GigaDevice Semiconductor Inc.

GD32A5x3 CAN 位时间问题的软件规避

应用笔记

AN222

1.1 版本

（2025 年 3 月）

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1. 前言

GD32A5x3xx 系列 MCU 在使用 CAN 模块时有一个限制。

当 MCU 作为 CAN 发送端时，如果发送端总延迟大于一定值，会触发芯片的位时间重同步机制，可能导致 CAN 发送端的位时间变长。此时若接收节点重同步能力不足以补偿位时间时，有一定概率会出现信号错误，通信失败。

对于发送 CAN 常规帧或者 FD 帧，情形总结如下：

表 1-1.CAN 帧位时间问题总结

序号	发送帧	发送问题
1	常规帧	发送节点会进行重同步，触发重同步后，会导致显性位时间拉长
2	FD帧+波特率切换禁能	发送节点会进行重同步，触发重同步后，会导致显性位时间拉长
3	FD帧+波特率切换使能	发送节点数据段不会进行重同步，控制段会进行重同步

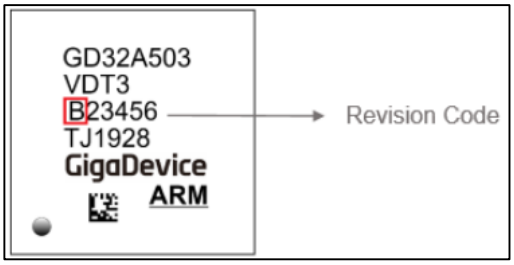
2. 受影响芯片型号

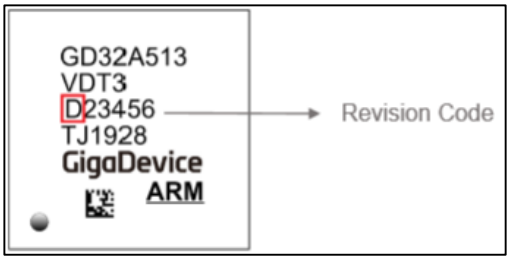
表 2-1.适用 MCU 产品

类型	型号	产品版本
MCU	GD32A503xx系列	B版
	GD32A513xx系列	D版

MCU 产品版本号查看可参考下图：

图 2-1. MCU 产品版本号





3. CAN 模块限制

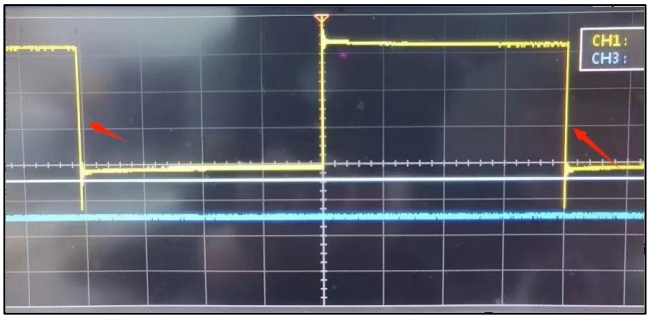
MCU CAN 模块的限制会引起以下的现象：

（1）MCU 发送的 CAN 帧实际位时间长度大于设定的波特率所代表的位时间长度。如下配置情况与实际发送情况所示，CAN 帧发送的显性位比隐性位长；

表 3-1.CAN 帧位时间问题配置示例

波特率（bps）	位包含位时间单元数量	显性电平时间（us）	隐性电平时间（us）	位时间单元
500K	25	2.04	2.00	80ns

图 3-1. CAN 帧位时间问题发送示例



（2）MCU CAN 帧有一定概率发送不成功，一直重发；
（3）MCU CAN 发送节点有一定概率发生 ACK 错误；
（4）接收节点有一定概率会发生帧格式错误，CRC 校验错误，出现信号错误，通信失败。

由*表 1-1.CAN 帧位时间问题总结*可得知对发送节点的仲裁段配置进行分析即可。因此 CAN 模块限制的触发需满足以下情况：

（1）MCU 作为 CAN 发送节点；
（2）MCU CAN 发送节点在发送 CAN 帧的隐性位到显性位时；
（3）MCU CAN 发送节点总延迟 $T_{delay\_total\_tx}$（MCU 端收发器延迟+内部处理的 2 个 CAN 时钟延迟）>T_{ss_tx} 同步段时间（1 个 T_{q_tx}）时；
（4）当接收节点重同步能力 $SJW_{rx}*T_{q\_rx}$ 小于 MCU CAN 发送端补偿时间时，补偿时间为 $\min\{ceil((T_{delay\_total\_tx} - T_{ss\_tx})/T_{CANCLK\_tx}), SJW_{tx}*T_{q\_tx}/T_{CANCLK\_tx}\}* T_{CANCLK\_tx}$。

注意：ceil()函数为向上取整函数。

4. 解决方案

4.1. 方案描述

4.1.1. 相关公式

$$T_{delay\_total\_tx} = T_{delay\_phy\_tx} + 2 \times T_{CANCLK\_tx}$$

$$T_{ss\_tx} = T_{q\_tx} = \frac{1}{Baudrate \times N_{q\_tx}}$$

发送节点补偿时间=$\min\{ceil((T_{delay\_total\_tx} - T_{ss\_tx})/T_{CANCLK\_tx}), SJW_{tx}*T_{q\_tx}/T_{CANCLK\_tx}\}* T_{CANCLK\_tx}$

接收节点重同步能力=$SJW_{rx}*T_{q\_rx}$

其中各名词解释如下：

$T_{delay\_total\_tx}$

为发送端总延迟。

$T_{delay\_phy\_tx}$

为发送端收发器延迟。

T_{CANCLK_tx}

为发送端 CAN 时钟时间。

T_{ss_tx}

为发送端同步段时间。

T_{q_tx}

为发送端位时间单元。

N_{q_tx}

为发送端位时间所占的时间单元数量。

SJW_{tx}

为发送端的再同步补偿占用的时间单元数量。

T_{q_rx}

为接收端位时间单元。

N_{q_rx}

为接收端位时间所占的时间单元数量。

SJW_{rx}

为接收端的再同步补偿占用的时间单元数量。

4.1.2. 解决步骤

为了规避这个问题：

1. CANCLK 需要配置为最大 CAN 时钟，在 GD32A5x3xx 产品中，系统时钟最大为 100M，配置 CANCLK 为 PCLK2 时钟 100M，则T_{CANCLK_tx}等于 10ns。

2. 查询发送端收发器数据手册，如下图，以 MCP2561 为例，需查看 TXD 到 RXD 的时间延迟参数。$T_{delay_phy_tx}$为最大 235ns 时，$T_{delay_total_tx}$等于 255ns。

图 4-1.收发器延迟参数查询

2.3 AC Characteristics

Electrical Characteristics: Extended (E): TAMB = -40°C to +125°C and High (H): TAMB = -40°C to +150°C; VDD = 4.5V to 5.5V, VIO = 1.8V to 5.5V (Note 2), RL = 60Ω; unless otherwise specified.

Param. No.	Sym.	Characteristic	Min.	Typ.	Max.	Units	Conditions
1	tBIT	Bit Time	1	—	69.44	µs	
2	fBIT	Bit Frequency	14.4	—	1000	kHz	
3	tTXD-BUSON	Delay TXD Low to Bus Dominant	—	—	70	ns	
4	tTXD-BUSOFF	Delay TXD High to Bus Recessive	—	—	125	ns	
5	tBUSON-RXD	Delay Bus Dominant to RXD	—	—	70	ns	
6	tBUSOFF-RXD	Delay Bus Recessive to RXD	—	—	110	ns	
7	tTXD - RXD	Propagation Delay TXD to RXD	—	—	125	ns	Negative edge on TXD
8			—	—	235		Positive edge on TXD
9	tFLTR(WAKE)	Delay Bus Dominant to RXD (Standby mode)	0.5	1	4	µs	Standby mode

3. T_{ss_tx}需要尽可能的大，假设 Baudrate 为 500Kbps，N_{q_tx}为 10，则$T_{ss_tx} = T_{q_tx}$等于 200ns。

4. SJW_{tx}配置为 2，则发送端具有调整 400ns 重同步的能力，适用于绝大多数场景。

5. 发送端在以上配置下时，隐性位到显性位时引入了 $\min\{ceil((T_{delay_total_tx} - T_{ss_tx})/T_{CANCLK_tx}), SJW_{tx}*T_{q_tx}/T_{CANCLK_tx}\}* T_{CANCLK_tx}$等于 min{ceil((255ns - 200ns)/10ns), 2*200ns/10ns}*10ns = min{ceil(5.5), 40}*10ns = 6*10ns = 60ns 的延迟。

6. 接收节点重同步能力 $SJW_{rx}*T_{q_rx}$需要尽可能大，至少满足 $SJW_{rx}*T_{q\_rx} \geq 60ns$，由于收发两端波特率需要相同，当 N_{q_rx} 数目固定不可配时，也即 T_{q_rx} 值不可调整时，需按照 $SJW_{rx} \geq 60ns*Baudrate*N_{q\_rx}$，即$SJW_{rx} \geq 0.03*N_{q_rx}$进行配置。

4.2. 方案示例

遵循以上分析，系统时钟为 100M，通信波特率位 500Kbps 时，发送端参考配置如下：

表 4-1. 发送端参考配置

```
void can_gpio_config(void)
{
    /* enable CAN clock */
    rcu_can_clock_config(CAN0, RCU_CANSRC_PCLK2); // CANCLK_tx = 100M, TCANCLK_tx=10ns
    rcu_periph_clock_enable(RCU_CAN0);
    /* enable CAN port clock */
```

```
    rcu_periph_clock_enable(RCU_GPIOB);

    /* configure CAN0 GPIO */
    gpio_output_options_set(GPIOB, GPIO_OTYPE_PP, GPIO_OSPEED_50MHZ, GPIO_PIN_13);
    gpio_mode_set(GPIOB, GPIO_MODE_AF, GPIO_PUPD_PULLUP, GPIO_PIN_13);
    gpio_af_set(GPIOB, GPIO_AF_6, GPIO_PIN_13);

    gpio_output_options_set(GPIOB, GPIO_OTYPE_PP, GPIO_OSPEED_50MHZ, GPIO_PIN_14);
    gpio_mode_set(GPIOB, GPIO_MODE_AF, GPIO_PUPD_NONE, GPIO_PIN_14);
    gpio_af_set(GPIOB, GPIO_AF_6, GPIO_PIN_14);
}

void can_config(void)
{
    can_parameter_struct can_parameter;

    /* initialize CAN register */
    can_deinit(CAN0);
    /* initialize CAN */
    can_struct_para_init(CAN_INIT_STRUCT, &can_parameter);

    /* initialize CAN parameters */
    can_parameter.internal_counter_source = CAN_TIMER_SOURCE_BIT_CLOCK;
    can_parameter.self_reception = DISABLE;
    can_parameter.mb_tx_order = CAN_TX_HIGH_PRIORITY_MB_FIRST;
    can_parameter.mb_tx_abort_enable = ENABLE;
    can_parameter.local_priority_enable = DISABLE;
    can_parameter.mb_rx_ide_rtr_type = CAN_IDE_RTR_FILTERED;
    can_parameter.mb_remote_frame = CAN_STORE_REMOTE_REQUEST_FRAME;
    can_parameter.rx_private_filter_queue_enable = DISABLE;
    can_parameter.edge_filter_enable = DISABLE;
    can_parameter.protocol_exception_enable = DISABLE;
    can_parameter.rx_filter_order = CAN_RX_FILTER_ORDER_MAILBOX_FIRST;
    can_parameter.memory_size = CAN_MEMSIZE_32_UNIT;
    /* filter configuration */
    can_parameter.mb_public_filter = 0x0;
    can_parameter.resync_jump_width = 2; //SJWtx=2*Tq_tx=400ns
    can_parameter.prop_time_segment = 2;
    can_parameter.time_segment_1 = 4;
    can_parameter.time_segment_2 = 3; //Nq_tx=1+PTS+PBS1+PBS2=10
    /* 500Kbps*/
```

```
    can_parameter.prescaler = 20; //Baudrate= CANCLK_tx/(prescaler*Nq_tx)=500Kbps
                                  //Tss_tx=Tq_tx=1/(Baudrate*Nq_tx)=prescaler/CANCLK_tx=200ns
    /* initialize CAN */
    can_init(CAN0, &can_parameter);

    can_operation_mode_enter(CAN0, CAN_NORMAL_MODE);
}
```

发送邮箱配置、测试数据参考如下，建议使用 8 个字节 0x55 数据进行测试：

表 4-2. 发送测试配置

```
int main(void)
{
    const uint8_t tx_data[8] = {0x55, 0x55, 0x55, 0x55, 0x55, 0x55, 0x55, 0x55};
    can_mailbox_descriptor_struct transmit_message;
    FlagStatus can_tx_state;
    uint8_t i = 0;
    ... ...

    can_struct_para_init(CAN_MDSC_STRUCT, &transmit_message);
    /* initialize transmit message */
    transmit_message.rtr = 0;
    transmit_message.ide = 0;
    transmit_message.code = CAN_MB_TX_STATUS_DATA;
    transmit_message.brs = 0;
    transmit_message.fdf = 0;
    transmit_message.prio = 0;
    transmit_message.data_bytes = 8;
    /* tx message content */
    transmit_message.data = (uint32_t *)(tx_data);
    transmit_message.id = 0x55;
    can_tx_state = RESET;
    ... ...
    while(1) {
        ... ...
        if((RESET == can_tx_state) || (SET == can_flag_get(CAN0, CAN_FLAG_MB1))){
            can_tx_state = SET;
            can_flag_clear(CAN0, CAN_FLAG_MB1);
            /* transmit message */
            can_mailbox_config(CAN0, 1, &transmit_message);

            printf("\r\nCAN0 transmit data: \r\n");
            for(i = 0; i < 8; i++) {
                printf("%02x\r\n", tx_data[i]);
```

```
            }
        }
        ... ...
    }
}
```

接收端参考配置如下：

表 4-3. 接收端参考配置

```
void can_gpio_config(void)
{
    /* enable CAN clock */
    rcu_can_clock_config(CAN1, RCU_CANSRC_PCLK2); // CANCLK_rx = 100M, TCANCLK_rx=10ns
    rcu_periph_clock_enable(RCU_CAN1);
    /* enable CAN port clock */
    rcu_periph_clock_enable(RCU_GPIOD);

    /* configure CAN1 GPIO */
    gpio_output_options_set(GPIOD, GPIO_OTYPE_PP, GPIO_OSPEED_50MHZ, GPIO_PIN_6);
    gpio_mode_set(GPIOD, GPIO_MODE_AF, GPIO_PUPD_PULLUP, GPIO_PIN_6);
    gpio_af_set(GPIOD, GPIO_AF_6, GPIO_PIN_6);

    gpio_output_options_set(GPIOD, GPIO_OTYPE_PP, GPIO_OSPEED_50MHZ, GPIO_PIN_7);
    gpio_mode_set(GPIOD, GPIO_MODE_AF, GPIO_PUPD_NONE, GPIO_PIN_7);
    gpio_af_set(GPIOD, GPIO_AF_6, GPIO_PIN_7);
}

void can_config(void)
{
    can_parameter_struct can_parameter;

    /* initialize CAN register */
    can_deinit(CAN1);
    /* initialize CAN */
    can_struct_para_init(CAN_INIT_STRUCT, &can_parameter);

    /* initialize CAN parameters */
```

```
    can_parameter.internal_counter_source = CAN_TIMER_SOURCE_BIT_CLOCK;
    can_parameter.self_reception = DISABLE;
    can_parameter.mb_tx_order = CAN_TX_HIGH_PRIORITY_MB_FIRST;
    can_parameter.mb_tx_abort_enable = ENABLE;
    can_parameter.local_priority_enable = DISABLE;
    can_parameter.mb_rx_ide_rtr_type = CAN_IDE_RTR_FILTERED;
    can_parameter.mb_remote_frame = CAN_STORE_REMOTE_REQUEST_FRAME;
    can_parameter.rx_private_filter_queue_enable = DISABLE;
    can_parameter.edge_filter_enable = DISABLE;
    can_parameter.protocol_exception_enable = DISABLE;
    can_parameter.rx_filter_order = CAN_RX_FILTER_ORDER_MAILBOX_FIRST;
    can_parameter.memory_size = CAN_MEMSIZE_32_UNIT;
    /* filter configuration */
    can_parameter.mb_public_filter = 0x0;
    can_parameter.resync_jump_width = 4; //SJWrx=4*Tq_rx=320ns
    can_parameter.prop_time_segment = 6;
    can_parameter.time_segment_1 = 11;
    can_parameter.time_segment_2 = 7; // Nq_rx=1+PTS+PBS1+PBS2=25
    /* 500Kbps */
    can_parameter.prescaler = 8; //Baudrate= CANCLK_rx/(prescaler*Nq_rx)=500Kbps
                                 //Tss_rx=Tq_rx=1/(Baudrate*Nq_rx)=prescaler/CANCLK_rx=80ns
    /* initialize CAN */
    can_init(CAN1, &can_parameter);

    /* configure CAN1 NVIC */
    nvic_irq_enable(CAN1_Message_IRQn, 0, 0);

    /* enable CAN MB0 interrupt */
    can_interrupt_enable(CAN1, CAN_INT_MB0);

    can_operation_mode_enter(CAN1, CAN_NORMAL_MODE);
}
```

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	2024 年 8 月 5 日
1.1	更新重要声明	2025 年 3 月 7 日

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