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## **Datasheet**

## **MM32L3xx**

### **32-bit Micro controller based on ARM Cortex M3**

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**Ver: 1.04\_n**

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## 1

# Introduction

## Introduction

### 1.1 Description

MM32L3xx(named as "the device" throughout this document) is ARM® Cortex™-M3 32-bit RISC core based micro controller family. The device has high speed embedded memory and the CPU, memory and AHB bus subsystem speed can attain up to 96MHz. The device also has integrated with extensive range of enhanced I/Os, two APB buses peripherals, 2 12-bit ADCs, 2 12-bit DACs, 3 general purpose 16-bit timers, 1 Advanced 16-bit timer, and standard communication interfaces device: 2 I2Cs, 2 SPIs, 1 USB, 1 CAN, and 3 UARTs.

The device works between 2.0V to 5.5V range. The normal temperature for the device is -40°C to +85°C and -40°C to +105°C extended temperature range devices are also available upon ordering. A comprehensive set of power-saving mode allows the design of low-power applications.

The devices are available in 4 different packages: LQFP64, LQFP48, LQFP32 and QFN32. Depending on the device chosen, different sets of peripherals are included.

The abundant peripheral configurations enable the device to fit wide range of applications in difference industries, Few examples are as follows:

- Motor drive and application control
- Healthcare and fitness equipment
- PC peripherals, gaming, GPS equipment
- Industrial Applications: Programmable Controllers (PLCs), Inverters, Printers and Scanners
- Alarm system, wired and wireless sensors, video intercom

### 1.2 Product Features

- Core and system
  - ARM® Cortex™-M3 CPU
  - Maximum operating frequency is up to 96MHz
- Memories
  - 128K Bytes of Flash memory
  - 20K Bytes of SRAM
  - Boot loader support Chip Flash and ISP (In-System Programming)
- Clock, reset and power management

- 2.0V to 5.5V application supply
  - Power-on/Power-down reset (POR/PDR), Programmable voltage detector (PVD)
  - External 8 to 24MHz high speed crystal oscillator
  - Embedded factory-tuned 48MHz high speed oscillator
  - PLL supports CPU running at 96MHz
  - External 32.768KHz low speed oscillator
- Low-power
  - Sleep, Stop and Standby modes
  - V<sub>BAT</sub> supply electricity for the RTC and the backup registers
- 2 12-bit ADCs, 1μS A/D converters (up to 16 channels)
  - Conversion range: 0 to V<sub>DDA</sub>
  - Support sampling time and resolution configuration
  - On-chip temperature sensor
  - On-chip voltage sensor
- 2 12-bit DACs
- 7 DMA controller
  - Supported peripherals: Timer, ADC, DAC, UART, I2C, SPI, USB and CAN
- Up to 51 fast I/Os:
  - All mappable on 16 external interrupt vectors
  - Almost all can work on 5V
- Debug mode
  - Serial wire debug (SWD) and JTAG interface
- Up to 7 timers
  - 1 16-bit 4-channel advanced-control timer for 4 channels PWM output, with deadtime generation and emergency stop
  - 3 16-bit timer, with up to 4 IC/OC, usable for IR control decoding
  - 2 watchdog timers (independent and window type)
  - SysTick timer: 24-bit downcounter
- Up to 9 Communication interfaces
  - 3 UARTs
  - 2 I2Cs
  - 2 SPIs
  - 1 CAN
  - 1 USB
- 96-bit unique ID (UID)
- Packages LQFP64, LQFP48, LQFP32 and QFN32

For more information about the complete product, refer to Section 2.2 of the data sheet. The relevant information about the Cortex™-M3, please refer to Cortex™-M3 technical reference manual.



## 2

## Specification

Specification

## 2.1 Device contrast

Table 1. MM32L3xx device features and peripheral counts

| Peripheral                         |                             | MM32L362PS/<br>MM32L373PS | MM32L362PF/<br>MM32L373PF | MM32L362PT/<br>MM32L373PT | MM32L362NT/<br>MM32L373NT |
|------------------------------------|-----------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| Flash memory -K Bytes              |                             | 64/128                    | 64/128                    | 64/128                    | 64/128                    |
| SRAM -K Bytes                      |                             | 20                        | 20                        | 20                        | 20                        |
| Timers                             | General purpose<br>(16 bit) | 3                         | 3                         | 3                         | 3                         |
|                                    | Advanced<br>control         | 1                         | 1                         | 1                         | 1                         |
| Common<br>interfaces               | UART                        | 3                         | 3                         | 2                         | 2                         |
|                                    | IIC                         | 2                         | 2                         | 1                         | 1                         |
|                                    | SPI                         | 2                         | 2                         | 1                         | 1                         |
|                                    | USB                         | 1                         | 1                         | 1                         | 1                         |
|                                    | CAN                         | 0/1                       | 0/1                       | 0/1                       | 0/1                       |
| GPIOs                              |                             | 51                        | 37                        | 23                        | 25                        |
| 12-bit ADC<br>(number of channels) |                             | 2<br>16 channels          | 2<br>10 channels          |                           |                           |
| AES                                |                             | YES                       |                           |                           |                           |
| Max CPU frequency                  |                             | 96 MHz                    |                           |                           |                           |
| Operating voltage                  |                             | 2.0V ~ 5.5V               |                           |                           |                           |
| Packages                           |                             | LQFP64                    | LQFP48                    | LQFP32                    | QFN32                     |

## 2.2 Summary

## 2.2.1 ARM® Cortex™-M3 and SRAM

The ARM® Cortex™-M3 is a generation of ARM processors for embedded systems. It has been developed to provide a low-cost platform that meets the needs of MCU implementation, with a reduced pin count and low-power consumption, while delivering outstanding computational performance and an advanced system response to interrupts.

The ARM® Cortex™-M3 processors feature exceptional code-efficiency, delivering the high performance expected from an ARM core, with memory sizes usually associated with 8- and 16-bit devices.

The devices have embedded ARM core and are compatible with all ARM tools and software.

### **2.2.2 Memory**

128K Bytes of embedded Flash memory.

### **2.2.3 SRAM**

20K Bytes of embedded SRAM.

### **2.2.4 Clocks and startup**

When the system is powered up, the default clock is from PLL with the resource from HSE 48 MHz oscillator. An external 8 ~ 24 MHz clock can also be configured to monitor the system during power up phases. If the system fails at power up, then the device will switch back to HSI clock directly. At the same time, a software interrupt can also be generated if it is enabled.

Several prescalers allow the application to configure the frequency of the AHB and the APB domains. The maximum frequency of the AHB and the APB domains is 96MHz. Refer to figure 3 for the clock drive block diagram.

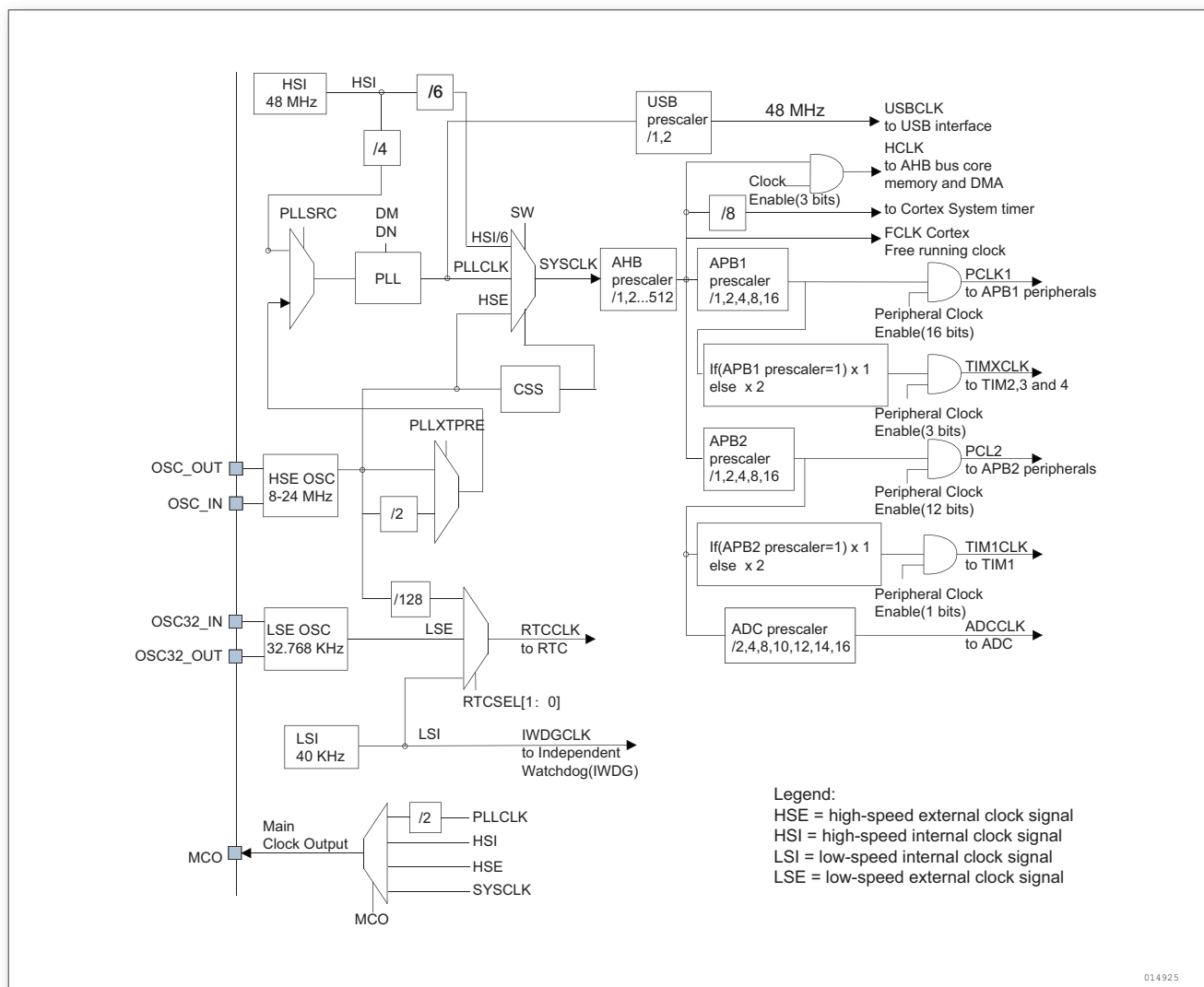


Figure 1. Clock tree

## 2.2.5 Cyclic Redundancy Check (CRC)

The CRC (Cyclic Redundancy Check) calculation unit uses a fixed polynomial generator to generate a CRC code from a 32-bit data word.

In many applications, CRC-based techniques are used to verify the consistency of data transmission or storage. Within the scope of the EN/IEC 60335-1 standard, it provides a means of detecting flash memory errors that can be used to compute the signature of the software in real time and to compare the generated signatures when linking and generating the software.

## 2.2.6 Nested vectored interrupt controller (NVIC)

The device embeds a nested vectored interrupt controller and is able to handle up to 68 maskable interrupt channels (not including the 16 interrupt lines of Cortex™-M3) with 16 priority levels.

- Closely coupled NVIC gives low latency interrupt processing
- Interrupt entry vector table address passed directly to the core
- Closely coupled NVIC core interface
- Allows early processing of interrupts
- Processing of late arriving higher priority interrupts
- Support for tail-chaining
- Processor state automatically saved
- Interrupt entry restored on interrupt exit with no instruction overhead

This hardware block provides flexible interrupt management features with minimal interrupt latency.

### 2.2.7 Extended interrupt/event controller (EXTI)

The extended interrupt/event controller consists of many edge detector lines are used to generate interrupt/event requests for waking up the system. Each line can be independently configured to select the trigger event (rising edge, falling edge, both) and can be masked independently. A pending register maintains the status of the interrupt requests. The EXTI can detect an external line with a pulse width shorter than the internal APB2 clock period. All GPIOs can be connected to the 16 external interrupt lines.

### 2.2.8 Boot modes

At startup, the boot pin and boot selector option bit are used to select one of the three boot options:

- Boot from User Flash memory
- Boot from System Memory
- Boot from embedded SRAM

The boot loader is located in System Memory. It is used to reprogram the Flash memory by using UART1.

### 2.2.9 Power supply schemes

- $V_{DD} = 2.0V \sim 5.5V$ : external power supply for I/Os and the internal regulator. Provided externally through  $V_{DD}$  pins.
- $V_{SSA}, V_{DDA} = 2.5V \sim 5.5V$ : external analog power supply for ADC, reset blocks, oscillators and PLL.  $V_{DDA}$  and  $V_{SSA}$  must be connected to  $V_{DD}$  and  $V_{SS}$ .
- $V_{BAT} = 1.8V \sim 5.5V$ : power supply for RTC, external clock 32 KHz oscillator and backup registers (through power switch) when  $V_{DD}$  is not present.

### 2.2.10 Power supply supervisors

The device has integrated power-on reset (POR) and power-down reset (PDR) circuits. They are always active, and ensure proper operation above a threshold of 1.8V. The device remains in reset mode when the monitored supply voltage is below a specified

threshold  $V_{POR/PDR}$ , without the need for an external reset circuit.

The device features an embedded programmable voltage detector (PVD) that monitors the  $V_{DD}/V_{DDA}$  power supply and compares it to the  $V_{PVD}$  threshold. An interrupt can be generated when VDD drops below the  $V_{PVD}$  threshold and/or when VDD is higher than the  $V_{PVD}$  threshold. The interrupt service routine can then generate a warning message and/or put the MCU into a safe state. The PVD is enabled by software.

### 2.2.11 Voltage regulator

The voltage regulator converts the external voltage to the internal digital logic and it is always enabled after reset.

### 2.2.12 Low-power modes

The device support three low-power modes to achieve the best compromise between low power consumption, short startup time and available wakeup sources.

#### Sleep mode

In Sleep mode, only the CPU is stopped. All peripherals continue to operate and can wake up the CPU when an interrupt/event occurs.

#### Stop mode

Stop mode achieves very low power consumption while retaining the content of SRAM and registers. the HSI and the HSE crystal oscillators are disabled. The voltage regulator can also be put either in normal or in low power mode.

#### Standby mode

Standby mode achieves the lowest power consumption of the system. This mode turns off the voltage regulator in CPU deep sleep mode. The entire 1.5V power supply area is powered down. PLL, HSI and HSE oscillators are also powered down. SRAM and register contents are missing. Only the backup registers and standby circuits remain powered.

### 2.2.13 Direct memory access controller (DMA)

The 7-channel general-purpose DMAs manage memory-to-memory, peripheral-to-memory and memory-to-peripheral transfers. The DMA supports circular buffer management, removing the need for user code intervention when the controller reaches the end of the buffer.

Each channel is connected to dedicated hardware DMA requests, with support for software trigger on each channel. Configuration is made by software and transfer sizes between source and destination are independent.

DMA can be used with the main peripherals: UART, I2C, SPI, DAC, USB, CAN, ADC general-purpose and advanced-control timers TIMx.

### 2.2.14 real-time clock register (RTC)

The real time clock is an independent timer. The RTC module has a set of counters that count continuously and provides the clock calendar function in the appropriate software configuration. Modify the value of the counter to reset the current time and date of the system. The RTC module and the clock configuration system (RCC\_BDCR register) are in the backup area, ie the RTC settings and time remain unchanged after a system reset or wake-up in standby mode.

### 2.2.15 Backup register (BKP)

The backup registers are ten 16-bit registers used to store 20 bytes of user application data when  $V_{DD}$  power is not present. They are still powered by  $V_{BAT}$ . They are also not reset when the system is woken up in standby mode, or when the system is reset or power is reset.

### 2.2.16 Timers and watchdogs

Medium capacity device include 1 advanced control , 3 general-purpose timers , 2 watch-dog timers and 1 SysTick timer.

The following table compares the features of the different timers:

Table 2. Timer feature comparison

| Timer type       | Timer | Counter resolution | Counter type      | Prescaler factor        | DMA request generation | Capture/-compare channels | Complementary outputs |
|------------------|-------|--------------------|-------------------|-------------------------|------------------------|---------------------------|-----------------------|
| Advanced control | TIM1  | 16-bit             | Up, down, up/down | integer from 1 to 65536 | Yes                    | 4                         | Yes                   |
| General purpose  | TIM2  | 16-bit             | Up, down, up/down | integer from 1 to 65536 | Yes                    | 4                         | No                    |
|                  | TIM3  | 16-bit             | Up, down, up/down | integer from 1 to 65536 | Yes                    | 4                         | No                    |
|                  | TIM4  | 16-bit             | Up                | integer from 1 to 65536 | Yes                    | 4                         | No                    |

### Advanced-control timer ( TIM1 )

The advanced-control timer can be seen as a three-phase PWM multiplexed on six channels. It has complementary PWM outputs with programmable inserted dead times. It can

also be seen as a complete general-purpose timer. The four independent channels can be used for:

- Input capture
- Output compare
- PWM generation (edge or center-aligned modes)
- One-pulse mode output

If configured as a standard 16-bit timer, it has the same features as the TIMx timer. If configured as the 16-bit PWM generator, it has full modulation capability (0 ~ 100%).

In debug mode, the counter can be frozen and the PWM output is disabled to cut off the switches controlled by these outputs.

Many features are shared with those of the standard timers which have the same architecture. The advanced control timer can therefore work together with the other timers via the Timer Link feature for synchronization or event chaining.

## General-purpose timers (TIMx)

There are 3 synchronizable general-purpose timers (TIM2、TIM3、TIM4).

## General-purpose timers 16-bit

### TIM3

The timer is based on a 16-bit auto-reload up/downcounter and a 16-bit prescaler. The feature is 4 independent channels each for input capture/output compare, PWM or one-pulse mode output.

The timer can work together or with the TIM1 advanced-control timer via the Timer Link feature for synchronization or event chaining. Their counter can be frozen in debug mode. Any of the general-purpose timers can be used to generate PWM outputs. They all have independent DMA request generation.

These timers are capable of handling quadrature (incremental) encoder signals and the digital outputs from 1 to 3 hall-effect sensors.

## Independent watchdog (IWDG)

The independent watchdog is based on an 8-bit prescaler and 12-bit downcounter with user-defined refresh window. It is clocked from an independent 40 KHz internal oscillator and as it operates independently from the main clock, it can operate in Stop and Standby modes. It can be used either as a watchdog to reset the device when a problem occurs, or as a free running timer for application timeout management. It is hardware or software configurable through the option bytes. The counter can be frozen in debug mode.

## System window watchdog (WWDG)

The system window watchdog is based on a 7-bit downcounter that can be set as free

running. It can be used as a watchdog to reset the device when a problem occurs. It is clocked from the APB clock (PCLK). It has an early warning interrupt capability and the counter can be frozen in debug mode.

### **SysTick timer**

This timer is dedicated to real-time operating systems, but could also be used as a standard down counter. It features:

- A 24-bit down counter
- Autoreload capability
- Maskable system interrupt generation when the counter reaches 0
- Programmable clock source

### **2.2.17 Universal asynchronous receiver/transmitter (UART)**

UART provides hardware management of the CTS, RTS.

Support LIN master-slave function.

All UART interface can be served by the DMA controller.

### **2.2.18 I2C interface**

The I2C interface can operate in multimaster or slave modes. It can support Standard mode, and Fast Mode.

It supports 7-bit and 10-bit addressing modes, multiple 7-bit slave addresses (two addresses, one with configurable mask).

### **2.2.19 Serial peripheral interface (SPI)**

The SPI interface, in slave or master mode, can be configured to 1 ~ 32 bits per frame.

All SPI interface can be served by the DMA controller.

### **2.2.20 Universal serial bus (USB)**

The microcontroller embeds a USB device peripheral compatible with the USB full-speed 12 Mbs. The USB interface implements a full-speed (12 Mbit/s) function interface. The dedicated 48 MHz clock is generated from the internal main PLL (the clock source must use a HSE crystal oscillator).

### **2.2.21 Controller area network (CAN)**

The CAN is compliant with specifications 2.0 A and B (active) with a bit rate up to 1 Mbit/s. It can receive and transmit standard frames with 11-bit identifiers as well as extended frames with 29-bit identifiers.



### 2.2.22 General-purpose inputs/outputs (GPIO)

Each of the GPIO pins can be configured by software as output (push-pull or open-drain), as input (with or without pull-up or pull-down) or as peripheral alternate function. Most of the GPIO pins are shared with digital or analog alternate functions. The I/O configuration can be locked if needed following a specific sequence in order to avoid spurious writing to the I/Os registers.

### 2.2.23 Analog-to-digital converter (ADC)

The two 12-bit analog-to-digital converters embedded into microcontrollers and the ADC shares up to 10 external channels, performing conversions in single-shot or scan modes. In scan mode, automatic conversion is performed on a selected group of analog inputs. The ADC can be served by the DMA controller.

The analog watchdog function allows very precise monitoring of all the way, multiple or all selected channels, and an interruption occurs when the monitored signal exceeds the preset threshold. The events generated by the general-purpose timers (TIMx) and the advanced-control timer (TIM1) can be internally connected to the ADC start trigger to allow the application to synchronize A/D conversion and timers.

### 2.2.24 Digital -to- analog converter (DAC)

Digital-to-analog conversion module (DAC) is a 12-bit digital input, voltage output digital-to-analog converter. The DAC can be configured in either 8-bit or 12-bit mode, or with the DMA controller. When the DAC is operating in 12-bit mode, the data can be set to left-justified or can be set to right-justified. The DAC has two output channels, each channel has a separate converter that can operate in dual DAC mode. In this mode, the output of two channels can be updated synchronously, and the conversion of the two channels can be performed simultaneously or separately.

This dual digital Interface supports the following features:

- two DAC converters: one for each output channel
- 8-bit or 12-bit monotonic output
- left or right data alignment in 12-bit mode
- synchronized update capability
- noise-wave generation
- triangular-wave generation
- dual DAC channel independent or simultaneous conversions
- DMA capability for each channel
- external triggers for conversion

### 2.2.25 Temperature sensor

The temperature sensor has to generate a voltage that varies linearly with temperature. The temperature sensor is internally connected to the input channel which is used to con-

vert the sensor output voltage into a digital value.

### 2.2.26 Serial single line SWD debug port (SW-DP)

Built-in ARM two-wire serial debug port (SW-DP) and Single line (JTAG).

An ARM SW-DP interface is provided to allow a serial wire debugging tool to be connected to the MCU.

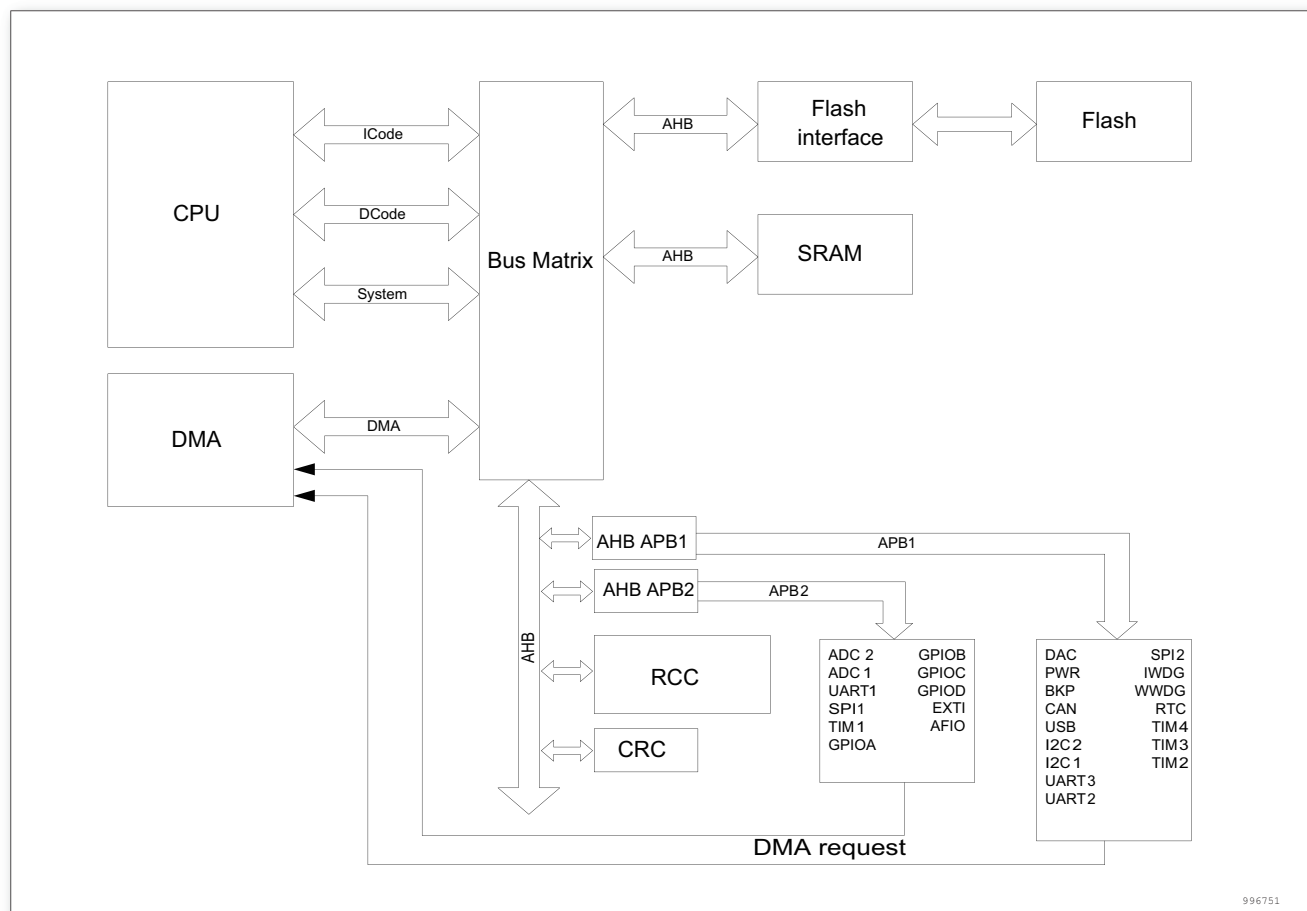
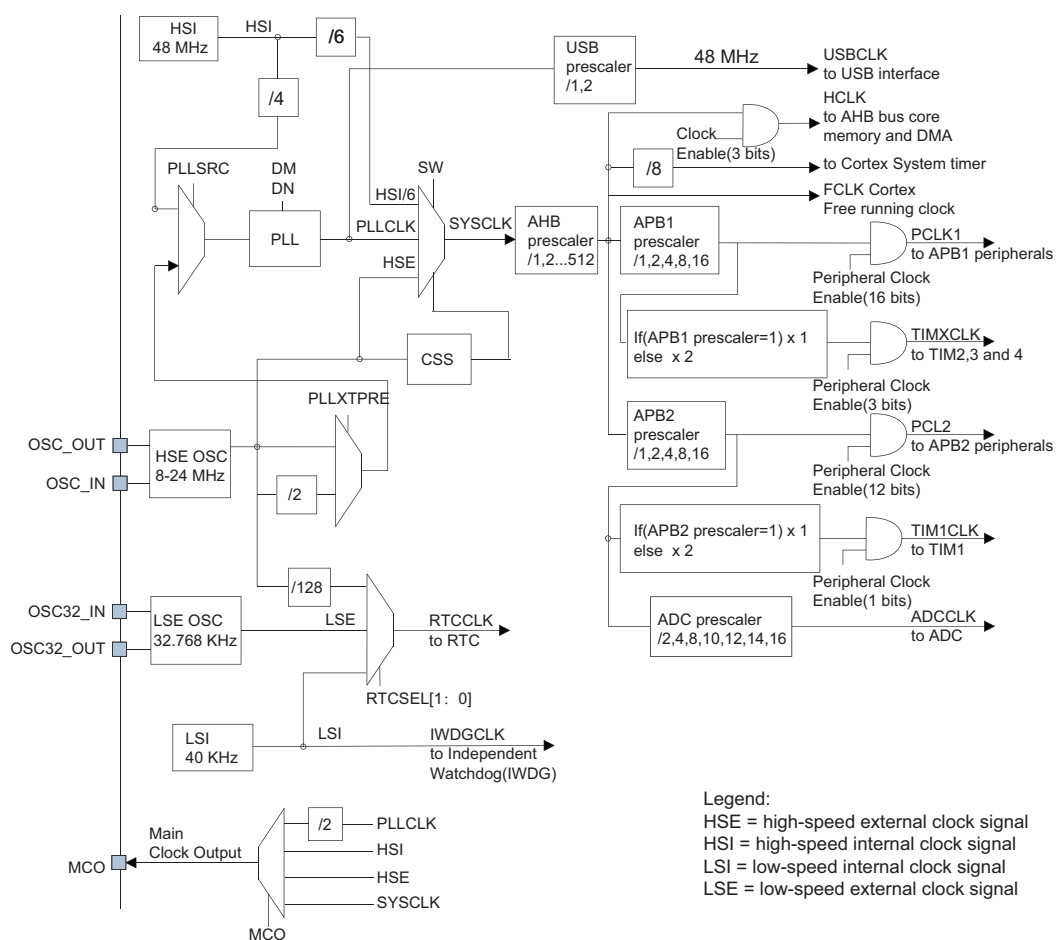


Figure 2. Block diagram



014925

Figure 3. Clock tree

## 3

## Pin definition

## Pin definition

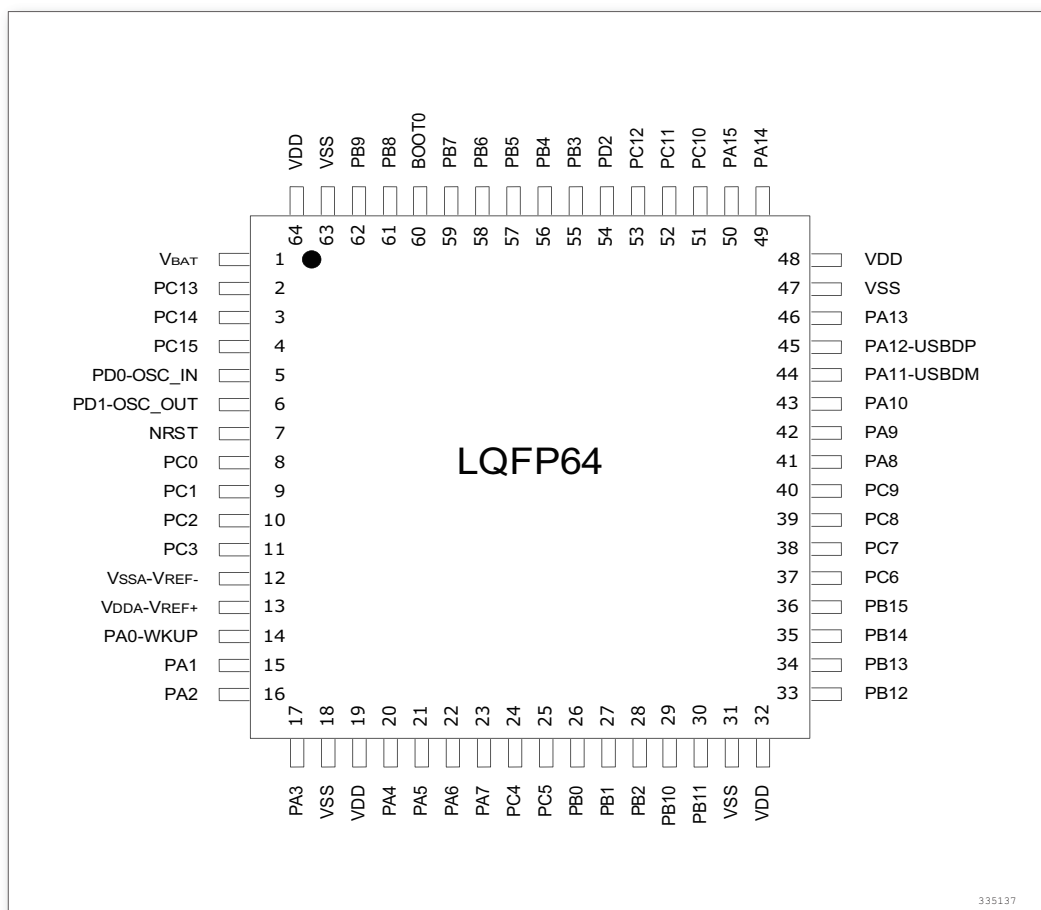


Figure 4. LQFP64 packet pinout

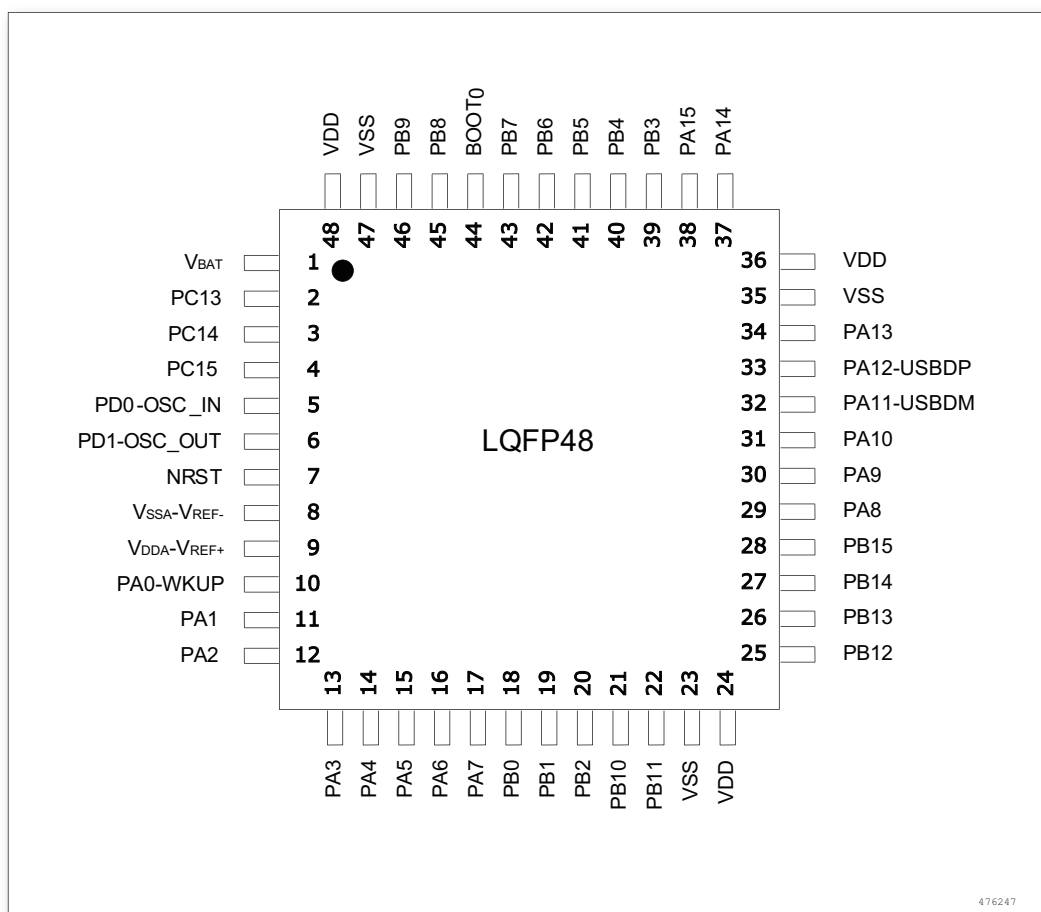


Figure 5. LQFP48 packet pinout

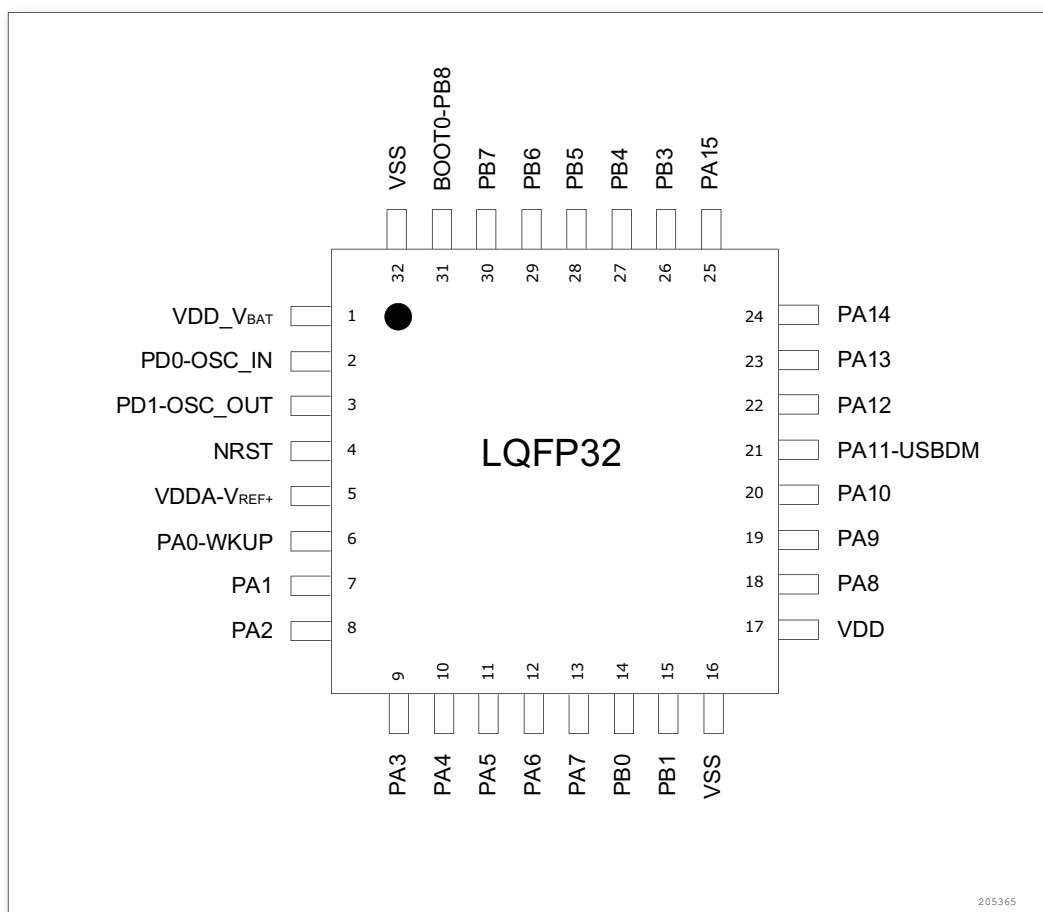


Figure 6. LQFP32 packet pinout

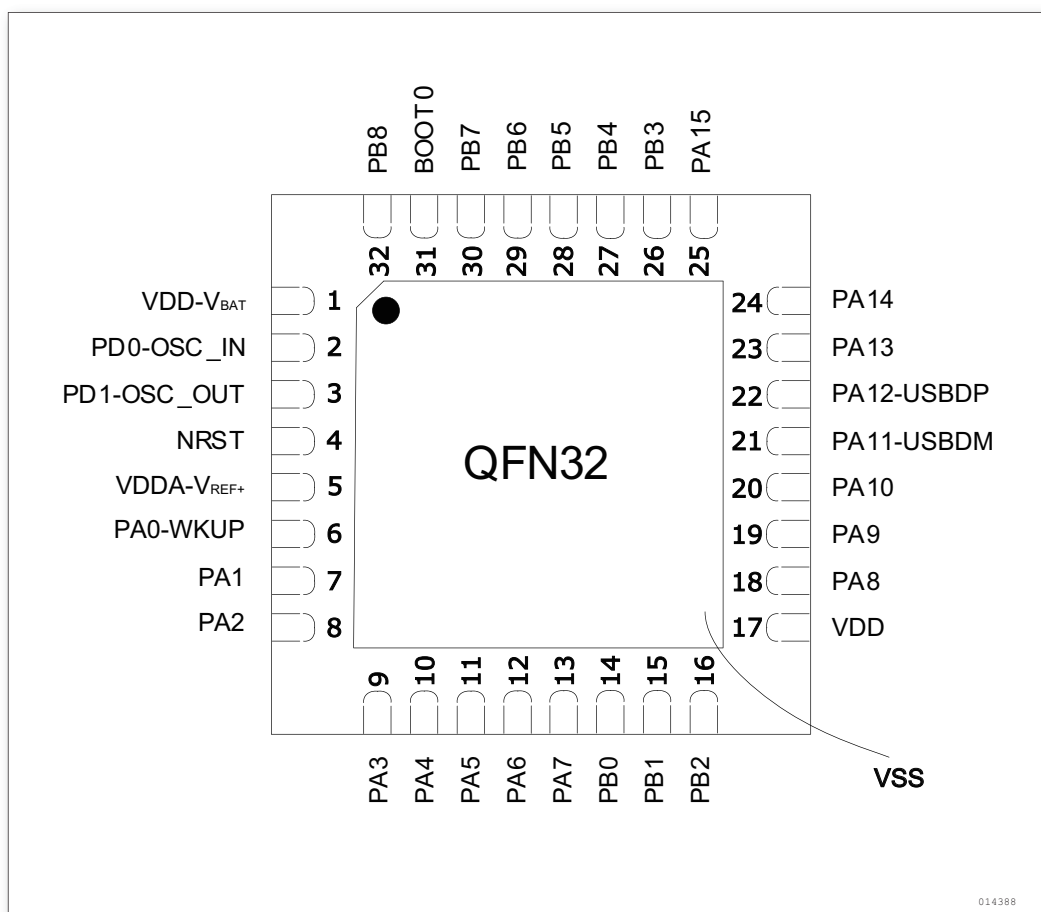


Figure 7. QFN32 packet pinout

Table 3. Pin definitions

| Pin number |         |         |        | Pin name         | Type <sup>(1)</sup> | I/O structure <sup>(2)</sup> | Main function    | Alternate functions | Additional functions |
|------------|---------|---------|--------|------------------|---------------------|------------------------------|------------------|---------------------|----------------------|
| LQFP 64    | LQFP 48 | LQFP 32 | QFN 32 |                  |                     |                              |                  |                     |                      |
| 1          | 1       | -       | -      | V <sub>BAT</sub> | S                   | -                            | V <sub>BAT</sub> | -                   | -                    |
| 2          | 2       | -       | -      | PC13-TAMPER-RTC  | I/O                 | -                            | PC13             | TAMPER-RTC          | -                    |
| 3          | 3       | -       | -      | PC14-OSC32_IN    | I/O                 | -                            | PC14             | OSC32_IN            | -                    |
| 4          | 4       | -       | -      | PC15-OSC32_OUT   | I/O                 | -                            | PC15             | OSC32_OUT           | -                    |
| 5          | 5       | 2       | 2      | PD0-OSC_IN       | I/O                 | -                            | OSC_IN           | -                   | -                    |
| 6          | 6       | 3       | 3      | PD1-OSC_OUT      | I/O                 | -                            | OSC_OUT          | -                   | -                    |
| 7          | 7       | 4       | 4      | NRST             | I/O                 | -                            | NRST             | -                   | -                    |
| 8          | -       | -       | -      | PC0              | I/O                 | -                            | PC0              | ADC2_IN2            | -                    |
| 9          | -       | -       | -      | PC1              | I/O                 | -                            | PC1              | ADC2_IN3            | -                    |

| Pin number |         |         |        | Pin name | Type <sup>(1)</sup> | I/O structure <sup>(2)</sup> | Main function | Alternate functions                              | Additional functions |
|------------|---------|---------|--------|----------|---------------------|------------------------------|---------------|--|----------------------|
| LQFP 64    | LQFP 48 | LQFP 32 | QFN 32 |          |                     |                              |               |  |                      |
| 10         | -       | -       | -      | PC2      | I/O                 | -                            | PC2           | ADC2_IN4   | -                    |
| 11         | -       | -       | -      | PC3      | I/O                 | -                            | PC3           | ADC2_IN5   | -                    |
| 12         | 8       | -       | -      | VSSA     | S                   | -                            | VSSA          | -  | -                    |
| 13         | 9       | 5       | 5      | VDDA     | S                   | -                            | VDDA          | -  | -                    |
| 14         | 10      | 6       | 6      | PA0-WKUP | I/O                 | -                            | PA0           | ADC1_IN0/<br>WKUP/<br>UART2_CTS/<br>TIM2_CH1_ETR | -                    |
| 15         | 11      | 7       | 7      | PA1      | I/O                 | -                            | PA1           | ADC1_IN1/<br>UART2_RTS/<br>TIM2_CH2              | -                    |
| 16         | 12      | 8       | 8      | PA2      | I/O                 | -                            | PA2           | ADC1_IN2/<br>UART2_TX/<br>TIM2_CH3               | -                    |
| 17         | 13      | 9       | 9      | PA3      | I/O                 | -                            | PA3           | ADC1_IN3/<br>UART2_RX/<br>TIM2_CH4               | -                    |
| 18         | -       | -       | 0      | VSS      | S                   | -                            | VSS           | -  | -                    |
| 19         | -       | 1       | 1      | VDD      | S                   | -                            | VDD           | -  | -                    |
| 20         | 14      | 10      | 10     | PA4      | I/O                 | -                            | PA4           | ADC1_IN4/<br>DAC1_OUT/<br>SPI1_NSS               | -                    |
| 21         | 15      | 11      | 11     | PA5      | I/O                 | -                            | PA5           | ADC1_IN5/<br>DAC2_OUT/<br>SPI1_SCK               | -                    |
| 22         | 16      | 12      | 12     | PA6      | I/O                 | -                            | PA6           | ADC1_IN6/<br>SPI1_MISO/<br>TIM3_CH1              | TIM1_BKIN            |
| 23         | 17      | 13      | 13     | PA7      | I/O                 | -                            | PA7           | ADC1_IN7/<br>SPI1_MOSI/<br>TIM3_CH2              | TIM1_CH1N            |
| 24         | -       | -       | -      | PC4      | I/O                 | -                            | PC4           | ADC2_IN6   | -                    |
| 25         | -       | -       | -      | PC5      | I/O                 | -                            | PC5           | ADC2_IN7   | -                    |
| 26         | 18      | 14      | 14     | PB0      | I/O                 | -                            | PB0           | ADC2_IN0/<br>TIM3_CH3                            | TIM1_CH2N            |
| 27         | 19      | 15      | 15     | PB1      | I/O                 | -                            | PB1           | ADC2_IN1/<br>TIM3_CH4                            | TIM1_CH3N            |



| Pin number |         |         |        | Pin name | Type <sup>(1)</sup> | I/O structure <sup>(2)</sup> | Main function | Alternate functions                         | Additional functions |
|------------|---------|---------|--------|----------|---------------------|------------------------------|---------------|---|----------------------|
| LQFP 64    | LQFP 48 | LQFP 32 | QFN 32 |          |                     |                              |               |   |                      |
| 28         | 20      | -       | 16     | PB2      | I/O                 | FT                           | PB2/<br>BOOT1 | -   | -                    |
| 29         | 21      | -       | -      | PB10     | I/O                 | FT                           | PB10          | I2C2_SCL/<br>UART3_TX                       | TIM2_CH3             |
| 30         | 22      | -       | -      | PB11     | I/O                 | FT                           | PB11          | I2C2_SDL/<br>UART3_RX                       | TIM2_CH4             |
| 31         | 23      | 16      | 0      | VSS      | S                   | -                            | VSS           | -   | -                    |
| 32         | 24      | 17      | 17     | VDD      | S                   | -                            | VDD           | -   | -                    |
| 33         | 25      | -       | -      | PB12     | I/O                 | FT                           | PB12          | SPI2_NSS/<br>I2C2_SMBAL/<br>TIM1_BKIN       | -                    |
| 34         | 26      | -       | -      | PB13     | I/O                 | FT                           | PB13          | SPI2_SCK/<br>UART3_CTS/<br>TIM1_CH1N        | -                    |
| 35         | 27      | -       | -      | PB14     | I/O                 | FT                           | PB14          | SPI2_MISO/<br>UART3_RTS/<br>TIM1_CH2N       | -                    |
| 36         | 28      | -       | -      | PB15     | I/O                 | FT                           | PB15          | SPI2_MOSI/<br>TIM1_CH3N                     | -                    |
| 37         | -       | -       | -      | PC6      | I/O                 | FT                           | PC6           | -   | TIM3_CH1             |
| 38         | -       | -       | -      | PC7      | I/O                 | FT                           | PC7           | -   | TIM3_CH2             |
| 39         | -       | -       | -      | PC8      | I/O                 | FT                           | PC8           | -   | TIM3_CH3             |
| 40         | -       | -       | -      | PC9      | I/O                 | FT                           | PC9           | -   | TIM3_CH4             |
| 41         | 29      | 18      | 18     | PA8      | I/O                 | FT                           | PA8           | TIM1_CH1/<br>MCO                            | -                    |
| 42         | 30      | 19      | 19     | PA9      | I/O                 | FT                           | PA9           | UART1_TX/<br>TIM1_CH2                       | -                    |
| 43         | 31      | 20      | 20     | PA10     | I/O                 | FT                           | PA10          | UART1_RX/<br>TIM1_CH3                       | -                    |
| 44         | 32      | 21      | 21     | PA11     | I/O                 | FT                           | PA11          | UART1_CTS/<br>USBDM/<br>CAN_RX/<br>TIM1_CH4 | -                    |
| 45         | 33      | 22      | 22     | PA12     | I/O                 | FT                           | PA12          | UART1_RTS/<br>USBDP/<br>CAN_TX/<br>TIM1_ETR | -                    |

| Pin number |         |         |        | Pin name | Type <sup>(1)</sup> | I/O structure <sup>(2)</sup> | Main function  | Alternate functions   | Additional functions                       |
|------------|---------|---------|--------|----------|---------------------|------------------------------|----------------|-----------------------|--|
| LQFP 64    | LQFP 48 | LQFP 32 | QFN 32 |          |                     |                              |                |                       |  |
| 46         | 34      | 23      | 23     | PA13     | I/O                 | FT                           | JTM/<br>SWDIO  | -                     | PA13                                       |
| 47         | 35      | 32      | 0      | VSS      | S                   | -                            | VSS            | -                     | -  |
| 48         | 36      | -       | -      | VDD      | S                   | -                            | VDD            | -                     | -  |
| 49         | 37      | 24      | 24     | PA14     | I/O                 | FT                           | JTCK/<br>SWCLK | -                     | PA14                                       |
| 50         | 38      | 25      | 25     | PA15     | I/O                 | FT                           | JTDI           | -                     | PA15/<br>TIM2_CH1<br>_ETR/<br>SPI1_NSS     |
| 51         | -       | -       | -      | PC10     | I/O                 | FT                           | PC10           | -                     | UART3_TX                                   |
| 52         | -       | -       | -      | PC11     | I/O                 | FT                           | PC11           | -                     | UART3_RX                                   |
| 53         | -       | -       | -      | PC12     | I/O                 | FT                           | PC12           | -                     | -  |
| 54         | -       | -       | -      | PD2      | I/O                 | FT                           | PD2            | TIM3_ETR              | -  |
| 55         | 39      | 26      | 26     | PB3      | I/O                 | FT                           | JTDO           | -                     | PB3/<br>TRACESWO/<br>TIM2_CH2/<br>SPI1_SCK |
| 56         | 40      | 27      | 27     | PB4      | I/O                 | FT                           | NJTRST         | -                     | PB4/<br>TIM3_CH1/<br>SPI1_MISO             |
| 57         | 41      | 28      | 28     | PB5      | I/O                 | -                            | PB5            | I2C1_SMBAL            | TIM3_CH2/<br>SPI1_MOSI                     |
| 58         | 42      | 29      | 29     | PB6      | I/O                 | FT                           | PB6            | I2C1_SCL/<br>TIM4_CH1 | UART1_TX                                   |
| 59         | 43      | 30      | 30     | PB7      | I/O                 | FT                           | PB7            | I2C1_SDA/<br>TIM4_CH2 | UART1_RX                                   |
| 60         | 44      | 31      | 31     | BOOT0    | I                   | -                            | BOOT0          | -                     | -  |
| 61         | 45      | 32      | 32     | PB8      | I/O                 | FT                           | PB8            | TIM4_CH3              | I2C1_SCL/<br>CAN_RX                        |
| 62         | 46      | -       | -      | PB9      | I/O                 | FT                           | PB9            | TIM4_CH4              | I2C1_SDA/<br>CAN_TX                        |
| 63         | 47      | 32      | 0      | VSS      | S                   | -                            | VSS            | -                     | -  |
| 64         | 48      | -       | -      | VDD      | S                   | -                            | VDD            | -                     | -  |

1. I = input, O = output, S = power supply, HiZ = high resistance.

2. FT: 5V tolerant, Input signal should be between VDD and 5V.

## 4

## Memory mapping

## Memory mapping

Table 4. Memory mapping

| Bus   | Boundary address          | Size   | Peripheral  | Notes |
|-------|---------------------------|--------|---|-------|
| Flash | 0x0000 0000 - 0x0001 FFFF | 128KB  | Main flash memory, system memory, or SRAM, depends on the configuration of BOOT |       |
|       | 0x000 20000 - 0x07FF FFFF | ~128KB | Reserved  |       |
|       | 0x0800 0000 - 0x0801 FFFF | 128KB  | Main Flash memory   |       |
|       | 0x0802 0000 - 0x0FFF FFFF | ~128KB | Reserved  |       |
|       | 0x1000 0000 - 0x1000 1FFF | 8KB    | Reserved  |       |
|       | 0x1000 2000 - 0x1FFD FFFF | ~256KB | Reserved  |       |
|       | 0x1FFE 0000 - 0x1FFE 01FF | 0.5KB  | Protect byte  |       |
|       | 0x1FFE 0200 - 0x1FFE 0FFF | 3KB    | Reserved  |       |
|       | 0x1FFE 1000 - 0x1FFE 1BFF | 3KB    | Security space  |       |
|       | 0x1FFE 1C00 - 0x1FFF F3FF | ~256KB | Reserved  |       |
|       | 0x1FFF F400 - 0x1FFF F7FF | 1KB    | System memory   |       |
|       | 0x1FFF F800 - 0x1FFF F80F | 16KB   | Option bytes  |       |
|       | 0x1FFF F810 - 0x1FFF FFFF | ~2KB   | Reserved  |       |
| SRAM  | 0x2000 0000 - 0x2000 4FFF | 20KB   | SRAM  |       |
|       | 0x2000 5000 - 0x3FFF FFFF | ~512MB | Reserved  |       |
| APB1  | 0x4000 0000 - 0x4000 03FF | 1KB    | TIM2  |       |
|       | 0x4000 0400 - 0x4000 07FF | 1KB    | TIM3  |       |
|       | 0x4000 0800 - 0x4000 0BFF | 1KB    | TIM4  |       |
|       | 0x4000 0C00 - 0x4000 27FF | 7KB    | Reserved  |       |
|       | 0x4000 2800 - 0x4000 2BFF | 1KB    | RTC   |       |
|       | 0x4000 2C00 - 0x4000 2FFF | 1KB    | WWDG  |       |
|       | 0x4000 3000 - 0x4000 33FF | 1KB    | IWWDG   |       |
|       | 0x4000 3400 - 0x4000 37FF | 1KB    | Reserved  |       |
|       | 0x4000 3800 - 0x4000 3BFF | 1KB    | SPI2  |       |
|       | 0x4000 3C00 - 0x4000 43FF | 2KB    | Reserved  |       |
|       | 0x4000 4400 - 0x4000 47FF | 1KB    | UART2   |       |
|       | 0x4000 4800 - 0x4000 4BFF | 1KB    | UART3   |       |
|       | 0x4000 4C00 - 0x4000 53FF | 2KB    | Reserved  |       |
|       | 0x4000 5400 - 0x4000 57FF | 1KB    | I2C1  |       |
|       | 0x4000 5800 - 0x4000 5BFF | 1KB    | I2C2  |       |

| Bus  | Boundary address          | Size | Peripheral      | Notes |
|------|---------------------------|------|-----------------|-------|
| APB1 | 0x4000 5C00 - 0x4000 5FFF | 1KB  | USB             |       |
|      | 0x4000 6000 - 0x4000 63FF | 1KB  | Reserved        |       |
|      | 0x4000 6400 - 0x4000 67FF | 1KB  | CAN             |       |
|      | 0x4000 6800 - 0x4000 6BFF | 1KB  | Reserved        |       |
|      | 0x4000 6C00 - 0x4000 6FFF | 1KB  | BKP             |       |
|      | 0x4000 7000 - 0x4000 73FF | 1KB  | PWR             |       |
|      | 0x4000 7400 - 0x4000 77FF | 34KB | DAC             |       |
|      | 0x4000 7800 - 0x4000 FFFF | 34KB | Reserved        |       |
| APB2 | 0x4001 0000 - 0x4001 03FF | 1KB  | AFIO            |       |
|      | 0x4001 0400 - 0x4001 07FF | 1KB  | EXTI            |       |
|      | 0x4001 0800 - 0x4001 0BFF | 1KB  | GPIOA           |       |
|      | 0x4001 0C00 - 0x4001 0FFF | 1KB  | GPIOB           |       |
|      | 0x4001 1000 - 0x4001 13FF | 1KB  | GPIOC           |       |
|      | 0x4001 1400 - 0x4001 17FF | 1KB  | GPIOD           |       |
|      | 0x4001 1800 - 0x4001 1BFF | 1KB  | Reserved        |       |
|      | 0x4001 1C00 - 0x4001 23FF | 2KB  | Reserved        |       |
|      | 0x4001 2400 - 0x4001 27FF | 1KB  | ADC1            |       |
|      | 0x4001 2800 - 0x4001 2BFF | 1KB  | ADC2            |       |
|      | 0x4001 2C00 - 0x4001 2FFF | 1KB  | TIM1            |       |
|      | 0x4001 3000 - 0x4001 33FF | 1KB  | SPI1            |       |
|      | 0x4001 3400 - 0x4001 37FF | 1KB  | Reserved        |       |
|      | 0x4001 3800 - 0x4001 3BFF | 1KB  | UART1           |       |
|      | 0x4001 3C00 - 0x4001 3FFF | 1KB  | Reserved        |       |
|      | 0x4001 4000 - 0x4001 43FF | 1KB  | Reserved        |       |
|      | 0x4001 4400 - 0x4001 47FF | 1KB  | Reserved        |       |
|      | 0x4001 4800 - 0x4001 4BFF | 1KB  | Reserved        |       |
|      | 0x4001 4C00 - 0x4001 7FFF | 13KB | Reserved        |       |
|      | 0x4001 8000 - 0x4001 FFFF | 32KB | Reserved        |       |
| AHB  | 0x4002 0000 - 0x4002 03FF | 1KB  | DMA             |       |
|      | 0x4002 0400 - 0x4002 0FFF | 3KB  | Reserved        |       |
|      | 0x4002 1000 - 0x4002 13FF | 1KB  | RCC             |       |
|      | 0x4002 1400 - 0x4002 1FFF | 3KB  | Reserved        |       |
|      | 0x4002 2000 - 0x4002 23FF | 1KB  | Flash interface |       |
|      | 0x4002 2400 - 0x4002 2FFF | 3KB  | Reserved        |       |
|      | 0x4002 3000 - 0x4002 33FF | 1KB  | CRC             |       |
|      | 0x4002 3400 - 0x4002 5FFF | 11KB | Reserved        |       |
|      | 0x4002 6000 - 0x4002 63FF | 4KB  | AES             |       |

## 5

## Electrical characteristics

### Electrical characteristics

### 5.1 Parameter conditions

Unless otherwise specified, all voltages are referenced to  $V_{SS}$ .

#### 5.1.1 Minimum and maximum values

Unless otherwise specified, the minimum and maximum values are guaranteed with an ambient temperature at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 3.3\text{V}$ .

#### 5.1.2 Typical values

Unless otherwise specified, typical data are based on  $T_A = 25^\circ\text{C}$  and  $V_{DD} = 3.3\text{V}$ . They are given only as design guidelines and are not tested.

#### 5.1.3 Typical curves

Unless otherwise specified, all typical curves are given only as design guidelines and are not tested.

#### 5.1.4 Loading capacitor

The load conditions used for pin parameter measurement are shown in the figure below.

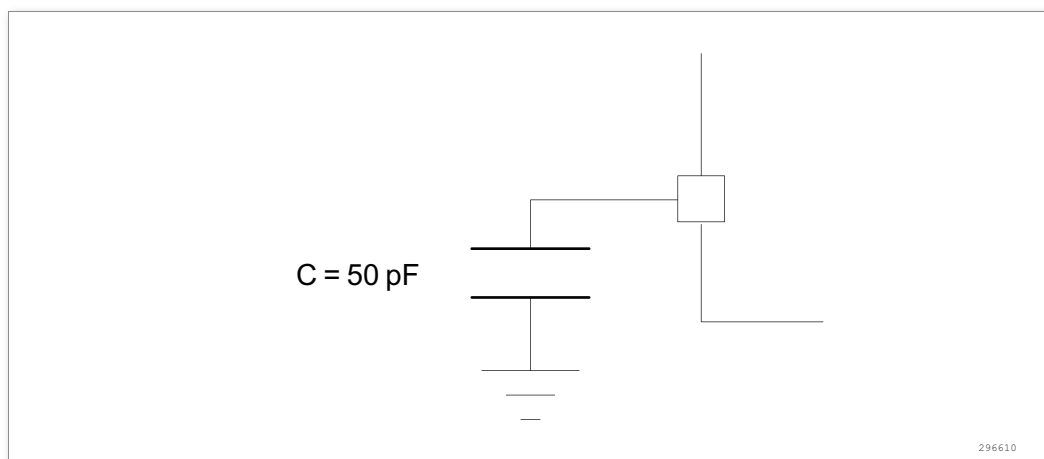


Figure 8. Pin loading conditions

### 5.1.5 Pin input voltage

The input voltage measurement on a pin of the device is shown in the figure below.

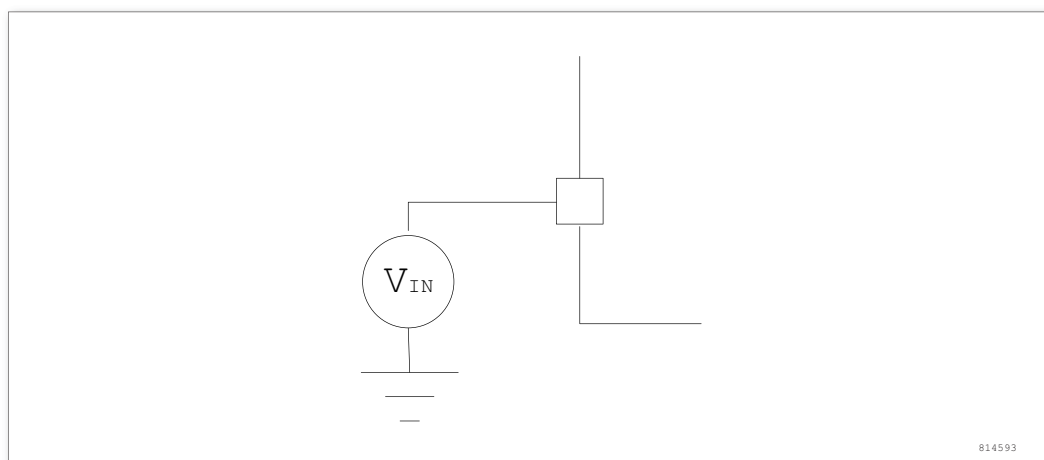


Figure 9. Pin input voltage

### 5.1.6 Power supply scheme

The power supply design scheme is shown in the figure below.

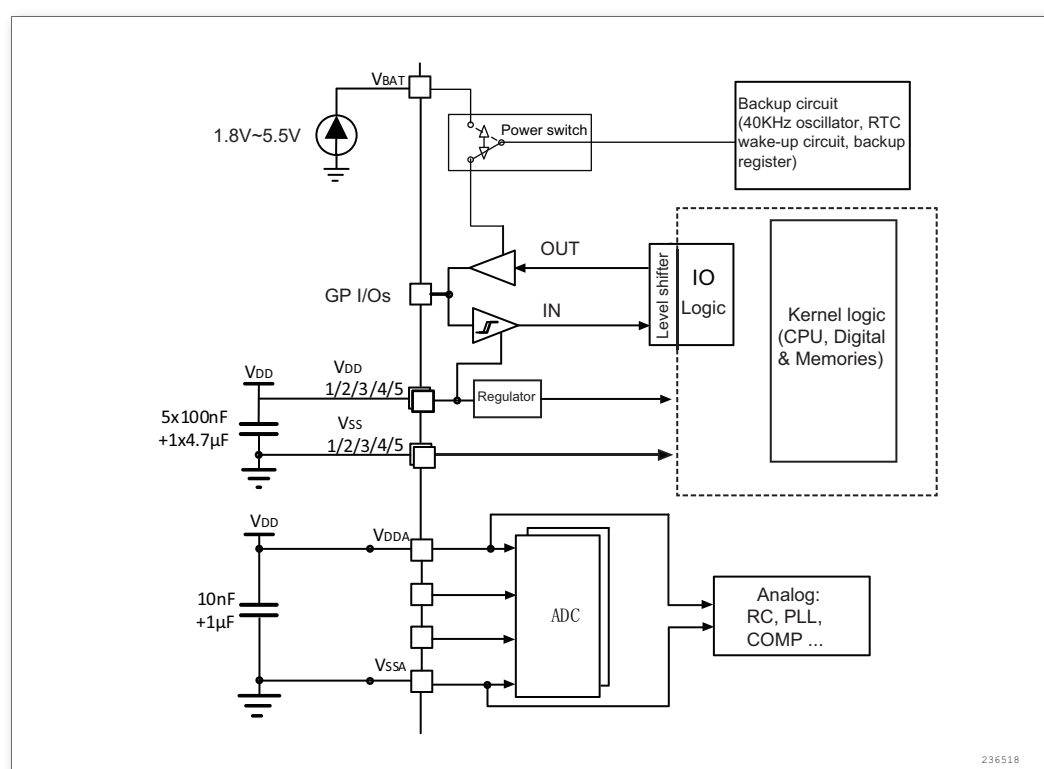


Figure 10. Power supply scheme

### 5.1.7 Current consumption measurement

The measurement of the current consumption on the pin is shown in the figure below.

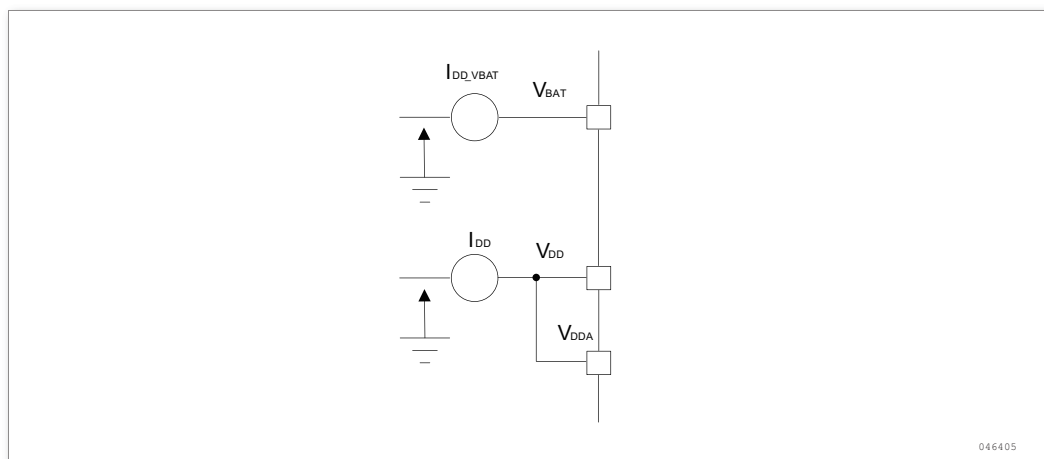


Figure 11. Current consumption measurement scheme

## 5.2 Absolute maximum ratings

Stresses above the absolute maximum ratings listed in Tables (Table 5, Table 6, Table 7) may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these conditions is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

Table 5. Voltage characteristics

| Symbol               | Definition   | Min            | Max | Unit |
|----------------------|--|----------------|-----|------|
| $V_{DD} - V_{SS}$    | External main supply voltage (including $V_{DDA}$ and $V_{SSA}$ ) <sup>(1)</sup> | - 0.3          | 5.5 | V    |
| $V_{IN}$             | Input voltage on FT and FTf pins <sup>(2)</sup>                                  | $V_{SS} - 0.3$ | 5.5 |      |
|                      | Input voltage on other pins <sup>(2)</sup>                                       | $V_{SS} - 0.3$ | 5.5 |      |
| $ \Delta V_{DDx} $   | Variations between different $V_{DD}$ power pins                                 |                | 50  | mV   |
| $ V_{SSx} - V_{SS} $ | Variations between all the different ground pins                                 |                | 50  |      |

1. All main power ( $V_{DD}$ ,  $V_{DDA}$ ) and ground ( $V_{SS}$ ,  $V_{SSA}$ ) pins must always be connected to the external power supply, in the permitted range.
2.  $V_{IN}$  maximum must always be respected. Refer to Table below for maximum allowed injected current values.

Table 6. Current characteristics

| Symbol    | Definition   | Max | Unit |
|-----------|--|-----|------|
| $I_{VDD}$ | Total current into sum of all $V_{DD}/V_{DDA}$ power lines (source) <sup>(1)</sup> | 150 | mA   |
| $I_{VSS}$ | Total current out of sum of all $V_{SS}$ ground lines (sink) <sup>(1)</sup>        | 150 | mA   |

| Symbol                      | Definition   | Max | Unit |
|-----------------------------|--|-----|------|
| $I_{IO}$                    | Output current sunk by any I/O and control pin                         | 20  | mA   |
| $I_{IO}$                    | Output current source by any I/O and control pin                       | -18 | mA   |
| $I_{INJ(PIN)}^{(2)(3)}$     | Injected current on NRST pins  | ±5  | mA   |
| $I_{INJ(PIN)}^{(2)(3)}$     | Injected current on OSC_IN pin of HSE and OSC_IN pin of LSE            | ±5  | mA   |
| $I_{INJ(PIN)}^{(2)(3)}$     | Injected current on other pins <sup>(4)</sup>                          | ±5  | mA   |
| $\Sigma I_{INJ(PIN)}^{(2)}$ | Total injected current(sum of all I/O and control pins) <sup>(4)</sup> | ±25 | mA   |

1. All main power( $V_{DD}$ ,  $V_{DDA}$ ) and ground( $V_{SS}$ ,  $V_{SSA}$ ) pins must always be connected to the external power supply, in the permitted range.
2.  $I_{INJ(PIN)}$  cannot exceed its limit, that is, to ensure that the  $V_{IN}$  does not exceed its maximum value. If  $V_{IN}$  does not guarantee that its maximum value is not exceeded, ensure that  $I_{INJ(PIN)}$  does not exceed its maximum value under external restrictions. When  $V_{IN} > V_{DD}$ , there is a forward injection current; when  $V_{IN} < V_{SS}$ , there is a reverse injection current.
3. Negative injection disturbs the analog performance of the device.
4. When several inputs are submitted to a current injection, the maximum  $I_{INJ(PIN)}$  is the absolute sum of the positive and negative injected currents (instantaneous values).

Table 7. Thermal characteristics

| Symbol    | Definition                   | Max          | Unit |
|-----------|------------------------------|--------------|------|
| $T_{STG}$ | Storage temperature range    | - 45 ~ + 150 | °C   |
| $T_J$     | Maximum junction temperature | 125          | °C   |

## 5.3 Operating conditions

### 5.3.1 General operating conditions

Table 8. General operating conditions

| Symbol         | Parameter                     | Conditions | Min | Max        | Unit |
|----------------|-------------------------------|------------|-----|------------|------|
| $f_{HCLK}$     | Internal AHB clock frequency  |            | 0   | 96         | MHz  |
| $f_{PCLK1}$    | Internal APB1 clock frequency |            | 0   | $f_{HCLK}$ |      |
| $f_{PCLK2}$    | Internal APB2 clock frequency |            | 0   | $f_{HCLK}$ |      |
| $V_{DD}^{(1)}$ | Standard operating voltage    |            | 2.0 | 5.5        | V    |



| Symbol    | Parameter   | Conditions  | Min | Max | Unit             |
|-----------|---|---|-----|-----|------------------|
| $V_{DDA}$ | Analog operating voltage  | Must be the same voltage as $V_{DD}$ <sup>(1)</sup> | 2.5 | 5.5 | V                |
| $V_{BAT}$ | Backup part of working voltage  |   | 1.8 | 5.5 | V                |
| $P_D$     | Power dissipation temperature:<br>$T_A = 85^\circ\text{C}$ <sup>(2)</sup> | LQFP64  |     | 203 | mW               |
|           |   | LQFP48  |     |     |                  |
|           |   | LQFP32/QFN32  |     |     |                  |
| $T_A$     | Ambient temperature:<br>$T_A = 85^\circ\text{C}$                          | Maximum power dissipation                           | -40 | 85  | $^\circ\text{C}$ |
|           |   | Low power dissipation <sup>(3)</sup>                | -40 | 105 |                  |
|           | Ambient temperature:<br>$T_A = 105^\circ\text{C}$                         | Maximum power dissipation                           | -40 | 105 | $^\circ\text{C}$ |
|           |   | Low power dissipation <sup>(3)</sup>                | -40 | 125 |                  |

1. It is recommended to use the same power supply for  $V_{DD}$  and  $V_{DDA}$ , the maximum permissible difference between  $V_{DD}$  and  $V_{DDA}$  is 300mV during power up and normal operation.
2. If  $T_A$  is low, higher  $P_D$  values are allowed as long as  $T_J$  does not exceed  $T_{Jmax}$  (See subsec 5.1).
3. In low power dissipation state,  $T_A$  can be extended to this range as long as  $T_J$  does not exceed  $T_{Jmax}$  (See subsec 5.1).

### 5.3.2 Operating conditions at power-up/power-down

The parameters given in the table below are based on tests under normal operating conditions.

Table 9. Operating conditions at power-up/power-down

| Symbol    | Parameter                | Conditions               | Min | Max      | Unit            |
|-----------|--------------------------|--------------------------|-----|----------|-----------------|
| $t_{VDD}$ | $V_{VDD}$ rise time rate | $T_A = 27^\circ\text{C}$ | 100 | $\infty$ | $\mu\text{S/V}$ |
|           | $V_{VDD}$ fall time rate |                          | 100 | $\infty$ |                 |

### 5.3.3 Embedded reset and power control block characteristics

The parameters given in the table below are based on the ambient temperature and the  $V_{DD}$  supply voltage listed in Table 8.

Table 10. Embedded reset and power control block characteristics

| Symbol | Parameter | Conditions                    | Min   | Typ   | Max   | Unit |
|--------|-----------|-------------------------------|-------|-------|-------|------|
|        |           | PLS[3: 0]=0000 (Rising edge)  | 1.813 | 1.819 | 1.831 | V    |
|        |           | PLS[3: 0]=0000 (Falling edge) |       | 1.705 |       | V    |
|        |           | PLS[3: 0]=0001 (Rising edge)  | 2.112 | 2.116 | 2.124 | V    |
|        |           | PLS[3: 0]=0001 (Falling edge) |       | 2.0   |       | V    |

| Symbol               | Parameter                     | Conditions                    | Min                 | Typ   | Max   | Unit |
|----------------------|-------------------------------|-------------------------------|---------------------|-------|-------|------|
|                      |                               | PLS[3: 0]=0010 (Rising edge)  | 2.411               | 2.414 | 2.421 | V    |
|                      |                               | PLS[3: 0]=0010 (Falling edge) |                     | 2.297 |       | V    |
|                      |                               | PLS[3: 0]=0011 (Rising edge)  | 2.711               | 2.714 | 2.719 | V    |
|                      |                               | PLS[3: 0]=0011 (Falling edge) |                     | 2.597 |       | V    |
|                      |                               | PLS[3: 0]=0100 (Rising edge)  | 3.011               | 3.013 | 3.018 | V    |
|                      |                               | PLS[3: 0]=0100 (Falling edge) |                     | 2.895 |       | V    |
|                      |                               | PLS[3: 0]=0101 (Rising edge)  | 3.311               | 3.313 | 3.317 | V    |
|                      |                               | PLS[3: 0]=0101 (Falling edge) |                     | 3.194 |       | V    |
|                      |                               | PLS[3: 0]=0110 (Rising edge)  | 3.611               | 3.613 | 3.616 | V    |
|                      |                               | PLS[3: 0]=0110 (Falling edge) |                     | 3.494 |       | V    |
|                      |                               | PLS[3: 0]=0111 (Rising edge)  | 3.91                | 3.913 | 3.916 | V    |
|                      |                               | PLS[3: 0]=0111 (Falling edge) |                     | 3.793 |       | V    |
|                      |                               | PLS[3: 0]=1000 (Rising edge)  | 4.21                | 4.212 | 4.215 | V    |
|                      |                               | PLS[3: 0]=1000 (Falling edge) |                     | 4.092 |       | V    |
|                      |                               | PLS[3: 0]=1001 (Rising edge)  | 4.51                | 4.512 | 4.515 | V    |
|                      |                               | PLS[3: 0]=1001 (Falling edge) |                     | 4.391 |       | V    |
|                      |                               | PLS[3: 0]=1010 (Rising edge)  | 4.809               | 4.811 | 4.813 | V    |
|                      |                               | PLS[3: 0]=1010 (Falling edge) |                     | 4.69  |       | V    |
| $V_{PVDhyst}^{(2)}$  | PVD hysteresis                |                               |                     | 100   |       | mV   |
| $V_{POR/PDR}$        | Power on/down reset threshold | Falling edge                  | 1.63 <sup>(1)</sup> | 1.66  | 1.68  | V    |
|                      |                               | Rising edge                   |                     | 1.75  |       | V    |
| $V_{PDRhys}^{(2)}$   | PDR hysteresis                |                               |                     | 90.9  |       | mV   |
| $T_{RSTTEMPO}^{(2)}$ | Reset duration                |                               |                     | 20    |       | ms   |

1. The product behavior is guaranteed by design down to the minimum value  $V_{POR/PDR}$ .
2. Guaranteed by design, not tested in production.

*Note: The reset duration is measured from power-on (POR reset) to the time when the user application code reads the first instruction.*

### 5.3.4 Embedded internal reference voltage

The parameters given in the table below are based on the ambient temperature and the  $V_{DD}$  supply voltage listed in Table 8.

Table 11. Embedded internal reference voltage<sup>(1)</sup>

| Symbol       | Parameter                  | Conditions   | Min | Typ | Max | Unit |
|--------------|----------------------------|--|-----|-----|-----|------|
| $V_{REFINT}$ | Internal reference voltage | $-40^{\circ}\text{C} < T_A < +105^{\circ}\text{C}$ |     | 1.2 |     | V    |
|              |                            | $-40^{\circ}\text{C} < T_A < +85^{\circ}\text{C}$  |     | 1.2 |     | V    |

| Symbol                 | Parameter   | Conditions | Min | Typ | Max | Unit    |
|------------------------|---|------------|-----|-----|-----|---------|
| $T_{S\_vrefint}^{(1)}$ | ADC sampling time when reading the internal reference voltage |            |     |     |     | $\mu S$ |

1. Shortest sampling time can be determined in the application by multiple iterations.

### 5.3.5 Supply current characteristics

The current consumption is a function of several parameters and factors such as the operating voltage, temperature, I/O pin loading, device software configuration, operating frequencies, I/O pin switching rate, program location in memory and executed binary code.

All Run-mode current consumption measurements given in this section are performed with a reduced code.

#### Maximum current consumption

The MCU is placed under the following conditions:

- All I/O pins are in analog input mode, and are connected to a static level —  $V_{DD}$  or  $V_{SS}$  (no load)
- All peripherals are disabled except when explicitly mentioned
- The Flash memory access time is adjusted to the  $f_{HCLK}$  (0 ~ 24 MHz is 0 waiting period, 24 ~ 48 MHz is 1 waiting period, 48 ~ 72 MHz is 2 waiting period, 72 ~ 96 MHz is 3 waiting period).
- The instruction prefetching function is on. When the peripherals are enabled:  
 $f_{PCLK1} = f_{HCLK}$ .

*Note: The instruction prefetching function must be set before setting the clock and bus divider.*

The parameters given in the table (Table 12、Table 13、Table 14) are based on the ambient temperature and the  $V_{DD}$  supply voltage listed in Table 8.

Table 12. Typical current consumption in Run mode, code executing from Flash memory

| Symbol   | Parameter                  | Conditions                    | $f_{HCLK}$ | Typ <sup>(1)</sup>                     |                          | Unit |
|----------|----------------------------|-------------------------------|------------|--|--------------------------|------|
|          |                            |                               |            | All peripherals enabled <sup>(2)</sup> | All peripherals disabled |      |
| $I_{DD}$ | Supply current in run mode | Internal clock <sup>(2)</sup> | 96MHz      | 26.23                                  | 15.2                     | mA   |
|          |                            |                               | 72MHz      | 20.52                                  | 12.19                    |      |
|          |                            |                               | 48MHz      | 14.71                                  | 9.13                     |      |
|          |                            |                               | 36MHz      | 11.76                                  | 7.58                     |      |
|          |                            |                               | 24MHz      | 8.84                                   | 6.03                     |      |
| $I_{DD}$ | Supply current in run mode | External clock <sup>(2)</sup> | 8MHz       | 4.1                                    | 3.14                     |      |

1. The typical value is tested at  $T_A = 25^\circ\text{C}$ . Guaranteed by design, not tested in production.
2. External clock is 8MHz, when  $f_{\text{HCLK}} > 8\text{MHz}$  enable PLL.

Table 13. Typical current consumption in Sleep mode, code executing from Flash memory or RAM

| Symbol          | Parameter                    | Conditions                    | $f_{\text{HCLK}}$ | Typ <sup>(1)</sup>                     |                          | Unit |
|-----------------|------------------------------|-------------------------------|-------------------|--|--------------------------|------|
|                 |                              |                               |                   | All peripherals enabled <sup>(2)</sup> | All peripherals disabled |      |
| $I_{\text{DD}}$ | Supply current in Sleep mode | External clock <sup>(2)</sup> | 96MHz             | 22.41                                  | 10.92                    | mA   |
|                 |                              |                               | 72MHz             | 17.57                                  | 8.96                     |      |
|                 |                              |                               | 48MHz             | 12.68                                  | 6.96                     |      |
|                 |                              |                               | 36MHz             | 10.29                                  | 5.95                     |      |
|                 |                              |                               | 24MHz             | 7.79                                   | 4.9                      |      |
|                 |                              |                               | 8MHz              | 3.46                                   | 2.8                      |      |

1. The typical value is tested at  $T_A = 25^\circ\text{C}$ . From a comprehensive evaluation, it is tested in terms of  $V_{\text{DDmax}}$  and  $f_{\text{HCLKmax}}$  enable peripherals in production.
2. External clock is 8MHz, when  $f_{\text{HCLK}} > 8\text{MHz}$  enable PLL.

Table 14. Maximum current consumption in Stop and Standby mode, code executing from Flash memory

| Symbol                | Parameter                         | Conditions   | Max                      | Unit          |
|-----------------------|-----------------------------------|--|--------------------------|---------------|
|                       |                                   |  | $T_A = 25^\circ\text{C}$ |               |
| $I_{\text{DD}}$       | Supply current in Stop mode       | Enter the stop mode after reset,<br>$V_{\text{DD}} = 3.3\text{V}$                    | 402                      | $\mu\text{A}$ |
|                       | Supply current in Standby mode    | Enter the standby mode after reset,<br>$V_{\text{DD}} = 3.3\text{V}$                 | 0.4                      |               |
| $I_{\text{DD\_VBAT}}$ | Supply current in the backup area | Low speed oscillator and RTC are on,<br>$V_{\text{DD}}/V_{\text{BAT}} = 3.3\text{V}$ | 0.2                      | $\mu\text{A}$ |

1. I/O status is analog input.

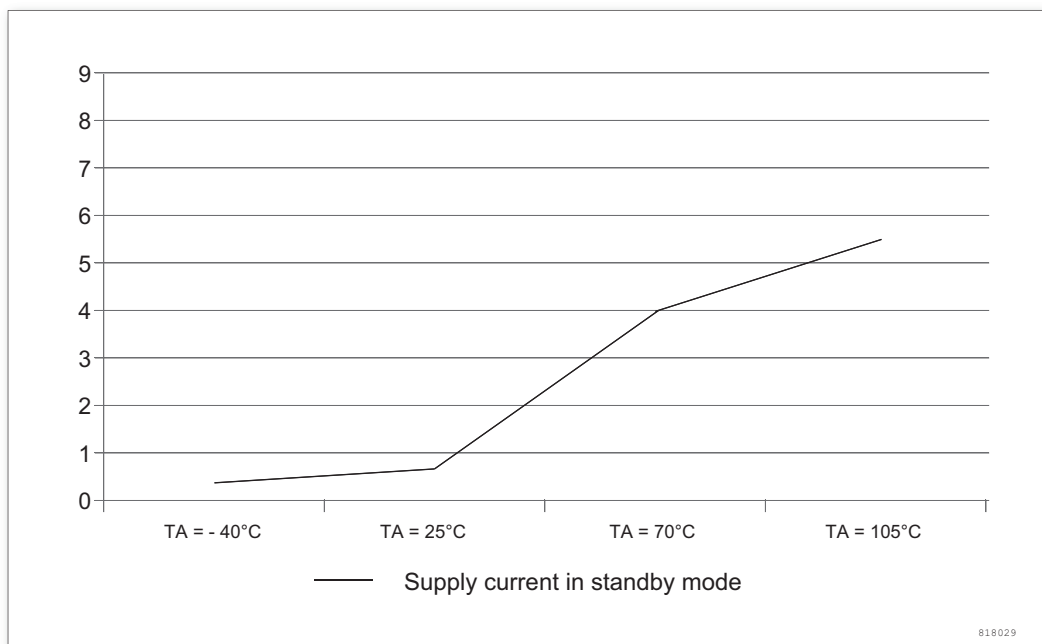


Figure 12. Typical current consumption in standby mode vs. temperature at  $V_{DD} = 3.3V$

### Typical current consumption

The MCU is placed under the following conditions:

- All I/O pins are in analog input configuration, and are connected to a static level —  $V_{DD}$  or  $V_{SS}$  (no load).
- All the peripherals are closed, unless otherwise specified.
- The Flash memory access time is adjusted to the  $f_{HCLK}$  (0 ~ 24 MHz is 0 waiting period, 24 ~ 48 MHz is 1 waiting period, 48 ~ 72 MHz is 2 waiting period, 72 ~ 96 MHz is 3 waiting period).
- The ambient temperature and  $V_{DD}$  supply voltage conditions are summarized in Table 8.
- The instruction prefetching function is on. When the peripherals are enabled:  
 $f_{PCLK1} = f_{HCLK}$ .

*Note: The instruction prefetch function must be set before the clock is set and the bus is divided.*

### On-chip peripheral current consumption

The current consumption of the on-chip peripherals is given in Table 15. The MCU is placed under the following conditions:

- All I/O pins are in analog input mode, and are connected to a static level —  $V_{DD}$  or  $V_{SS}$  (no load).
- All peripherals are disabled except when explicitly mentioned.
- The given value is calculated by measuring the current consumption.
  - with all peripherals clocked OFF
  - with only one peripheral clocked on
- Ambient operating temperature and supply voltage conditions  $V_{DD}$  summarized in Ta-

ble 8.

Table 15. On-chip peripheral current consumption<sup>(1)</sup>

| Peripheral |       | Typical consumption at 25 °C | Unit | Peripheral |       | Typical consumption at 25 °C | Unit |
|------------|-------|------------------------------|------|------------|-------|------------------------------|------|
| APB1       | TIM2  | 0.098                        | mA   | APB2       | GPIOA | 0.045                        | mA   |
|            | TIM3  | 0.062                        |      |            | GPIOB | 0.046                        |      |
| APB1       | TIM4  | 0.055                        | mA   | APB2       | GPIOC | 0.052                        | mA   |
|            | SPI2  | 0.133                        |      |            | GPIOD | 0.046                        |      |
|            | UART2 | 0.077                        |      |            | ADC1  | 0.051                        |      |
|            | UART3 | 0.078                        |      |            | ADC2  | 0.052                        |      |
|            | I2C1  | 0.132                        |      |            | TIM1  | 0.121                        |      |
|            | I2C2  | 0.134                        |      |            | SPI1  | 0.122                        |      |
|            | USB   | 0.058                        |      |            | UART1 | 0.078                        |      |
|            | CAN   | 0.033                        |      |            |       |                              |      |

1.  $f_{HCLK} = 96\text{MHz}$ ,  $f_{APB1} = f_{HCLK}/2$ ,  $f_{APB2} = f_{HCLK}$ , the prescale coefficient for each device is the default value.

### 5.3.6 External clock source characteristics

#### High-speed external user clock generated from an external source

The characteristic parameters given in the following table are measured using a high-speed external clock source, ambient temperature and power supply voltage meet the conditions of General operating conditions.

Table 16. High-speed external user clock characteristics

| Symbol                       | Parameter   | Conditions                       | Min         | Typ | Max         | Unit |
|------------------------------|---|----------------------------------|-------------|-----|-------------|------|
| $f_{HSE\_ext}$               | User external clock source frequency <sup>(1)</sup> |                                  | 2           | 8   | 24          | MHz  |
| $V_{HSEH}$                   | OSC_IN input pin high level voltage                 |                                  | $0.7V_{DD}$ |     | $V_{DD}$    | V    |
| $V_{HSEL}$                   | OSC_IN input pin low level voltage                  |                                  | $V_{SS}$    |     | $0.3V_{DD}$ |      |
| $t_{w(HSE)}$                 | OSC_IN high or low time <sup>(1)</sup>              |                                  | 16          |     |             | nS   |
| $t_{r(HSE)}$<br>$t_{f(HSE)}$ | OSC_IN rise or fall time <sup>(1)</sup>             |                                  |             |     | 20          |      |
| $C_{in(HSE)}$                | OSC_IN input capacitance <sup>(1)</sup>             |                                  |             | 5   |             | pF   |
| $DuCy_{(HSE)}$               | Duty cycle  |                                  | 45          |     | 55          | %    |
| $I_L$                        | OSC_IN input leakage current                        | $V_{SS} \leq V_{IN} \leq V_{DD}$ |             |     | $\pm 1$     | uA   |

1. Guaranteed by design, not tested in production.

### Low-speed external user clock characteristics

The characteristic parameters given in the following table are measured using a low-speed external clock source, ambient temperature and power supply voltage meet the conditions of General operating conditions.

Table 17. Low-speed external user clock characteristics

| Symbol         | Parameter   | Conditions                       | Min  | Typ    | Max | Unit |
|----------------|---|----------------------------------|------|--------|-----|------|
| $f_{LSE\_ext}$ | User external clock source frequency <sup>(1)</sup> |                                  | 16   | 32.768 | 200 | KHz  |
| $V_{LSEH}$     | OSC_IN input pin high level voltage                 |                                  |      |        | 1.2 | V    |
| $V_{LSEL}$     | OSC_IN input pin low level voltage                  |                                  | 0.25 |        |     | V    |
| $t_{w(LSE)}$   | OSC_IN high or low time <sup>(1)</sup>              |                                  |      | 15259  |     | nS   |
| $t_{r(LSE)}$   | OSC_IN rise time <sup>(1)</sup>                     |                                  |      | 30     |     | nS   |
| $t_{f(LSE)}$   | OSC_IN fall time <sup>(1)</sup>                     |                                  |      | 30     |     | nS   |
| $C_{in(LSE)}$  | OSC_IN input capacitance <sup>(1)</sup>             |                                  |      | 5      |     | pF   |
| $DuCy_{(LSE)}$ | Duty cycle  |                                  |      | 50     |     | %    |
| $I_L$          | OSC_IN input leakage current                        | $V_{SS} \leq V_{IN} \leq V_{DD}$ |      | 0.03   |     | uA   |

1. Guaranteed by design, not tested in production.

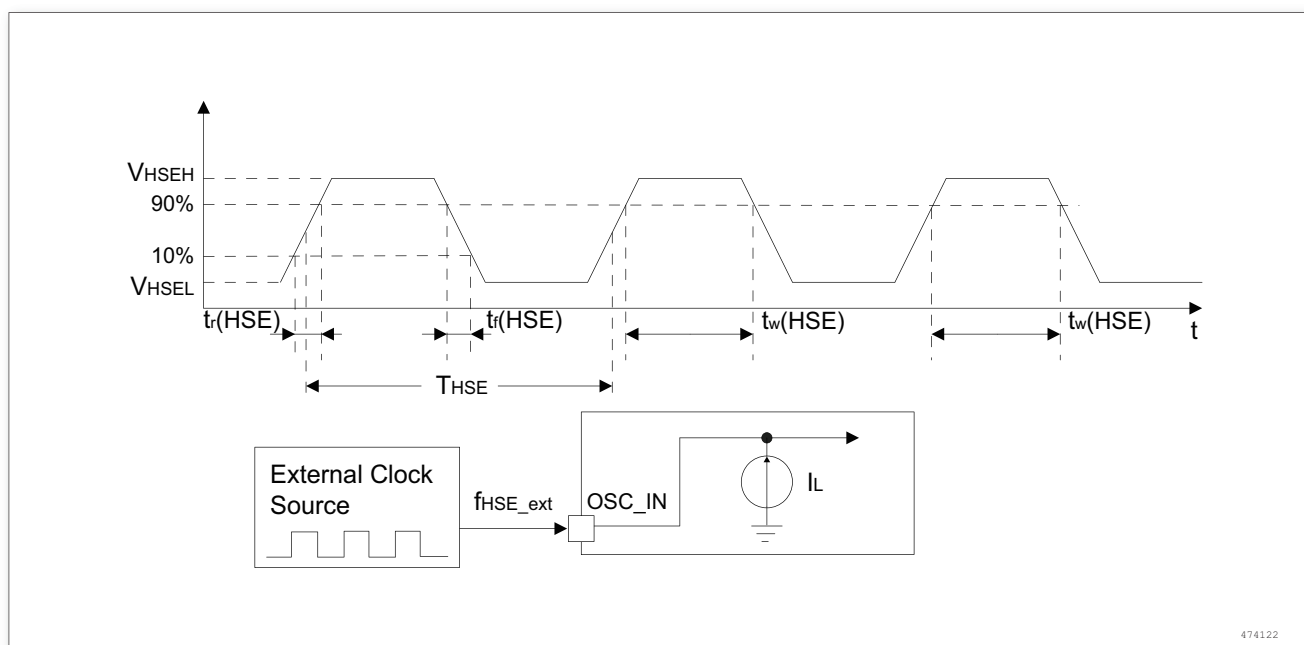


Figure 13. High-speed external clock source AC timing diagram

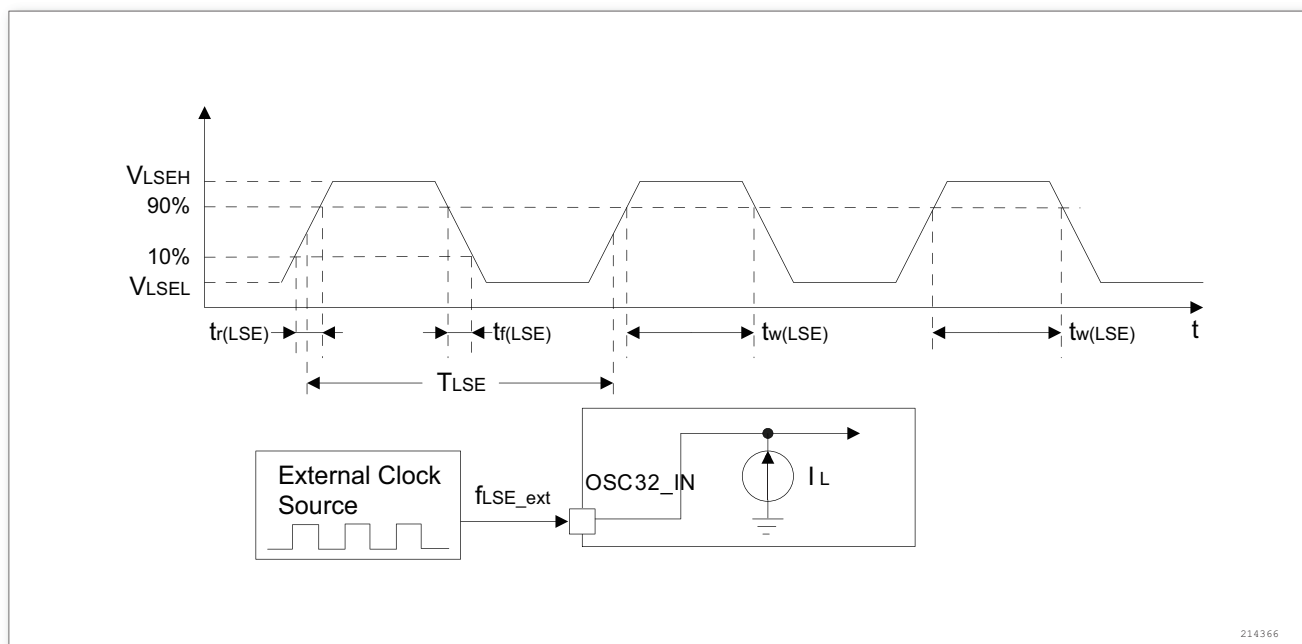


Figure 14. Low-speed external clock source AC timing diagram

### High-speed external clock generated from a crystal/ceramic resonator

The high-speed external (HSE) clock can be supplied with an 2 to 24 MHz crystal/ceramic resonator oscillator. All the information given in this paragraph are based on design simulation results obtained with typical external components specified in the table below. In the application, the resonator and the load capacitors have to be placed as close as possible to the oscillator pins in order to minimize output distortion and startup stabilization time. Refer to the crystal resonator manufacturer for more details on the resonator characteristics (frequency, package, accuracy...).

Table 18. HSE oscillator characteristics<sup>(1)(2)</sup>

| Symbol                     | Parameter  | Conditions  | Min | Typ  | Max | Unit       |
|----------------------------|--|---|-----|------|-----|------------|
| $f_{OSC\_IN}$              | Oscillator frequency   |   | 2   | 8    | 24  | MHz        |
| $R_F$                      | Feedback resistor  | $R_S = 30\Omega$                                  |     | 1000 |     | k $\Omega$ |
| $C_{L1}$<br>$C_{L2}^{(3)}$ | The proposed load capacitance corresponds to the crystal serial impedance ( $R_S$ ) <sup>(4)</sup> | $V_{DD} = 3.3V$<br>$V_{IN} = V_{SS}$<br>30pF load |     | 30   |     | pF         |
| $I_2$                      | HSE current consumption  | Startup   |     |      | 1   | mA         |
| $g_m$                      | Oscillator transconductance  | $V_{DD}$ is stabilized                            | 25  |      |     | mA/V       |
| $t_{SU(HSE)}^{(5)}$        | Startup time   | $R_S = 30\Omega$                                  |     | 2    |     | mS         |

1. Resonator characteristics given by the crystal/ceramic resonator manufacturer characteristics Parameter.



2. Guaranteed by design, not tested in production.
3. For  $C_{L1}$  and  $C_{L2}$ , it is recommended to use high-quality external ceramic capacitors in the 5 pF to 25 pF range (Typ.) , designed for high-frequency applications, and selected to match the requirements of the crystal or resonator.  $C_{L1}$  and  $C_{L2}$  are usually the same size. The crystal manufacturer typically specifies a load capacitance which is the series combination of  $C_{L1}$  and  $C_{L2}$ . PCB and MCU pin capacitance must be included (10 pF can be used as a rough estimate of the combined pin and board capacitance) when sizing  $C_{L1}$  and  $C_{L2}$ .
4. The relatively low value of the RF resistance can be used to avoid problems arising from the use of wet conditions to provide protection, this environment resulting in leakage and bias conditions have changed. However, if the MCU is applied in bad wet conditions, the design needs to take this parameter into account.
5.  $t_{SU(HSE)}$  is the startup time measured from the moment it is enabled (by software) to a stabilized 8 MHz oscillation is reached. This value is measured for a standard crystal resonator and it can vary significantly with the crystal manufacturer.

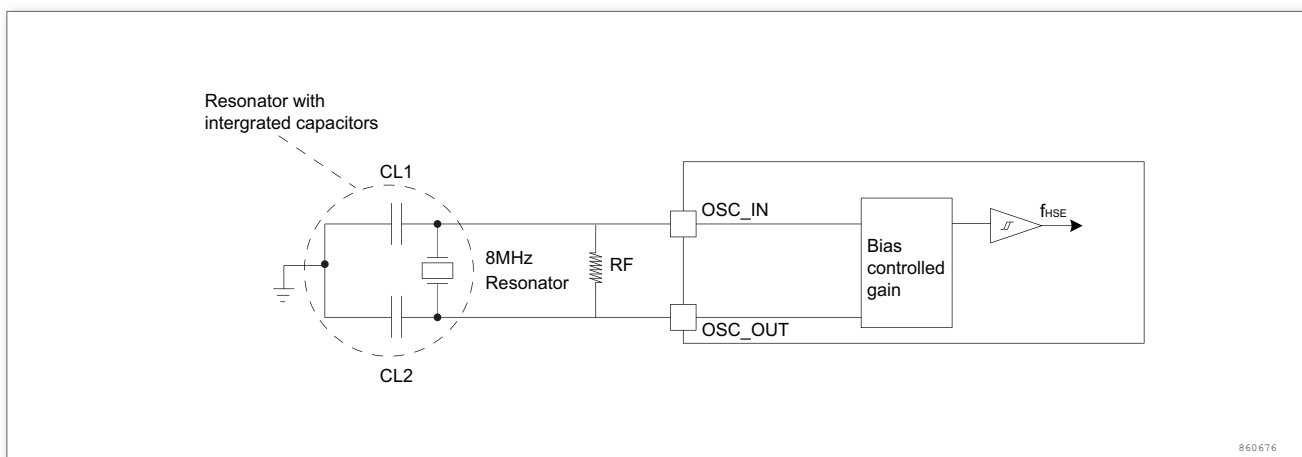


Figure 15. Typical application with an 8 MHz crystal

## Low-speed external clock generated from a crystal/ceramic resonator

The low-speed external (LSE) clock can be supplied with a 32.768 kHz crystal/ceramic resonator oscillator. All the information given in this paragraph are based on characterization results obtained with typical external components specified in the table below. In the application, the resonator and the load capacitors have to be placed as close as possible to the oscillator pins in order to minimize output distortion and startup stabilization time. Refer to the crystal resonator manufacturer for more details on the resonator characteristics (frequency, package, accuracy). Note: For  $C_{L1}$  and  $C_{L2}$ , it is recommended to use a high quality ceramic capacitor between 5pF and 15pF and select the crystal or resonator that meets the requirements. Usually  $C_{L1}$  and  $C_{L2}$  have the same parameters. Crystal manufacturers typically give the parameters of the load capacitance in a serial combination of  $C_{L1}$  and  $C_{L2}$ . The load capacitance  $C_L$  is calculated by:  $C_L = C_{L1} \times C_{L2} / (C_{L1} + C_{L2}) + C_{stray}$ , where  $C_{stray}$  is the capacitance of the pin and the capacitance associated with the PCB or PCB. Its typical value is between 2pF and 7pF. **WARNING:** To avoid exceeding

the maximum value of  $C_{L1}$  and  $C_{L2}$  (15pF), it is highly recommended to use a resonator with a load capacitance of  $C_L \leq 7\text{pF}$ . A resonator with a load capacitance of 12.5pF cannot be used. For example, if a resonator with a load capacitance of  $C_L = 6\text{pF}$  is selected and  $C_{\text{stray}} = 2\text{pF}$ , then  $C_{L1} = C_{L2} = 8\text{pF}$ .

Table 19. LSI oscillator characteristics ( $f_{\text{LSE}}=32.768\text{KHz}$ ) <sup>(1)</sup>

| Symbol                              | Parameter  | Conditions                                  | Min | Typ  | Max | Unit            |
|-------------------------------------|--|---|-----|------|-----|-----------------|
| $R_F$                               | Feedback resistor  |   |     | 25   |     | $M\Omega$       |
| $C_{L1}$<br>$C_{L2}$ <sup>(2)</sup> | The proposed load capacitance corresponds to the crystal serial impedance ( $R_S$ ) <sup>(3)</sup> | $R_S = 30\Omega$                            |     |      | 4   | pF              |
| $I_2$                               | LSE current consumption  | $V_{DD} = 3.3\text{V}$<br>$V_{IN} = V_{SS}$ |     | 0.08 |     | $\mu\text{A}$   |
| $g_m$                               | Oscillator transconductance  |   |     | 0.5  |     | $\mu\text{A/V}$ |
| $t_{\text{SU(HSE)}}^{(4)}$          | Startup time   | $V_{DD}$ is stabilized                      |     | 1    | 4   | S               |

1. Guaranteed by design, not tested in production.
2. See the note and warning paragraphs above this table.
3. Selecting a high quality oscillator with a small  $R_S$  value (such as MSIV-TIN 32.768KHz) optimizes current consumption. Please consult the crystal manufacturer for details.
4.  $t_{\text{SU(HSE)}}$  is the start-up time, which is measured from the time the software enables HSE until a stable 8MHz oscillation is obtained. This value is measured on a standard crystal resonator, which may vary greatly depending on the crystal manufacturer.

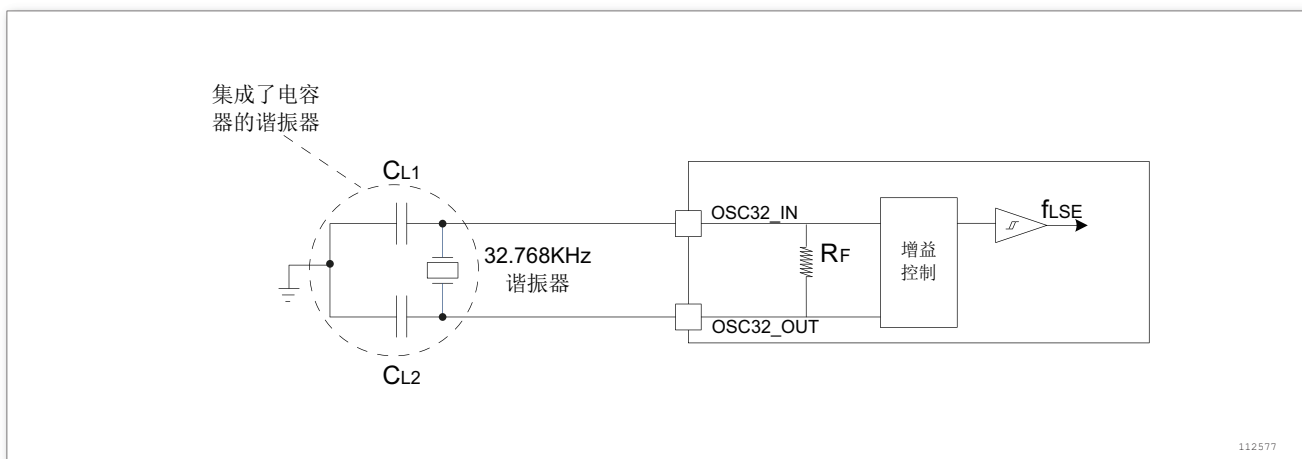


Figure 16. Typical application with a 32.768 kHz crystal

### 5.3.7 Internal clock source characteristics

The characteristic parameters given in the table below are measured using ambient temperature and supply voltage in accordance with general operating conditions.

#### High-speed internal (HSI) oscillator

Table 20. HSI oscillator characteristics<sup>(1)(2)</sup>

| Symbol                    | Parameter                        | Conditions   | Min | Typ | Max | Unit          |
|---------------------------|----------------------------------|--|-----|-----|-----|---------------|
| $f_{\text{HSI}}$          | Frequency                        |  | 40  | 48  | 64  | MHz           |
| $\text{ACC}_{\text{HSI}}$ | Accuracy of the HSI oscillator   | $T_A = -40^{\circ}\text{C} \sim 105^{\circ}\text{C}$ | -5  |     | 5   | %             |
| $\text{ACC}_{\text{HSI}}$ | Accuracy of the HSI oscillator   | $T_A = -10^{\circ}\text{C} \sim 85^{\circ}\text{C}$  | -3  |     | 3   | %             |
| $\text{ACC}_{\text{HSI}}$ | Accuracy of the HSI oscillator   | $T_A = 0^{\circ}\text{C} \sim 70^{\circ}\text{C}$    | -2  |     | 2   | %             |
| $\text{ACC}_{\text{HSI}}$ | Accuracy of the HSI oscillator   | $T_A = 25$   | -1  |     | 1   | %             |
| $t_{\text{SU(HSI)}}$      | HSI oscillator startup time      |  |     |     | 2   | $\mu\text{S}$ |
| $I_{\text{DD(HSI)}}$      | HSI oscillator power consumption |  |     | 81  | 200 | $\mu\text{A}$ |

1.  $V_{\text{DD}} = 3.3\text{V}$ ,  $T_A = -40^{\circ}\text{C} \sim 105^{\circ}\text{C}$ , unless otherwise specified.
2. Guaranteed by design, not tested in production.

### Low-speed internal (LSI) oscillator

Table 21. LSI oscillator characteristics<sup>(1)</sup>

| Symbol                     | Parameter                        | Conditions | Min | Typ | Max | Unit          |
|----------------------------|----------------------------------|------------|-----|-----|-----|---------------|
| $f_{\text{LSI}}^{(2)}$     | Frequency                        |            | 31  | 40  | 75  | KHz           |
| $t_{\text{SU(LSI)}}^{(2)}$ | LSI oscillator startup time      |            |     |     | 1   | $\mu\text{S}$ |
| $I_{\text{DD(LSI)}}^{(3)}$ | LSI oscillator power consumption |            |     | 1.1 | 1.7 | $\mu\text{A}$ |

1.  $V_{\text{DD}} = 3.3\text{V}$ ,  $T_A = -40^{\circ}\text{C} \sim 105^{\circ}\text{C}$ , Unless otherwise stated
2. Comprehensive assessment, not tested in production.
3. Guaranteed by design, not tested in production.

### Wake-up times from low power mode

The wake-up times listed in the table below are measured during the wake-up phase of the internal clock HSI. The clock source used when waking up depends on the current operating mode:

- Stop or Standby mode: The clock source is the oscillator
- Sleep mode: The clock source is the clock used when entering sleep mode

All times are measured using ambient temperature and supply voltage in accordance with common operating conditions.

Table 22. Low-power mode wakeup timings

| Symbol              | Parameter   | Conditions  | Max | Unit    |
|---------------------|---|---|-----|---------|
| $t_{WUSLEEP}^{(1)}$ | Wakeup from Sleep mode                                  | HSI clock wakeup  | 4.2 | $\mu S$ |
| $t_{WUSTOP}^{(1)}$  | Wakeup from Stop mode<br>(The regulator is in run mode) | HSI clock wakeup = $2\mu S$   | 6.3 |         |
| $t_{WUSTDBY}^{(1)}$ | Wakeup from Standby mode                                | HSI clock wakeup = $2\mu S$<br>The regulator wakes up from the off mode = $38\mu S$ | 47  | mS      |

1. The wake-up time is measured from the start of the wake-up event to the user program to read the first instruction.

### 5.3.8 PLL characteristics

The parameters listed in the table below are measured using ambient temperature and supply voltage in accordance with common operating conditions.

Table 23. PLL characteristics<sup>(1)</sup>

| Symbol         | Parameter                      | Min | Typ | Max | Unit    |
|----------------|--------------------------------|-----|-----|-----|---------|
| $f_{PLL\_IN}$  | PLL input clock <sup>(2)</sup> | 2   |     | 24  | MHz     |
|                | PLL input clock duty cycle     | 40  |     | 60  | %       |
| $f_{PLL\_OUT}$ | PLL multiplier output clock    | 40  |     | 200 | MHz     |
| $t_{LOCK}$     | PLL lock time                  |     |     | 100 | $\mu S$ |

1. Guaranteed by design, not tested in production.  
 2. Take care to use the appropriate multiplier factors to obtain PLL input clock values compatible with the range defined by  $f_{PLL\_OUT}$ .

### 5.3.9 Memory characteristics

#### Flash memory

The characteristics are given at  $T_A = -40^\circ C \sim 105^\circ C$  unless otherwise specified.

Table 24. Flash memory characteristics

| Symbol     | Parameter              | Conditions                           | Min | Typ | Max | Unit    |
|------------|------------------------|--------------------------------------|-----|-----|-----|---------|
| $t_{prog}$ | 8-bit programming time | $T_A = -40^\circ C \sim 125^\circ C$ | 4   |     |     | $\mu S$ |

| Symbol      | Parameter                    | Conditions   | Min | Typ    | Max      | Unit |
|-------------|------------------------------|--|-----|--------|----------|------|
| $t_{ERASE}$ | Page (512K bytes) erase time | $T_A = -40^{\circ}\text{C} \sim 125^{\circ}\text{C}$ |     | 4      | 5        | mS   |
| $t_{ME}$    | Mass erase time              | $T_A = -40^{\circ}\text{C} \sim 125^{\circ}\text{C}$ | 20  |        | 40       | mS   |
| $I_{DD}$    | Supply current               | Read mode, $f_{HCLK} = 48\text{MHz}$                 |     | 5      | 6        | mA   |
|             |                              | Write mode, $f_{HCLK} = 48\text{MHz}$                |     |        | 7        | mA   |
|             |                              | Erase mode, $f_{HCLK} = 48\text{MHz}$                |     |        | 2        | mA   |
| $I_{SB}$    | Standby current              |  |     | 1@25°C | 50@125°C | μA   |
| $I_{DEP}$   | Deep Standby current         |  |     | 0.5    | 15@125°C | μA   |

Table 25. Flash memory endurance and data retention<sup>(1)(2)</sup>

| Symbol    | Parameter   | Conditions  | Min | Typ | Max | Unit    |
|-----------|---|---|-----|-----|-----|---------|
| NEND      | Endurance<br>(Annotation:<br>Erase<br>number of<br>times) | $T_A = -40^{\circ}\text{C} \sim 85^{\circ}\text{C}$<br>$T_A = -40^{\circ}\text{C} \sim 105^{\circ}\text{C}$ | 10  |     |     | K cycle |
| $t_{RET}$ | Data<br>retention   | 1 K cycle <sup>(2)</sup> at $T_A = 85^{\circ}\text{C}$  | 30  |     |     | Year    |
|           |   | 1 K cycle <sup>(1)(2)</sup> at $T_A = 105^{\circ}\text{C}$  | 10  |     |     |         |
|           |   | 10 K cycle <sup>(1)(2)</sup> at $T_A = 55^{\circ}\text{C}$  | 20  |     |     |         |

1. Guaranteed by design, not tested in production.
2. Cycle tests are carried out in the whole temperature range.

### 5.3.10 EMC characteristics

Susceptibility tests are performed on a sample basis during device characterization.

#### Functional EMS (electromagnetic susceptibility)

While a simple application is executed on the device (toggling 2 LEDs through I/O ports), the device is stressed by two electromagnetic events until a failure occurs. The failure is indicated by the LEDs:

- Electrostatic discharge (ESD) (positive and negative) is applied to all device pins until a functional disturbance occurs. This test is compliant with the IEC 61000-4-2 standard.
- FTB: A Burst of Fast Transient voltage (positive and negative) is applied to VDD and VSS through a 100 pF capacitor, until a functional disturbance occurs. This test is

compliant with the IEC 1000-4-4 standard.

A device reset allows normal operations to be resumed.

The test results are given in the following table. They are based on the EMS levels and classes defined in application note.

Table 26. EMS characteristics

| Symbol    | Parameter   | Conditions   | Level/Class |
|-----------|---|--|-------------|
| $V_{EFT}$ | Fast transient voltage burst limits to be applied through 100 pF on $V_{DD}$ and $V_{SS}$ pins to induce a functional disturbance | $V_{DD} = 3.3V, T_A = +25^{\circ}C$ ,<br>$f_{HCLK} = 48MHz$ . Conforming to IEC 1000-4-4 | TBD         |

## Designing hardened software to avoid noise problems

EMC characterization and optimization are performed at component level with a typical application environment and simplified MCU software. It should be noted that good EMC performance is highly dependent on the user application and the software in particular.

Therefore it is recommended that the user applies EMC software optimization and pre-qualification tests in relation with the EMC level requested for his application.

## Software recommendations

The software flowchart must include the management of runaway conditions such as:

- Corrupted program counter
- Unexpected reset
- Critical Data corruption (for example control registers)

## Prequalification trials

Most of the common failures (unexpected reset and program counter corruption) can be reproduced by manually forcing a low state on the NRST pin or the Oscillator pins for 1 second.

To complete these trials, ESD stress can be applied directly on the device, over the range of specification values. When unexpected behavior is detected, the software can be hardened to prevent unrecoverable errors.

### 5.3.11 Absolute Maximum (Electrical Sensitivity)

Based on three different tests (ESD, LU) using specific measurement methods, the device is stressed in order to determine its performance in terms of electrical sensitivity.

## Electrostatic discharge (ESD)

Electrostatic discharges (a positive then a negative pulse separated by 1 second) are applied to the pins of each sample according to each pin combination. The sample size depends on the number of supply pins in the device (3 parts  $\times$  (n+1) supply pins). This test conforms to the JESD22-A114/C101 standard.

## Static latch-up

Two complementary static tests are required on six parts to assess the latch-up performance:

- A supply overvoltage is applied to each power supply pin
- A current injection is applied to each input, output and configurable I/O pin

These tests are compliant with EIA/JESD78A IC latch-up standard.

Table 27. ESD characteristics

| Symbol         | Parameter  | Conditions  | Type | Max  | Unit |
|----------------|--|---|------|------|------|
| $V_{ESD(HBM)}$ | Electrostatic discharge voltage<br>(Human body model)      | $T_A = +25^\circ\text{C}$ ,<br>Conforming to<br>JESD22-A114 |      | 2000 | V    |
| $V_{ESD(CDM)}$ | Electrostatic discharge voltage<br>(Charging device model) | $T_A = +25^\circ\text{C}$ ,<br>Conforming to<br>JESD22-C101 |      | 500  |      |
| $I_{LU}$       | Latch-up current   | $T_A =$<br>$+25^\circ\text{C}$ , Conforming to<br>JESD78A   |      | 200  | mA   |

## 5.3.12 I/O port characteristics

### General input/output characteristics

Unless otherwise specified, the parameters given in Table 5 are derived from tests.

Table 28. I/O static characteristics

| Symbol    | Parameter  | Conditions        | Min  | Typ | Max | Unit          |
|-----------|--|-------------------|------|-----|-----|---------------|
| $V_{IL}$  | Low level input voltage                              | CMOS Port         | -0.5 |     | 1.1 | V             |
| $V_{IH}$  | High level input voltage                             | CMOS Port         | 2.08 |     |     | V             |
| $V_{hys}$ | Schmitt trigger hysteresis <sup>(1)</sup>            |                   | 500  | 700 | 800 | mV            |
| $I_{lkg}$ | Input leakage current <sup>(2)</sup>                 |                   |      |     | 1   | $\mu\text{A}$ |
| $R_{PU}$  | Weak pull-up equivalent<br>resistor <sup>(3)</sup>   | $V_{IN} = V_{SS}$ | 30   | 50  | 100 | $k\Omega$     |
| $R_{PD}$  | Weak pull-down equivalent<br>resistor <sup>(3)</sup> | $V_{IN} = V_{DD}$ | 30   | 50  | 100 |               |

| Symbol   | Parameter           | Conditions | Min | Typ | Max | Unit |
|----------|---------------------|------------|-----|-----|-----|------|
| $C_{IO}$ | I/O pin capacitance |            |     |     | 5   | pF   |

1. Schmitt Trigger switching hysteresis voltage level. Data based on design simulation only. Not tested in production.
2. The leakage could be higher than the maximum value, if negative current is injected on adjacent pins.
3. Pull-up and pull-down resistors are designed with a true resistance in series with a switchable PMOS/NMOS. This PMOS/NMOS contribution to the series resistance is minimal (10% order).

All I/Os are CMOS (no software configuration required). Their characteristics cover more than the strict CMOS-technology.

- For  $V_{IH}$ :
  - If  $V_{DD}$  is between [2.50V~ 3.08V]; use CMOS features.
  - If  $V_{DD}$  is between [3.08V~ 3.60V]; include CMOS.
- For  $V_{IL}$ :
  - Use CMOS features.

## Output driving current

The GPIOs (general purpose input/outputs) can sink or source up to  $\pm 20\text{mA}$ .

In the user application, the number of I/O pins which can drive current must be limited to respect the absolute maximum rating specified in 5.2:

- The sum of the currents obtained from  $V_{DD}$  for all I/O ports, plus the maximum operating current that the MCU obtains on  $V_{DD}$ , cannot exceed the absolute maximum rating  $I_{VDD}$ .
- The sum of the currents drawn by all I/O ports and flowing out of  $V_{SS}$ , plus the maximum operating current of the MCU flowing out on  $V_{SS}$ , cannot exceed the absolute maximum rating  $I_{VSS}$ .

## Output voltage levels

Unless otherwise stated, the parameters listed in the table below are measured using the ambient temperature and  $V_{DD}$  supply voltage in accordance with the condition Table 5. All I/O ports are CMOS compatible.

Table 29. Output voltage characteristics

| Symbol         | Parameter   | Conditions  | Min | Max | Unit |
|----------------|---|---|-----|-----|------|
| $V_{OL}^{(1)}$ | Output low level voltage for an I/O pin, when 8 pins absorb current | CMOS Port, $I_{IO} = +8\text{mA}$<br>$2.7\text{V} < V_{DD} < 3.6\text{V}$ |     | 0.4 |      |



| Symbol            | Parameter  | Conditions   | Min         | Max | Unit |
|-------------------|--|--|-------------|-----|------|
| $V_{OH}^{(2)}$    | Output high level voltage for an I/O pin, when 8 pins output current | CMOS Port, $I_{IO} = +8mA$<br>$2.7V < V_{DD} < 3.6V$ | $0.8V_{DD}$ |     | V    |
| $V_{OL}^{(1)(3)}$ | Output low level voltage for an I/O pin, when 8 pins absorb current  | $I_{IO} = +20mA$<br>$2.7V < V_{DD} < 3.6V$           |             | 0.4 |      |
| $V_{OH}^{(2)(3)}$ | Output high level voltage for an I/O pin, when 8 pins output current |  | $0.8V_{DD}$ |     |      |
| $V_{OL}^{(2)(3)}$ | Output low level voltage for an I/O pin, when 8 pins absorb current  | $I_{IO} = +6mA$<br>$2V < V_{DD} < 2.7V$              |             | TBD |      |
| $V_{OH}^{(2)(3)}$ | Output high level voltage for an I/O pin, when 8 pins output current | $I_{IO} = +6mA$<br>$2V < V_{DD} < 2.7V$              | TBD         |     |      |

1. The current absorbed by the chip  $I_{IO}$  must always follow the absolute maximum ratings given in the table, and the sum of  $I_{IO}$  (all I/O feet and control pins) must not exceed  $I_{VSS}$ .
2. The current output  $I_{IO}$  of the chip must always follow the absolute maximum rating given in the table, and the sum of  $I_{IO}$  (all I/O pins and control pins) must not exceed  $I_{VDD}$ .
3. Data based on characterization results. Not tested in production.

## Input/output AC characteristics

The definitions and values of the input and output AC characteristics are given in figure 17 and Table 30, respectively.

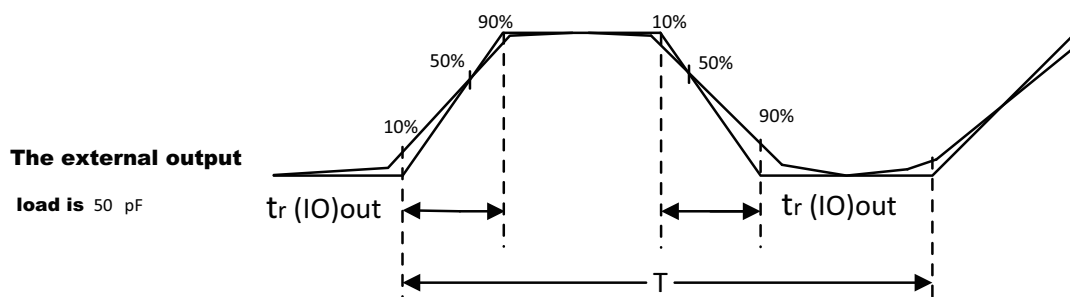
Unless otherwise stated, the parameters listed in Table 30 are measured using the ambient temperature and supply voltage in accordance with the condition Table 5.

Table 30. I/O AC characteristics<sup>(1)</sup>

| OSPEEDRy<br>[1:0] value (1) | Symbol           | Parameter                        | Conditions                                | Min | Max         | Unit |
|-----------------------------|------------------|----------------------------------|---|-----|-------------|------|
| 01<br>(10MHz)               | $f_{max(IO)out}$ | Maximum frequency <sup>(2)</sup> | $C_L = 50pF$ ,<br>$V_{DD} = 2V \sim 3.6V$ |     | 10          | MHz  |
|                             | $t_{f(IO)out}$   | Output fall time                 | $C_L = 50pF$ ,<br>$V_{DD} = 2V \sim 3.6V$ |     | $25^{(3)}$  | nS   |
|                             | $t_{r(IO)out}$   | Output rise time                 |   |     | $25^{(3)}$  |      |
| 10<br>(20MHz)               | $f_{max(IO)out}$ | Maximum frequency <sup>(2)</sup> | $C_L = 50pF$ ,<br>$V_{DD} = 2V \sim 3.6V$ |     | 20          | MHz  |
|                             | $t_{f(IO)out}$   | Output fall time                 | $C_L = 50pF$ ,<br>$V_{DD} = 2V \sim 3.6V$ |     | $125^{(3)}$ | nS   |

| OSPEEDRy<br>[1:0] value (1) | Symbol           | Parameter   | Conditions                                  | Min | Max                | Unit |
|-----------------------------|------------------|---|---|-----|--------------------|------|
|                             | $t_{r(IO)out}$   | Output rise time  |   |     | 125 <sup>(3)</sup> |      |
| 11<br>(50MHz)               | $f_{max(IO)out}$ | Maximum frequency <sup>(2)</sup>                                | $C_L = 30pF$ ,<br>$V_{DD} = 2.7V \sim 3.6V$ |     | 50                 | MHz  |
|                             |                  |   | $C_L = 50pF$ ,<br>$V_{DD} = 2.7V \sim 3.6V$ |     | 30                 |      |
|                             |                  |   | $C_L = 50pF$ ,<br>$V_{DD} = 2V \sim 2.7V$   |     | 20                 |      |
|                             | $t_{f(IO)out}$   | Output fall time  | $C_L = 30pF$ ,<br>$V_{DD} = 2.7V \sim 3.6V$ |     | 5                  | nS   |
|                             |                  |   | $C_L = 50pF$ ,<br>$V_{DD} = 2.7V \sim 3.6V$ |     | 8                  |      |
|                             |                  |   | $C_L = 50pF$ ,<br>$V_{DD} = 2V \sim 2.7V$   |     | 12                 |      |
|                             | $t_{r(IO)out}$   | Output rise time  | $C_L = 30pF$ ,<br>$V_{DD} = 2.7V \sim 3.6V$ |     | 5                  |      |
|                             |                  |   | $C_L = 50pF$ ,<br>$V_{DD} = 2.7V \sim 3.6V$ |     | 8                  |      |
|                             |                  |   | $C_L = 50pF$ ,<br>$V_{DD} = 2V \sim 2.7V$   |     | 12                 |      |
|                             | $t_{EXTIpw}$     | Pulse width of external signals detected by the EXTI controller |   | 10  |                    | nS   |

1. The speed of the I/O port can be configured via MODEx[1:0]. See the description of the GPIO Port Configuration Register in this chip reference manual.
2. The maximum frequency is defined in figure 17.



Maximum frequency is achieved if  $((t_r + t_f) \leq 2/3)T$ , and if the duty cycle is (45 ~ 55%) when loaded by  $C_L$  (see the i/O AC characteristics definition)

868304

Figure 17. I/O AC characteristics

### 5.3.13 NRST pin characteristics

The NRST pin input driver uses the CMOS technology. It is connected to a permanent pullup resistor,  $R_{PU}$ .

Unless otherwise stated, the parameters listed in the table below are measured using the ambient temperature and  $V_{DD}$  supply voltage in accordance with the condition Table 5.

Table 31. NRST pin characteristics

| Symbol               | Parameter                                       | Conditions        | Min  | Typ         | Max      | Unit       |
|----------------------|---|-------------------|------|-------------|----------|------------|
| $V_{IL(NRST)}^{(1)}$ | NRST input low level voltage                    |                   | -0.5 |             | 0.8      | V          |
| $V_{IH(NRST)}^{(1)}$ | NRST input high level voltage                   |                   | 2    |             | $V_{DD}$ |            |
| $V_{hys(NRST)}$      | NRST Schmitt trigger voltage hysteresis         |                   |      | $0.2V_{DD}$ |          | V          |
| $R_{PU}$             | Weak pull-up equivalent resistor <sup>(2)</sup> | $V_{IN} = V_{SS}$ |      | 15          |          | k $\Omega$ |
| $V_{F(NRST)}^{(1)}$  | NRST input filtered pulse                       |                   |      |             | 100      | ns         |
| $V_{NF(NRST)}^{(1)}$ | NRST input not filtered pulse                   |                   | 300  |             |          |            |

1. Data based on design simulation only. Not tested in production.
2. The pull-up is designed with a true resistance in series with a switchable PMOS. This PMOS contribution to the series resistance is minimal (10% order).

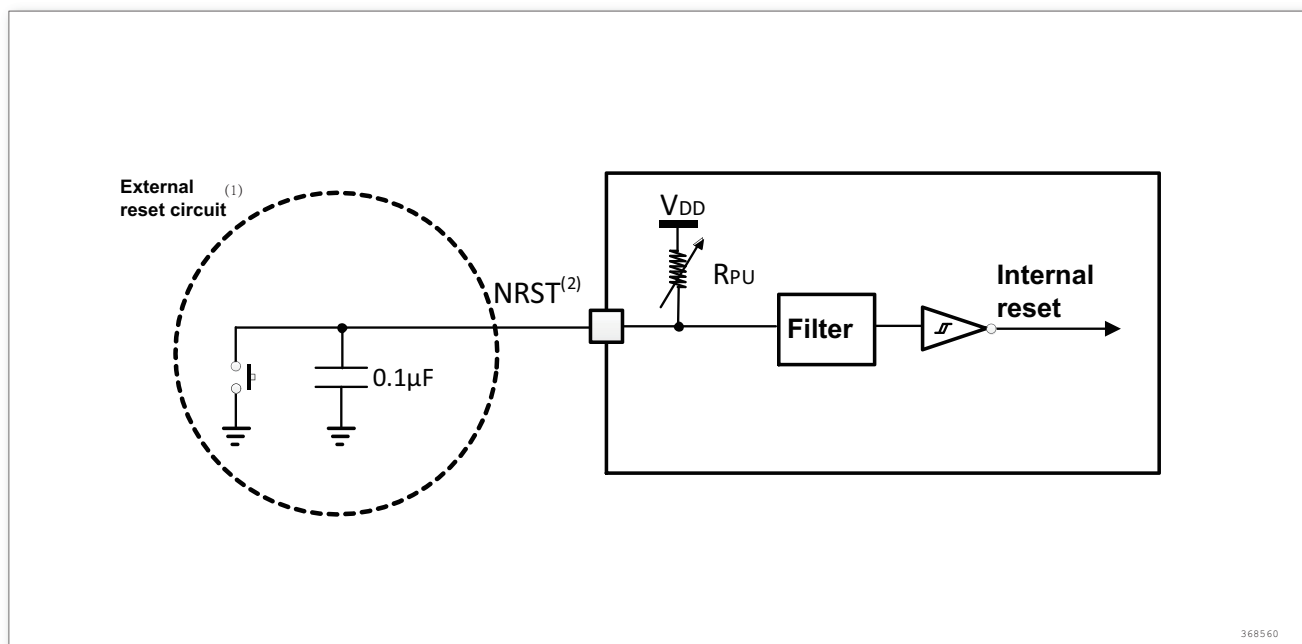


Figure 18. Recommended NRST pin protection

1. The reset network is to prevent parasitic reset
2. The user must ensure that the potential of the NRST pin is below the maximum  $V_{IL(NRST)}$  listed in Table 31, otherwise the MCU cannot be reset.

### 5.3.14 Timer characteristics

The parameters given in the following tables are guaranteed by design.

For details on the characteristics of the I/O multiplexing function pins (output compare, input capture, external clock, PWM output) , see subsubsec 5.3.12.

Table 32. TIMx<sup>(1)</sup> characteristics

| Symbol           | Parameter                                    | Conditions            | Min    | Max                  | Unit          |
|------------------|--|-----------------------|--------|----------------------|---------------|
| $t_{res(TIM)}$   | Timer resolution time                        |                       | 1      |                      | $t_{TIMxCLK}$ |
|                  |  | $f_{TIMxCLK} = 96MHz$ | 10.4   |                      | nS            |
| $f_{EXT}$        | Timer external clock frequency on CH1 to CH4 |                       | 0      | $f_{TIMxCLK}/2$      | MHz           |
|                  |  | $f_{TIMxCLK} = 96MHz$ | 0      | 48                   |               |
| $Res_{TIM}$      | Timer resolution                             |                       |        | 16                   | Bit           |
| $t_{COUNTER}$    | 16-bit timer maximum period                  |                       | 1      | 65536                | $t_{TIMxCLK}$ |
|                  |  | $f_{TIMxCLK} = 96MHz$ | 0.0104 | 682                  | µS            |
| $t_{MAX\_COUNT}$ | The maximum possible count                   |                       |        | $65536 \times 65536$ | $t_{TIMxCLK}$ |
|                  |  | $f_{TIMxCLK} = 96MHz$ |        | 44.7                 | S             |

1. TIMx is a generic name, representing TIM4.

### 5.3.15 Communication interfaces

#### I2C interface characteristics

Unless otherwise specified, the parameters given in Table 33 are derived from tests performed under the ambient temperature,  $f_{PCLK1}$  frequency and supply voltage conditions summarized in Table 8: General operating conditions.

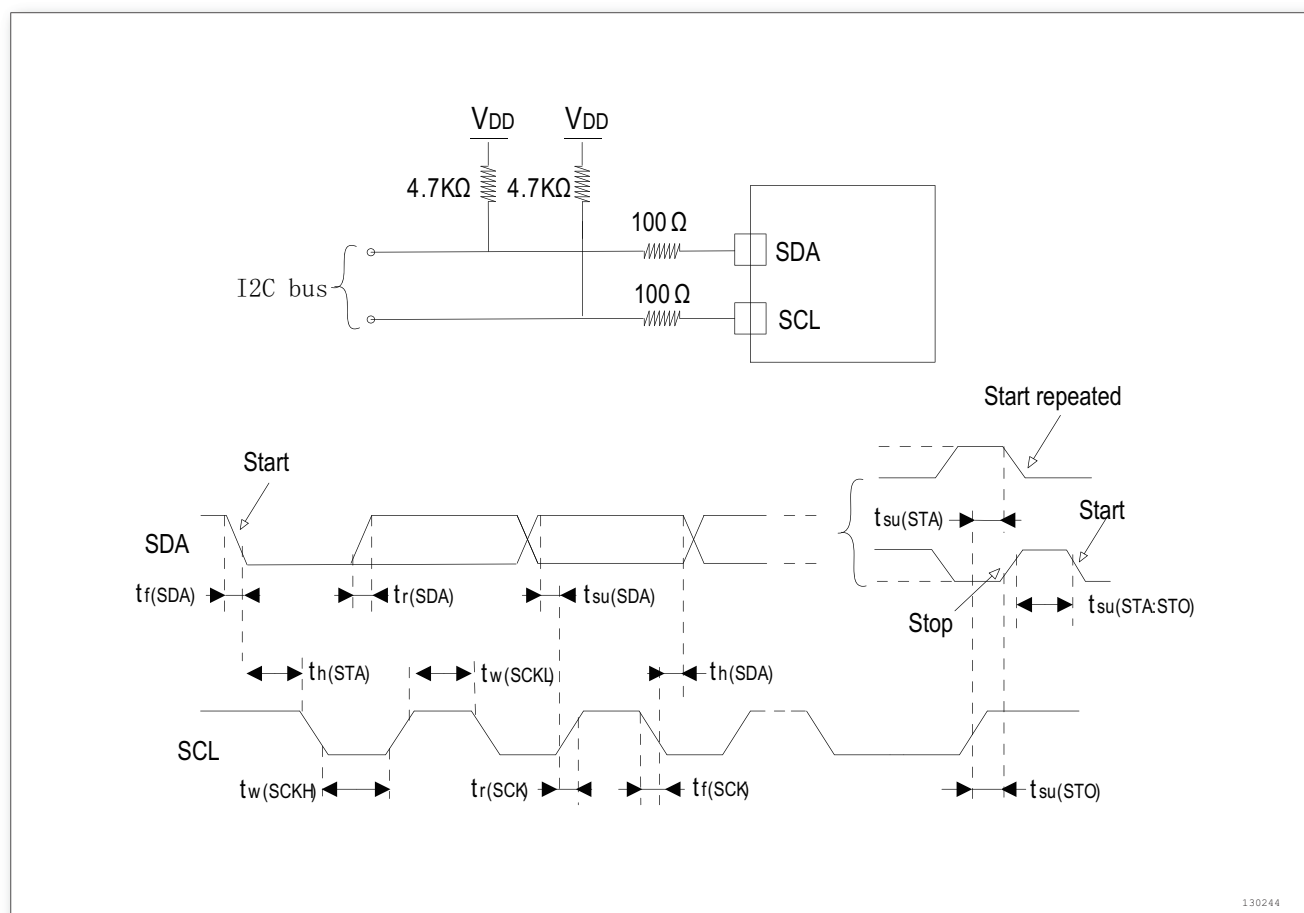
The I2C interface conforms to the standard I2C communication protocol, but has the following limitations: SDA and SCL are not true pins. When configured as open-drain output, the PMOS transistor between the pin and  $V_{DD}$  Was closed but still exists.

The I2C I/Os characteristics are listed in Table 33, the alternate function characteristics of I/Os (SDA and SCL) refer to subsubsec 5.3.12.

Table 33. I2C characteristics

| Symbol                | Parameter                                   | Standard I2C <sup>(1)</sup> |      | Fast I2C <sup>(1)(2)</sup> |                    | Unit    |
|-----------------------|---|-----------------------------|------|----------------------------|--------------------|---------|
|                       |   | Min                         | Max  | Min                        | Max                |         |
| $t_{w(SCL)}$          | SCL clock fall time                         | 4.7                         |      | 1.3                        |                    | $\mu s$ |
| $t_{w(SCLH)}$         | SCL clock rise time                         | 4.0                         |      | 0.6                        |                    | $\mu s$ |
| $t_{su(SDA)}$         | SDA setup time                              | 250                         |      | 100                        |                    | ns      |
| $t_h(SDA)$            | SDA data hold time                          | 0 <sup>(3)</sup>            |      | 0 <sup>(4)</sup>           | 900 <sup>(3)</sup> |         |
| $t_r(SDA) \ t_r(SDL)$ | SDA and SCL rise time                       |                             | 1000 | $2.0+0.1C_b$               | 300                |         |
| $t_f(SDA) \ t_f(SDL)$ | SDA and SCL fall time                       |                             | 300  |                            | 300                |         |
| $t_h(STA)$            | Start condition hold time                   | 4.0                         |      | 0.6                        |                    | $\mu s$ |
| $t_{su(STA)}$         | Start condition setup time                  | 4.7                         |      | 0.6                        |                    |         |
| $t_{su(STO)}$         | Stop condition setup time                   | 4.0                         |      | 0.6                        |                    |         |
| $t_{w(STO:STA)}$      | Time from Stop condition to Start condition | 4.7                         |      | 1.3                        |                    |         |
| $C_b$                 | Capacitive load of each bus                 |                             | 400  |                            | 400                | pF      |

1. Guaranteed by design, not tested in production.
2.  $f_{PCLK1}$  must be at least 3MHz to achieve standard mode I2C frequencies. It must be at least 12MHz to achieve fast mode I2C frequencies.
3. The maximum Data hold time has only to be met if the interface does not stretch the low period of SCL signal.
4. In order to span the undefined area of the falling edge of SCL, it must ensure that the SDA signal has a hold time of at least 300ns.

Figure 19. I2C bus AC waveform and measurement circuit<sup>(1)</sup>

1. Measurement point is set to the CMOS level:  $0.3V_{DD}$  and  $0.7V_{DD}$ .

## SPI characteristics

Unless otherwise specified, the parameters given in Table 34 are derived from tests performed under the ambient temperature,  $f_{PCLKx}$  frequency and  $V_{DD}$  supply voltage conditions summarized in Table 8.

Refer to subsubsec 5.3.12 for more details on the input/output alternate function characteristics (NSS, SCK, MOSI, MISO).

Table 34. SPI characteristics<sup>(1)</sup>

| Symbol                                     | Parameter                    | Conditions  | Min         | Max | Unit |
|--|------------------------------|---|-------------|-----|------|
| $f_{SCK} 1/t_{c(SCK)}$                     | SPI clock frequency          | Master mode   | 0           | 36  | MHz  |
|  |                              | Slave mode  | 0           | 18  |      |
| $t_{r(SCK)}$<br>$t_{f(SCK)}$               | SPI clock rise and fall time | Load capacitance: $C = 30pF$                                  |             | 8   | ns   |
| $t_{su(NSS)}^{(2)}$                        | NSS setup time               | Slave mode  | $4t_{PCLK}$ |     |      |
| $t_{h(NSS)}^{(2)}$                         | NSS hold time                | Slave mode  | 73          |     |      |
| $t_{w(SCKH)}^{(2)}$<br>$t_{w(SCKL)}^{(2)}$ | SCK high and low time        | Master mode, $f_{PCLK} = 36MHz$ ,<br>prescale coefficient = 4 | 50          | 60  |      |

| Symbol             | Parameter                             | Conditions | Min | Max | Unit |
|--------------------|---------------------------------------|------------|-----|-----|------|
| $t_{su(MI)}^{(2)}$ | Data input setup time,<br>Master mode | SPI1       | 1   |     |      |
| $t_{su(SI)}^{(2)}$ | Data input setup time,<br>Slave mode  |            | 1   |     |      |

| Symbol                 | Parameter                            | Conditions  | Min | Max         | Unit |
|------------------------|--------------------------------------|---|-----|-------------|------|
| $t_{h(MI)}^{(2)}$      | Data input hold time,<br>Master mode | SPI1  | 1   |             | ns   |
| $t_{h(SI)}^{(2)}$      | Data input hold time,<br>Slave mode  |   | 3   |             |      |
| $t_{a(SO)}^{(2)(3)}$   | Data output access time              | Slave mode, $f_{PCLK} = 36\text{MHz}$ ,<br>prescale coefficient = 4 | 0   | 55          |      |
|                        |                                      | Slave mode, $f_{PCLK} = 24\text{MHz}$                               |     | $4t_{PCLK}$ |      |
| $t_{dis(SO)}^{(2)(4)}$ | Data output disable time             | Slave mode  | 10  |             |      |
| $t_{v(SO)}^{(2)(1)}$   | Data output valid time               | Slave mode (after enable edge)                                      |     | 25          |      |
| $t_{v(MO)}^{(2)(1)}$   | Data output valid time               | Master mode (after enable<br>edge)                                  |     | 3           |      |
| $t_{h(SO)}^{(2)}$      | Data output hold time                | Slave mode (after enable edge)                                      | 25  |             |      |
| $t_{h(MO)}^{(2)}$      |                                      | Master mode (after enable<br>edge)                                  | 4   |             |      |

1. Remapping SPI1 characteristics needs to be further determined.
2. Data based on characterization results. Not tested in production.
3. Min time is for the minimum time to drive the output and the max time is for the maximum time to validate the data.
4. Min time is for the minimum time to invalidate the output and the max time is for the maximum time to put the data in Hi-Z.



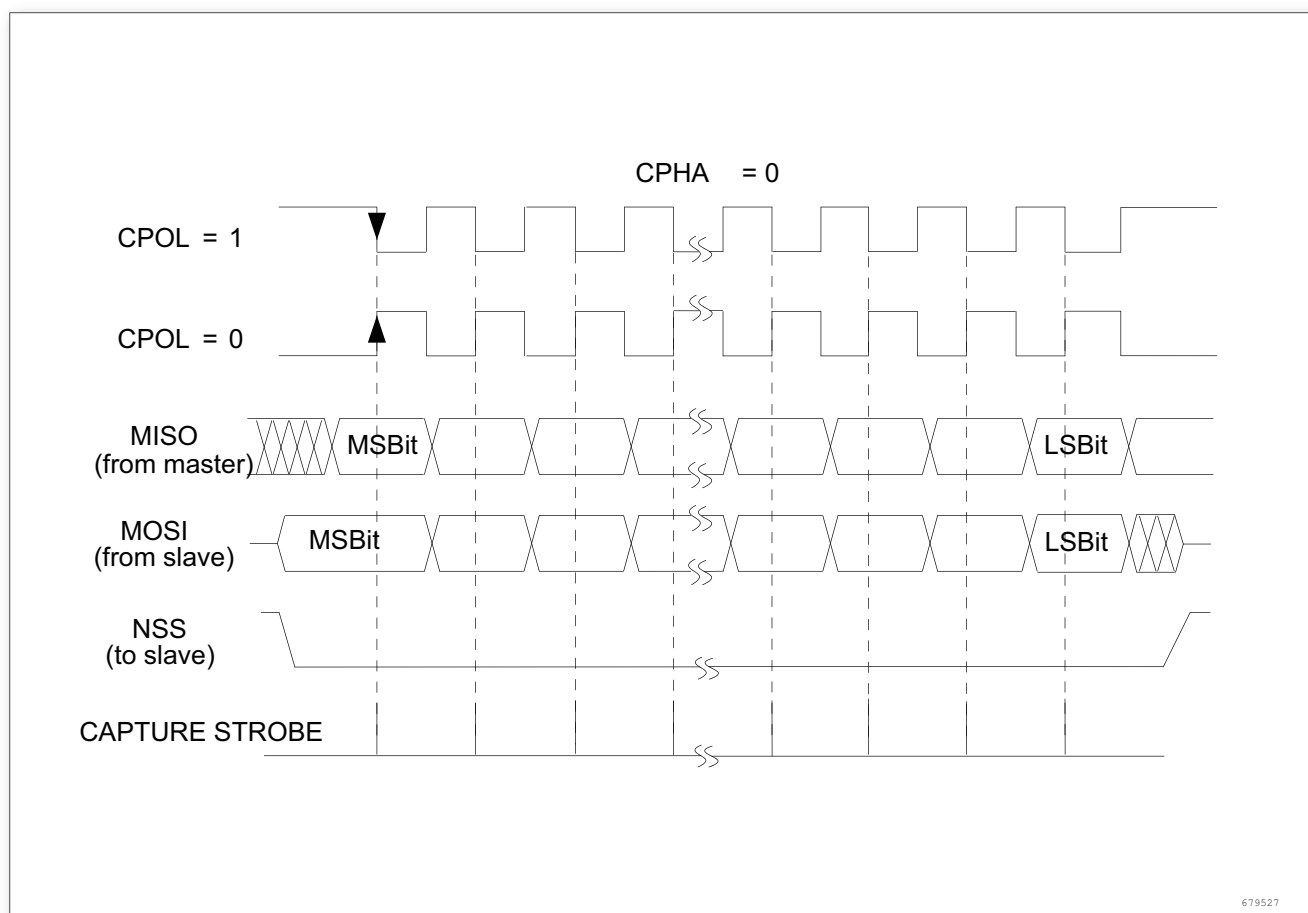
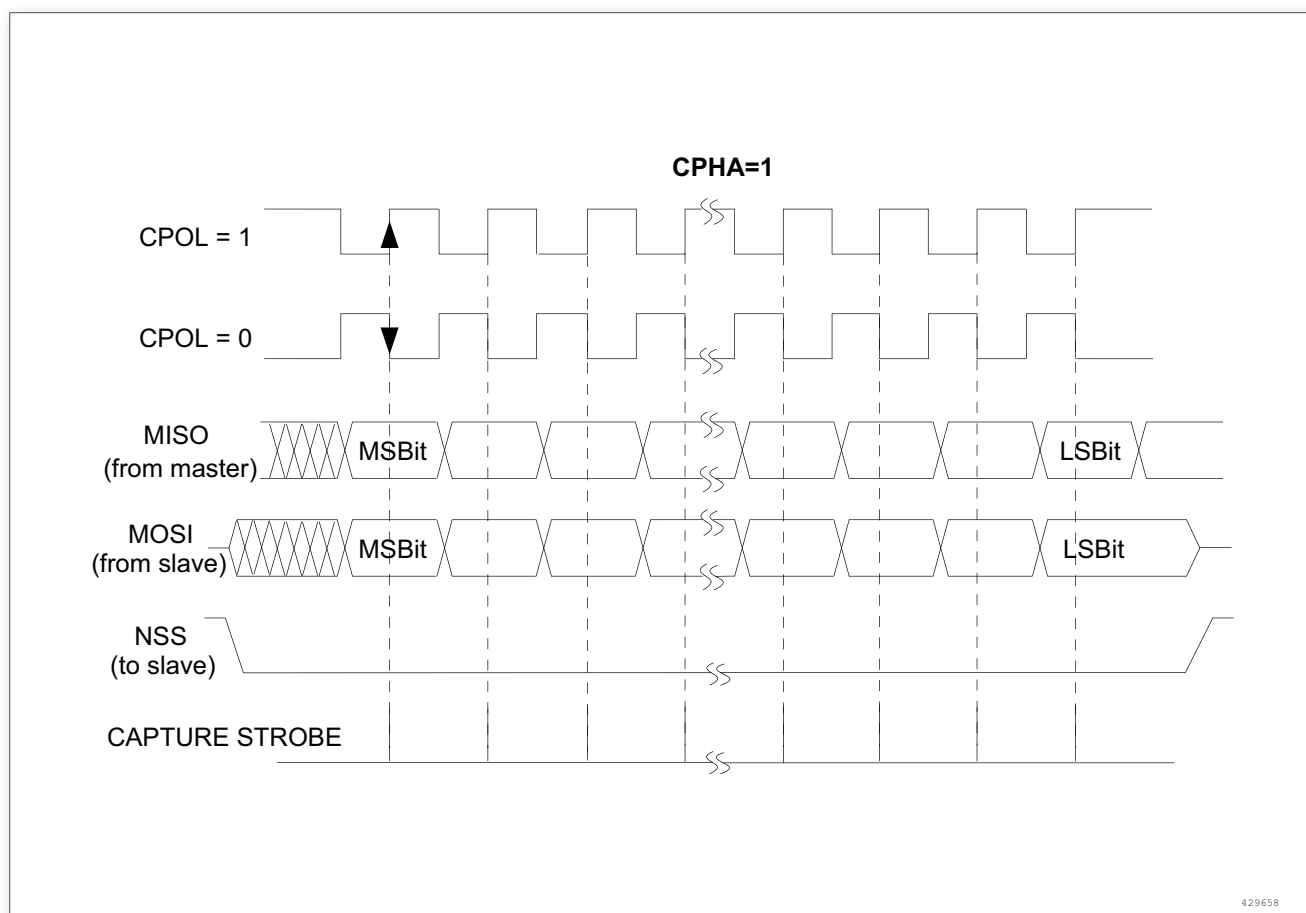
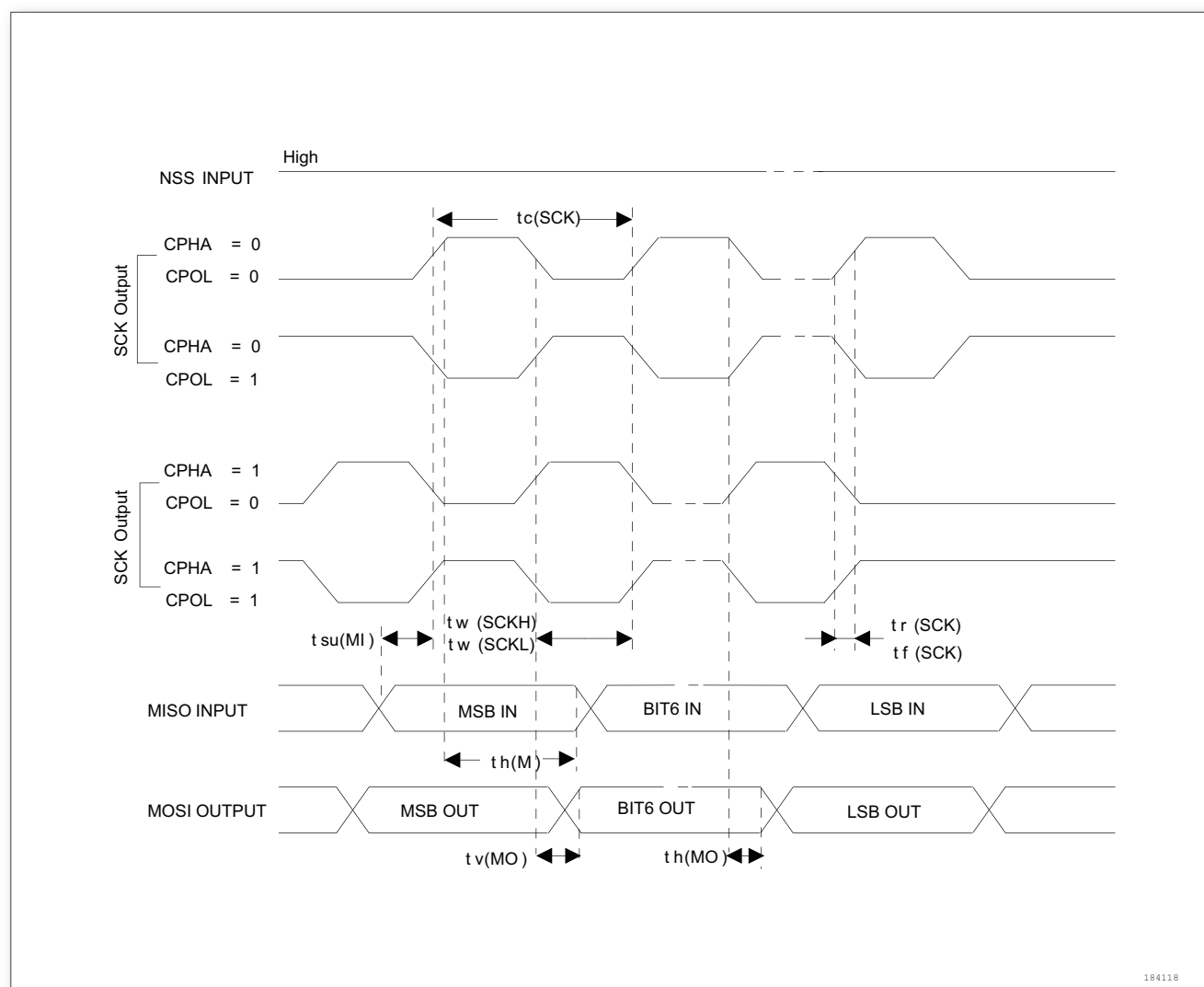


Figure 20. SPI timing diagram-slave mode and CPHA = 0

Figure 21. SPI timing diagram-slave mode and CPHA = 1<sup>(1)</sup>

1. Measurement points are done at CMOS levels: 0.3V<sub>DD</sub> and 0.7V<sub>DD</sub>.

Figure 22. SPI timing diagram-master mode<sup>(1)</sup>

1. Measurement points are done at CMOS levels:  $0.3V_{DD}$  and  $0.7V_{DD}$ .

## USB characteristics

Table 35. USB startup time

| Symbol            | Parameter                    | Max | Unit    |
|-------------------|------------------------------|-----|---------|
| $t_{START}^{(1)}$ | USB transceiver startup time | 1   | $\mu s$ |

1. Guaranteed by design. Not tested in production.

Table 36. USB DC electrical characteristics

| Symbol         | Parameter                            | Conditions      | Min <sup>(1)</sup> | Max <sup>(1)</sup> | Unit |
|----------------|--------------------------------------|-----------------|--------------------|--------------------|------|
| Input levels   |                                      |                 |                    |                    |      |
| $V_{DD}$       | USB operating voltage <sup>(2)</sup> |                 | 3.0 <sup>(3)</sup> | 3.6                | V    |
| $V_{DI}^{(4)}$ | Differential input sensitivity       | I(USBDP, USBDM) | 0.2                |                    |      |

| Symbol                         | Parameter                       | Conditions   | Min <sup>(1)</sup> | Max <sup>(1)</sup> | Unit |
|--------------------------------|---------------------------------|--|--------------------|--------------------|------|
| V <sub>CM</sub> <sup>(4)</sup> | Differential common mode range  | Includes V <sub>DI</sub> range                           | 0.8                | 2.5                |      |
| V <sub>SE</sub> <sup>(4)</sup> | Single ended receiver threshold |  | 1.3                | 2                  |      |
| Output levels                  |                                 |  |                    |                    |      |
| V <sub>OL</sub>                | Static output level low         | R <sub>L</sub> of 1.5kΩ to 3.6V <sup>(5)</sup>           |                    | 0.3                | V    |
| V <sub>OH</sub>                | Static output level high        | R <sub>L</sub> of 15kΩ to V <sub>SS</sub> <sup>(5)</sup> | 2.8                | 3.6                |      |

1. All the voltages are measured from the local ground potential.
2. To be compliant with the USB 2.0 full-speed electrical specification, USB DP (D +) pin has a built-in 1.5k $\Omega$  resistor connected to the  $V_{DD}$ , no need to external connect.
3. The USB functionality is ensured down to 2.7V but not the full USB electrical characteristics which are degraded in the 2.7V ~ 3.6V  $V_{DD}$  voltage range.
4. Guaranteed by design. Not tested in production.
5.  $R_L$  is the load connected on the USB drivers

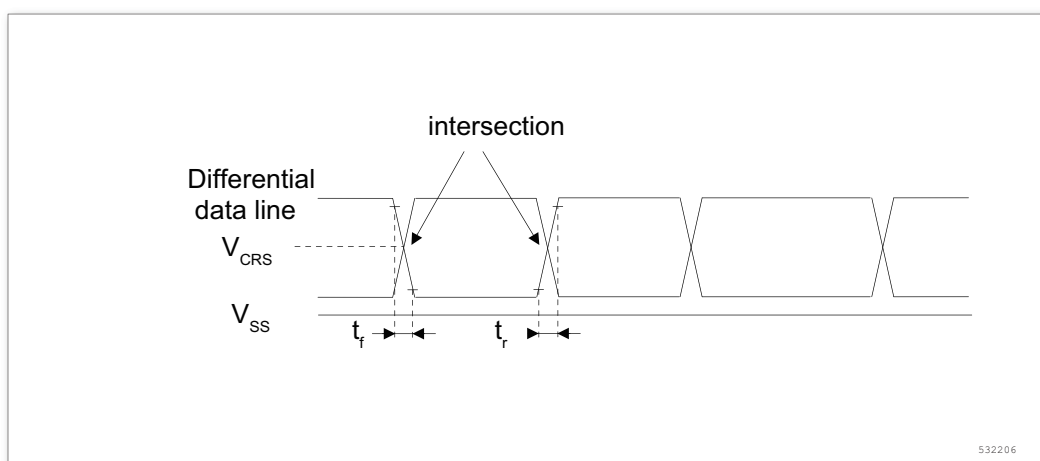


Figure 23. USB timing diagram: definition of data signal rise and fall time

Table 37. USB Full-speed electrical characteristics<sup>(1)</sup>

| Symbol    | Parameter                       | Conditions             | Min   | Max   | Unit |
|-----------|---------------------------------|------------------------|-------|-------|------|
| $t_r$     | Rise time <sup>(2)</sup>        | $C_L \leq 50\text{pF}$ | 7.041 | 23.13 | ns   |
| $t_f$     | Fall time <sup>(2)</sup>        | $C_L \leq 50\text{pF}$ | 6.866 | 26.76 | ns   |
| $t_{rfm}$ | Rise/fall time matching         | $t_r/t_f$              | 96.52 | 125.1 | %    |
| $V_{CRS}$ | Output signal crossover voltage |                        | 1.391 | 2.967 | V    |

1. Guaranteed by design. Not tested in production.
2. Measured from 10% to 90% of the data signal. For more detailed information, please refer to USB Specification - Section 7 (version 2.0).

### 5.3.16 CAN (controller area network) interface

Refer to subsubsec 5.3.12 for more details on the input/output alternate function characteristics (CAN\_TX and CAN\_RX).

### 5.3.17 12-bit ADC characteristics

Unless otherwise specified, The parameters in the table below are measured using the ambient temperature,  $f_{PCLK2}$  frequency and  $V_{DDA}$  supply voltage in accordance with the conditions of Table 8.

*Note: It is recommended to perform a calibration after each power-up*

Table 38. ADC characteristics

| Symbol             | Parameter                                       | Conditions               | Min   | Type      | Max        | Unit          |
|--------------------|---|--------------------------|---|-----------|------------|---------------|
| $V_{DDA}$          | Supply voltage                                  |                          | 2.5   | 5         | 5.5        | V             |
| $V_{REF+}$         | Positive reference voltage                      |                          |   | $V_{DDA}$ |            | V             |
| $f_{ADC}^{(1)(3)}$ | ADC clock frequency                             |                          |   |           | 15         | MHz           |
| $f_s^{(1)(3)}$     | Sampling rate                                   |                          |   |           | 1          | MHz           |
| $f_{TRIG}^{(1)}$   | External trigger frequency                      | $f_{ADC} = 15\text{MHz}$ |   |           | 833        | KHz           |
|                    |   |                          |   |           | 18         | $1/f_{ADC}$   |
| $V_{AIN}^{(2)}$    | Conversion voltage range                        |                          | 0 ( $V_{SSA}$ or $V_{REF-}$ connected to ground)          |           | $V_{REF+}$ | V             |
| $R_{AIN}^{(1)}$    | External sample and hold capacitor              |                          | See Formulas 1 and Table 39                               |           |            | $k\Omega$     |
| $R_{ADC}^{(1)}$    | Sampling switch resistance                      |                          |   |           | 0.75       | $k\Omega$     |
| $C_{ADC}^{(1)}$    | Internal sample and hold capacitor              |                          |   | 10        |            | pF            |
| $t_s^{(1)}$        | Sampling time                                   | $f_{ADC} = 15\text{MHz}$ | 0.1   |           | 16         | $\mu\text{s}$ |
|                    |   |                          | 1.5   |           | 239.5      | $1/f_{ADC}$   |
| $t_{STAB}^{(1)}$   | Stabilization time                              |                          |   | 1         |            | $\mu\text{s}$ |
| $t_{conv}^{(1)}$   | Total conversion time (including Sampling time) | $f_{ADC} = 15\text{MHz}$ | 1   |           | 17.44      | $\mu\text{s}$ |
|                    |   |                          | 15 ~ 253 (sampling $t_{s+}$ ) stepwise approximation 13.5 |           |            | $1/f_{ADC}$   |

1. Guaranteed by design. Not tested in production.
2. In this series of products,  $V_{REF+}$  is internally connected to  $V_{DDA}$ ,  $V_{REF-}$  is internally connected to  $V_{SSA}$ .
3.  $f_{ADC}$  Maximum support 15MHz,  $f_s$  Maximum support 1MHz ( $f_{PCLK2} = 60\text{MHz}$ , ADC Prescaler = 4,  $f_{ADC} = 15\text{MHz}$ ,  $T_s = 1.5$ )

Formula 1: Maximum  $R_{AIN}$  Formula

$$R_{AIN} < \frac{T_S}{f_{ADC} \times C_{ADC} \times (N + 3) \times \ln(2)} - R_{ADC}$$

The above formula (Equation 1) is used to determine the maximum external impedance so that the error can be less than 1/4 LSB. Where  $N = 12$  (representing 12-bit resolution) .  $\ln(2) = 0.69314718$ .

Table 39. Maximum  $R_{AIN}$  at  $f_{ADC} = 15\text{MHz}$ <sup>(1)</sup>

| $T_S$ (cycles) | $t_S$ ( $\mu\text{s}$ ) | $R_{AIN}$ max ( $k\Omega$ ) |
|----------------|-------------------------|-----------------------------|
| 1.5            | 0.1                     | 0.2                         |
| 7.5            | 0.5                     | 4.1                         |
| 13.5           | 0.9                     | 7.9                         |
| 28.5           | 1.9                     | 17.5                        |
| 41.5           | 2.8                     | 25.9                        |
| 55.5           | 3.7                     | 34.8                        |
| 71.5           | 4.8                     | NA                          |
| 239.5          | 16.0                    | NA                          |

1. Guaranteed by design. Not tested in production.

Table 40. ADC Accuracy - Limit Test Conditions<sup>(1)(2)</sup>

| Symbol | Parameter                    | Test Conditions   | Type | Max | Unit |
|--------|------------------------------|---|------|-----|------|
| ET     | Comprehensive error          | $f_{PCLK2} = 60\text{MHz}, f_{ADC} = 15\text{MHz}, R_{AIN} < 10k\Omega, V_{DDA} = 5V, T_A = 25^\circ\text{C}$ | 8    | 10  | LSB  |
| EO     | Offset error                 |   | 3    | 3   |      |
| EG     | Gain error                   |   | 1    | 1   |      |
| ED     | Differential linearity error |   | 6.5  | 7   |      |
| EL     | Integral linearity error     |   | 8    | 8   |      |

1. ADC Accuracy vs. Negative Injection Current: Injecting negative current on any of the standard (non-robust) analog input pins should be avoided as this significantly reduces the accuracy of the conversion being performed on another analog input. It is recommended to add a Schottky diode (pin to ground) to standard analog pins which may potentially inject negative current.

Any positive injection current within the limits specified for  $I_{INJ(PIN)}$  and  $\Sigma I_{INJ(PIN)}$  in subsubsec 5.3.13 does not affect the ADC accuracy.

2. Guaranteed based on test during characterization. Not tested in production.

ET = Total unadjusted error: The maximum deviation between the actual and ideal transmission curves.

EO = Offset error: The deviation between the first actual conversion and the first ideal conversion.

EG = Gain error: The deviation between the last ideal transition and the last actual transition.

ED = Differential linearity error: The maximum deviation between the actual step and the ideal value.

EL = Integral linearity error: The maximum deviation between any actual conversion and the associated line of the endpoint.

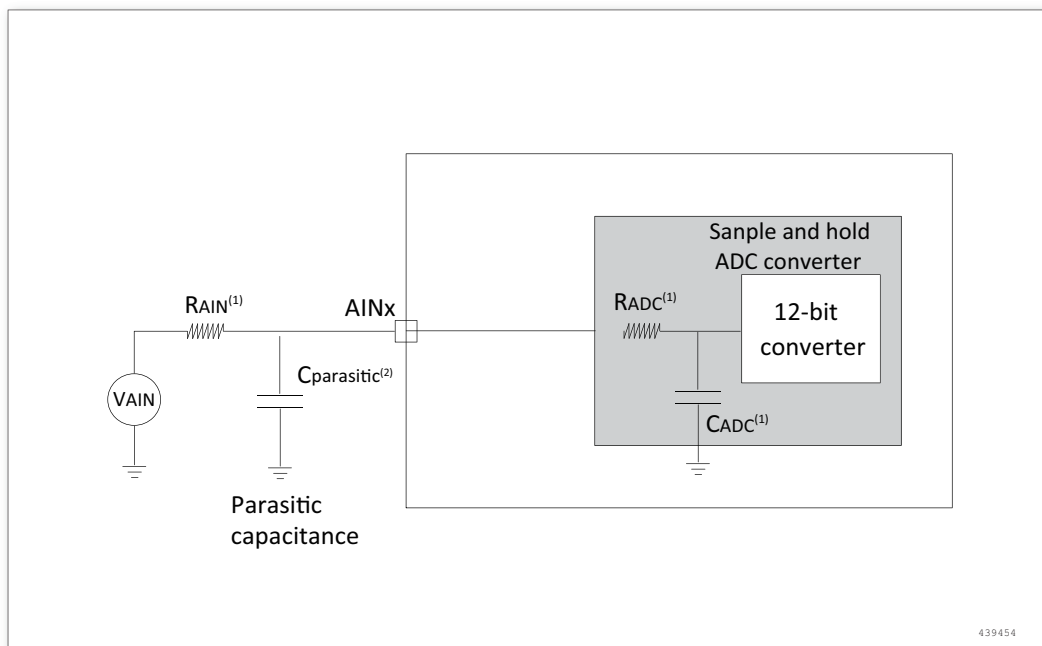


Figure 24. Typical connection diagram using the ADC

1. See Table 40 for the values of  $R_{AIN}$ ,  $R_{ADC}$  and  $C_{ADC}$ .
2.  $C_{parasitic}$  represents the capacitance of the PCB (dependent on soldering and PCB layout quality) plus the pad capacitance (roughly 7pF) . A high  $C_{parasitic}$  value will downgrade conversion accuracy. To remedy this,  $f_{ADC}$  should be reduced.

## PCB design recommendations

The power supply must be connected as shown below. The 10nF capacitor in the figure must be a ceramic capacitor (good quality) , and they should be as close as possible to the MCU chip.

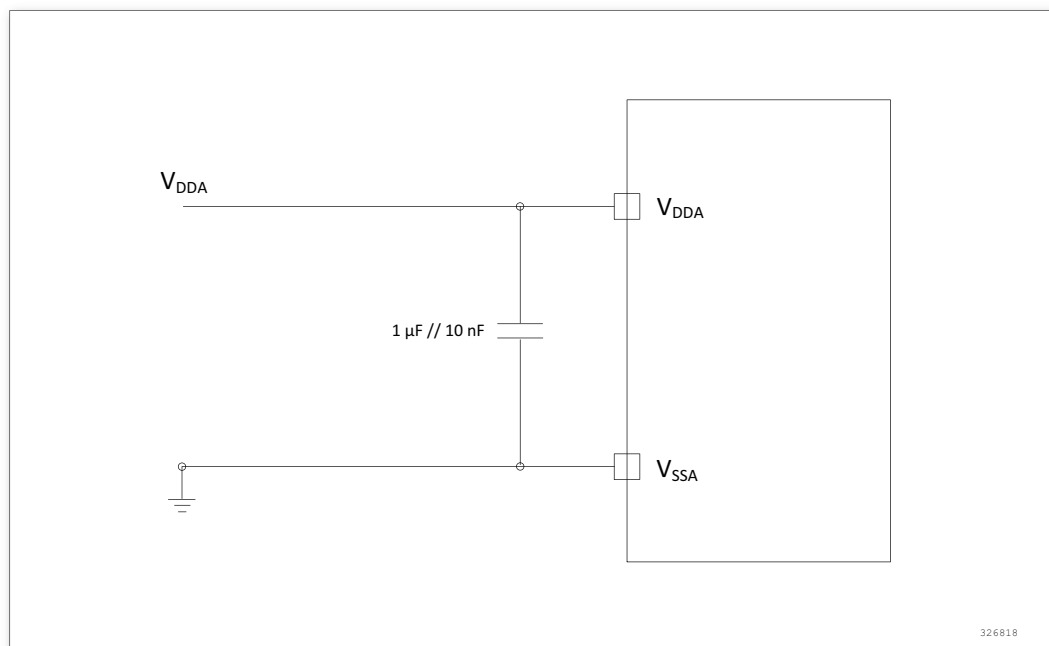


Figure 25. Power supply and reference power supply decoupling circuit

### 5.3.18 Temperature sensor characteristics

Table 41. Temperature sensor characteristics<sup>(3)</sup> (4)

| Symbol                   | Parameter   | Min   | Type    | Max   | Unit                   |
|--------------------------|---|-------|---------|-------|------------------------|
| $T_L^{(1)}$              | $V_{SENSE}$ linearity with respect to temperature |       | $\pm 5$ |       | $^{\circ}\text{C}$     |
| Avg_Slope <sup>(1)</sup> | Average slope                                     | 4.571 | 4.801   | 5.984 | mV/ $^{\circ}\text{C}$ |
| $V_{25}^{(1)}$           | Voltage at 25 $^{\circ}\text{C}$                  | 1.433 | 1.451   | 1.467 | V                      |
| $t_{start}^{(2)}$        | Setup time  |       |         | 10    | $\mu\text{s}$          |
| $T_{S\_temp}^{(2)}$      | ADC sampling time when reading temperature        | 10    |         |       | $\mu\text{s}$          |

1. Guaranteed based on test during characterization. Not tested in production.
2. Guaranteed by design. Not tested in production.
3. The shortest Sampling time can be determined by the application through multiple iterations.
4.  $V_{DD} = 3.3\text{V}$ .

### 5.3.19 DAC characteristics

Table 42. DAC characteristics

| Symbol     | Parameter                | Comment                                   | Min | Type      | Max | Unit |
|------------|--------------------------|---|-----|-----------|-----|------|
| $V_{DDA}$  | Analog supply voltage    |   | 2   | 5         | 5.5 | V    |
| $V_{REF+}$ | Reference supply voltage | $V_{REF+}$ must always be below $V_{DDA}$ |     | $V_{DDA}$ |     | V    |



| Symbol                | Parameter  | Comment   | Min | Type | Max            | Unit       |
|-----------------------|--|---|-----|------|----------------|------------|
| $V_{SSA}$             | Ground   |   |     | 0    |                | V          |
| $R_{LOAD}^{(1)}$      | $V_{SSA}$ Aresistive load with buffer ON                                     |   |     |      |                | k $\Omega$ |
|                       | $V_{DDA}$ Aresistive load with buffer ON                                     |   |     |      |                | k $\Omega$ |
| $R_O^{(1)}$           | Impedance output with buffer OFF   | When the Buffer is OFF, the Minimum impedance between DAC_OUT and $V_{DD}$ is 1.5 M $\Omega$  |     |      | 20             | k $\Omega$ |
| $C_{LOAD}^{(1)}$      | Capacitive load  | Maximum capacitive load at DAC_OUT pin (when the buffer is ON).   |     |      | 50             | pF         |
| $DAC\_OUTmin^{(1)}$   | Lower DAC_OUT voltage with buffer ON   | Giving the DAC a maximum output offset, which is equivalent to giving a 12-bit input between 0x0E0 and 0xF1C at $V_{REF+} = 3.6V$ or a 12-bit input between 0x155 and |     |      | 0.2            | V          |
| $DAC\_OUTmax^{(1)}$   | Higher DAC_OUT voltage with buffer ON  |   |     |      | $V_{DDA}-0.2$  | V          |
| $DAC\_OUTmin^{(1)}$   | Lower DAC_OUT voltage with buffer ON   | 0xEAB at $V_{REF+} = 2.4V$ It gives the maximum output excursion of the DAC.  |     |      | 0.5            | mV         |
| $DAC\_OUTmax^{(1)}$   | Higher DAC_OUT voltage with buffer ON  |   |     |      | $V_{DDA}-0.01$ | V          |
| $I_{DDVREF+}$         | DAC DC current consumption in quiescent mode (Standby mode)                  | No load, $V_{REF+} = 3.6V$ , Enter the DC loss for worst case value 0x0E4   |     | 50   |                | $\mu A$    |
| $I_{DDA}$             | DAC DC current consumption in quiescent mode (Standby mode)                  | No load, enter the median value of 0x800  |     | 630  |                | $\mu A$    |
|                       |  | No load, $V_{REF+} = 3.6V$ , Enter the DC loss at worst-case value 0xF1C  |     | 703  |                | $\mu A$    |
| $DNL^{(2)}$           | Differential linearity, the difference between two consecutive values (LSBs) | Given for the DAC in 12-bit configuration   |     |      | $\pm 3$        | LSB        |
| $INL^{(2)}$           | Integral nonlinearity  | Given for the DAC in 12-bit configuration   |     |      | $\pm 4$        | LSB        |
| offset <sup>(2)</sup> | Offset error (difference between measured value                              | Given for the DAC in 12-bit configuration   |     |      | $\pm 10$       |            |

| Symbol                     | Parameter  | Comment  | Min | Type | Max       | Unit    |
|----------------------------|--|--|-----|------|-----------|---------|
|                            | at Code(0x800) and the ideal value = VREF+/2)  | Given for the DAC in 12-bit configuration, $V_{REF+} = 5.5V$ |     |      | $\pm 12$  |         |
| Gain error <sup>(2)</sup>  | Gain error   | Given for the DAC in 12-bit configuration                    |     |      | $\pm 0.5$ | %       |
| $t_{SETTLING}^{(2)}$       | Settling time  | $C_{LOAD} \leq 50pF, R_{LOAD} \geq 5k\Omega$                 |     |      | 4         | $\mu s$ |
| Updata rate <sup>(2)</sup> | Max frequency for a correct DAC_OUT change when small variation in the input code(from code i to i+1LSB) | $C_{LOAD} \leq 50pF, R_{LOAD} \geq 5k\Omega$                 |     |      | 1         | MS/s    |
| $t_{WAKEUP}^{(2)}$         | Wake-up Time in Shut-down (ENx is Configured in DAC Control Register)                                    | $C_{LOAD} \leq 50pF, R_{LOAD} \geq 5k\Omega$                 |     |      | 10        | $\mu s$ |
| PSRR+ <sup>(1)</sup>       | Power Supply Rejection Ratio $V_{DDA}$ (Static DC Measurement)   | 无 $R_{LOAD}, C_{LOAD} = 50pF$                                |     |      | -40       | dB      |

1. Guaranteed by design, not tested in production.
2. Preliminary data.

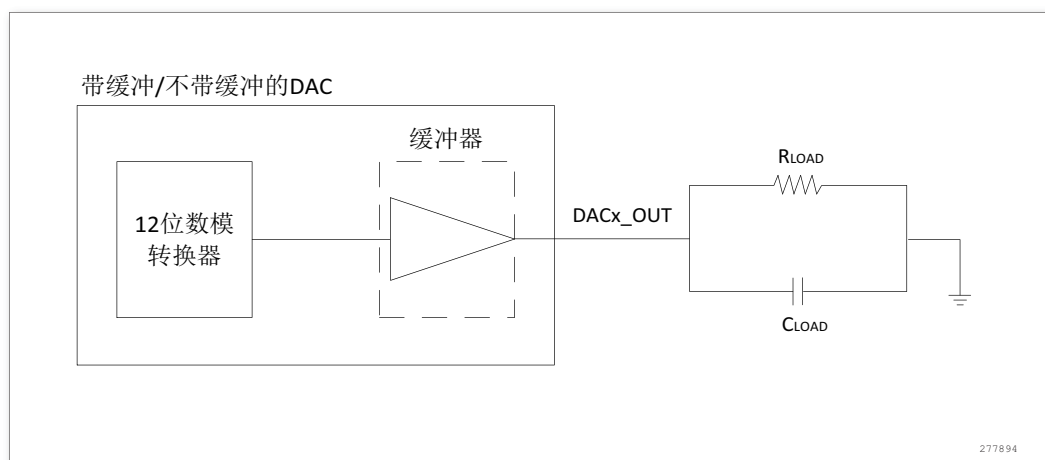


Figure 26. 12Bit buffered /non-buffered DAC

## 6

## Package information

## Package information

## 6.1 LQFP64 Package information

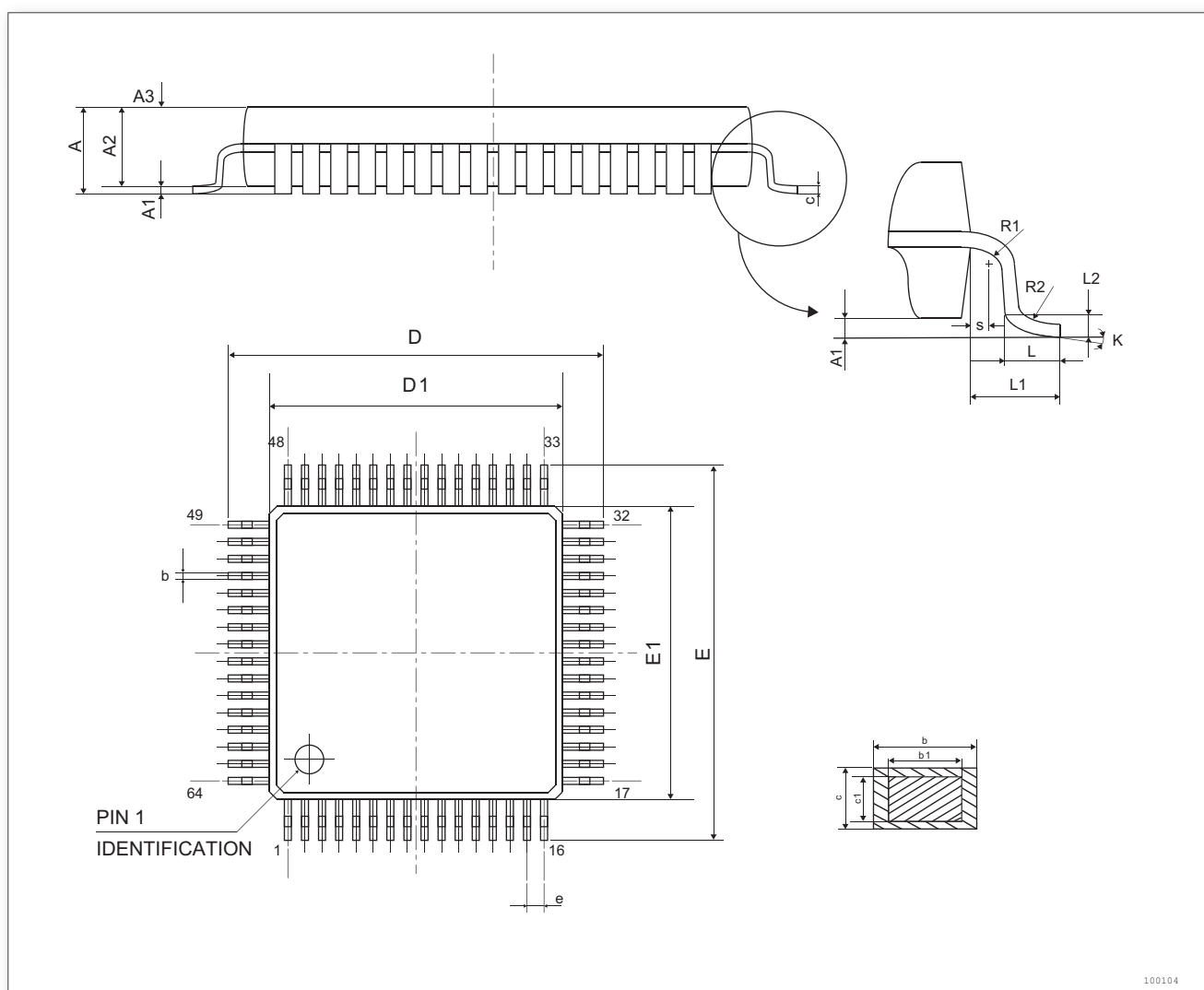


Figure 27. LQFP64 - 64-pin low-profile quad flat package outline

1. Drawing is not to scale.
2. Dimensions are expressed in millimeters.

Table 43. LQFP64 mechanical data

| Symbol | Millimeters         |       |       |
|--------|---------------------|-------|-------|
|        | Min                 | Typ   | Max   |
| A      |                     |       | 1.60  |
| A1     | 0.05                |       | 0.15  |
| A2     | 1.35                | 1.40  | 1.45  |
| A3     | 0.59                | 0.64  | 0.69  |
| b      | 0.18                |       | 0.27  |
| b1     | 0.17                | 0.20  | 0.23  |
| c      | 0.13                |       | 0.18  |
| c1     | 0.12                | 0.127 | 0.134 |
| D      | 11.80               | 12.00 | 12.20 |
| D1     | 9.90                | 10.00 | 10.10 |
| E      | 11.80               | 12.00 | 12.20 |
| E1     | 9.90                | 10.00 | 10.10 |
| e      |                     | 0.50  |       |
| L      | 0.45                | 0.60  | 0.75  |
| L1     | 1.00REF             |       |       |
| L2     | 0.25BSC             |       |       |
| R1     | 0.08                |       |       |
| R2     | 0.08                |       | 0.20  |
| S      | 0.20                |       |       |
| N      | Number of pins = 64 |       |       |

## 6.2 LQFP48 Package information

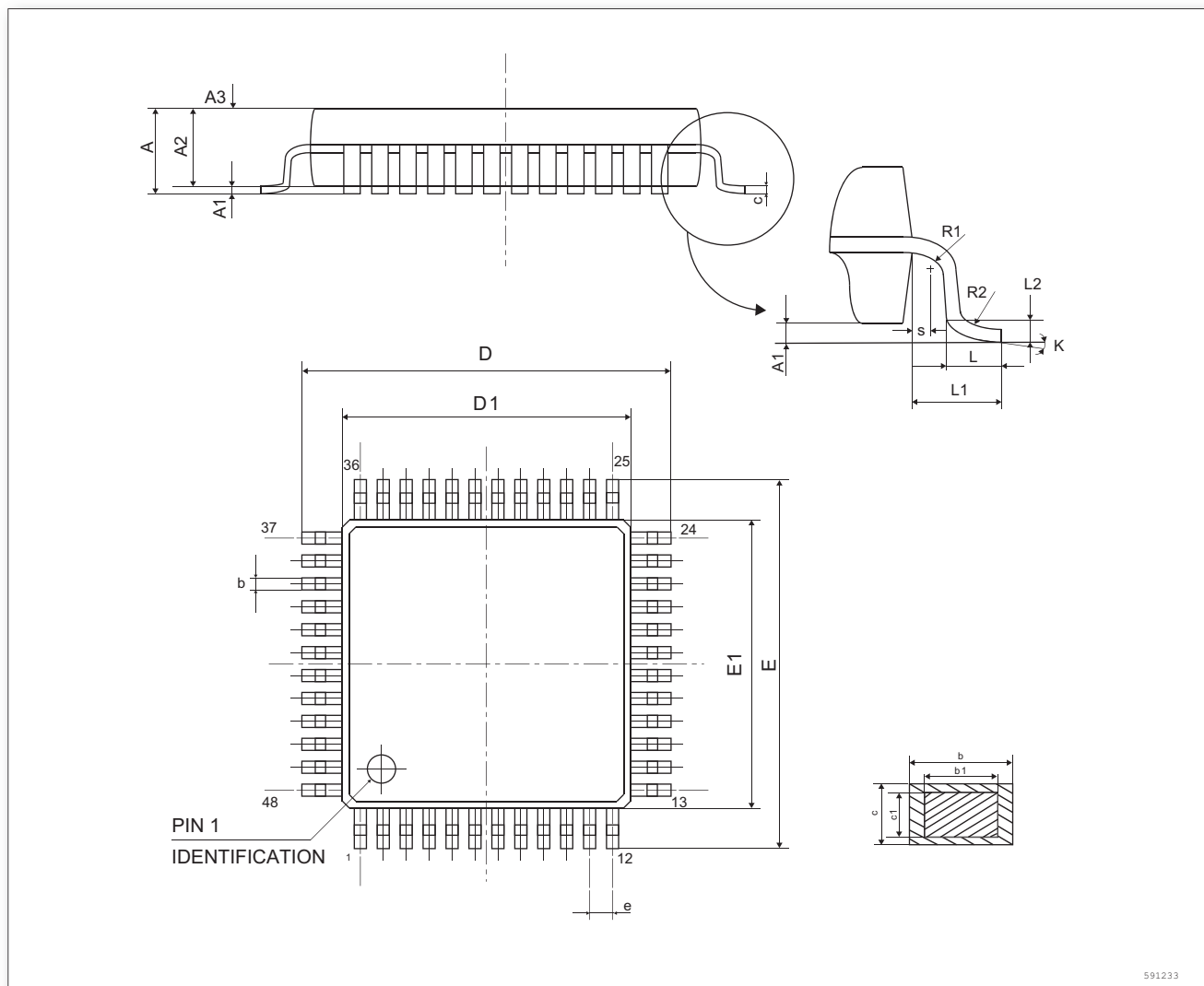


Figure 28. LQFP48 - 48-pin low-profile quad flat package outline

1. Drawing is not to scale.
2. Dimensions are expressed in millimeters.

Table 44. LQFP48 mechanical data

| Symbol | Millimeters |       |       |
|--------|-------------|-------|-------|
|        | Min         | Typ   | Max   |
| A      |             |       | 1.60  |
| A1     | 0.05        |       | 0.15  |
| A2     | 1.35        | 1.40  | 1.45  |
| A3     | 0.59        | 0.64  | 0.69  |
| b      | 0.18        |       | 0.27  |
| b1     | 0.17        | 0.20  | 0.23  |
| c      | 0.13        |       | 0.18  |
| c1     | 0.12        | 0.127 | 0.134 |

| Symbol | Millimeters         |      |      |
|--------|---------------------|------|------|
|        | Min                 | Typ  | Max  |
| D      | 8.80                | 9.00 | 9.20 |
| D1     | 6.90                | 7.00 | 7.10 |
| E      | 8.80                | 9.00 | 9.20 |
| E1     | 6.90                | 7.00 | 7.10 |
| e      |                     | 0.50 |      |
| L      | 0.45                | 0.60 | 0.75 |
| L1     | 1.00REF             |      |      |
| L2     | 0.25BSC             |      |      |
| R1     | 0.08                |      |      |
| R2     | 0.08                |      | 0.20 |
| S      | 0.20                |      |      |
| N      | Number of pins = 48 |      |      |

### 6.3 LQFP32 Package information

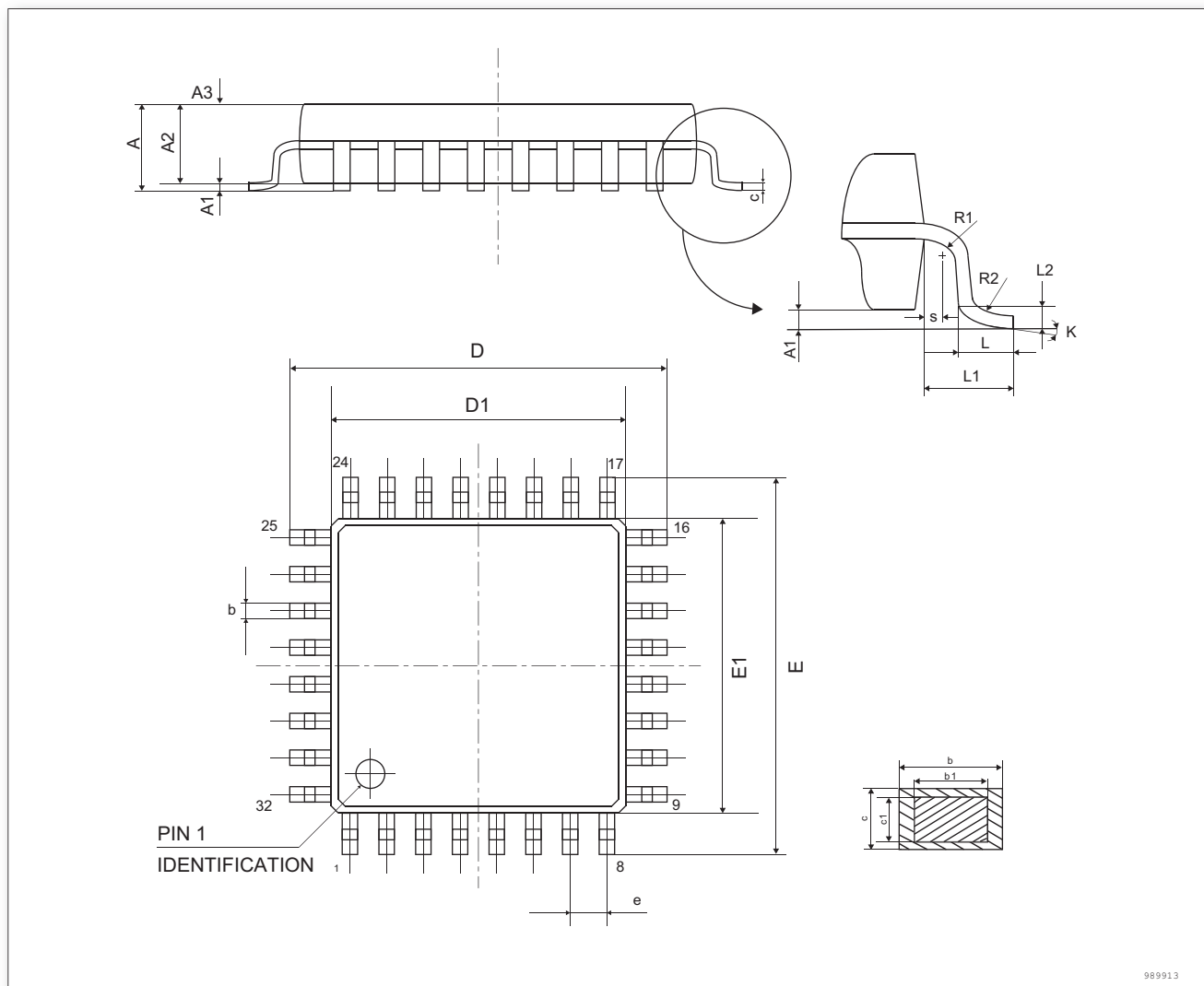


Figure 29. LQFP32 - 32-pin low-profile quad flat package outline

1. Drawing is not to scale.
2. Dimensions are expressed in millimeters.

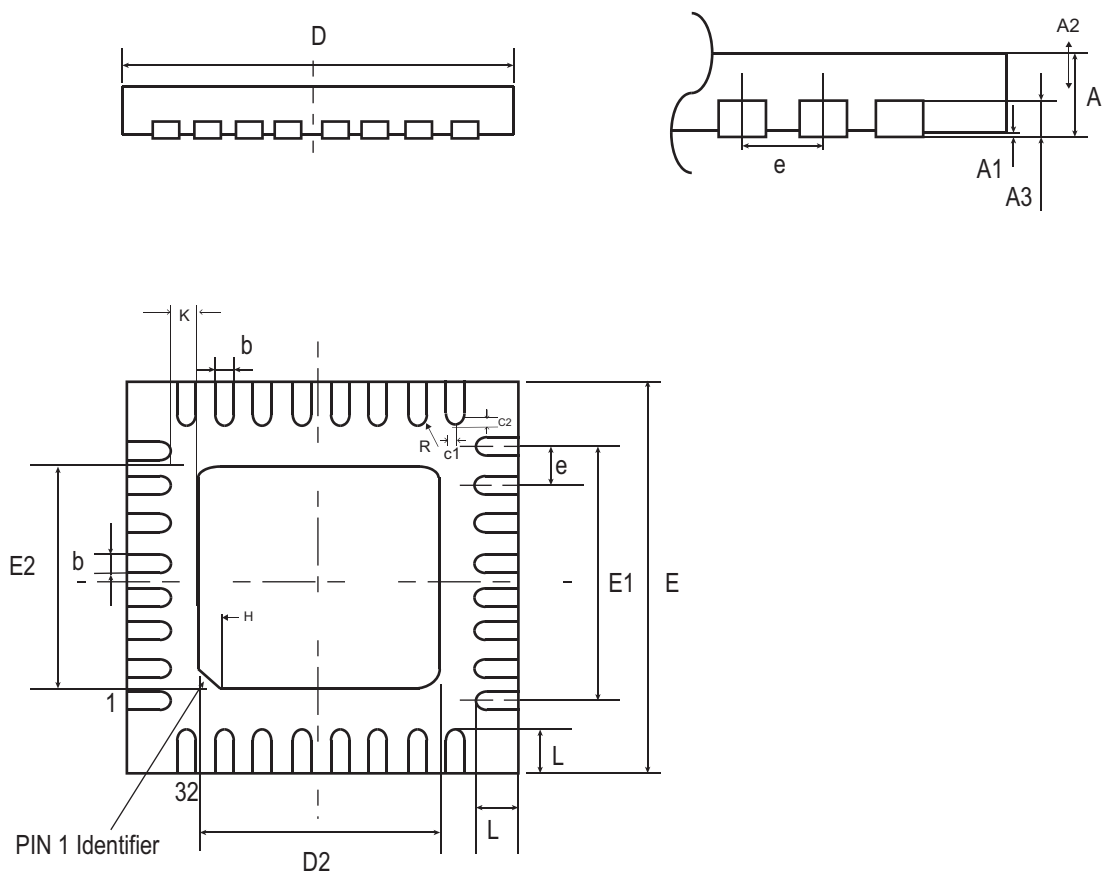
Table 45. LQFP32 mechanical data

| Symbol | Millimeters |       |       |
|--------|-------------|-------|-------|
|        | Min         | Typ   | Max   |
| A      |             |       | 1.60  |
| A1     | 0.05        |       | 0.15  |
| A2     | 1.35        | 1.40  | 1.45  |
| A3     | 0.59        | 0.64  | 0.69  |
| b      | 0.32        |       | 0.43  |
| b1     | 0.31        | 0.35  | 0.39  |
| c      | 0.13        |       | 0.18  |
| c1     | 0.12        | 0.127 | 0.134 |

| Symbol | Millimeters         |      |      |
|--------|---------------------|------|------|
|        | Min                 | Typ  | Max  |
| D      | 8.80                | 9.00 | 9.20 |
| D1     | 6.90                | 7.00 | 7.10 |
| E      | 8.80                | 9.00 | 9.20 |
| E1     | 6.90                | 7.00 | 7.10 |
| e      |                     | 0.80 |      |
| L      | 0.45                | 0.60 | 0.75 |
| L1     | 1.00REF             |      |      |
| L2     | 0.25BSC             |      |      |
| R1     | 0.08                |      |      |
| R2     | 0.08                |      | 0.20 |
| S      | 0.20                |      |      |
| N      | Number of pins = 32 |      |      |



## 6.4 QFN32 Package information



978941

Figure 30. QFN32 - 32-pin quad flat no-leads package outline

1. Drawing is not to scale.
2. Dimensions are expressed in millimeters.

Table 46. QFN32 mechanical data

| Symbol | Millimeters |      |      |
|--------|-------------|------|------|
|        | Min         | Typ  | Max  |
| A      | 0.7         | 0.75 | 0.80 |
| A1     | 0.00        | 0.02 | 0.05 |
| A2     | 0.50        | 0.55 | 0.60 |
| A3     | 0.20REF     |      |      |
| b      | 0.20        | 0.25 | 0.30 |
| D      | 4.90        | 5.00 | 5.10 |
| E      | 4.90        | 5.00 | 5.10 |
| D2     | 3.40        | 3.50 | 3.60 |

| Symbol | Millimeters         |      |      |
|--------|---------------------|------|------|
|        | Min                 | Typ  | Max  |
| E2     | 3.40                | 3.50 | 3.60 |
| e      |                     | 0.5  |      |
| H      | 0.30REF             |      |      |
| K      | 0.35REF             |      |      |
| L      | 0.35                | 0.40 | 0.45 |
| R      | 0.09                |      |      |
| c1     |                     | 0.08 |      |
| c2     |                     | 0.08 |      |
| N      | Number of pins = 32 |      |      |

## 7

## Ordering information

Ordering information

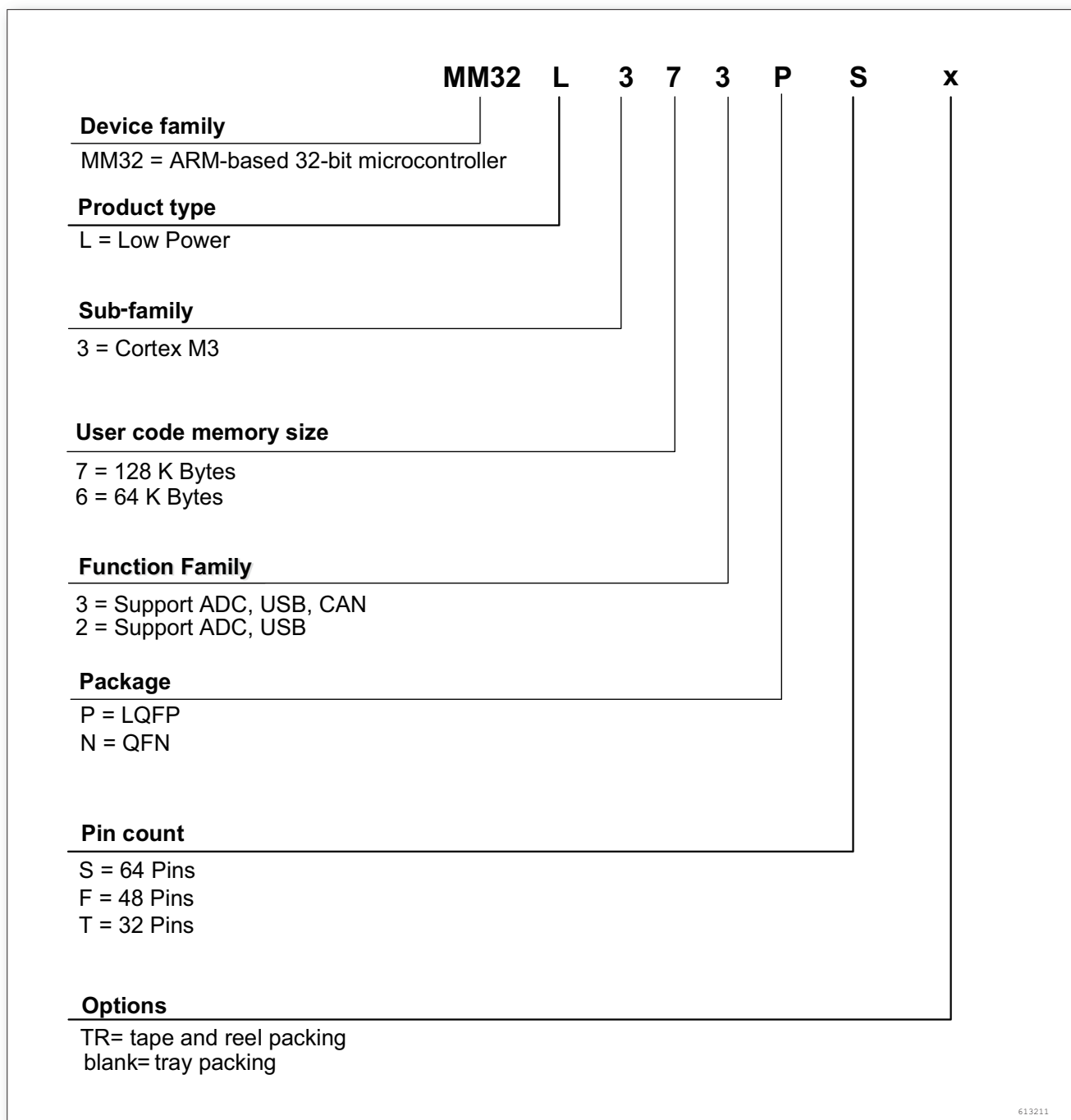


Figure 31. Ordering information scheme

## 8

## Revision history

### Revision history

Table 47. Document revision history

| Revision | Changes                           | Date       |
|----------|-----------------------------------|------------|
| Rev1.04  | Modify the package parameters.    | 2019/3/11  |
| Rev1.03  | Modify ADC electrical parameters. | 2019/1/7   |
| Rev1.02  | Modify electrical parameters.     | 2018/10/11 |
| Rev1.01  | Modify electrical parameters.     | 2018/9/14  |
| Rev1.00  | Initial release.                  | 2018/4/12  |