuf[i]);
        }

        printf("Master Tx data...\n");
        I2C_MasterBulkWrite(I2C, I2C_ADDR_7BIT, I2C_Slave_ADDR, gau8TxBuf,
gu32BuffSize);
    }
    else
    {
        printf("Master Rx data...\n");
        /*Read the data had sent to the slave back and put them in 'gau8RxBuf'*/
        I2C_MasterBulkRead(I2C, I2C_ADDR_7BIT, I2C_Slave_ADDR, gau8RxBuf,
gu32BuffSize);

        /*To check the datum sent and received are the same*/
        estatus = Check_Receive_Data();
        if(estatus == ERROR)
        {
            return;
        }
    }

    /*
     * In the interface of 'I2C_MasterBulkWriteData()', master will wait for the
Tx FIFO empty
     * after this bulk, in other words, the master will sent a 'STOP' CMD to the
IIC, and
     * then sent a 'RESTART' at the next bulk. we can count the bulk we has sent
to get
     * the INT count had entered.
     */
    u32IsrCnt += 1;

    /* Wait for I2C INT done */
    Delay_Us(300);

    /*
     * Check interrupt counter, if the INT count is not equal the bulk we has
sent, there
     * must be something wrong had happened.
     */
    if (gu32_cnt_i2c_stop_isr != u32IsrCnt)
    {
        printf("[Error]@%4d: I2C ISR counter not right. expect %d, but is %d",
__LINE__,
               u32IsrCnt, gu32_cnt_i2c_stop_isr);
    }
    else
    {
        printf("Success\n");
    }
}

int main()
{
    FLASH_WALLOW();

    FLASH_SetTiming(200000000);
    /* Disable flash write access after flash operation had done */
    FLASH_WDIS();

    CLOCK_InitWithRCO(CLOCK_HCLK_200MHZ);

    Delay_Init();
    /*
     * Init the UART
     *
     * 1.Set the GPIO34/35 as UART FUNC
     *
     * 2.Enable the UART CLK
     *
     * 3.Set the rest para
     */
    GPIO_SetPinChannel(GPIO_34, GPIO34_UART_TXD);
    GPIO_SetPinChannel(GPIO_35, GPIO35_UART_RXD);
    CLOCK_EnableModule(UART_MODULE);
    UART_Init(UART, 38400);

    /* Config GPIO as I2C function */
    GPIO_SetPinChannel(SDA_GPIO, SDA_GPIO_FUNC);
    GPIO_SetPinChannel(SCL_GPIO, SCL_GPIO_FUNC);

    /*
     * Set Output Strength as 20mA, in case of many more
     * slaves are linking to the master.
     */
    GPIO_SetOutStrength(SDA_GPIO, GPIO_OUT_STRENGTH_20MA);
    GPIO_SetOutStrength(SCL_GPIO, GPIO_OUT_STRENGTH_20MA);

    /*
    * Rx FIFO threshold set as 0 means letting MCU process data once
    * FIFO has one entry data.
    */
    I2C_SetTxFIFOThreshold(I2C, 0xF);
    I2C_SetRxFIFOThreshold(I2C, 0x0);


    /* Disable All INT */
    I2C_DisableAllInt(I2C);

    /* Enable the INT of detecting the STOP of I2C */
    I2C_EnableStopDetectInt(I2C);

    /* Clear All INT */
    I2C_ClearInt(I2C, I2C_INT_ALL);

    /* Init I2C as Master */
    estatus = I2C_MasterInit(I2C, I2C_SPEED);
    if (estatus == ERROR)
    {
        return 0;
    }

    /* Enable CM4 INT Request */
    NVIC_EnableIRQ(I2C_IRQn);

    /* Master start to transmit and receive data */
    Master_Bulk_TxRX_data();

    while (1)
    {

    }
}

void I2C_IRQHandler(void)
```

```
{
    if (I2C_GetStopDetectIntRawFlag(I2C))
    {
        gu32_cnt_i2c_stop_isr ++ ;

        I2C_ClearInt(I2C, I2C_INT_STOP_DET);
    }
    else
    {
        printf("[%s Error] Stop detect interrupt error\n", __func__);
    }
}
```

3.1.2 从机发送与接收

本示例中演示 I2C 作为从机使用 Bulk 传输模式进行发送数据和接收数据。当示例的 SLAVE_TRANSMIT 宏为 1 时进行发送数据，当 SLAVE_TRANSMIT 宏为 0 时进行接收数据，其配置流程如下：

- 初始化系统时钟，UART 调试口以及初始化 I2C 的 GPIO；
- 调用 I2C_EnableStopDetectInt()函数使能探测 STOP 信号中断，通过判断是否进入中断来判断通信是否完成；
- 调用 I2C_SlaveInit()函数初始化 I2C 为 slave 设备，并初始化速度为 400K；
- 调用 I2C_SlaveBulkWrite()或者 I2C_SlaveBulkRead()函数进行发送或者接收数据；

Bulk 传输(从机发送与接收)

```
#define                     SDA_GPIO                    GPIO_38
#define                     SCL_GPIO                    GPIO_39
#define                     SDA_GPIO_FUNC                GPIO38_I2C_SDA
#define                     SCL_GPIO_FUNC                GPIO39_I2C_SCL

#define                     DEBUG_INFO                  1                         /* The
controlling flag of printf info*/
#define                     SLAVE_TRANSMIT               0                         /* 1:
slave transmit 0: slave receive */

#define                     T_BUFFER_SIZE                128
#define                     I2C_SPEED                   400000
#define                     I2C_Slave_ADDR               0x9                       /* IIC
Slave ADDR */

uint32_t                    gu32BuffSize                 = T_BUFFER_SIZE;
uint8_t                     gau8TxBuf[T_BUFFER_SIZE];
uint8_t                     gau8RxBuf[T_BUFFER_SIZE];
ErrorStatus                  estatus;

uint32_t gu32_cnt_i2c_stop_isr;


static ErrorStatus Check_Receive_Data(void)
{
    int i;
    uint8_t u8Data = 0;

    /*To check the datum sent and received are the same*/
    for(i = 0; i < gu32BuffSize; i++)
    {
        if (gau8RxBuf[i] != u8Data)
        {
            printf("[Error]@%4d: TX(0x%02X) != RX(0x%02X)\n", __LINE__, u8Data,
gau8RxBuf[i] );

            return ERROR;
        }
        else
        {
            printf("%3d: TX(0x%02X) == RX(0x%02X)\n", i, u8Data, gau8RxBuf[i] );
        }

        u8Data++;
    }

    return SUCCESS;
}


void Slave_TxRX_data(I2C_REGS *I2Cx)
{
    int i;
    uint8_t u8Data = 0;
    uint32_t u32IsrCnt = 0;                              /*Interrupt Check
variable*/

    if (SLAVE_TRANSMIT)
    {
        /* Generate random datum to transmit */
        for(i=0; i < gu32BuffSize; i++)
        {
            gau8TxBuf[i] = u8Data++;

            printf("gau8TxBuf[%d] = 0x%x\n", i, gau8TxBuf[i]);
        }

        printf("Slave Tx data...\n");
        I2C_SlaveBulkWrite(I2C, gau8TxBuf, gu32BuffSize);
    }
    else
    {
        printf("Slave Rx data...\n");

        /*Read the data had sent to the slave back and put them in 'gau8RxBuf'*/
        I2C_SlaveBulkRead(I2C, gau8RxBuf, gu32BuffSize);

        /*To check the datum sent and received are the same*/
        estatus = Check_Receive_Data();
        if(estatus == ERROR)
        {
            return;
        }
    }

    /*
     * The master will sent a 'STOP' CMD to the IIC, and then sent a 'RESTART'
at the
     * next bulk. we can count the bulk we has sent to get the INT count had
entered.
     */
    u32IsrCnt += 1;
    /* Wait for I2C INT done */
    Delay_Us(300);


    /*
     * Check interrupt counter, if the INT count is not equal the bulk we has
sent, there
     * must be something wrong had happened.
     */
    if (gu32_cnt_i2c_stop_isr != u32IsrCnt)
    {
        printf("[Error]@%4d: I2C ISR counter not right. expect %d, but is %d",
__LINE__,
                u32IsrCnt, gu32_cnt_i2c_stop_isr);
    }
    else
    {
        printf("Success\n");
    }
}

int main()
{
    FLASH_WALLOW();

    FLASH_SetTiming(200000000);
    /* Disable flash write access after flash operation had done */
    FLASH_WDIS();

    CLOCK_InitWithRCO(CLOCK_HCLK_200MHZ);

    Delay_Init();

    /*
     * Init the UART
     *
     * 1.Set the GPIO34/35 as UART FUNC
     *
     * 2.Enable the UART CLK
     *
     * 3.Set the rest para
     */
    GPIO_SetPinChannel(GPIO_34, GPIO34_UART_TXD);
    GPIO_SetPinChannel(GPIO_35, GPIO35_UART_RXD);
    CLOCK_EnableModule(UART_MODULE);
    UART_Init(UART, 38400);

    /* Config GPIO as I2C function */
    GPIO_SetPinChannel(SDA_GPIO, SDA_GPIO_FUNC);
    GPIO_SetPinChannel(SCL_GPIO, SCL_GPIO_FUNC);

    /*
     * Set Output Strength as 20mA, in case of many more
     * slaves are linking to the master.
     */
    GPIO_SetOutStrength(SDA_GPIO, GPIO_OUT_STRENGTH_20MA);
    GPIO_SetOutStrength(SCL_GPIO, GPIO_OUT_STRENGTH_20MA);

    /*
    * Rx FIFO threshold set as 0 means letting MCU process data once
    * FIFO has one entry data.
    */
    I2C_SetTxFIFOThreshold(I2C, 0xF);
    I2C_SetRxFIFOThreshold(I2C, 0x0);

    /* Disable All INT */
    I2C_DisableAllInt(I2C);

    /* Enable the INT of detecting the STOP of I2C */
    I2C_EnableStopDetectInt(I2C);

    /* Clear All INT */
    I2C_ClearInt(I2C, I2C_INT_ALL);

    /* Init I2C as Slave and set the speed as 400K */
    estatus = I2C_SlaveInit(I2C, I2C_ADDR_7BIT, I2C_Slave_ADDR, I2C_SPEED);
    if (estatus == ERROR)
    {
        printf("[IIC slave init FAIL] I2C clock is not fast enough to support
the speed\n");
        return 0;
    }

    /* Enable CM4 INT Request */
    NVIC_EnableIRQ(I2C_IRQn);

    /* Master start to transmit and receive data */
    Slave_TxRX_data(I2C);

    while (1)
    {

    }
}

void I2C_IRQHandler(void)
{
    if (I2C_GetStopDetectIntRawFlag(I2C))
    {
        gu32_cnt_i2c_stop_isr ++ ;

        I2C_ClearInt(I2C, I2C_INT_STOP_DET);
    }
    else
    {
        printf("[%s Error] Stop detect interrupt error\n", __func__);
    }
}
```

3.2 Poll 传输模式

3.2.1 主机发送与接收

本示例中演示 I2C 作为从机使用 Poll 传输模式进行发送数据和接收数据。当示例的 MASTER_TRANSMIT 宏为 1 时进行发送数据，当 MASTER_TRANSMIT 宏为 0 时进行接收数据，其配置流程如下：

- 初始化系统时钟，UART 调试口以及初始化 I2C 的 GPIO；
- 调用 I2C_EnableStopDetectInt()函数使能探测 STOP 信号中断，通过判断是否进入中断来判断通信是否完成；
- 调用 I2C_MasterInit ()函数初始化 I2C 为 master 设备，并初始化速度为 400K；
- 调用 I2C_MasterWrite()或者 I2C_MasterRead()函数进行发送或者接收数据；

Polling 模式（主机发送与接收）

```
/* I2C GPIO Config*/
#define                         SDA_GPIO                GPIO_38
#define                         SCL_GPIO                GPIO_39
#define                         SDA_GPIO_FUNC            GPIO38_I2C_SDA
#define                         SCL_GPIO_FUNC            GPIO39_I2C_SCL

#define                         DEBUG_INFO                1
#define                         MASTER_TRANSMIT            1                      /* 1:
master transmit 0: master receive */

#define                         T_BUFFER_SIZE            128
#define                         I2C_Slave_ADDR           0x9                    /* IIC
Slave ADDR */
#define                         I2C_SPEED               400000

uint32_t                         gu32BuffSize             = T_BUFFER_SIZE;
uint32_t                         gu32_cnt_i2c_stop_isr;
uint8_t                          gau8TxBuf[T_BUFFER_SIZE];
uint8_t                          gau8RxBuf[T_BUFFER_SIZE];
ErrorStatus                       estatus;

static ErrorStatus Check_Receive_Data(void)
{
    int i;
    uint8_t u8Data = 0;

    /*To check the datum sent and received are the same*/
    for(i = 0; i < gu32BuffSize; i++)
    {
        if (gau8RxBuf[i] != u8Data)
        {
            printf("[Error]@%4d: TX(0x%02X) != RX(0x%02X)\n", __LINE__, u8Data,
gau8RxBuf[i] );

            return ERROR;
        }
        else
        {
            printf("%3d: TX(0x%02X) == RX(0x%02X)\n", i, u8Data, gau8RxBuf[i] );
        }
        u8Data++;
    }

    return SUCCESS;
}


void Master_TxRX_data(void)
{
    int i;
    uint8_t u8Data = 0;
    uint32_t u32IsrCnt = 0;                                /*Interrupt Check
variable*/

    if (MASTER_TRANSMIT)
    {
        /* Generate random datum to transmit */
        for(i=0; i < gu32BuffSize; i++)
        {
            gau8TxBuf[i] = u8Data++;

            printf("gau8TxBuf[%d] = 0x%x\n", i, gau8TxBuf[i]);
        }

        printf("Master Tx data...\n");
        I2C_MasterWrite(I2C, I2C_ADDR_7BIT, I2C_Slave_ADDR, gau8TxBuf,
gu32BuffSize);
    }
    else
    {
        printf("Master Rx data...\n");

        /* Read the data had sent to the slave back and put them in 'gau8RxBuf'
*/
        I2C_MasterRead(I2C, I2C_ADDR_7BIT, I2C_Slave_ADDR, gau8RxBuf,
gu32BuffSize);

        /*To check the datum sent and received are the same*/
        estatus = Check_Receive_Data();
        if(estatus == ERROR)
        {
            return;
        }
    }

    /*
     * In the interface of 'I2C_MasterWriteData()', master will wait for the Tx
FIFO empty
     * after every byte, in other words, the master will sent a 'STOP' CMD to
the IIC, and
     * then sent a 'RESTART' at the next byte. we can count the bytes we has
sent to get
     * the INT count had entered.
     */
    u32IsrCnt += gu32BuffSize;

    /* Wait for I2C INT done */
    Delay_Us(300);

    /*
     * Check interrupt counter, if the INT count is not equal the bytes we has
sent, there
     * must be something wrong had happened.
     */
    if (gu32_cnt_i2c_stop_isr != u32IsrCnt)
    {
        printf("[Error]@%4d: I2C ISR counter not right. expect %d, but is %d",
__LINE__,
                u32IsrCnt, gu32_cnt_i2c_stop_isr);
    }
    else
    {
        printf("Success\n");
    }

}

int main()
{
    FLASH_WALLOW();

    FLASH_SetTiming(200000000);
    /* Disable flash write access after flash operation had done */
    FLASH_WDIS();

    CLOCK_InitWithRCO(CLOCK_HCLK_200MHZ);

    Delay_Init();

    /*
     * Init the UART
     *
     * 1.Set the GPIO34/35 as UART FUNC
     *
     * 2.Enable the UART CLK
     *
     * 3.Set the rest para
     */
    GPIO_SetPinChannel(GPIO_34, GPIO34_UART_TXD);
    GPIO_SetPinChannel(GPIO_35, GPIO35_UART_RXD);
    CLOCK_EnableModule(UART_MODULE);
    UART_Init(UART, 38400);

    /* Config GPIO as I2C function */
    GPIO_SetPinChannel(SDA_GPIO, SDA_GPIO_FUNC);
    GPIO_SetPinChannel(SCL_GPIO, SCL_GPIO_FUNC);

    /*
     * Set Output Strength as 20mA, in case of many more
     * slaves are linking to the master.
     */
    GPIO_SetOutStrength(SDA_GPIO, GPIO_OUT_STRENGTH_20MA);
    GPIO_SetOutStrength(SCL_GPIO, GPIO_OUT_STRENGTH_20MA);

    /*
    * Rx FIFO threshold set as 0 means letting MCU process data once
    * FIFO has one entry data.
    */
    I2C_SetTxFIFOThreshold(I2C, 0xF);
    I2C_SetRxFIFOThreshold(I2C, 0x0);

    /* Disable All INT */
    I2C_DisableAllInt(I2C);

    /* Enable the INT of detecting the STOP of I2C */
    I2C_EnableStopDetectInt(I2C);
    /* Clear All INT */
    I2C_ClearInt(I2C, I2C_INT_ALL);

    /* Init I2C as Master */
    estatus = I2C_MasterInit(I2C, I2C_SPEED);
    if (estatus == ERROR)
    {
        printf("[IIC master init FAIL] I2C clock is not fast enough to support 
the speed\n");
        return 0;
    }

    /* Enable CM4 INT Request */
    NVIC_EnableIRQ(I2C_IRQn);

    /* Master start to transmit and receive data */
    Master_TxRX_data();

    while (1)
    {

    }
}

void I2C_IRQHandler(void)
{
    if (I2C_GetStopDetectIntRawFlag(I2C))
    {
        gu32_cnt_i2c_stop_isr ++ ;

        I2C_ClearInt(I2C, I2C_INT_STOP_DET);
    }
    else
    {
        printf("[%s Error] Stop detect interrupt error\n", __func__);
    }
}
```

3.2.2 从机发送与接收

本示例中演示 I2C 作为从机使用 Poll 传输模式进行发送数据和接收数据。当示例的 SLAVE_TRANSMIT 宏为 1 时进行发送数据，当 SLAVE_TRANSMIT 宏为 0 时进行接收数据，其配置流程如下：

- 初始化系统时钟，UART 调试口以及初始化 I2C 的 GPIO；
- 调用 I2C_EnableStopDetectInt()函数使能探测 STOP 信号中断，通过判断是否进入中断来判断通信是否完成；
- 调用 I2C_SlaveInit()函数初始化 I2C 为 slave 设备，并初始化速度为 400K；
- 调用 I2C_SlaveWrite()或者 I2C_SlaveRead()函数进行发送或者接收数据；

Poll 模式（从机发送与接收）

```
#define                 SDA_GPIO                GPIO_38
#define                 SCL_GPIO                GPIO_39
#define                 SDA_GPIO_FUNC            GPIO38_I2C_SDA
#define                 SCL_GPIO_FUNC            GPIO39_I2C_SCL

#define                 DEBUG_INFO              1                      /* The
controlling flag of printf info*/
#define                 SLAVE_TRANSMIT           0                      /* 1: slave
transmit 0: slave receive */

#define                 T_BUFFER_SIZE            128
#define                 I2C_Slave_ADDR           0x9                    /* IIC Slave
ADDR */
#define                 I2C_SPEED               400000

uint32_t                gu32BuffSize             = T_BUFFER_SIZE;
uint8_t                 gau8TxBuf[T_BUFFER_SIZE];
uint8_t                 gau8RxBuf[T_BUFFER_SIZE];
ErrorStatus              estatus;

uint32_t gu32_cnt_i2c_stop_isr;

static ErrorStatus Check_Receive_Data(void)
{
    int i;
    uint8_t u8Data = 0;

    /*To check the datum sent and received are the same*/
    for(i = 0; i < gu32BuffSize; i++)
    {
        if (gau8RxBuf[i] != u8Data)
        {
            printf("[Error]@%4d: TX(0x%02X) != RX(0x%02X)\n", __LINE__, u8Data,
gau8RxBuf[i] );

            return ERROR;
        }
        else
        {
            printf("%3d: TX(0x%02X) == RX(0x%02X)\n", i, u8Data, gau8RxBuf[i] );
        }

        u8Data++;
    }

    return SUCCESS;
}


void Slave_TxRX_data(I2C_REGS *I2Cx)
{
    int i;
    uint8_t u8Data = 0;
    uint32_t u32IsrCnt = 0;                                  /* Interrupt Check
variable */

    if (SLAVE_TRANSMIT)
    {
        /* Generate random datum to transmit */
        for(i=0; i < gu32BuffSize; i++)
        {
            gau8TxBuf[i] = u8Data++;

            printf("gau8TxBuf[%d] = 0x%x\n", i, gau8TxBuf[i]);
        }

        printf("Slave Tx data...\n");
        I2C_SlaveWrite(I2C, gau8TxBuf, gu32BuffSize);
    }
    else
    {
        printf("Slave Rx data...\n");

        /* Read the data had sent to the master just now back and put them into
the 'gau8RxBuf' */
        I2C_SlaveRead(I2C, gau8RxBuf, gu32BuffSize);

        /*To check the datum sent and received are the same*/
        estatus = Check_Receive_Data();
        if(estatus == ERROR)
        {
            return;
        }
    }

    u32IsrCnt += gu32BuffSize;

    /* Wait for I2C INT done */
    Delay_Us(300);

    /*
     * Check interrupt counter, if the INT count is not equal the bytes we has
sent, there
     * must be something wrong had happened.
     */
    if(gu32_cnt_i2c_stop_isr != u32IsrCnt)
    {
        printf("[Error]@%4d: I2C ISR counter not right. expect %d, but is %d",
__LINE__,
                                        u32IsrCnt, gu32_cnt_i2c_stop_isr);
    }
    else
    {
        printf("Success\n");
    }
}

int main()
{
    FLASH_WALLOW();

    FLASH_SetTiming(200000000);
    /* Disable flash write access after flash operation had done */
    FLASH_WDIS();

    CLOCK_InitWithRCO(CLOCK_HCLK_200MHZ);

    Delay_Init();

    /*
     * Init the UART
     *
     * 1.Set the GPIO34/35 as UART FUNC
     *
     * 2.Enable the UART CLK
     *
     * 3.Set the rest para
     */
    GPIO_SetPinChannel(GPIO_34, GPIO34_UART_TXD);
    GPIO_SetPinChannel(GPIO_35, GPIO35_UART_RXD);
    CLOCK_EnableModule(UART_MODULE);
    UART_Init(UART, 38400);

    /* Config GPIO as I2C function */
    GPIO_SetPinChannel(SDA_GPIO, SDA_GPIO_FUNC);
    GPIO_SetPinChannel(SCL_GPIO, SCL_GPIO_FUNC);

    /*
     * Set Output Strength as 20mA, in case of many more
     * slaves are linking to the master.
     */
    GPIO_SetOutStrength(SDA_GPIO, GPIO_OUT_STRENGTH_20MA);
    GPIO_SetOutStrength(SCL_GPIO, GPIO_OUT_STRENGTH_20MA);

    /*
    * Rx FIFO threshold set as 0 means letting MCU process data once
    * FIFO has one entry data.
    */
    I2C_SetTxFIFOThreshold(I2C, 0xF);
    I2C_SetRxFIFOThreshold(I2C, 0x0);

    /* Disable All INT */
    I2C_DisableAllInt(I2C);

    /* Enable the INT of detecting the STOP of I2C */
    I2C_EnableStopDetectInt(I2C);

    /* Clear All INT */
    I2C_ClearInt(I2C, I2C_INT_ALL);

    /* Init I2C as Slave and set the speed as 400K */
    estatus = I2C_SlaveInit(I2C, I2C_ADDR_7BIT, I2C_Slave_ADDR, I2C_SPEED);
    if (estatus == ERROR)
    {
        printf("[IIC slave init FAIL] I2C clock is not fast enough to support
the speed\n");
        return 0;
    }

    /* Enable CM4 INT Request */
    NVIC_EnableIRQ(I2C_IRQn);

    /* Master start to transmit and receive data */
    Slave_TxRX_data(I2C);

    while (1)
    {

    }
}

void I2C_IRQHandler(void)
{
    if (I2C_GetStopDetectIntRawFlag(I2C))
    {
        gu32_cnt_i2c_stop_isr ++ ;
        I2C_ClearInt(I2C, I2C_INT_STOP_DET);
    }
    else
    {
        printf("[%s Error] Stop detect interrupt error\n", __func__);
    }
}
```

3.3 中断传输模式

3.3.1 主机发送与接收

本示例中演示 I2C 作为主机使用中断传输模式进行发送数据和接收数据。当示例的 MASTER_TRANSMIT 宏为 1 时进行发送数据，当 MASTER_TRANSMIT 宏为 0 时进行接收数据，其配置流程如下：

- 初始化系统时钟，UART 调试口以及初始化 I2C 的 GPIO；
- 调用 I2C_MasterInit ()函数初始化 I2C 为 master 设备，并初始化速度为 400K；
- 调用 I2C_SetAddressMode()与 I2C_SetTargetAddress()函数进行设置 I2C 地址模式以及设备地址；
- 当为接收时需要调用 I2C_MasterReadCmd()函数给从机发送读请求；
- 调用 I2C_SetTxFIFOThreshold()或者 I2C_SetRxFIFOThreshold()函数设置发送或者接收 FIFO 的阈值；
- 调用 I2C_EnableTxDataRequestInt()与 I2C_EnableRxDataAvailableInt()函数使能发送与接收中断；
- 在中断服务函数中根据发送与接收 FIFO 的状态进行发送或者接收数据；

中断模式（主机发送与接收）

```
/* I2C GPIO Config*/
#define                    SDA_GPIO                GPIO_38
#define                    SCL_GPIO                GPIO_39
#define                    SDA_GPIO_FUNC            GPIO38_I2C_SDA
#define                    SCL_GPIO_FUNC            GPIO39_I2C_SCL

#define                    DEBUG_INFO               1
#define                    MASTER_TRANSMIT           1                    /* 1: master
transmit 0: master receive */
#define                    Rx_FIFO_INT_TH            0xf                  /* Rx
threshold as 16 entry */
#define                    Tx_FIFO_INT_TH            0x0                  /* Tx
threshold as 1 entry */
#define                    TxRx_DATA_LEN            16                   /* Send
receive 16 Byte */


#define                    T_BUFFER_SIZE            128
#define                    I2C_SPEED               400000
#define                    I2C_Slave_ADDR            0x9                  /* IIC Slave
ADDR */

uint32_t                   gu32BuffSize               = T_BUFFER_SIZE;
uint8_t                    gau8TxBuf[T_BUFFER_SIZE];
uint8_t                    gau8RxBuf[T_BUFFER_SIZE];
uint32_t                   u32IsrCnt = 0;
ErrorStatus                 estatus;
uint32_t                   num;

uint8_t                    u32DetectStart = 0;

static ErrorStatus Check_Receive_Data(void)
{
    int i;
    uint8_t u8Data = 0;

    /*To check the datum sent and received are the same*/
    for(i = 0; i < gu32BuffSize; i++)
    {
        if (gau8RxBuf[i] != u8Data)
        {
            printf("[Error]@%4d: TX(0x%02X) != RX(0x%02X)\n", __LINE__, u8Data,
gau8RxBuf[i] );

            return ERROR;
        }
        else
        {
            printf("%3d: TX(0x%02X) == RX(0x%02X)\n", i, u8Data, gau8RxBuf[i] );
        }

        u8Data++;
    }

    return SUCCESS;
}

void I2C_Master_TxRX_data(I2C_REGS *I2Cx, I2C_AddrModeEnum eAddrMode, uint16_t
u16TargetAddr, uint32_t u32Count)
{
    uint32_t i;
    uint8_t u8Data = 0;

    /* Set Address Mode */
    I2C->I2CMASTERADDR.bit.MASTERADDR10B = eAddrMode;

    /* Set Target Slave Address*/
    I2C->I2CMASTERADDR.bit.TARADDR = u16TargetAddr;

    if (MASTER_TRANSMIT)
    {
        /* Generate random datum to transmit */
        for(i = 0; i < gu32BuffSize; i++)
        {
            gau8TxBuf[i] = u8Data++;

            printf("gau8TxBuf[%d] = 0x%x\n", i, gau8TxBuf[i]);
        }

        printf("Master Tx data...\n");

        I2C_SetTxFIFOThreshold(I2C, Tx_FIFO_INT_TH);

        I2C_EnableTxDataRequestInt(I2C);
    }
    else
    {
        for (i = 0; i < TxRx_DATA_LEN; i++)
        {
            I2C_MasterReadCmd(I2C);

            if (u32DetectStart == 0)
            {
                while(I2C_GetStartDetectIntRawFlag(I2C) == 0) {}
                u32DetectStart = 1;
            }
        }

        printf("Master Rx data...\n");

        I2C_SetRxFIFOThreshold(I2C, Rx_FIFO_INT_TH);

        I2C_EnableRxDataAvailableInt(I2C);
    }

}

int main()
{
    FLASH_WALLOW();

    FLASH_SetTiming(200000000);
    /* Disable flash write access after flash operation had done */
    FLASH_WDIS();

    CLOCK_InitWithRCO(CLOCK_HCLK_200MHZ);

    Delay_Init();

    /*
     * Init the UART
     *
     * 1.Set the GPIO34/35 as UART FUNC
     *
     * 2.Enable the UART CLK
     *
     * 3.Set the rest para
     */
    GPIO_SetPinChannel(GPIO_34, GPIO34_UART_TXD);
    GPIO_SetPinChannel(GPIO_35, GPIO35_UART_RXD);
    CLOCK_EnableModule(UART_MODULE);
    UART_Init(UART, 38400);

    /* Config GPIO as I2C function */
    GPIO_SetPinChannel(SDA_GPIO, SDA_GPIO_FUNC);
    GPIO_SetPinChannel(SCL_GPIO, SCL_GPIO_FUNC);

    /*
     * Set Output Strength as 20mA, in case of many more
     * slaves are linking to the master.
     */
    GPIO_SetOutStrength(SDA_GPIO, GPIO_OUT_STRENGTH_20MA);
    GPIO_SetOutStrength(SCL_GPIO, GPIO_OUT_STRENGTH_20MA);


    /* Disable All INT */
    I2C_DisableAllInt(I2C);

    /* Clear All INT */
    I2C_ClearInt(I2C, I2C_INT_ALL);

    /* Init I2C as Master */
    estatus = I2C_MasterInit(I2C, I2C_SPEED);
    if (estatus == ERROR)
    {
        printf("[IIC master init FAIL] I2C clock is not fast enough to support
the speed\n");
        return 0;
    }
    /* Enable CM4 INT request */
    NVIC_EnableIRQ(I2C_IRQn);

    /* Master start to transmit and receive data */
    I2C_Master_TxRX_data(I2C, I2C_ADDR_7BIT, I2C_Slave_ADDR, gu32BuffSize);

    while (1)
    {

    }
}

void I2C_IRQHandler(void)
{
    int i;

    if (MASTER_TRANSMIT && (u32IsrCnt < T_BUFFER_SIZE))
    {
        /* Wait I2C Bus Idle */
        while (I2C_IsActivity(I2C)) { }

        if (I2C_IsTxEmpty(I2C))
        {
            for (i = 0; i < TxRx_DATA_LEN; i++)
            {
                I2C_WriteByte(I2C, gau8TxBuf[u32IsrCnt++]);

                if (u32DetectStart == 0)
                {
                    while(I2C_GetStartDetectIntRawFlag(I2C) == 0) {}
                    u32DetectStart = 1;
                }
            }
        }
    }
    else if (!MASTER_TRANSMIT && (u32IsrCnt < T_BUFFER_SIZE))
    {
        /* Read RxFIFO, Read Data */
        while(I2C_IsRxNotEmpty(I2C))
        {
            gau8RxBuf[u32IsrCnt++] = I2C_ReadByte(I2C);
        }

        for (i = 0; i < TxRx_DATA_LEN; i++)
        {
            I2C_MasterReadCmd(I2C);
        }
    }

    if (u32IsrCnt == T_BUFFER_SIZE)
    {
        if (MASTER_TRANSMIT)
        {
            I2C_DisableTxDataRequestInt(I2C);
        }
        else
        {
            I2C_DisableRxDataAvailableInt(I2C);
            estatus = Check_Receive_Data();
            if (estatus == ERROR)
            {
                return;
            }
        }

        printf("Success\n");
    }
    I2C_ClearInt(I2C, I2C_INT_ALL);
}
```

3.3.2 从机发送与接收

本示例中演示 I2C 作为从机使用中断传输模式进行发送数据和接收数据。当示例的 SLAVE_TRANSMIT 宏为 1 时进行发送数据，当 SLAVE_TRANSMIT 宏为 0 时进行接收数据，其配置流程如下：

- 初始化系统时钟，UART 调试口以及初始化 I2C 的 GPIO；
- 调用 I2C_SlaveInit()函数初始化 I2C 为 slave 设备，并初始化速度为 400K；
- 调用 I2C_SetTxFIFOThreshold()或者 I2C_SetRxFIFOThreshold()函数设置发送或者接收 FIFO 的阈值；
- 调用 I2C_EnableTxDataRequestInt()与 I2C_EnableRxDataAvailableInt()函数使能发送与接收中断；
- 在中断服务函数中根据发送与接收 FIFO 的状态进行发送或者接收数据；

中断模式（从机发送与接收）

```
#define                     SDA_GPIO                    GPIO_38
#define                     SCL_GPIO                    GPIO_39
#define                     SDA_GPIO_FUNC                GPIO38_I2C_SDA
#define                     SCL_GPIO_FUNC                GPIO39_I2C_SCL

#define                     DEBUG_INFO                  1
#define                     SLAVE_TRANSMIT               0                    /* 1: slave
transmit 0: slave receive */

#define                     Rx_FIFO_INT_TH               0xf                  /* Rx
threshold as 1 entry */
#define                     Tx_FIFO_INT_TH               0x0                  /* Tx
threshold as 1 entry */
#define                     TxRx_DATA_LEN                16                   /* Send
receive 16 Byte */
#define                     T_BUFFER_SIZE                128
#define                     I2C_SPEED                   400000
#define                     I2C_Slave_ADDR               0x9                  /* IIC Slave
ADDR */

uint32_t                    gu32BuffSize                 = T_BUFFER_SIZE;
uint8_t                     gau8TxBuf[T_BUFFER_SIZE];
uint8_t                     gau8RxBuf[T_BUFFER_SIZE];
uint32_t                    u32IsrCnt = 0;
ErrorStatus                  estatus;
uint32_t                    num;

static ErrorStatus Check_Receive_Data(void)
{
    int i;
    uint8_t u8Data = 0;
    /*To check the datum sent and received are the same*/
    for(i = 0; i < gu32BuffSize; i++)
    {
        if (gau8RxBuf[i] != u8Data)
        {
            printf("[Error]@%4d: TX(0x%02X) != RX(0x%02X)\n", __LINE__, u8Data,
gau8RxBuf[i] );

            return ERROR;
        }
        else
        {
            printf("%3d: TX(0x%02X) == RX(0x%02X)\n", i, u8Data, gau8RxBuf[i] );
        }

        u8Data++;
    }

    return SUCCESS;
}

void I2C_Slave_TxRX_data(I2C_REGS* I2Cx)
{
    int i;
    uint8_t u8Data = 0;

    if (SLAVE_TRANSMIT)
    {
        /* Generate random datum to transmit */
        for(i = 0; i < gu32BuffSize; i++)
        {
            gau8TxBuf[i] = u8Data++;

            printf("gau8TxBuf[%d] = 0x%x\n", i, gau8TxBuf[i]);
        }

        printf("Slave Tx data...\n");

        I2C_SetTxFIFOThreshold(I2Cx, Tx_FIFO_INT_TH);

        I2C_EnableTxDataRequestInt(I2Cx);
    }
    else
    {
        printf("Slave Rx data...\n");

        I2C_SetRxFIFOThreshold(I2Cx, Rx_FIFO_INT_TH);

        I2C_EnableRxDataAvailableInt(I2Cx);
    }
}

int main()
{
    FLASH_WALLOW();

    FLASH_SetTiming(200000000);
    /* Disable flash write access after flash operation had done */
    FLASH_WDIS();

    CLOCK_InitWithRCO(CLOCK_HCLK_200MHZ);

    Delay_Init();
    /*
     * Init the UART
     *
     * 1.Set the GPIO34/35 as UART FUNC
     *
     * 2.Enable the UART CLK
     *
     * 3.Set the rest para
     */
    GPIO_SetPinChannel(GPIO_34, GPIO34_UART_TXD);
    GPIO_SetPinChannel(GPIO_35, GPIO35_UART_RXD);
    CLOCK_EnableModule(UART_MODULE);
    UART_Init(UART, 38400);

    /* Config GPIO as I2C function */
    GPIO_SetPinChannel(SDA_GPIO, SDA_GPIO_FUNC);
    GPIO_SetPinChannel(SCL_GPIO, SCL_GPIO_FUNC);

    /*
     * Set Output Strength as 20mA, in case of many more
     * slaves are linking to the master.
     */
    GPIO_SetOutStrength(SDA_GPIO, GPIO_OUT_STRENGTH_20MA);
    GPIO_SetOutStrength(SCL_GPIO, GPIO_OUT_STRENGTH_20MA);

    /* Disable All INT */
    I2C_DisableAllInt(I2C);

    /* Clear All INT */
    I2C_ClearInt(I2C, I2C_INT_ALL);

    /* Init I2C as Slave and set the speed as 400K */
    estatus = I2C_SlaveInit(I2C, I2C_ADDR_7BIT, I2C_Slave_ADDR, I2C_SPEED);
    if (estatus == ERROR)
    {
        printf("[IIC slave init FAIL] I2C clock is not fast enough to support
the speed\n");
        return 0;
    }

    /* Enable CM4 INT request */
    NVIC_EnableIRQ(I2C_IRQn);

    /* Slave start to transmit and receive data */
    I2C_Slave_TxRX_data(I2C);

    while (1)
    {

    }
}

void I2C_IRQHandler(void)
{
    int i;

    if (SLAVE_TRANSMIT && (u32IsrCnt < T_BUFFER_SIZE))
    {
        if (I2C_IsTxEmpty(I2C))
        {
            for(i = 0; i < TxRx_DATA_LEN; i++)
            {
                /* Wait Until Detect Read Request */
                while(!I2C_GetReadRequestIntRawFlag(I2C)) { }

                /* Clear Event Flag */
                I2C_ClearInt(I2C, I2C_INT_RD_REQ);
                /* Write TxFIFO, Send Data */
                I2C_WriteByte(I2C, gau8TxBuf[u32IsrCnt]);

                u32IsrCnt++;
            }

        }
    }
    else if (!SLAVE_TRANSMIT && (u32IsrCnt < T_BUFFER_SIZE))
    {
        while(I2C_IsRxNotEmpty(I2C))
        {
            gau8RxBuf[u32IsrCnt] = I2C_ReadByte(I2C);
            u32IsrCnt++;
        }
    }

    if (u32IsrCnt == T_BUFFER_SIZE)
    {
        if (SLAVE_TRANSMIT)
        {
            I2C_DisableTxDataRequestInt(I2C);
        }
        else
        {
            I2C_DisableRxDataAvailableInt(I2C);
            estatus = Check_Receive_Data();
            if (estatus == ERROR)
            {
                return;
            }
        }

        u32IsrCnt = 0;

        printf("Success\n");
    }

    I2C_ClearInt(I2C, I2C_INT_ALL);
}
```