# GigaDevice Semiconductor Inc.

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

# Application Note
# AN044

# Table of Contents

# List of Figures

# List of Tables

# 1. Introduction

GD32F10x microcontrollers can use the internal IRC8M oscillator to run. When temperature is 25°C and working voltage is 3.3V, the accuracy range of IRC8M is ±1%. When temperature is 40 to 105°C, the accuracy range of IRC8M is -2.5% to 1.5%. Therefore, the actual application environment will determine the clock frequency of the IRC8M. GD32F10x microcontroller provides the possibility of IRC8M calibration, which can calibrate the working frequency of IRC8M to achieve the compensation of working temperature.

This application note describes how to use LXTAL (low-speed external clock) to calibrate the internal high-speed clock IRC8M.

# 2. IRC8M calibration principle

IRC8M frequency of the GD32F10x microcontroller can be calibrated to 8MHz ± 1% ( 25°C, 3.3V) by the factory. When the system is powered on, IRC8MCALIB[7:0] in the RCU_CTL register will be initialized to the factory calibration value, and the value of IRC8MADJ[4:0] in the RCU_CTL register is initialized to 16. The system can calibrate IRC8M by modifying the value of IRC8MADJ[4:0], and the calibration step is about 40KHz. That is, every time a step is increased, the frequency of IRC8M will increase by 40KHz.

Calibration principle refer to ***Figure 2-1. The principle of LXTAL calibration IRC8M***. In the calibration process, the 64 divider of the RTC clock can be used as the reference clock. The calibration steps are as follows:

1. Select the LXTAL (32.768KHz) as RTC clock source, set the COEN bit in the BKP_OCTL register, and turn on the RTC clock calibration output function. The output signal frequency is 512Hz.
2. Connect the RTC clock calibration output pin (PC13) to the TIMER capture input pin and use the TIMER capture value to calculate the actual operating frequency of the IRC8M.
3. Use the error between the actual operating frequency and the ideal value of 8M to determine how to modify the value of IRC8MADJ[4:0], and finally select the adjustment value with the smallest error to calibrate the IRC8M.

Assuming that N times update events and 1 time rising edge capture event are generated during one RTC calibration output cycle, the time of one capture cycle Tcapture is:

$$\text{Tcapture} = ((N * \text{CARL}) + \text{capture\_value}) / \text{Ftimerclk} \qquad (2\text{-}1)$$

and

$$\text{Tcapture} = 1 / \text{Fref} \qquad (2\text{-}2)$$

In among, the capture value is capture_value, the update count value is CARL, the timer count frequency is Ftimerclk, and Fref is the reference clock.

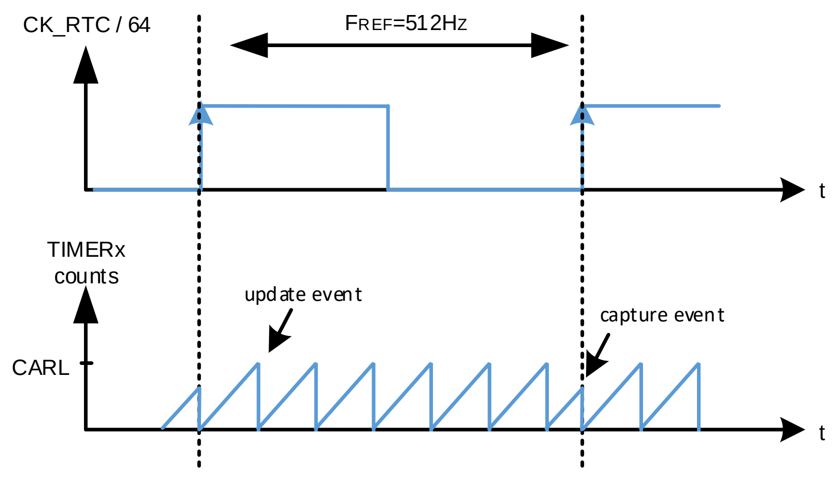
Assuming that the scale factor between the Timer counting period and IRC8M is m, that is:

$$\text{Ftimerclk} \approx m * \text{FIRC8M} \qquad (2\text{-}3)$$

then:

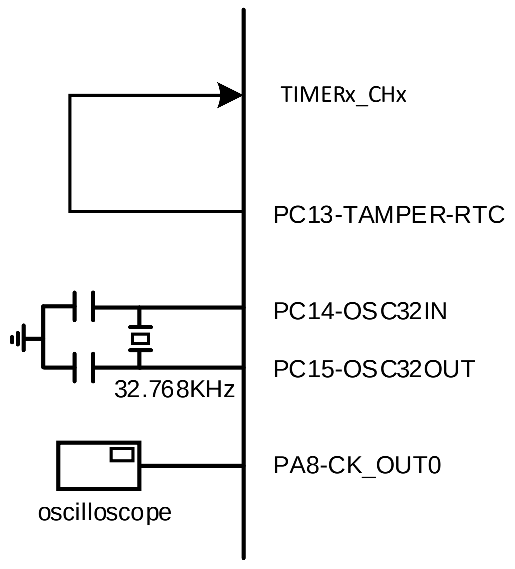
$$\text{FIRC8M} = \text{Fref}*((N * \text{CARL}) + \text{capture\_value}) / m \qquad (2\text{-}4)$$

**Figure 2-1. The principle of LXTAL calibration IRC8M**



During the calibration process, the IRC8M clock can be output to the oscilloscope for observation through the CK_OUT0 (PA8) pin. The hardware connection block diagram is as follows:

**Figure 2-2. Hardware connection block diagram**



# 3. Software implementation

In this software implementation, the system frequency works at 108MHz. In among, the system clock source is selected as the PLL clock, and the PLL clock source is selected as IRC8M. The TIMER clock is 1MHz working frequency after pre-frequency division. The code implementation part is as follows:

1. Select LXTAL as the clock source of RTC and enable RTC clock calibration output.

```
void rtc_calibration_output_config(void) {
      /* enable PMU and BKPI clock */
      rcu_periph_clock_enable(RCU_PMU);
      rcu_periph_clock_enable(RCU_BKPI);
      pmu_backup_write_enable();
      /* turn on the LXTAL clock */
      rcu_osci_on(RCU_LXTAL);
      while(!rcu_osci_stab_wait(RCU_LXTAL));
      /* configure the RTC clock source as LXTAL */
      rcu_rtc_clock_config(RCU_RTCSRC_LXTAL);
      /* enable RTC clock calibration output */
      bkp_rtc_calibration_output_enable();
}
```

2. TIMER input capture configuration

```
void timer_capture_config (void)
{
       timer_ic_parameter_struct timer_icinitpara;
       timer_parameter_struct timer_initpara;
       /* configure the NVIC and TIMER interrupt */
       nvic_priority_group_set(NVIC_PRIGROUP_PRE1_SUB3);
       nvic_irq_enable(TIMER2_IRQn, 1, 1);
       rcu_periph_clock_enable(RCU_GPIOA);
       rcu_periph_clock_enable(RCU_AF);
       /* configure PA6 (TIMER2 CH0) as alternate function */
       gpio_init(GPIOA, GPIO_MODE_IN_FLOATING, GPIO_OSPEED_50MHZ, GPIO_PIN_6);
       /* configure TIMER2 CH0 pin (PA6) */
      rcu_periph_clock_enable(RCU_TIMER2);
      timer_deinit(TIMER2);
      timer_initpara.prescaler                = 107;
      timer_initpara.alignedmode              = TIMER_COUNTER_EDGE;
      timer_initpara.counterdirection         = TIMER_COUNTER_UP;
      timer_initpara.period                   = TIMER_PERIOD_VALUE -1 ;
      timer_initpara.clockdivision            = TIMER_CKDIV_DIV1;
      timer_initpara.repetitioncounter        = 0;
      timer_init(TIMER2, &timer_initpara);
```

```
    /* TIMER2 CH0 input capture configuration */
    timer_icinitpara.icpolarity   = TIMER_IC_POLARITY_RISING;
    timer_icinitpara.icselection = TIMER_IC_SELECTION_DIRECTTI;
    timer_icinitpara.icprescaler = TIMER_IC_PSC_DIV1;
    timer_icinitpara.icfilter       = 0x0;
    timer_input_capture_config(TIMER2, TIMER_CH_0,&timer_icinitpara);

    /* auto-reload preload enable */
    timer_auto_reload_shadow_enable(TIMER2);
    /* clear channel 0 interrupt bit */
    timer_interrupt_flag_clear(TIMER2, TIMER_INT_FLAG_CH0);
    timer_interrupt_flag_clear(TIMER2, TIMER_INT_FLAG_UP);
    /* channel 0 interrupt enable */
    timer_interrupt_enable(TIMER2, TIMER_INT_CH0);
    timer_interrupt_enable(TIMER2, TIMER_INT_UP);
    /* TIMER2 counter enable */
    timer_enable(TIMER2);
}
```

3. TIMER interrupt processing

```
    void TIMER2_IRQHandler(void)
    {
         if(SET == timer_interrupt_flag_get(TIMER2, TIMER_INT_UP)) {
              timer_interrupt_flag_clear(TIMER2, TIMER_INT_UP);
              /* count the update event */
              up_event_counts ++;
         }
        if(SET == timer_interrupt_flag_get(TIMER2,TIMER_INT_CH0)) {
              timer_counter_value_config(TIMER2, 0);
              timer_interrupt_flag_clear(TIMER2, TIMER_INT_CH0);
             if(0 != capture_event_counts)
             {
                     /* get the capture value and calculate n times capture period */
                     capture_value =
             timer_channel_capture_value_register_read(TIMER2,TIMER_CH_0);
                     ref_period_counts = up_event_counts*(TIMER_PERIOD_VALUE) +
             capture_value;
                     n_time_ref_period_counts += ref_period_counts;
              }
              up_event_counts = 0;
              if(capture_event_counts++ == TIMER_CAPTURE_NUMS)
              {
                     /* calculate average capture period */
                     n_time_average_counts          =(uint32_t)(n_time_ref_period_counts          /
TIMER_CAPTURE_NUMS);
                        n_time_ref_period_counts = 0;
                        capture_event_counts = 0;
                    }
                }
            }
```

4. According to the adjustment value, calculate the IRC8M measurement frequency under each adjustment value.

```
void get_irc8m_adjust_value_array(uint32_t irc8m_measure_array[], uint8_t array_len)
{
    uint8_t i =0;
    do {
        /* get the IRC8M measurement frequency of every adjust value */
        rcu_irc8m_adjust_value_set(i);
        delay_1ms(100);
        irc8m_measure_value[i] = IRC_8M_REAL;
    } while(i++ < array_len);
}
```

5. According to the measurement frequency of IRC8M, find the adjustment value with the smallest error accuracy.

```
uint8_t get_min_error_adjust_value(uint32_t irc8m_measure_array[], uint8_t array_len)
{
    uint8_t i =0;
    uint8_t min_error_adjust_value = 0;
    uint32_t min_measure_error_value = 0xFFFFFFFF;
    uint32_t measure_error_absolute = 0;
    /* get the adjust value of smallest error */
    do{
        if(irc8m_measure_array[i] > IRC8M_IDEAL_VALUE){
            measure_error_absolute = irc8m_measure_array[i] - IRC8M_IDEAL_VALUE;
        }else{
            measure_error_absolute = IRC8M_IDEAL_VALUE - irc8m_measure_array[i];
      }
        if(measure_error_absolute < min_measure_error_value){
            min_measure_error_value = measure_error_absolute;
            min_error_adjust_value = i;
        }
    }while(i++ < array_len);
    return min_error_adjust_value;
}
```

6. Main program and experimental results

```
#define IRC8M_MEASURE            (4096*n_time_average_counts)
```

```
#define IRC8M_IDEAL_VALUE       (8000000)
#define ARRAY_LEN               (0x20)
/* measure value array of IRC8M */
uint32_t irc8m_measure_value[ARRAY_LEN] = {0};
extern uint32_t n_time_average_counts;
int main(void)
{
    uint8_t index;
    systick_config();
    rtc_calibration_output_config();
    timer_capture_config();
    ckout_config();
    gd_eval_com_init(EVAL_COM0);
    while(1){
        get_irc8m_adjust_value_array(irc8m_measure_value,ARRAY_LEN);
        index = get_min_error_adjust_value(irc8m_measure_value,ARRAY_LEN);
        /* adjust IRC8M as minium error */
        rcu_irc8m_adjust_value_set(index);
        delay_1ms(100);
        printf("\r\n%d==>%d\r\n", index, irc8m_measure_value[index]);
    }
}
```

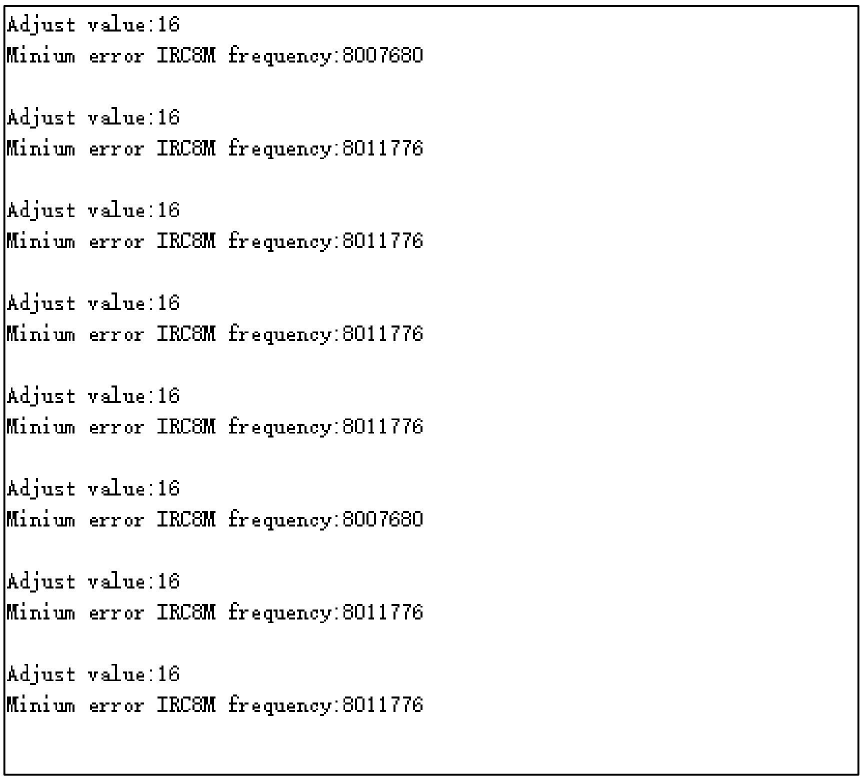
7. CKOUT configuration

```
void ckout_config(void)
{
    rcu_periph_clock_enable(RCU_GPIOA);
    /* configure clock output pin */
    gpio_init(GPIOA, GPIO_MODE_AF_PP, GPIO_OSPEED_10MHZ, GPIO_PIN_8);
    rcu_ckout0_config(RCU_CKOUT0SRC_IRC8M);
}
```

# 4. Experimental results

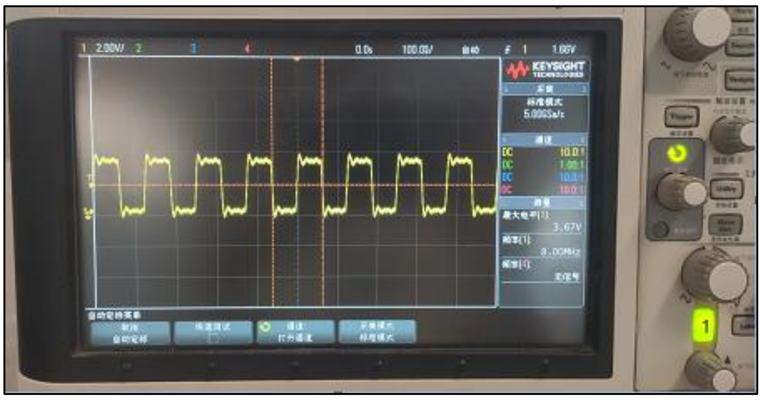
*Figure 4-1. Serial output IRC8M measuring frequency* and *Figure 4-2. Oscilloscope output IRC8M actual frequency***Figure 4-2. Oscilloscope output IRC8M** show the measured frequency and actual frequency respectively after IRC8M calibration.

**Figure 4-1. Serial output IRC8M measuring frequency**



```
Adjust value:16
Minium error IRC8M frequency:8007680

Adjust value:16
Minium error IRC8M frequency:8011776

Adjust value:16
Minium error IRC8M frequency:8011776

Adjust value:16
Minium error IRC8M frequency:8011776

Adjust value:16
Minium error IRC8M frequency:8011776

Adjust value:16
Minium error IRC8M frequency:8007680

Adjust value:16
Minium error IRC8M frequency:8011776

Adjust value:16
Minium error IRC8M frequency:8011776
```

**Figure 4-2. Oscilloscope output IRC8M actual frequency**



## 5. Revision history

**Table 5-1. Revision history**

| Revision No. | Description | Date |
|---|---|---|
| 1.0 | Initial Release | Oct.27,2021 |

## Important Notice