ARM®-based 32-bit Cortex®-M4 MCU+FPU, 64 to 256 KB Flash, sLib, 15 timers, 1 ADC, 18 communication interfaces (2 CAN and 1 OTGFS)

Features

- **Core: ARM® 32-bit Cortex®-M4 CPU**
  - 150 MHz maximum frequency, with a memory protection unit (MPU), single-cycle multiplication and hardware division
  - Floating point unit (FPU)
  - DSP instructions

- **Memories**
  - 64 to 256 KBytes of internal Flash memory
  - 20 Kbytes of boot memory used as a Bootloader or as a general instruction/data memory (one-time-configurable)
  - sLib: configurable part of main Flash as a library area with code executable but secured, non-readable
  - Up to 48 KBytes of SRAM
  - External memory controller (XMC) with 16-bit data bus supporting multiplexed PSRAM and NOR memories

- **XMC as LCD parallel interface, 8080/6800 modes**

- **Power control (PWC)**
  - 2.4 to 3.6 V supply
  - Power on reset (POR), low voltage reset (LVR), and power voltage monitoring (PVM)
  - Low power modes: Sleep, Deepsleep, and Standby modes
  - 20x 32-bit battery powered registers (BPR)

- **Clock and reset management (CRM)**
  - 4 to 25 MHz crystal oscillator (HEXT)
  - 48 MHz internal factory-trimmed high speed clock (HICK), 1 % accuracy at T_A = 25 °C and 2.5 % accuracy at T_A = -40 to +105 °C, with automaitc clock calibration (ACC)
  - 32 kHz crystal oscillator (LEXT)
  - Low speed internal clock (LICK)

- **Analog**
  - 1x 12-bit 5.33 MSPS A/D converter, up to 24 external input channels; 12/10/8/6-bit resolution, hardware over-sampling up to equivalent 16-bit resolution
  - Temperature sensor (V_{TS}), internal reference voltage (V_{INTRV})
  - 2x 12-bit D/A converters

- **DMA:**
  - 2 x 7-channel DMA controllerswith flexible mapping capability

- **Up to 87 fast GPIOs**
  - All mappable on 16 external interrupts (EXINT)
  - Almost all 5 V-tolerant

- **Up to 15 timers (TMR)**
  - 1x 16-bit 7-channel motor control PWM advanced timer with dead-time generator and emergency break
  - Up to 8x 16-bit + 1x 32-bit general-purpose timers, each with up to 4 IC/OC/PWM or pulse counter and quadrature encoder input
  - 2x 16-bit basic timers
  - 2x watchdog timers (general WDT and windowed WWDT)
  - SysTick timer: a 24-bit downcounter

- **ERTC: enhanced RTC with auto-wakeup, alarm, subsecond accuracy, and hardware calendar, with calibration feature**

- **Up to 18 communication interfaces**
  - Up to 3x I²C interfaces (SMBus/PMBus)
  - Up to 3x SPIs (36 Mbit/s), all with multiplexed half-duplex I²S; 2x half-duplex I²S combined for full-duplex mode
  - Up to 8x USARTs support master synchronization SPI and modem control, ISO7816 interface, LIN, IrDA, and RS485 driver enable, TX/RX swap
  - Up to 2x CAN (2.0B Active), each with dedicated 256 KB buffer
  - OTGFS controller with on-chip PHY, dedicated 1280KB buffer, supporting crystal-less in device mode
  - Infrared transmitter (IRTMR)

- **CRC calculation unit**

- **96-bit unique ID (UID)**

- **Debug mode**
  - SWD and JTAG interfaces

- **Operating temperatures: -40 to +105 °C**

■ **Packages**

- LQFP100 14 x 14 mm
- LQFP64 10 x 10 mm
- LQFP64 7 x 7 mm
- LQFP48 7 x 7 mm
- QFN48 6 x 6 mm
- QFN36 6 x 6 mm
- QFN32 4 x 4 mm

Table 1. Device summary

Flash	Part number
256 KBytes	AT32F423VCT7, AT32F423RCT7, AT32F423RCT7-7, AT32F423CCT7, AT32F423CCU7, AT32F423TCU7, AT32F423KCU7-4
128 KBytes	AT32F423VBT7, AT32F423RBT7, AT32F423RBT7-7, AT32F423CBT7, AT32F423CBU7, AT32F423TBU7, AT32F423KBU7-4
64 KBytes	AT32F423V8T7, AT32F423R8T7, AT32F423R8T7-7, AT32F423C8T7, AT32F423C8U7, AT32F423T8U7, AT32F423K8U7-4

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1 Descriptions

The AT32F423 series is based on the high-performance ARM®Cortex®-M4 32-bit RISC core operating at a frequency of up to 150 MHz. The Cortex®-M4 core features a Floating point unit (FPU) single precision supporting all ARM® single-precision data processing instructions and data types. It also implements a full set of DSP instructions and a memory protection unit (MPU) that enhances application security.

The AT32F423 incorporates high-speed embedded memories (up to 256 KBytes of Flash memory, 48 KBytes of SRAM), and a wide range of enhanced GPIO ports and peripherals connected to two APB buses. Any block of the embedded Flash memory can be protected by the "sLib" (security library), functioning as a security area with code-executable only. In addition, the AT32F423 device includes a high-level memory extension: an external memory controller (XMC).

The AT32F423 offers one 12-bit ADC, two 12-bit DACs, eight general-purpose 16-bit timers plus one general-purpose 32-bit timer, two basic timers, one advanced timer and one low-power ERTC. It also features standard and advanced communication interfaces: up to three I²Cs, three SPIs (multiplexed as I²Ss), eight USARTs, two CANs, an OTGFS, and infrared transmitter.

The AT32F423 operates in the -40 to +105 °C temperature range, from a 2.4 to 3.6 V power supply. A comprehensive set of power-saving mode allows the design of low-power application.

The AT32F423 offers devices in different package types. They are fully pin-to-pin, software and functionally compatible throughout the AT32F423 series, except that the configurations of peripherals are not fully identical depending on the package types.

Table 2. AT32F423 features and peripheral counts

Part number				AT32F423xxU7-4			AT32F423xxU7			AT32F423xxU7			AT32F423xxT7			AT32F423xxT7-7			AT32F423xxT7			AT32F423xxT7		
				KC	KB	K8	TC	TB	T8	CC	CB	C8	CC	CB	C8	RC	RB	R8	RC	RB	R8	VC	VB	V8
Frequency (MHz)				150																				
Flash (KB)				256	128	64	256	128	64	256	128	64	256	128	64	256	128	64	256	128	64	256	128	64
SRAM (KB)				48	48	32	48	48	32	48	48	32	48	48	32	48	48	32	48	48	32	48	48	32
XMC				-			-			-			-			$1^{(1)}$			$1^{(1)}$			1		
Timers	Advanced			1			1			1			1			1			1			1		
	32-bit general-purpose			1			1			1			1			1			1			1		
	16-bit general-purpose			8			8			8			8			8			8			8		
	Basic			2			2			2			2			2			2			2		
	SysTick			1			1			1			1			1			1			1		
	WDT			1			1			1			1			1			1			1		
	WWDT			1			1			1			1			1			1			1		
	ERTC			1			1			1			1			1			1			1		
Communication interfaces	I²C			3			3			3			3			3			3			3		
	SPI$^{(2)}$			3			3			3			3			3			3			3		
	I²S (half duplex) $^{(2)(3)}$			3			3			3			3			3			3			3		
	USART + UART			$4 + 3^{(4)}$			$4 + 3^{(4)}$			$4 + 3^{(4)}$			$4 + 3^{(4)}$			$5 + 3^{(5)}$			$5 + 3^{(5)}$			8 + 0		
	CAN			2			2			2			2			2			2			2		
	OTGFS			1			1			1			1			1			1			1		
	IRTMR			1			1			1			1			1			1			1		

Part number				AT32F423xxU7-4			AT32F423xxU7			AT32F423xxU7			AT32F423xxT7			AT32F423xxT7-7			AT32F423xxT7			AT32F423xxT7		
				KC	KB	K8	TC	TB	T8	CC	CB	C8	CC	CB	C8	RC	RB	R8	RC	RB	R8	VC	VB	V8
Analog	12-bit ADC numbers/external channels			1			1			1			1			1			1			1		
				11			11			17			17			23			23			24		
	12-bit DAC			2			2			2			2			2			2			2		
GPIO				27			29			39			39			53			53			87		
Operating temperatures				-40 °C to +105 °C																				
Packages				QFN32 4 x 4 mm			QFN36 6 x 6 mm			QFN48 6 x 6 mm			LQFP48 7 x 7 mm			LQFP64 7 x 7 mm			LQFP64 10 x 10 mm			LQFP100 14 x 14 mm		

(1) For LQFP64 package, XMC only supports the 8-bit mode LCD panel.
(2) Half-duplex I^2S shares the same pin with SPI
(3) Two half-duplex I^2S can be configured by hardware to achieve full-duplex I^2S function.
(4) For 48-pin packages and smaller, USART8 is not available, and USART5/6/7 can only be used as UART for no CK pinout.
(5) For 64-pin packages, USART5/7/8 can only be used as UART for no CK pinout.

2 Functionality overview

2.1 ARM®Cortex®-M4 with FPU

The ARM®Cortex®-M4 processor is the latest generation of ARM® processor for embedded systems. It is a 32-bit RISC high-performance processor that features exceptional code efficiency, outstanding computational performance and advanced response to interrupts. The processor supports a set of DSP instructions that enable efficient signal processing and complex algorithm execution. Its single precision FPU (floating point unit) speeds up floating point calculation while avoiding saturation.

2.2 Memory

2.2.1 Flash memory

Up to 256 Kbytes of embedded Flash memory s available for storing programs and data. Any part of the embedded Flash memory can be protected by sLib (security library), a security area that is code-executable only but non-readable. "sLib" is a mechanism designed to protect the intelligence of solution venders and facilitate the second-level development by customers.

There is another 20-Kbyte boot memory in which the bootloader is stored. If it is not needed, this boot memory can be used as a general instruction/data memory (one-time-configurable), instead.

A User System Data block is included, which is used to configure hardware operations such as access/erase/write protection and watchdog self-enable. User System Data allows the independent configuration of Flash memory erase/write and access protection. The access protection is divided into low-level and high-level protections.

2.2.2 Memory protection unit (MPU)

The memory protection unit (MPU) is used to manage the CPU accesses to memory to prevent one task to accidentally corrupt the memory or resources used by any other active task. This memory area consists of up to 8 protected areas that can further be divided up into 8 subareas. The protection area sizes are between 32 bytes and the whole 4 gigabytes of addressable memory. The MPU is especially suited to the applications where some critical or certified code has to be protected against the misbehavior of other tasks. It is usually managed by an RTOS (real-time operating system).

2.2.3 Embedded SRAM

Up to 48 Kbytes of embedded SRAM (read/write) is accessible at CPU clock speed with 0 wait state.

2.2.4 External memory controller (XMC)

The AT32F423 device embeds an XMC. It has three Chip Select outputs supporting the following modes: multiplexed PSRAM and NOR memory.

Main features:

- Write buffer area
- Code execution from external memory of the multiplexed PSRAM/NOR

The XMC can be configured to interface with many graphic LCD controllers. It supports the Intel

8080 and Motorola 6800 modes.

2.3　Interrupts

2.3.1　Nested vectored interrupt controller (NVIC)

The AT32F423 embeds a nested vectored interrupt controller that is able to manage 16 priority levels and handle maskable interrupt channels plus the 16 interrupt lines of the Cortex®-M4. This hardware block provides flexible interrupt management features with minimal interrupt latency.

2.3.2　External interrupts (EXINT)

The external interrupt (EXINT), which is connected directly to NVIC, consists of 25 edge-detector lines used to generate interrupt requests. 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 external interrupt lines connects up to 16 GPIOs.

2.4　Power control (PWC)

2.4.1　Power supply schemes

- V_{DD} = 2.4~3.6 V: power supply for GPIOs and the internal blocks such as ERTC, external 32 kHz crystal (LEXT), battery-powered register (BPR) and voltage regulator (LDO), provided externally via V_{DD} pins
- V_{DDA} = 2.4~3.6 V: power supply for ADC and DAC. V_{DDA} and V_{SSA} must be the same voltage potential as V_{DD} and V_{SS}, respectively, provided externally V_{DDA} via pins

2.4.2　Reset and power voltage monitoring (POR / LVR / PVM)

The device has an integrated power-on reset (POR) and low-voltage reset (LVR) circuitry. It is always active and allows proper operation starting from 2.4 V. The device remains in reset mode when V_{DD} goes below a specified threshold (V_{LVR}), without the need for an external reset circuit.

The device embeds a power voltage monitor (PVM) that monitors the V_{DD} power supply and compares it to the V_{PVM} threshold. An interrupt is generated when V_{DD} drops below the V_{PVM} threshold and/or when V_{DD} rises above the V_{PVM} threshold. The PVM is enabled by software.

2.4.3　Voltage regulator (LDO)

The LDO has three operating modes: normal, low-power, and power down.

- Normal mode is used in Run/Sleep mode or in Deepsleep mode;
- Low-power mode is used in Deepsleep mode;
- Power down mode is used in Standby mode. The regulator LDO output is in high impedance and the kernel circuitry is powered down but the contents of the registers and SRAM are lost.

This LDO operates always in normal mode after reset.

LDO output voltage is software configurable, including 1.3 V and 1.0 V in addition to default 1.2 V, so as to ensure the best trade-off between good performance and power consumption. *Table 11* shows the maximum AHB and APB clock frequencies corresponding to different LDO voltages. Therefore, it is highly advised for users to follow AT32F423 reference manual to perform LDO voltage switching and system clock configuration.

2.4.4 Low-power modes

The AT32F423 supports three low-power modes:

● **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.

● **Deepsleep mode**

Deepsleep mode achieves low-power consumption while holding the content of SRAM and registers. All clocks in the LDO power domain are stopped, disabling the PLL, the HICK clock and the HEXT crystal. The voltage regulator (LDO) can also be put in normal or low-power mode.

The device can be woken up from Deepsleep mode by any of the EXINT line. The EXINT line source can be one of the 16 external lines, the PVM output, an ERTC alarm, wakeup, tamper, time stamp event, or OTG wakeup signal.

● **Standby mode**

The Standby mode is used to acquire the lowest power consumption. The internal LDO is switched off so that the entire LDO power domain is powered off. The PLL, the HICK clock and the HEXT crystal are also switched off. After entering Standby mode, SRAM and register contents are lost except for ERTC and BPR registers and Standby circuitry.

The device exits Standby mode when an external reset (NRST pin), a WDT reset, a rising edge on the WKUPx pin, or an ERTC alarm/wakeup/tamper/time stamp occurs.

Note: The ERTC and the corresponding clock sources are not stopped by entering Deepsleep or Standby mode. WDT depends on the User System Data settings.

2.5 Boot modes

At startup, BOOT0 pin and nBOOT1 bit in the User System Data are used to select one of three boot options:

● Boot from Flash memory;

● Boot from boot memory;

● Boot from embedded SRAM.

The bootloader is stored in the boot memory. It is used to reprogram the Flash memory through USART1, USART2, USART3 or OTGFS1 (crystal-less support). *Table 3* provides the pin configurations for bootloader.

Table 3. Pin configurations for bootloader

Peripherals	Part number	Pins
USART1	All part numbers	PA9: USART1_TX PA10: USART1_RX
USART2	AT32F423VxT7	PD5: USART2_TX PD6: USART2_RX
	Other part numbers	PA2: USART2_TX PA3: USART2_RX
USART3	AT32F423VxT7, AT32F423RxT7, AT32F423RxT7-7	PC10: USART3_TX PC11: USART3_RX or PB10: USART3_TX PB11: USART3_RX
	AT32F423CxT7, AT32F423CxU7	PB10: USART3_TX PB11: USART3_RX
	Other part numbers	Not support
OTGFS1	All part numbers	PA11: OTGFS1_D- PA12: OTGFS1_D+

2.6 Clocks

The internal 48 MHz clock (HICK) divided by 6 (that is 8 MHz) is selected as the default CPU clock after any reset. An external 4 to 25 MHz clock (HEXT) can be selected, in which case it is monitored for failure. If a failure is detected, HEXT will be switched off and the system automatically switches back to the internal HICK. A software interrupt is generated. Similarly, the system takes the same action once HEXT fails when it is used as the source of PLL.

Several prescalers are available to allow the configuration of the AHB and the APB (APB1 and APB2) frequencies. The maximum frequency of the AHB and APB2 domains is 150 MHz, and APB1 120 MHz.

The AT32F423 series embeds an automatic clock calibration (ACC) block, which calibrates the internal 48 MHz HICK, assuring the most precise accuracy of the HICK in the full range of the operating temperatures.

2.7 General-purpose inputs / outputs (GPIOs)

Each of the GPIO pins can be configured by software as output (push-pull or open-drain with or without pull-up or pull-down), as input (floating with or without pull-up or pull-down), or as multiplexed functions. Most of the GPIO pins are shared with digital or analog peripherals. All GPIOs are high current-capable.

The GPIO's configuration can be locked, if needed, in order to avoid false writing to the GPIO's registers by following a specific sequence.

2.8 Direct Memory Access Controller (DMA)

The AT32F423 series features two general-purpose DMA controllers (7-channel DMA1 and 7-channel DMA2) able to manage memory-to-memory, peripheral-to-memory, and memory-to-peripheral transfers. These DMA channels can be connected to peripherals for flexible mapping.

The DMA controller 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.

The DMA can be used with the main peripherals: SPI/I^{2}S, I^{2}C, USART, all TMRs, ADC and DAC.

2.9 Timers (TMR)

The AT32F423 series device includes an advanced timer, up to nine general-purpose timers, two basic timers and a SysTick timer.

The table below compares the features of the advanced, general-purpose, and basic timers.

Table 4. Timer feature comparison

Type	Timer	Counter resolution	Counter type	Prescaler factor	DMA request generation	Capture/compare channels	Complementary output
Advanced	TMR1	16-bit	Up, down, up/down	Any integer between 1 and 65536	Yes	4	3
General-purpose	TMR2	16-bit or 32-bit	Up, down, up/down	Any integer between 1 and 65536	Yes	4	No
	TMR3 TMR4	16-bit	Up, down, up/down	Any integer between 1 and 65536	Yes	4	No
	TMR9 TMR12	16-bit	Up, down, up/down	Any integer between 1 and 65536	Yes	2	2
	TMR10 TMR11 TMR13 TMR14	16-bit	Up, down, up/down	Any integer between 1 and 65536	Yes	1	1
Basic	TMR6 TMR7	16-bit	Up	Any integer between 1 and 65536	Yes	No	No

2.9.1 Advanced timer (TMR1)

The advanced timer (TMR1) can be seen as a three-phase PWM multiplexed on 6 channels. It has complementary PWM outputs with programmable dead-time insertion. 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-cycle mode output

If configured as a standard 16-bit timer, it has the same features as those of the TMRx timer. If configured as a 16-bit PWM generator, it boasts full modulation capability (0 to 100%).

In debug mode, the advanced timer counter can be frozen, and the PWM outputs are disabled to turn off any power switch driven by these outputs.

Many features are shared with those of the general-purpose TMRs that have the same architecture. Thus, the advanced timer can work together with the general-purpose TMR timers via the link feature for synchronization or event chaining.

2.9.2 General-purpose timers (TMR2~4 and TMR9~14)

Up to nine synchronizable general-purpose timers are available in the AT32F423 series.

- **TMR2, TMR3 and TMR4**

  The TMR2 timer is based on a 32-bit auto-reload upcounter/downcounter and a 16-bit prescaler. TMR3 and TMR4 timers are based on a 16- bit auto-reload upcounter/downcounter and a 16-bit prescaler. They can offer four independent channels on the largest packages. Each channel can be used for input capture/output compare, PWM or one-cycle mode outputs.

  These general-purpose timers can work with the advanced timer via the link feature for synchronization or event chaining. Any of these general-purpose timers can be used to generate PWM outputs. Each timer has its individual DMA request mechanism.

  They are capable of handling incremental quadrature encoder signals and the digital outputs coming from 1 to 3 hall-effect sensors. In debug mode, counters can be frozen.

- **TMR9 and TMR12**

  TMR9 and TMR12 are based on a 16-bit auto-reload upcounter/downcounter, a 16-bit prescaler, and two independent channels and two complementary channels for input capture/output compare, PWM, or one-cycle mode output. They can be synchronized with the TMR2, TMR3, and TMR4 full-featured general-purpose timers. They can also be used as simple timers. In debug mode, counters can be frozen. These timers have their separate DMA request generation mechanism.

- **TMR10, TMR11, TMR13 and TMR14**

  These timers are based on a 16-bit auto-reload upcounter/downcounter, a 16-bit prescaler, and one independent channel and one complementary channel for input capture/output compare, PWM, or one-cycle mode output. They can be synchronized with the TMR2, TMR3, and TMR4 full-featured general-purpose timers. They can also be used as simple timers. In debug mode, ounters can be frozen. Each of these timers has its separate DMA request mechanism.

2.9.3 Basic timers (TMR6 and TMR7)

Both timers are mainly used to generate DAC trigger signals, but they could also be used as a generic 16-bit time base.

2.9.4 SysTick timer

This timer is dedicated to real-time operating systems, but it could also be used as a standard downcounter. Its features include:

- A 24-bit downcounter

- Auto-reload capability

- Maskable system interrupt generation when the counter reaches 0

- Programmable clock source (HCLK or HCLK/8)

2.10 Watchdog (WDT)

The watchdog consists of a 12-bit downcounter and 8-bit prescaler. It is clocked by an independent internal LICK clock. As it operates independently from the main clock, it can operate in Deepsleep and Standby modes. It can be used either as a watchdog to reset the device when an error occurs, or as a free running timer for application timeout management. It is self-enabled or not through the User System Data. The counter can be frozen in debug mode.

2.11 Window watchdog (WWDT)

The window watchdog embeds a 7-bit downcounter that can be set as free running. It can be used as a watchdog to reset the device when an error occurs. It is clocked by the main clock. It has an early warning interrupt capability, and the counter can be frozen in debug mode.

2.12 Enhanced real-time clock (ERTC) and battery powered registers (BPR)

The battery powered domain includes:

- Enhanced real-time clock (ERTC)

- 20x 32-bit battery powered registers (BPRs)

The enhanced real-time clock (ERTC) is an independent BCD timer/counter. It supports the following features:

- Calendar with second, minute, hour (12 or 24 format), week day, date, month, year, in BCD (binary-coded decimal) format.

- Support sub-seconds value in binary format.

- Automatic correction for 28, 29 (leap year), 30, and 31 days of the month.

- Programmable alarms and periodic interrupts wakeup from Deepsleep or Standby mode.
- To compensate quartz crystal inaccuracy, ERTC can be calibrated via a 512 Hz external output.

These two alarm registers are used to generate an alarm at a specific time whereas the calendar fields can be independently masked for alarm comparison. To generate a periodic interrupt, a 16-bit programmable binary auto-reload downcounter with programmable resolution is available and allows automatic wakeup and periodic alarms from every 120 µs to every 36 hours. Other 32-bit registers also feature programmable sub-second, second, minute, hour, week day and date.

A prescaler is used as a time base clock. It is by default configured to generate a time base of 1 second from a clock at 32.768 kHz.

The battery powered registers (BPR) are 32-bit registers used to store 80 bytes of user application data. Battery powered registers are not reset by a system or power reset, nor when the device is woken up from the Standby mode.

Note: *With regard to ERTC, LEXT and BPR-related functions, when V_{DD} power-on rate is lower than 1.3 ms/V, it is necessary for code to wait 60 ms until the V_{DD} is higher than 2.57 V before accessing battery powered domain registers. Doing so can guarantee normal access operation even if V_{DD} voltage drops below 2.57 V later. Refer to AT32F423 errata sheet for details.*

2.13 Communication interfaces

2.13.1 Serial peripheral interface (SPI)

There are up to three SPIs able to communicate at up to 32 Mbits/s in slave and master modes in full-duplex and half-duplex modes. The frame is configurable to 8 bits or 16 bits. The hardware CRC generation/verification supports basic SD card/MMC/SDHC modes. All SPIs can be served by the DMA controller.

The SPI interface can be configured to operate in TI mode for communications in master and slave modes.

2.13.2 Inter-integrated sound interface (I²S)

Three standard I²S interfaces (multiplexed with SPI) are available, which can be operated in master or slave mode, in half-duplex mode. The prescaler can be used to generate multiple master mode frequencies. These interfaces can be configured to operate with 16/24/32-bit resolution, as input or output channels. Audio sampling frequencies ranges from 8 kHz up to 192 kHz. When I²S is configured in master mode, the master clock can be output at 256 times the sampling frequency.

All I²Ss can be served by the DMA controller.

In addition, any two of I²S interfaces in half-duplex mode can be combined (through hardware) to achieve full-duplex communication function, while the remaining one can still operate independently or used as a SPI.

2.13.3 Universal synchronous / asynchronous receiver transmitter (USART)

The AT32F423 series embeds eight universal synchronous/asynchronous receiver transmitters (USART1~8).

These eight interfaces provide asynchronous communication, IrDA SIR ENDEC support, multiprocessor communication mode, single-wire half-duplex communication mode, LIN Master/Slave capability, RS485 drive enable signal, Smart Card mode (ISO 7816 compliant) and SPI-like communication capability.

USART1~4 also provide hardware management of the CTS and RTS signals. All interfaces can be served by the DMA controller, with TX/RX swap support.

USART1 and USART6 are able to communicate at a speed of up to 10.5 Mbit/s, while other USART interfaces can be up to 7.5 Mbit/s.

2.13.4 Inter-integrated-circuit interface (I^{2}C)

Three I^{2}C bus interfaces can operate in multi-master and slave modes. They can support standard mode (max. 100 kHz), fast mode (max. 400 kHz). Specifically, I^{2}C1 and I^{2}C2 support fast mode plus (max. 1 MHz). Some GPIOs provide ultra-high sink current of 20 mA.

They support 7-bit/10-bit addressing mode and 7-bit dual addressing mode (as slave). A hardware CRC generation/verification is embedded.

They can be served by DMA and they support SMBus 2.0/PMBus.

2.13.5 Controller area network (CAN)

The AT32F423 offers two CAN (The controller area network (CAN)) interfaces. The CAN is compliant with specifications 2.0A and 2.0B (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. It has three transmit mailboxes, two receive FIFOs with 3 stages, and 14 scalable filter banks. Each CAN has dedicated 256 bytes of buffer, which is not shared with any other CAN or peripherals.

To guarantee CAN transmission quality, the CAN 2.0 protocol states that its clock souce must come from the HEXT-based PLL clock.

2.13.6 Universal serial bus On-The-Go full-speed (OTGFS)

The AT32F423 series embeds one USB OTG full-speed (12 Mb/s) device/host peripheral with integrated transceivers (PHY). It has software-configurable endpoint settings and supports suspend/resume. The OTGFS controller requires a dedicated 48 MHz clock. When used in master mode, its clock source must come from the HEXT-based PLL clock; when used in device mode, the HICK 48 MHz clock source can be used as the OTGFS clock directly.

OTGFS has the major features such as:

● Dedicated 1280 bytes of buffer (not shared with any other peripherals)

● 8 IN + 8 OUT endpoints (endpoint 0 included, device mode)

● 16 channels (host mode)

● SOF and OE output

● In accordance with the USB 2.0 Specification, the supported transfer speeds are:

  − Host mode: full-speed and low-speed

  − Device mode: full-speed

2.13.7 Infrared transmitter (IRTMR)

The AT32F423 series device provides an infrared transmitter solution. The solution is based on the internal connection between TMR10, USART1, or USART2 and TMR11. TMR11 is used to provide carrier frequency, while TMR10, USART1, or USART2 provides the main signal to be sent.

To generate infrared remote control signals, TMR10 channel 1 and TMR11 channel 1 must be correctly configured to generate correct waveforms. All standard IR pulse modulation modes can be obtained by programming two timer output compare channels.

2.14 Cyclic redundancy check (CRC) calculation unit

The CRC (cyclic redundancy check) calculation unit is used to get a CRC code from a 32-bit data word using a fixed generator polynomial. Among other applications, CRC-based techniques are used to verify data transmission or storage integrity.

2.15 Analog-to-digital converter (ADC)

A 12-bit analog-to-digital converter (ADC) is embedded in AT32F423 device and features below:

● Configurable 12-bit, 10-bit, 8-bit, 6-bit resolution with self-calibration.

● 5.33 MSPS maximum conversion rate in 12-bit resolution. Conversion time can be cut through the reduction of resolution

● Share up to 24 external channels, including 6 fast channels.

● Two internal channels dedicated to internal temperature sensor (V_{TS}), internal reference voltage (V_{INTRV})

● Channel-by-channel programmable sampling time

● 2 to 256 times hardware over-sampling, equivalent maximum 16-bit resolution.

● Trigger option for both regular and preempted conversion:

  − Software

  − Polarity-configurable hardware (internal timer event or GPIO input event)

● Converting modes:

  − Single mode or sequential mode.

  − In sequential mode, each trigger performs conversions on a selected group of channels.

  − Repeated mode converts the selected channels continuously.

  − Separated mode

● A voltage monitor feature allows very precise monitoring of the converted voltage of one, some or all selected channels. An interrupt is generated when the converted voltage is outside the programmed thresholds.

● The ADC can be served by the DMA controller.

2.15.1 Temperature sensor (V$_{TS}$)

The temperature sensor generates a voltage V$_{TS}$ that varies linearly with temperature. The temperature sensor is internally connected to the ADC1_IN16 input channel which is used to convert the sensor output voltage into a digital value.

The offset of this line varies from chip to chip due to process variation. The internal temperature sensor is more suited to applications that detect temperature variations instead of absolute temperatures. If accurate temperature readings are needed, an external temperature sensor part should be used.

2.15.2 Internal reference voltage (V$_{INTRV}$)

The internal reference voltage (V$_{INTRV}$) provides a stable voltage source for ADC. The V$_{INTRV}$ is internally connected to the ADC1_IN17 input channel.

2.16 Digital-to-analog converter (DAC)

The two 12-bit buffered DACs can be used to convert two digital signals into two analog voltage signal outputs.

This DAC has the following features:

- Two DAC converters: one for each output channel
- 8-bit or 12-bit monotonic output
- Left- or right-aligned data in 12-bit mode
- Synchronized update capability
- Noise-wave generation
- Triangular-wave generation
- Dual DAC channel independent or simultaneous conversions
- DMA capability for each DAC
- External triggers for conversion
- Input voltage reference V$_{REF+}$

Several DAC trigger inputs are used in the AT32F423 series. DAC outputs are triggered through the timer update outputs that are also connected to different DMA channels.

2.17 Serial wire debug (SWD)/JTAG debug port

The ARM®SWJ-DP interface is embedded in the AT32F423 device, and it is a combined serial wire debug port and JTAG that enables either a serial wire debug or a JTAG probe to be connected to the target. The JTAG TMS and TCK pins are shared with SWDIO and SWCLK, respectively. In addition, the SWO feature is availabel for asynchronous tracing in debug mode.

3 Pin functional definitions

Figure 1. AT32F423 LQFP100 pinout
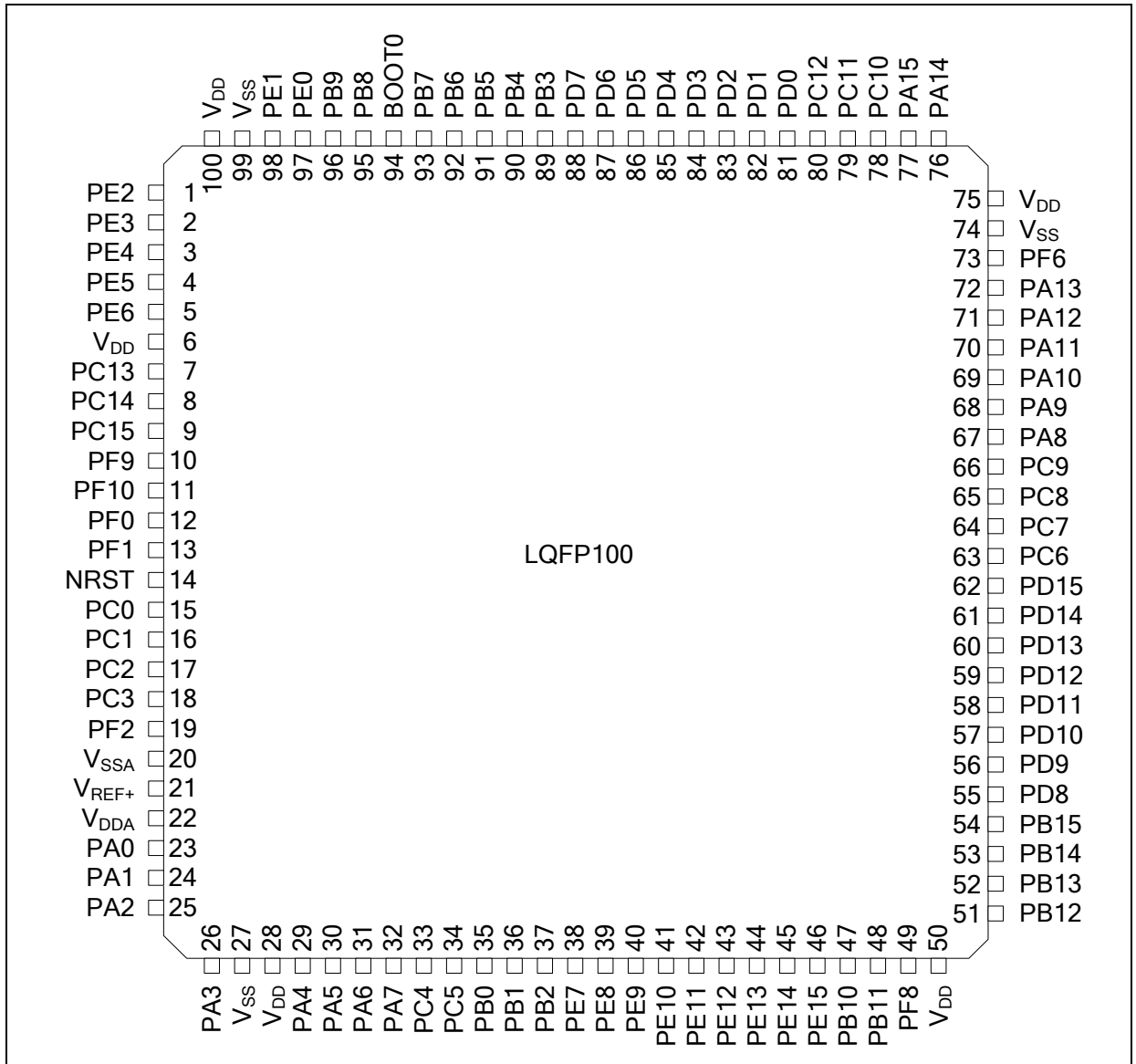
Figure 2. AT32F423 LQFP64 pinout
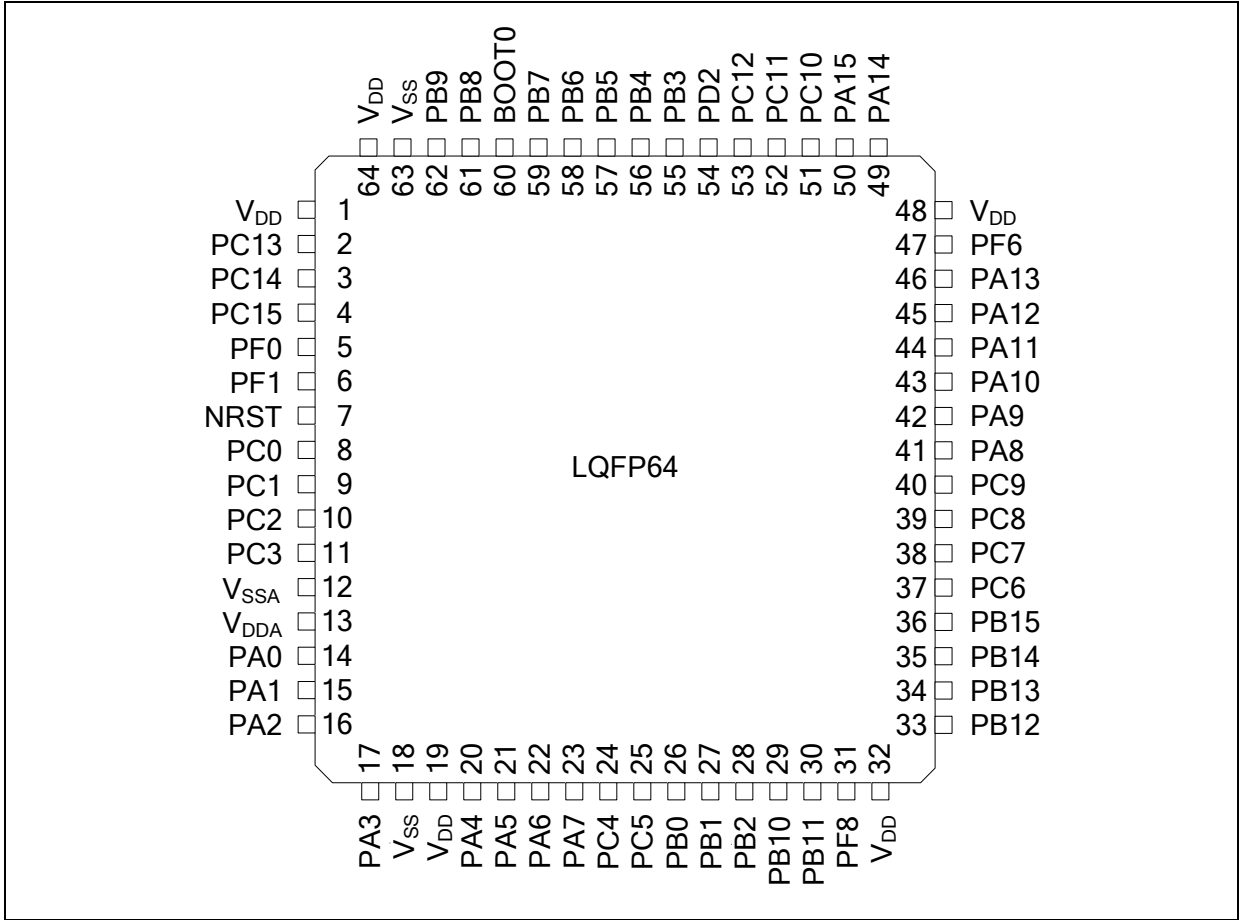
Figure 3. AT32F423 LQFP48 pinout
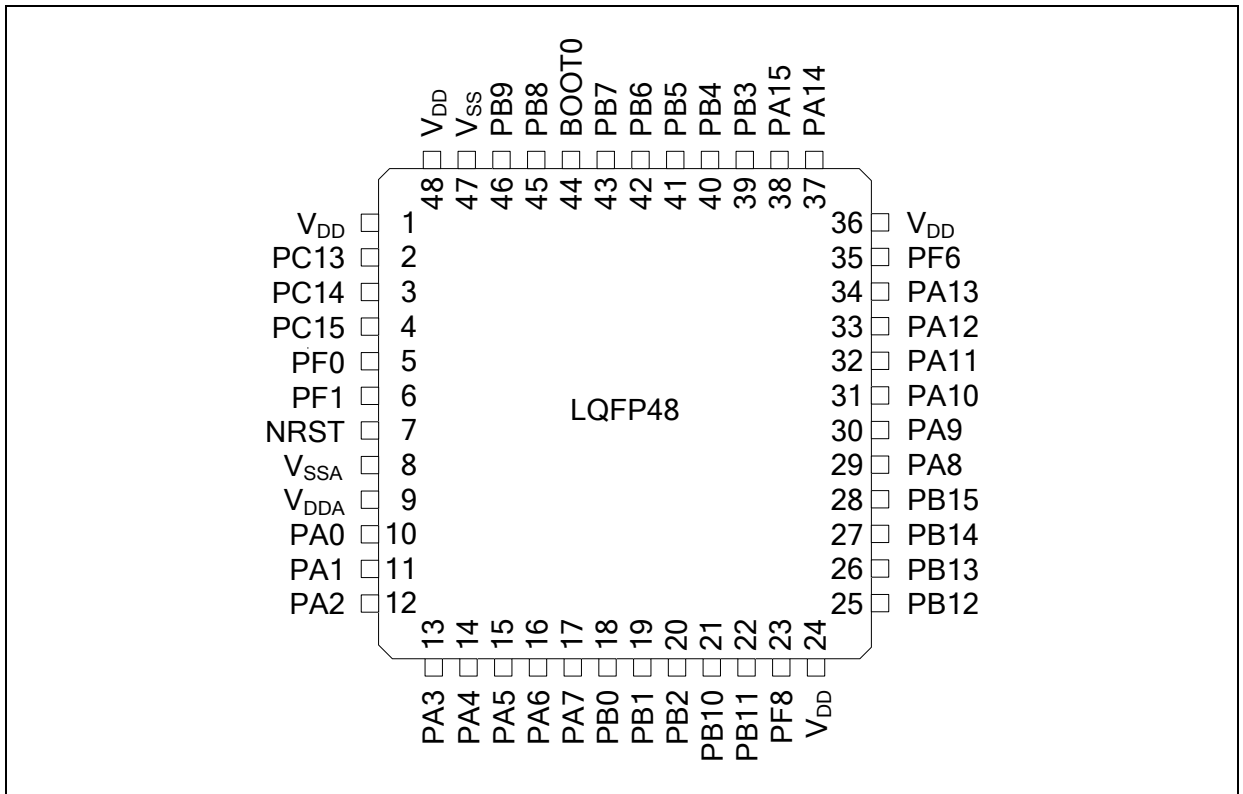
Figure 4. AT32F423 QFN48 pinout
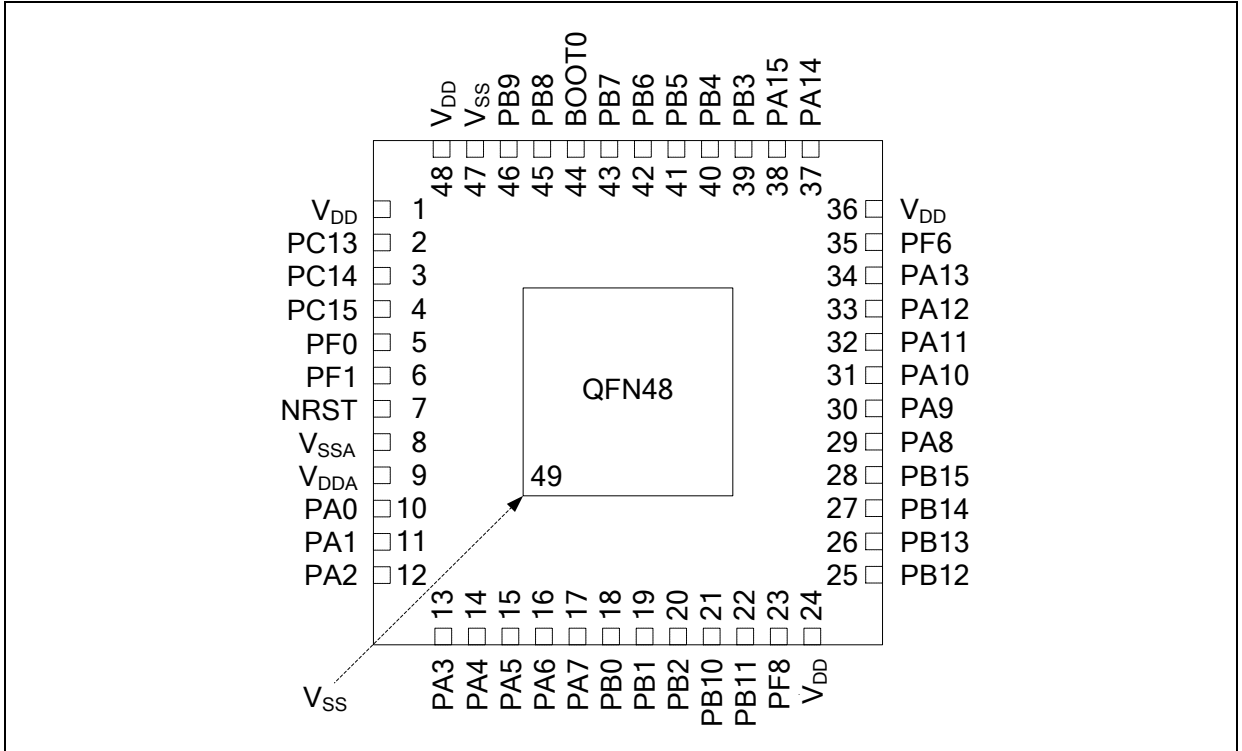
Figure 5. AT32F423 QFN36 pinout
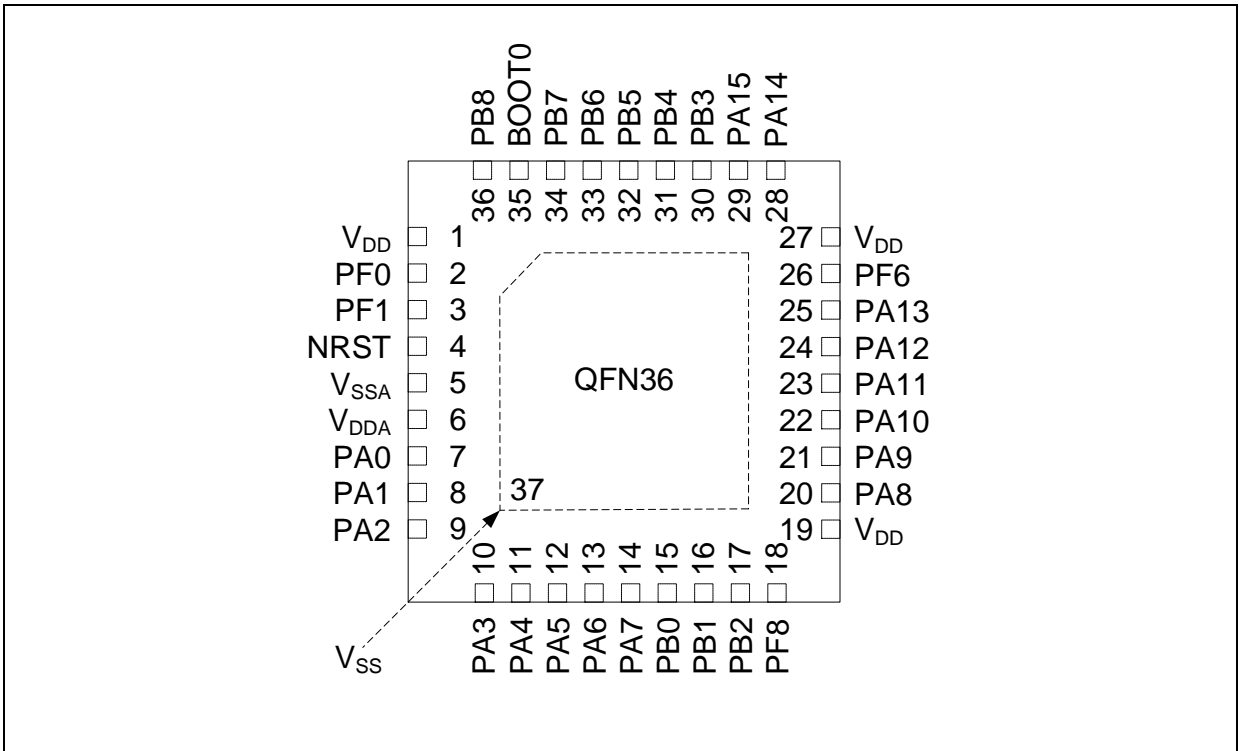
Figure 6. AT32F423 QFN32 pinout
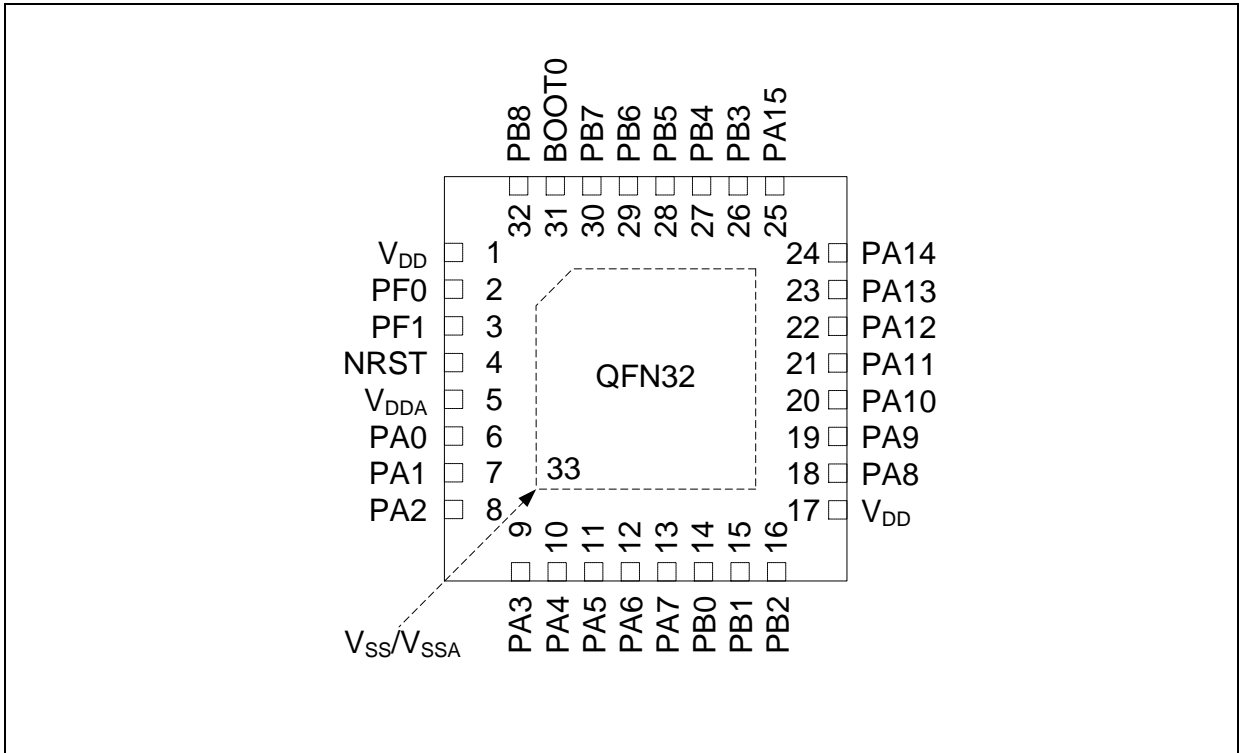
The table below is the pin definition of the AT32F423 series. "-" represents that there is no such pinout on the related package. Unless descriptions in ( ) under pin name, the functions during reset and after reset are the same as those of the actual pin name. Unless otherwise specified, all GPIOs are set as input floating during reset and after reset. Pin multiplexed functions are selected through GPIOx_MUXx registers and the additional functions are directly selected/enabled through peripheral registers.

Table 5. AT32F423 series pin definitions

Pin number					Pin name (function after reset)	Type[1]	GPIO level[2]	Multiplexed functions[3]	Additional functions
QFN32	QFN36	LQFP48/ QFN48	LQFP64	LQFP100					
-	-	-	-	1	PE2	I/O	FT	TMR3_EXT / TMR9_BRK / TMR14_CH1C / XMC_A23	-
-	-	-	-	2	PE3	I/O	FT	TMR3_CH1 / TMR9_CH2C / TMR14_BRK / XMC_A19	-
-	-	-	-	3	PE4	I/O	FT	TMR3_CH2 / TMR9_CH1C / XMC_A20	-
-	-	-	-	4	PE5	I/O	FT	TMR3_CH3 / TMR9_CH1 / XMC_A21	-
-	-	-	-	5	PE6	I/O	FT	TMR3_CH4 / TMR9_CH2 / XMC_A22	-
-	-	1	1	6	V_{DD}	S	-	Digital power supply	
-	-	2	2	7	PC13[4][5]	I/O	FT	-	ERTC_OUT / TAMP1 / WKUP2
-	-	3	3	8	PC14[4]	I/O	TC	-	LEXT_IN
-	-	4	4	9	PC15[4]	I/O	TC	-	LEXT_OUT
-	-	-	-	10	PF9	I/O	FT	TMR4_CH1 / USART6_TX / TMR12_CH1	-
-	-	-	-	11	PF10	I/O	FT	TMR4_CH2 / USART6_RX / TMR12_CH2	-
2	2	5	5	12	PF0	I/O	TC	TMR1_CH1 / I2C1_SDA	HEXT_IN
3	3	6	6	13	PF1	I/O	TC	TMR1_CH2C / I2C1_SCL / SPI2_CS / I2S2_WS	HEXT_OUT
4	4	7	7	14	NRST	I/O	R	Device reset input/internal reset output (active low)	
-	-	-	8	15	PC0	I/O	FTa	I2C3_SCL / I2C1_SCL / USART6_TX / USART7_TX	ADC1_IN10[6]
-	-	-	9	16	PC1	I/O	FTa	I2C3_SDA / SPI3_MOSI / I2S3_SD / SPI2_MOSI / I2S2_SD / I2C1_SDA / USART6_RX / USART7_RX	ADC1_IN11[6]
-	-	-	10	17	PC2	I/O	FTa	SPI2_MISO / I2S2_MCK / I2S_SDEXT / USART8_TX / XMC_NWE	ADC1_IN12[6]
	-	-	11	18	PC3	I/O	FTa	SPI2_MOSI / I2S2_SD / USART8_RX / XMC_A0	ADC1_IN13[6]
	-	-	-	19	PF2	I/O	FT	SPI2_SCK / I2S2_CK / USART7_CK_DE	-
-	5	8	12	20	V_{SSA}	S	-	Analog ground	
-	-	-	-	21	V_{REF+}	S	-	Positive reference voltage	
5	6	9	13	22	V_{DDA}	S	-	Analog power supply	
6	7	10	14	23	PA0	I/O	FTa	TMR2_CH1 / TMR2_EXT / TMR9_CH2C / I2C2_SCL / USART2_RX / USART2_CTS / USART4_TX	ADC1_IN0[6] / TAMP2 / WKUP1

Pin number					Pin name (function after reset)	Type[1]	GPIO level[2]	Multiplexed functions[3]	Additional functions
QFN32	QFN36	LQFP48/ QFN48	LQFP64	LQFP100					
7	8	11	15	24	PA1	I/O	FTa	TMR2_CH2 / TMR9_CH1C / I2C2_SDA / I2C1_SMBA / SPI3_CS / I2S3_WS USART2_RTS_DE / USART4_RX	ADC1_IN1[6]
8	9	12	16	25	PA2	I/O	FTa	TMR2_CH3 / TMR9_CH1 / USART2_TX / CAN2_RX / XMC_D4	ADC1_IN2
9	10	13	17	26	PA3	I/O	FTa	TMR2_CH4 / TMR9_CH2 / I2S2_MCK / USART2_RX / CAN2_TX / XMC_D5	ADC1_IN3
-	-	-	18	27	V$_{SS}$	S	-	Digital ground	
-	-	-	19	28	V$_{DD}$	S	-	Digital power supply	
10	11	14	20	29	PA4	I/O	FTa	I2C1_SCL / SPI1_CS / I2S1_WS / SPI3_CS / I2S3_WS / USART2_CK / USART6_TX / TMR14_CH1 / OTGFS1_OE / XMC_D6	ADC1_IN4 / DAC1_OUT
11	12	15	21	30	PA5	I/O	FTa	TMR2_CH1 / TMR2_EXT / SPI1_SCK / I2S1_CK / USART3_CK / USART3_RX / USART6_RX / TMR13_CH1C / XMC_D7	ADC1_IN5 / DAC2_OUT
12	13	16	22	31	PA6	I/O	FTa	TMR1_BRK / TMR3_CH1 / SPI1_MISO / I2S1_MCK / I2S2_MCK / USART3_CTS / USART3_RX / TMR13_CH1	ADC1_IN6
13	14	17	23	32	PA7	I/O	FTa	TMR1_CH1C / TMR3_CH2 / I2C3_SCL / SPI1_MOSI / I2S1_SD / USART3_TX / TMR14_CH1	ADC1_IN7
-	-	-	24	33	PC4	I/O	FTa	TMR9_CH1 / I2S1_MCK / USART3_TX / TMR13_CH1 / XMC_NE4	ADC1_IN14
-	-	-	25	34	PC5	I/O	FTa	TMR9_CH2 / I2C1_SMBA / USART3_RX / TMR13_CH1C / XMC_NOE	ADC1_IN15
14	15	18	26	35	PB0	I/O	FTa	TMR1_CH2C / TMR3_CH3 / SPI1_MISO / I2S1_MCK / SPI3_MOSI / I2S3_SD / USART2_RX / USART3_CK	ADC1_IN8
15	16	19	27	36	PB1	I/O	FTa	TMR1_CH3C / TMR3_CH4 / SPI1_MOSI / I2S1_SD / SPI2_SCK / I2S2_CK / USART2_CK / USART3_RTS_DE / TMR14_CH1	ADC1_IN9
16	17	20	28	37	PB2	I/O	FTa	TMR2_CH4 / TMR3_EXT / I2C3_SMBA / SPI3_MOSI / I2S3_SD / TMR14_CH1C	ADC1_IN20
-	-	-	-	38	PE7	I/O	FTa	TMR1_EXT / USART5_CK / USART7_RX / XMC_D4	ADC1_IN27
-	-	-	-	39	PE8	I/O	FT	TMR1_CH1C / USART4_TX / USART7_TX / XMC_D5	-
-	-	-	-	40	PE9	I/O	FT	TMR1_CH1 / USART4_RX / XMC_D6	-
-	-	-	-	41	PE10	I/O	FT	TMR1_CH2C / USART5_TX / XMC_D7	-
-	-	-	-	42	PE11	I/O	FT	TMR1_CH2 / USART5_RX / XMC_D8	-
-	-	-	-	43	PE12	I/O	FT	TMR1_CH3C / SPI1_CS / I2S1_WS / XMC_D9	-

Pin number					Pin name (function after reset)	Type[1]	GPIO level[2]	Multiplexed functions[3]	Additional functions
QFN32	QFN36	LQFP48/ QFN48	LQFP64	LQFP100					
-	-	-	-	44	PE13	I/O	FT	TMR1_CH3 / SPI1_SCK / I2S1_CK / XMC_D10	-
-	-	-	-	45	PE14	I/O	FT	TMR1_CH4 / SPI1_MISO / I2S1_MCK / XMC_D11	-
-	-	-	-	46	PE15	I/O	FT	TMR1_BRK / SPI1_MOSI / I2S1_SD / XMC_D12	-
-	-	21	29	47	PB10	I/O	FTa	TMR2_CH3 / I2C2_SCL / SPI2_SCK / I2S2_CK / I2S3_MCK / USART3_TX / XMC_NOE	ADC1_IN21
-	-	22	30	48	PB11	I/O	FTa	TMR2_CH4 / I2C2_SDA / USART3_RX / TMR13_BRK	ADC1_IN22
-	18	23	31	49	PF8	I/O	FT	TMR2_CH2 / I2C2_SDA / USART7_TX	-
17	19	24	32	50	V$_{DD}$	S	-	Digital power supply	
-	-	25	33	51	PB12	I/O	FTa	TMR1_BRK / TMR12_BRK / I2C2_SMBA / SPI2_CS / I2S2_WS / SPI3_SCK / I2S3_CK / USART3_CK / CAN2_RX / XMC_D13	ADC1_IN23
-	-	26	34	52	PB13	I/O	FTa	CLKOUT / TMR1_CH1C / TMR12_CH1C / I2C3_SMBA / SPI2_SCK / I2S2_CK / I2C3_SCL / USART3_CTS / CAN2_TX	ADC1_IN24
-	-	27	35	53	PB14	I/O	FTa	TMR1_CH2C / I2C3_SDA / SPI2_MISO / I2S2_MCK / I2S_SDEXT / USART3_RTS_DE / TMR12_CH1 / XMC_D0	ADC1_IN25
-	-	28	36	54	PB15	I/O	FTa	ERTC_REFIN / TMR1_CH3C / TMR12_CH1C / I2C3_SCL / SPI2_MOSI / I2S2_SD / TMR12_CH2	ADC1_IN26 / WKUP7
-	-	-	-	55	PD8	I/O	FT	USART3_TX / TMR12_CH2C / XMC_D13	-
-	-	-	-	56	PD9	I/O	FT	USART3_RX / XMC_D14	-
-	-	-	-	57	PD10	I/O	FT	USART3_CK / USART4_TX / XMC_D15	-
-	-	-	-	58	PD11	I/O	FT	I2C2_SMBA / USART3_CTS / XMC_A16	-
-	-	-	-	59	PD12	I/O	FTf	TMR4_CH1/ I2C2_SCL / USART3_RTS_DE / USART8_CK_DE / XMC_A17	-
-	-	-	-	60	PD13	I/O	FTf	TMR4_CH2/ I2C2_SDA / USART8_TX / XMC_A18	-
-	-	-	-	61	PD14	I/O	FT	TMR4_CH3 / I2C3_SCL / USART8_RX / XMC_D0	-
		-	-	62	PD15	I/O	FT	TMR4_CH4 / I2C3_SDA / USART7_CK_DE / XMC_D1	-
-	-	-	37	63	PC6	I/O	FT	TMR1_CH1 / TMR3_CH1 / I2C1_SCL / I2S2_MCK / USART6_TX / USART7_TX / XMC_D1	-
-	-	-	38	64	PC7	I/O	FT	TMR1_CH2 / TMR3_CH2 / I2C1_SDA / SPI2_SCK / I2S2_CK / I2S3_MCK / USART6_RX / USART7_RX / XMC_NADV	-
-	-	-	39	65	PC8	I/O	FT	TMR1_CH3 / TMR3_CH3 / USART8_TX / USART6_CK	-

Pin number					Pin name (function after reset)	Type[1]	GPIO level[2]	Multiplexed functions[3]	Additional functions
QFN32	QFN36	LQFP48/ QFN48	LQFP64	LQFP100					
-	-	-	40	66	PC9	I/O	FT	CLKOUT / TMR1_CH4 / TMR3_CH4 / I2C3_SDA / USART8_RX / I2C1_SDA / OTGFS1_OE	-
18	20	29	41	67	PA8	I/O	FT	CLKOUT / TMR1_CH1 / TM9_BRK / I2C3_SCL / USART1_CK / USART2_TX / USART7_RX / OTGFS1_SOF	-
19	21	30	42	68	PA9	I/O	FT	CLKOUT / TMR1_CH2 / I2C3_SMBA / SPI2_SCK / I2S2_CK / USART1_TX / I2C1_SCL / TRM14_BRK / OTGFS1_VBUS	-
20	22	31	43	69	PA10	I/O	FT	ERTC_REFIN / TMR1_CH3 / SPI2_MOSI / I2S2_SD / USART1_RX / I2C1_SDA / OTGFS1_ID	-
21	23	32	44	70	PA11	I/O	TC	TMR1_CH4 / I2C2_SCL / SPI2_CS / I2S2_WS / I2C1_SMBA / USART1_CTS / USART6_TX / CAN1_RX	OTGFS1_D-
22	24	33	45	71	PA12	I/O	TC	TMR1_EXT / I2C2_SDA / SPI2_MISO / I2S2_MCK / USART1_RTS_DE / USART6_RX / CAN1_TX	OTGFS1_D+
23	25	34	46	72	PA13 (JTMS / SWDIO)	I/O	FT	PA13 / IR_OUT / I2C1_SDA / I2S_SDEXT / SPI3_MISO / I2S3_MCK / OTGFS1_OE	-
-	26	35	47	73	PF6	I/O	FT	TMR2_CH1 / I2C2_SCL / USART7_RX	-
	-	-	-	74	VSS	S	-	Digital ground	
	27	36	48	75	VDD	S	-	Digital power supply	
24	28	37	49	76	PA14 (JTCK / SWCLK)	I/O	FT	PA14 / I2C1_SMBA / SPI3_MOSI / I2S3_SD / USART2_TX	-
25	29	38	50	77	PA15 (JTDI)	I/O	FT	PA15 / TMR2_CH1 / TMR2_EXT / SPI1_CS / I2S1_WS / SPI3_CS / I2S3_WS / USART1_TX / USART2_RX / USART7_TX / USART4_RTS_DE / XMC_NE2	-
-	-	-	51	78	PC10	I/O	FT	SPI3_SCK / I2S3_CK / USART3_TX / USART4_TX	-
-	-	-	52	79	PC11	I/O	FT	I2S_SDEXT / SPI3_MISO / I2S3_MCK / USART3_RX / USART4_RX / XMC_D2	-
-	-	-	53	80	PC12	I/O	FT	TMR11_CH1 / I2C2_SDA / SPI3_MOSI / I2S3_SD / USART3_CK / USART4_CK / USART5_TX / XMC_D3	-
-	-	-	-	81	PD0	I/O	FT	SPI3_MOSI / I2S3_SD / SPI2_CS / I2S2_WS / USART4_RX / CAN1_RX / XMC_D2	-
-	-	-	-	82	PD1	I/O	FT	SPI2_SCK / I2S2_CK / SPI2_CS / I2S2_WS / USART4_TX / CAN1_TX / XMC_D3	-
-	-	-	54	83	PD2	I/O	FT	TMR3_EXT / USART3_RTS_DE / USART5_RX / XMC_NWE	-

QFN32	QFN36	LQFP48/ QFN48	LQFP64	LQFP100	Pin name (function after reset)	Type[1]	GPIO level[2]	Multiplexed functions[3]	Additional functions
-	-	-	-	84	PD3	I/O	FT	SPI2_SCK / I2S2_CK / SPI2_MISO / I2S2_MCK / USART2_CTS / XMC_CLK	-
-	-	-	-	85	PD4	I/O	FT	SPI2_MOSI / I2S2_SD / USART2_RTS_DE / XMC_NOE	-
-	-	-	-	86	PD5	I/O	FT	USART2_TX / XMC_NWE	-
-	-	-	-	87	PD6	I/O	FT	SPI3_MOSI / I2S3_SD / USART2_RX / XMC_NWAIT	-
-	-	-	-	88	PD7	I/O	FT	USART2_CK / XMC_NE1	-
26	30	39	55	89	PB3 (JTDO)	I/O	FT	PB3 / SWO / TMR2_CH2 / I2C2_SDA / SPI1_SCK / I2S1_CK / SPI3_SCK / I2S3_CK / USART1_RX / USART1_RTS_DE / USART7_RX / USART5_TX	-
27	31	40	56	90	PB4 (NJTRST)	I/O	FT	PB4 / TMR3_CH1 / TMR11_BRK / I2C3_SDA / SPI1_MISO / I2S1_MCK / SPI3_MISO / I2S3_MCK / USART1_CTS / I2S_SDEXT / USART7_TX / USART5_RX	-
28	32	41	57	91	PB5	I/O	FT	TMR3_CH2 / TMR10_BRK / I2C3_SMBA / SPI1_MOSI / I2S1_SD / SPI3_MOSI / I2S3_SD / USART1_CK / USART5_RX / CAN2_RX / USART5_DE	WKUP6
29	33	42	58	92	PB6	I/O	FT	TMR4_CH1 / TMR10_CH1C / I2C1_SCL / I2S1_MCK / SPI3_CS / I2S3_WS USART1_TX / USART5_TX / CAN2_TX / USART4_CK	-
30	34	43	59	93	PB7	I/O	FT	TMR4_CH2 / TMR11_CH1C / I2C1_SDA / SPI3_SCK / I2S3_CK / USART1_RX / USART4_CTS / XMC_NADV	-
31	35	44	60	94	BOOT0	I	B	Boot mode select 0	
32	36	45	61	95	PB8	I/O	FT	TMR2_CH1 / TMR2_EXT / TRM4_CH3 / TMR10_CH1 / I2C1_SCL / SPI3_MISO / I2S3_MCK / USART1_TX / USART5_RX / CAN1_RX	-
-	-	46	62	96	PB9	I/O	FT	IR_OUT / TMR2_CH2 / TMR4_CH4 / TMR11_CH1 / I2C1_SDA / SPI2_CS / I2S2_WS / SPI3_MOSI / I2S3_SD / I2C2_SDA / USART5_TX / CAN1_TX / I2S1_MCK	-
-	-	-	-	97	PE0	I/O	FT	TMR4_EXT / USART8_RX / TMR13_CH1 / XMC_LB	-
-	-	-	-	98	PE1	I/O	FT	TMR1_CH2C / USART8_TX / TMR14_CH1 / XMC_UB	-
-	-	47	63	99	Vss	S	-	Digital ground	
1	1	48	64	100	VDD	S	-	Digital power supply	
-	37	-/49	-	-	EPAD (Vss)	S	-	Digital ground	

Pin number					Pin name (function after reset)	Type[1]	GPIO level[2]	Multiplexed functions[3]	Additional functions
QFN32	QFN36	LQFP48/ QFN48	LQFP64	LQFP100					
33	-	-	-	-	EPAD (V$_{SS}$/V$_{SSA}$)	S	-	Digital ground /Analog ground	

(1) I = input, O = output, S = supply.

(2) TC = standard 3.3 V GPIO, FT = general 5 V-tolerant GPIO, FTa = 5 V-tolerant GPIO with analog function, FTf = 5 V-tolerant GPIO with 20 mA sink current capability, R = bidirectional reset pin with embedded weak pull-up resistor, B = dedicated BOOT0 pin with embedded weak pull-down resistor. Of those, FTa pin has 5 V-tolerant characteristics when configured as input floating, input pull-up, or input pull-down mode. However, it cannot be 5 V-tolerant when analog mode. In this case, its input level should not be higher than V$_{DD}$ + 0.3 V.

(3) Function availability depend on the selected product part number. Any of GPIOs has EVENTOUT feature.

(4) PC13, PC14, and PC15 are supplied through power switch. Since the switch only drives a limited amount of current (3 mA), the use of GPIOs PC13 to PC15 in output mode is limited not to be used as a current source (e.g. to drive an LED).

(5) There are limitations to the use of PC13 and its additional functions. See AT32F423 Errata sheet for details.

(6) PA0, PA1, PC0, PC1, PC2 and PC3 represent fast ADC channel, others slow ADC channels.

4 Electrical characteristics

4.1 Test conditions

4.1.1 Minimum and maximum values

The minimum and maximum values are obtained in the worst conditions. Data based on characterization results, design simulation and/or technology characteristics are indicated in the table footnotes and are not tested in production. The minimum and maximum values represent the mean value plus or minus three times the standard deviation (mean ± 3σ).

4.1.2 Typical values

Typical values are based on T_A = 25 °C, V_{DD} = 3.3 V.

4.1.3 Typical curves

All typical curves are provided only as design guidelines and are not tested.

4.1.4 Power supply scheme

Figure 7. Power supply scheme
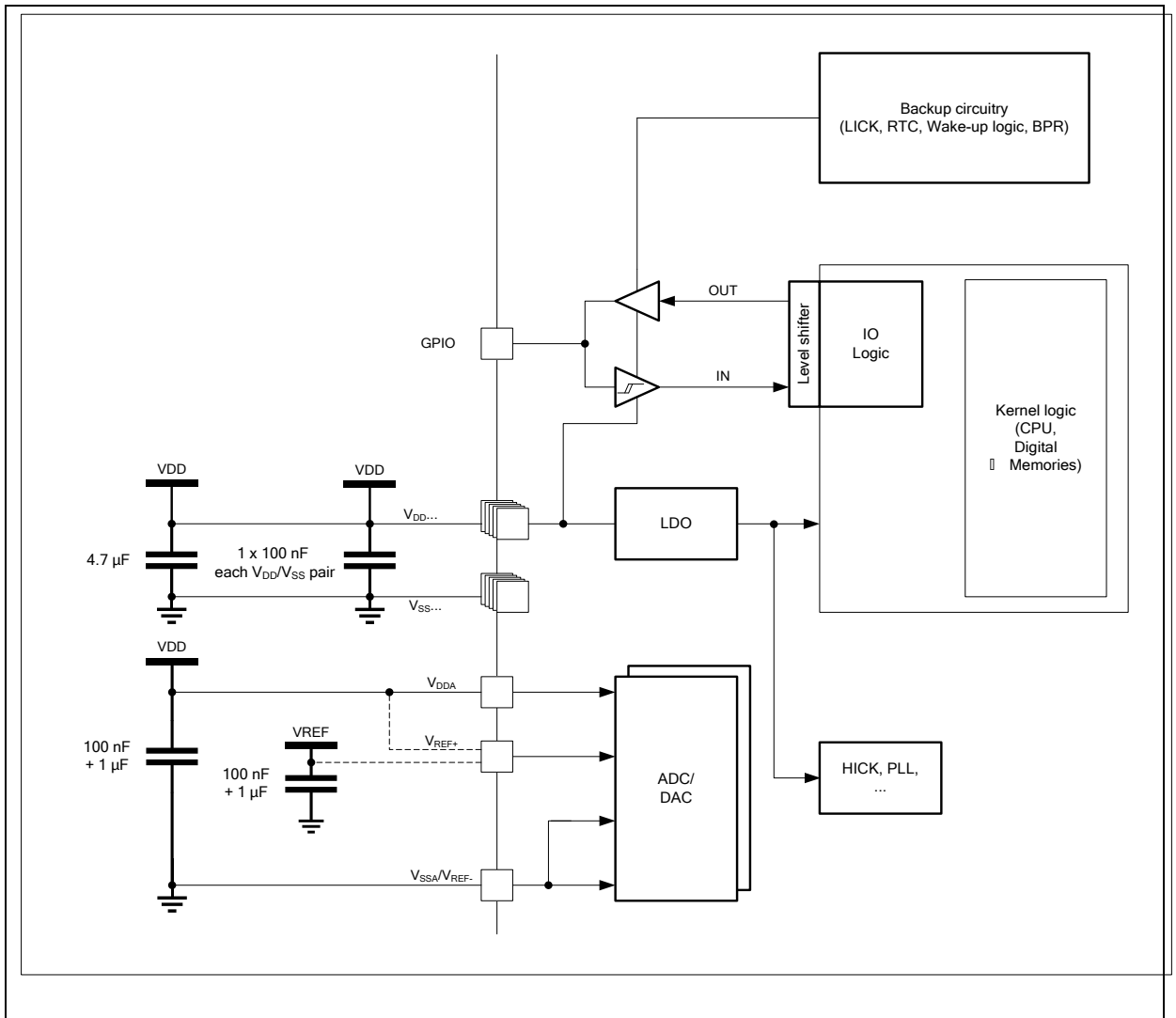
4.2 Absolute maximum values

4.2.1 Ratings

If stresses were out of the absolute maximum ratings listed in *Table 6*, *Table 7* and *Table 8*, it may cause permanent damage to the device. These are the maximum stresses only that the device could withstand, but the functional operation of the device under these conditions is not implied. Exposure to maximum rating conditions for an extended period of time may affect device reliability.

Table 6. Voltage characteristics

Symbol	Description	Min	Max	Unit
V_{DDx}-V_{SS}	External main supply voltage	-0.3	4.0	V
V_{IN}	Input voltage on FT and FTf GPIO	V_{SS}-0.3	6.0	
	Input voltage on FTa GPIO (set as input floating, input pull-up, or input pull-down mode)			
	Input voltage on TC GPIO	V_{SS}-0.3	4.0	
	Input voltage on FTa GPIO (set as analog mode)			
$|\Delta V_{DDx}|$	Variations between different V_{DD} power pins	-	50	mV
$|V_{SSx}$-$V_{SS}|$	Variations between all the different ground pins	-	50	

Table 7. Current characteristics

Symbol	Description	Max	Unit
I_{VDD}	Total current into V_{DD} power lines (source)	150	mA
I_{VSS}	Total current out of V_{SS} ground lines (sink)	150	
I_{IO}	Output current sunk by any GPIO and control pin	25	
	Output current source by any GPIO and control pin	-25	

Table 8. Temperature characteristics

Symbol	Description	Max	Unit
T_{STG}	Storage temperature range	-60 ~ +150	°C
T_J	Maximum junction temperature	125	

4.2.2 Electrical sensitivity

Based on three different tests (HBM, CDM, and 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 are applied to the pins of each sample according to each pin combination. This test is in accordance with the JS-001-2017/JS-002-2018 standard.

Table 9. ESD values

Symbol	Parameter	Conditions	Class	Min	Unit
$V_{ESD(HBM)}$	Electrostatic discharge voltage (human body model)	T_A = +25 °C, conform to JS-001-2017	3A	±4000	V
$V_{ESD(CDM)}$	Electrostatic discharge voltage (charge device model)	T_A = +25 °C, conform to JS-002-2018	III	±1000	

Static latch-up

Tests compliant with EIA/JESD78E IC latch-up standard are required 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 GPIO pin.

Table 10. Latch-up values

Symbol	Parameter	Conditions	Level/Class
LU	Static latch-up class	T_A = +105 °C, conform to EIA/JESD78E	II level A (±200 mA)

4.3 Specifications

4.3.1 General operating conditions

Table 11. General operating conditions

Symbol	Parameter	Conditions		Min	Max	Unit
f_{HCLK}	Internal AHB clock frequency	LDO voltage	1.3 V	0	150	MHz
			1.2 V	0	120	
			1.0 V	0	64	
f_{PCLK1}	Internal APB1 clock frequency	LDO voltage	1.3 V	0	120	MHz
			1.2 V, 1.0 V	0	f_{HCLK}	
f_{PCLK2}	Internal APB2 clock frequency	-		0	f_{HCLK}	MHz
V_{DD}	Digital operating voltage	-		2.4	3.6	V
V_{DDA}	Analog operating voltage	Must be the same potential as V_{DD}		V_{DD}		V
P_D	Power dissipation: T_A = 105 °C	LQFP100 – 14 x 14 mm		-	264	mW
		LQFP64 – 10 x 10 mm		-	238	
		LQFP64 – 7 x 7 mm		-	216	
		LQFP48 – 7 x 7 mm		-	216	
		QFN48 – 6 x 6 mm		-	350	
		QFN36 – 6 x 6 mm		-	350	
		QFN32 – 4 x 4 mm		-	280	
T_A	Ambient temperature	-		-40	105	°C

4.3.2 Operating conditions at power-up / power-down

Table 12. Operating conditions at power-up/power-down

Symbol	Parameter	Min	Max	Unit
t_{VDD}	V_{DD} rise time rate	0	∞[1]	ms/V
	V_{DD} fall time rate	20	∞	µs/V

(1) When V_{DD} rise time rate is lower than 1.3 ms/V, it is necessary for code to wait 60 ms until the V_{DD} is higher than 2.57 V before accessing battery powered domain registers. Refer to AT32F423 errata sheet for details.

4.3.3 Embedded reset and power control block characteristics

Table 13. Embedded reset and power management block characteristics

Symbol	Parameter	Min	Typ	Max	Unit
V_{POR}	Power on reset threshold	1.81	2.1	2.4	V
V_{LVR}	Low voltage reset threshold	1.68[2]	1.9	2.08	V
$V_{LVRhyst}$	LVR hysteresis	-	180	-	mV
$T_{RESTTEMPO}$	Reset temporization: CPU starts execution after V_{DD} keeps higher than V_{POR} for $T_{RESTTEMPO}$	-	3.5	-	ms

(1) Guaranteed by characterization results, not tested in production.
(2) The product behavior is guaranteed by design down to the minimum V_{LVR} value.

Figure 8. Power on reset and low voltage reset waveform
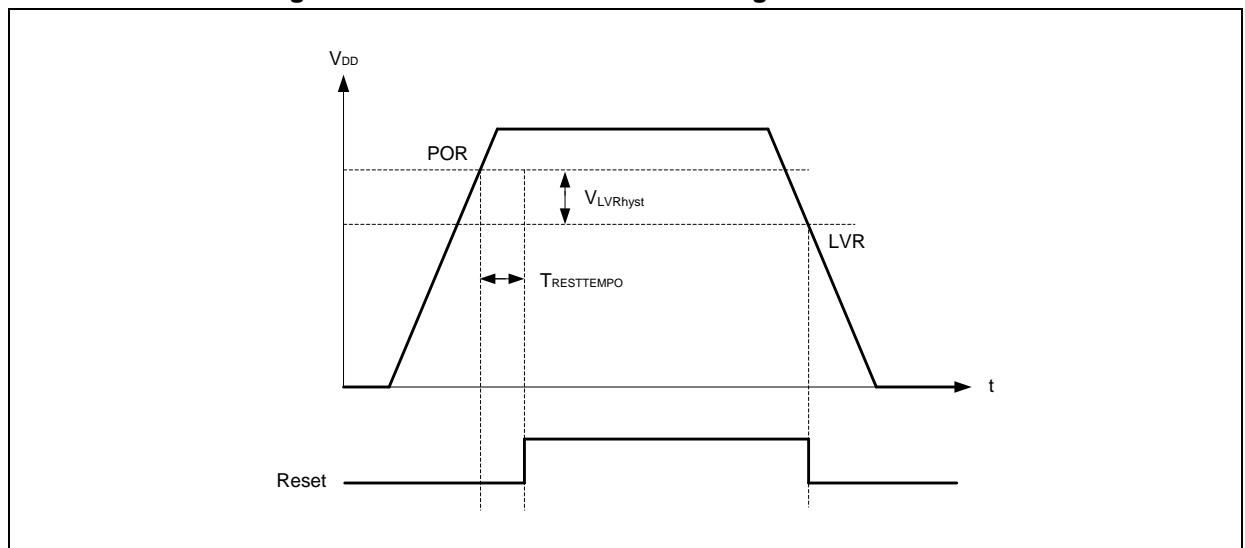
Table 14. Programmable voltage regulator characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{PVM1}	PVM threshold 1 (PVMSEL[2:0] = 001)	Rising edge [1]	2.19	2.28	2.37	V
		Falling edge [1]	2.09	2.18	2.27	V
V_{PVM2}	PVM threshold 2 (PVMSEL[2:0] = 010)	Rising edge [1]	2.28	2.38	2.48	V
		Falling edge [1]	2.18	2.28	2.38	V
V_{PVM3}	PVM threshold 3 (PVMSEL[2:0] = 011)	Rising edge [1]	2.38	2.48	2.58	V
		Falling edge [1]	2.28	2.38	2.48	V
V_{PVM4}	PVM threshold 4 (PVMSEL[2:0] = 100)	Rising edge [1]	2.47	2.58	2.69	V
		Falling edge [1]	2.37	2.48	2.59	V
V_{PVM5}	PVM threshold 5 (PVMSEL[2:0] = 101)	Rising edge [1]	2.57	2.68	2.79	V
		Falling edge [1]	2.47	2.58	2.69	V
V_{PVM6}	PVM threshold 6 (PVMSEL[2:0] = 110)	Rising edge [1]	2.66	2.78	2.9	V
		Falling edge [1]	2.56	2.68	2.8	V
V_{PVM7}	PVM threshold 7 (PVMSEL[2:0] = 111)	Rising edge	2.76	2.88	3	V
		Falling edge	2.66	2.78	2.9	V
V_{HYS_P} [1]	PVM hysteresis	-	-	100	-	mV
$I_{DD (PVM)}$ [1]	PVM current dissipation	-	-	20	30	µA

(1) Guaranteed by characterization results, not tested in production.

4.3.4 Memory characteristics

Table 15. Internal Flash memory characteristics

Symbol	Parameter	Conditions	Typ[1]	Max[1]	Unit
T_{PROG}	Programming time	-	40	42	µs
t_{SE}	Sector erase time (2 KB)	AT32F423xC	13.2	16	ms
	Sector erase time (1 KB)	AT32F423xB AT32F423x8	6.6	8	
t_{ME}	Mass erase time	-	8.2	10	ms

(1) Guaranteed by design, not tested in production.

Table 16. Internal Flash memory endurance and data retention [1]

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
N_{END}	Endurance	T_A = -40 ~ 105 °C	100	-	-	kcycles
t_{RET}	Data retention	T_A = 105 °C	10	-	-	year

(1) Guaranteed by design, not tested in production.

4.3.5 Supply current characteristics

The current consumption, obtained by characterization results and not tested in production, is subjected to several parameters and factors such as the operating voltage, ambient temperature, GPIO pin loading, device software configuration, operating frequencies, GPIO pin switching rate, and executed binary code.

Typical and maximum current consumption

The MCU is placed under the following conditions:

- All GPIO pins are in analog mode.
- Flash memory access time depends on the f_{HCLK} frequency (0 ~ 32 MHz : zero-wait state; 33 ~ 64 MHz: one wait state; 65 ~ 96 MHz: two wait states; 97 ~ 128 MHz: three wait states; 129 MHz and above: four wait states)
- Prefetch ON
- When peripherals are enabled:
  - If f_{HCLK} > 120 MHz, then f_{PCLK1} = f_{HCLK}/2, f_{PCLK2} = f_{HCLK}, f_{ADCCLK} = f_{PCLK2}/2
  - If f_{HCLK} ≤ 120 MHz, then f_{PCLK1} = f_{HCLK}, f_{PCLK2} = f_{HCLK}, f_{ADCCLK} = f_{PCLK2}/2
- Unless otherwise specified, the typical values are measured with V_{DD} = 3.3 V and T_A = 25 °C condition, and the maximum values are measured with V_{DD} = 3.6 V.

Table 17. Typical current consumption in Run mode

Symbol	Parameter	Conditions	f_{HCLK}	LDO voltage (V)	Typ		Unit
					All peripherals enabled	All peripherals disabled	
I_{DD}	Supply current in Run mode	High speed external crystal (HEXT)[1][2]	150 MHz	1.3	38.4	16.8	mA
			120 MHz	1.2	33.5	13.2	
			108 MHz	1.2	30.2	12.0	
			72 MHz	1.2	20.4	8.22	
			64 MHz	1.0	15.3	6.29	
			48 MHz	1.0	11.9	5.18	
			36 MHz	1.0	9.13	4.07	
			24 MHz	1.0	6.60	3.22	
			16 MHz	1.0	4.64	2.39	
			8 MHz	1.0	2.44	1.28	
			4 MHz	1.0	1.62	0.99	
			2 MHz	1.0	1.21	0.85	
			1 MHz	1.0	1.01	0.78	
		High speed internal clock (HICK)[2]	150 MHz	1.3	38.4	16.8	mA
			120 MHz	1.2	33.4	13.1	
			108 MHz	1.2	30.1	11.9	
			72 MHz	1.2	20.3	8.09	
			64 MHz	1.0	15.2	6.15	
			48 MHz	1.0	11.8	5.03	
			36 MHz	1.0	9.02	3.92	
			24 MHz	1.0	6.46	3.08	
			16 MHz	1.0	4.50	2.23	
			8 MHz	1.0	2.30	1.11	
			4 MHz	1.0	1.47	0.84	
			2 MHz	1.0	1.05	0.69	
			1 MHz	1.0	0.85	0.62	

(1) External clock is 8 MHz.
(2) PLL is on when f_{HCLK} > 8 MHz.

Table 18. Typical current consumption in Sleep mode

Symbol	Parameter	Conditions	f_{HCLK}	LDO voltage (V)	Typ		Unit
					All peripherals enabled	All peripherals disabled	
I_{DD}	Supply current in sleep mode	High speed external crystal (HEXT)[1][2]	150 MHz	1.3	31.5	6.14	mA
			120 MHz	1.2	27.0	5.18	
			108 MHz	1.2	24.3	4.74	
			72 MHz	1.2	16.5	3.42	
			64 MHz	1.0	12.4	2.69	
			48 MHz	1.0	9.73	2.47	
			36 MHz	1.0	7.47	2.03	
			24 MHz	1.0	5.50	1.87	
			16 MHz	1.0	3.90	1.49	
			8 MHz	1.0	2.08	0.83	
			4 MHz	1.0	1.44	0.77	
			2 MHz	1.0	1.12	0.74	
			1 MHz	1.0	0.96	0.72	
		High speed internal clock (HICK) [2]	150 MHz	1.3	31.5	6.13	mA
			120 MHz	1.2	26.9	5.05	
			108 MHz	1.2	24.2	4.61	
			72 MHz	1.2	16.4	3.28	
			64 MHz	1.0	12.2	2.53	
			48 MHz	1.0	9.59	2.32	
			36 MHz	1.0	7.35	1.88	
			24 MHz	1.0	5.35	1.72	
			16 MHz	1.0	3.75	1.33	
			8 MHz	1.0	1.93	0.67	
			4 MHz	1.0	1.29	0.61	
			2 MHz	1.0	0.97	0.58	
			1 MHz	1.0	0.81	0.56	

(1) External clock is 8 MHz.
(2) PLL is on when f_{HCLK} > 8 MHz.

Table 19. Maximum current consumption in Run mode

Symbol	Parameter	Conditions	f_{HCLK}	LDO voltage (V)	Max		Unit
					T_A = 85 °C	T_A = 105 °C	
I_{DD}	Supply current in Run mode	High speed external crystal (HEXT)[1], all peripherals enabled	150 MHz	1.3	40.6	42.7	mA
			120 MHz	1.2	34.4	35.2	
			108 MHz	1.2	31.1	31.9	
			72 MHz	1.2	21.2	22.0	
			64 MHz	1.0	15.8	16.4	
			48 MHz	1.0	12.5	13.0	
			36 MHz	1.0	9.64	10.2	
			24 MHz	1.0	7.11	7.61	
			16 MHz	1.0	5.14	5.64	
			8 MHz	1.0	3.02	3.54	
		High speed external crystal (HEXT)[1], all peripherals disabled	150 MHz	1.3	18.8	19.6	mA
			120 MHz	1.2	13.9	14.6	
			108 MHz	1.2	12.7	13.4	
			72 MHz	1.2	8.91	9.60	
			64 MHz	1.0	6.78	7.28	
			48 MHz	1.0	5.66	6.16	
			36 MHz	1.0	4.55	5.04	
			24 MHz	1.0	3.71	4.21	
			16 MHz	1.0	2.88	3.37	
			8 MHz	1.0	1.77	2.26	

(1) External clock is 8 MHz, and PLL is on when f_{HCLK} > 8 MHz.

Table 20. Maximum current consumption in Sleep mode

Symbol	Parameter	Conditions	f_HCLK	LDO voltage (V)	Max		Unit
					T_A = 85 °C	T_A = 105 °C	
I_DD	Supply current in Sleep mode	High speed external crystal (HEXT)[1], all peripherals enabled	150 MHz	1.3	32.8	34.8	mA
			120 MHz	1.2	27.8	28.7	
			108 MHz	1.2	25.2	26.0	
			72 MHz	1.2	17.3	18.0	
			64 MHz	1.0	12.9	13.4	
			48 MHz	1.0	10.3	10.8	
			36 MHz	1.0	7.99	8.49	
			24 MHz	1.0	6.00	6.51	
			16 MHz	1.0	4.40	4.90	
			8 MHz	1.0	2.66	3.17	
		High speed external crystal (HEXT)[1], all peripherals disabled	150 MHz	1.3	6.97	7.56	mA
			120 MHz	1.2	5.87	6.56	
			108 MHz	1.2	5.43	6.11	
			72 MHz	1.2	4.10	4.77	
			64 MHz	1.0	3.19	3.68	
			48 MHz	1.0	2.97	3.46	
			36 MHz	1.0	2.53	3.02	
			24 MHz	1.0	2.37	2.86	
			16 MHz	1.0	1.98	2.47	
			8 MHz	1.0	1.32	1.81	

(1) External clock is 8 MHz, and PLL is on when f_HCLK > 8 MHz.

Table 21. Typical and maximum current consumptions in Deepsleep and Standby modes

Symbol	Parameter	Conditions	Typ[1]		Max[2]			Unit
			V_{DD} = 2.4 V	V_{DD} = 3.3 V	T_A = 25 °C	T_A = 85 °C	T_A = 105 °C	
I_{DD}	Supply current in Deepsleep mode	LDO in Run mode, HICK and HEXT OFF, WDT OFF	281	286	330	910	1540	µA
		LDO in low-power mode, HICK and HEXT OFF, WDT OFF	141	143	160	550	980	
	Supply current in Standby mode	LEXT and ERTC OFF	2.6	3.9	5.0	6.8	8.1	µA
		LEXT and ERTC ON	3.6	5.4	6.5	8.8	12.9	

(1) Typical values are measured at T_A = 25 °C.
(2) Guaranteed by characterization results, not tested in production.

Figure 9. Typical current consumption in Deepsleep mode with LDO

in run mode vs. temperature at different V_{DD}
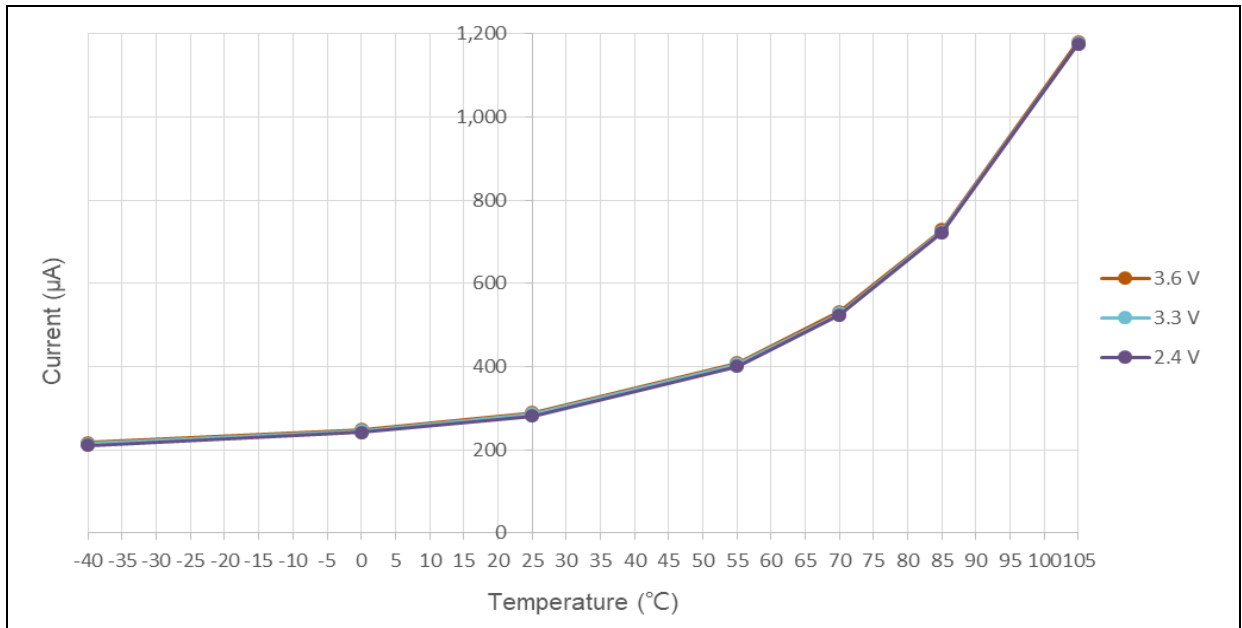
Figure 10. Typical current consumption in Deepsleep mode with LDO in low-power mode vs. temperature at different V$_{DD}$
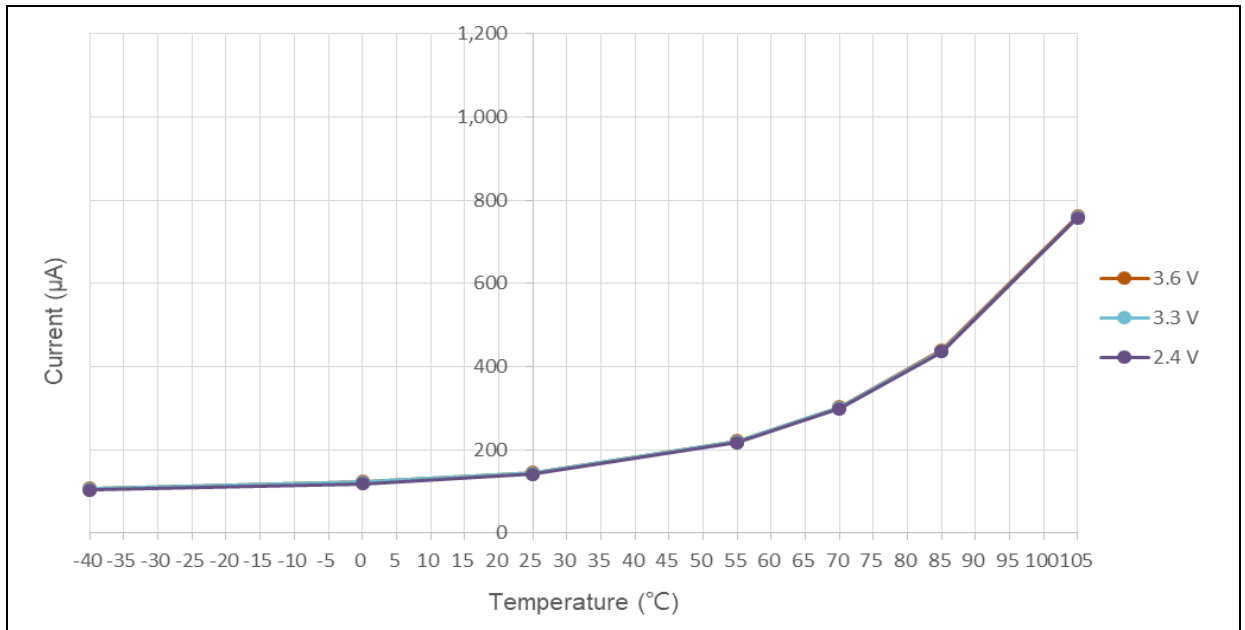
Figure 11. Typical current consumption in Standby mode vs. temperature at different V$_{DD}$
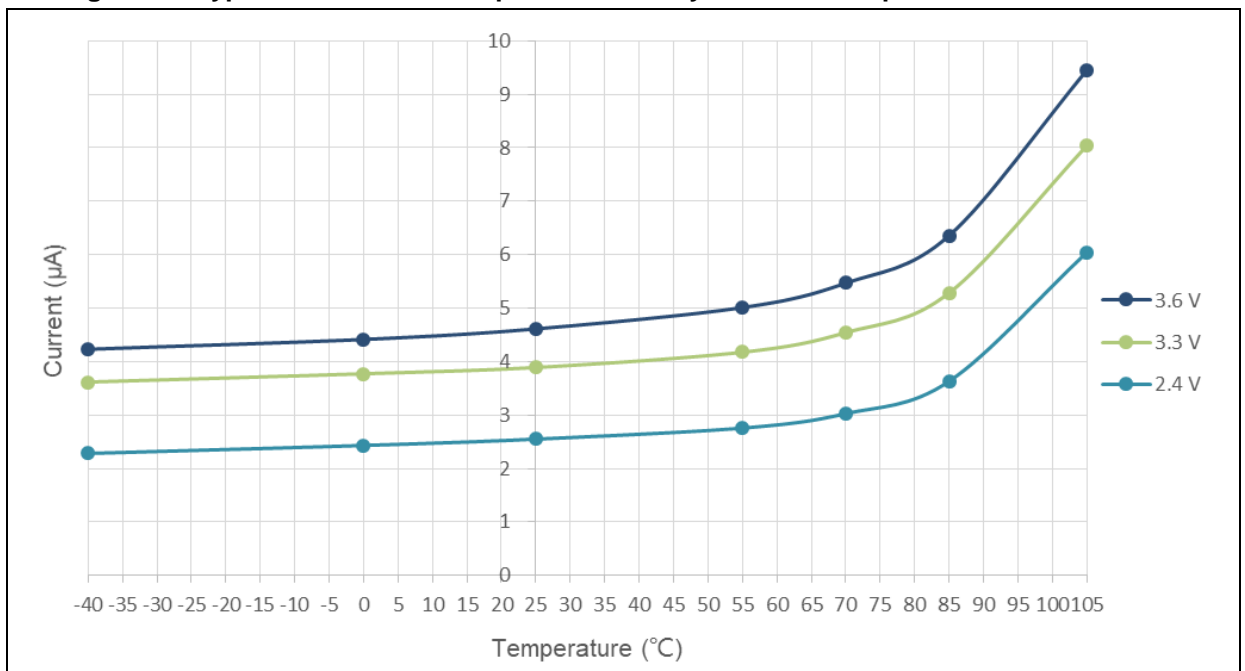
On-chip peripheral current consumption

The MCU is placed under the following conditions:

● All GPIO pins are in analog mode.
● The given value is calculated by measuring the current consumption difference between "all peripherals clocked OFF" and "only one peripheral clocked ON".

Table 22. Peripheral current consumption

Peripheral		LDO voltage (V)			Unit
		1.3	**1.2**	**1.0**	
AHB	DMA1	4.38	3.98	3.29	µA/MHz
	DMA2	4.30	3.91	3.25	
	SRAM	1.02	0.93	0.77	
	Flash	12.47	11.25	9.58	
	GPIOA	0.75	0.68	0.56	
	GPIOB	0.72	0.66	0.54	
	GPIOC	0.74	0.68	0.56	
	GPIOD	0.67	0.61	0.50	
	GPIOE	0.69	0.62	0.52	
	GPIOF	0.76	0.71	0.58	
	XMC	5.31	4.82	3.98	
	CRC	0.51	0.47	0.39	
	OTGFS1	25.34	23.04	19.14	
APB1	TMR2	9.98	9.12	7.62	µA/MHz
	TMR3	7.10	6.49	5.41	
	TMR4	7.12	6.49	5.40	
	TMR6	0.85	0.78	0.66	
	TMR7	0.84	0.77	0.64	
	TMR12	6.89	6.27	5.22	
	TMR13	4.19	3.82	3.17	
	TMR14	4.26	3.89	3.21	
	WWDT	0.51	0.46	0.38	
	SPI2/I^{2}S2	3.10	2.83	2.35	
	SPI3/I^{2}S3	3.60	3.28	2.72	
	USART2	5.30	4.86	4.04	
	USART3	5.21	4.76	3.97	
	USART4	2.68	2.45	2.03	
	USART5	2.65	2.40	1.99	
	I^{2}C1	6.67	6.09	5.08	
	I^{2}C2	6.44	5.90	4.93	
	I^{2}C3	6.57	5.99	4.97	
	CAN1	3.05	2.77	2.31	
	CAN2	2.53	2.31	1.93	
	PWC	0.89	0.83	0.69	
	DAC	3.67	1.90	1.56	
	USART7	2.63	2.42	1.98	
	USART8	2.64	2.42	1.99	

Peripheral		LDO voltage (V)			Unit
		1.3	**1.2**	**1.0**	
APB2	TMR1	10.14	9.26	7.73	µA/MHz
	USART1	5.11	4.66	3.88	
	USART6	2.72	2.48	2.06	
	ADC1	9.12	8.33	6.93	
	SPI1/I^{2}S1	3.23	2.97	2.48	
	SCFG	0.22	0.21	0.18	
	TMR9	6.16	5.64	4.69	
	TMR10	3.85	3.52	2.94	
	TMR11	4.13	3.77	3.13	
	ACC	0.28	0.26	0.23	

4.3.6 External clock source characteristics

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

The high-speed external (HEXT) clock can be supplied with a 4 to 25 MHz 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).

Table 23. HEXT 4 ~ 25 MHz crystal characteristics [1][2]

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{HEXT_IN}	Oscillator frequency	-	4	8	25	MHz
$t_{SU(HEXT)}$[3]	Startup time	V_{DD} is stabilized	-	2	-	ms

(1) Oscillator characteristics are given by the crystal/ceramic resonator manufacturer.
(2) Guaranteed by characterization results, not tested in production.
(3) $t_{SU(HEXT)}$ is the startup time measured from the moment HEXT 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.

For C_{L1} and C_{L2}, it is recommended to use high-quality external ceramic capacitors in the 5 pF to 20 pF range (typ.), designed for high-frequency applications, and selected to meet 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 that is the series combination of C_{L1} and C_{L2}. PCB and MCU pin capacitance must be taken into account (10 pF can be used as a rough estimate of the combined pin and board capacitance) when selecting C_{L1} and C_{L2}.

Figure 12. HEXT typical application with an 8 MHz crystal
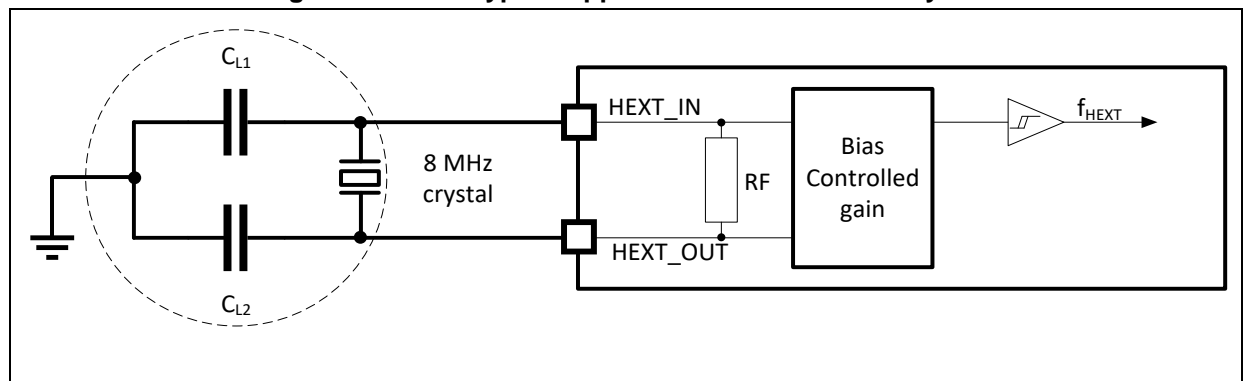
High-speed external clock generated from an external source

The characteristics given in the table below come from tests performed using a high-speed external clock source.

Table 24. HEXT external source characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{HEXT_ext}	User external clock source frequency [1]		1	8	25	MHz
V_{HEXTH}	HEXT_IN input pin high level voltage		$0.7V_{DD}$	-	V_{DD}	V
V_{HEXTL}	HEXT_IN input pin low level voltage		V_{SS}	-	$0.3V_{DD}$	
$t_{w(HEXT)}$ $t_{w(HEXT)}$	HEXT_IN high or low time[1]	-	5	-	-	ns
$t_{r(HEXT)}$ $t_{f(HEXT)}$	HEXT_IN rise or fall time[1]		-	-	20	
$C_{in(HEXT)}$	HEXT_IN input capacitance [1]	-	-	5	-	pF
$Duty_{(HEXT)}$	Duty cycle	-	45	-	55	%
I_L	HEXT_IN input leakage current	$V_{SS} \leq V_{IN} \leq V_{DD}$	-	-	±1	µA

(1) Guaranteed by design, not tested in production.

Figure 13. High-speed external source AC timing diagram

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

The low-speed external (LEXT) 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).

Table 25. LEXT 32.768 kHz crystal characteristics [1][2]

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$t_{SU(LEXT)}$	Startup time	V_{DD} is stabilized	-	200	-	ms

(1) Oscillator characteristics given by the crystal/ceramic resonator manufacturer.
(2) Guaranteed by characterization results, not tested in production.

For C_{L1} and C_{L2}, it is recommended to use high-quality ceramic capacitors in the 5 pF to 15 pF range and select to meet 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 that is the series combination of C_{L1} and C_{L2}.

Load capacitance C_L is based on the following formula: $C_L = C_{L1} \times C_{L2} / (C_{L1} + C_{L2}) + C_{stray}$ where C_{stray} is the pin capacitance and board or PCB-related capacitance. Typically, it is between 2 pF and 7 pF.

Figure 14. LEXT typical application with a 32.768 kHz crystal
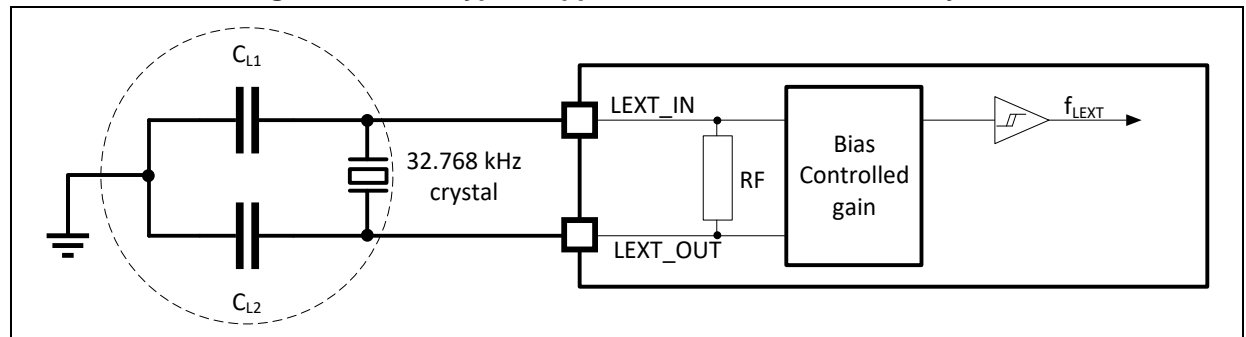
Note: No external resistor is required between LEXT_IN and LEXT_OUT and it is also prohibited to add it.

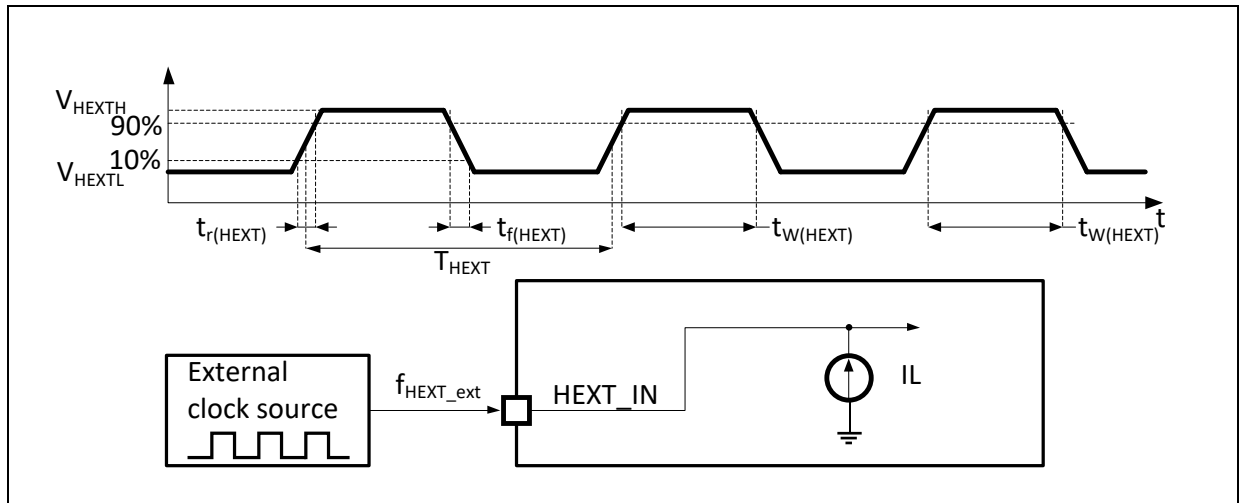**Low-speed external clock generated from an external source**

The characteristics given in the table below come from tests performed using a low-speed external clock source.

Table 26. LEXT external source characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{LEXT_ext}	User External clock source frequency [1]		-	32.768	1000	kHz
V_{LEXTH}	LEXT_IN input pin high level voltage		$0.7V_{DD}$	-	V_{DD}	V
V_{LEXTL}	LEXT_IN input pin low level voltage		V_{SS}	-	$0.3V_{DD}$	
$t_{w(LEXT)}$ $t_{w(LEXT)}$	LEXT_IN high or low time [1]	-	450	-	-	ns
$t_{r(LEXT)}$ $t_{f(LEXT)}$	LEXT_IN rise or fall time [1]		-	-	50	
$C_{in(LEXT)}$	LEXT_IN input capacitance[1]	-	-	5	-	pF
$Duty_{(LEXT)}$	Duty cycle	-	30	-	70	%
I_L	LEXT_IN input leakage current	$V_{SS} \leq V_{IN} \leq V_{DD}$	-	-	±1	µA

(1) Guaranteed by design, not tested in production.

Figure 15. Low-speed external source AC timing diagram
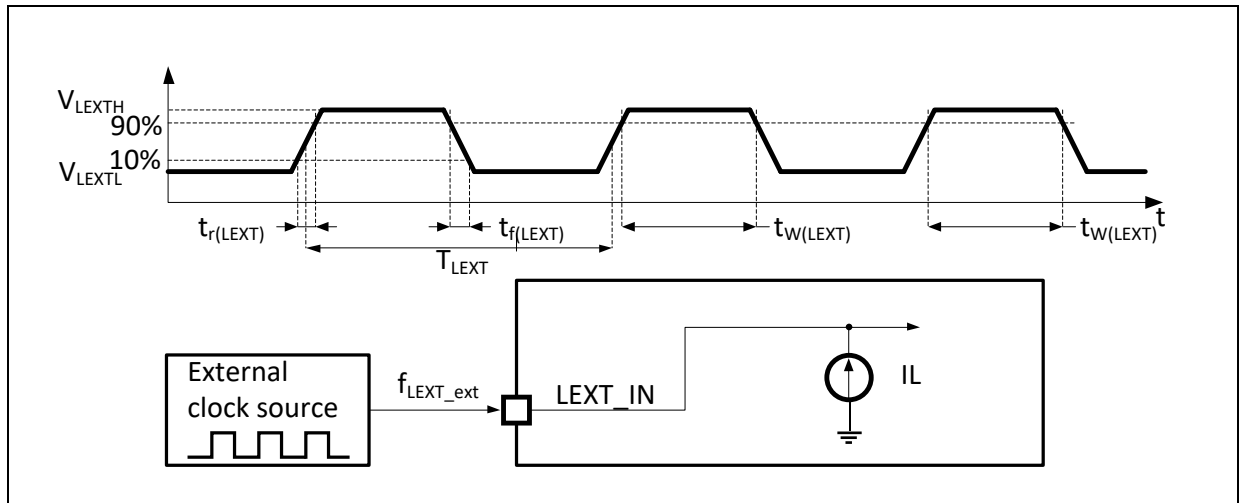
4.3.7 Internal clock source characteristics

High-speed internal clock (HICK)

Table 27. HICK clock characteristics

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
f_{HICK}	Frequency	-		-	48	-	MHz
$DuCy_{(HICK)}$	Duty cycle	-		45	-	55	%
ACC_{HICK}	HICK clock accuracy	User-trimmed with the CRM_CTRL register [1]		-1	-	1	%
		ACC-trimmed[1]		-0.25	-	0.25	
		Factory-calibrated [2]	T_A = -40 ~ 105 °C	-2.5	-	2.5	
			T_A = -40 ~ 85 °C	-2	-	2	
			T_A = 0 ~ 70 °C	-1.5	-	1.5	
			T_A = 25 °C	-1	0.5	1	
$t_{SU(HICK)}$[2]	HICK clock startup time	-		-	-	10.5	µs
$I_{DD(HICK)}$[2]	HICK clock power consumption	-		-	300	330	µA

(1) Guaranteed by design, not tested in production.
(2) Guaranteed by characterization results, not tested in production.

Figure 16. HICK clock frequency accuracy vs. temperature
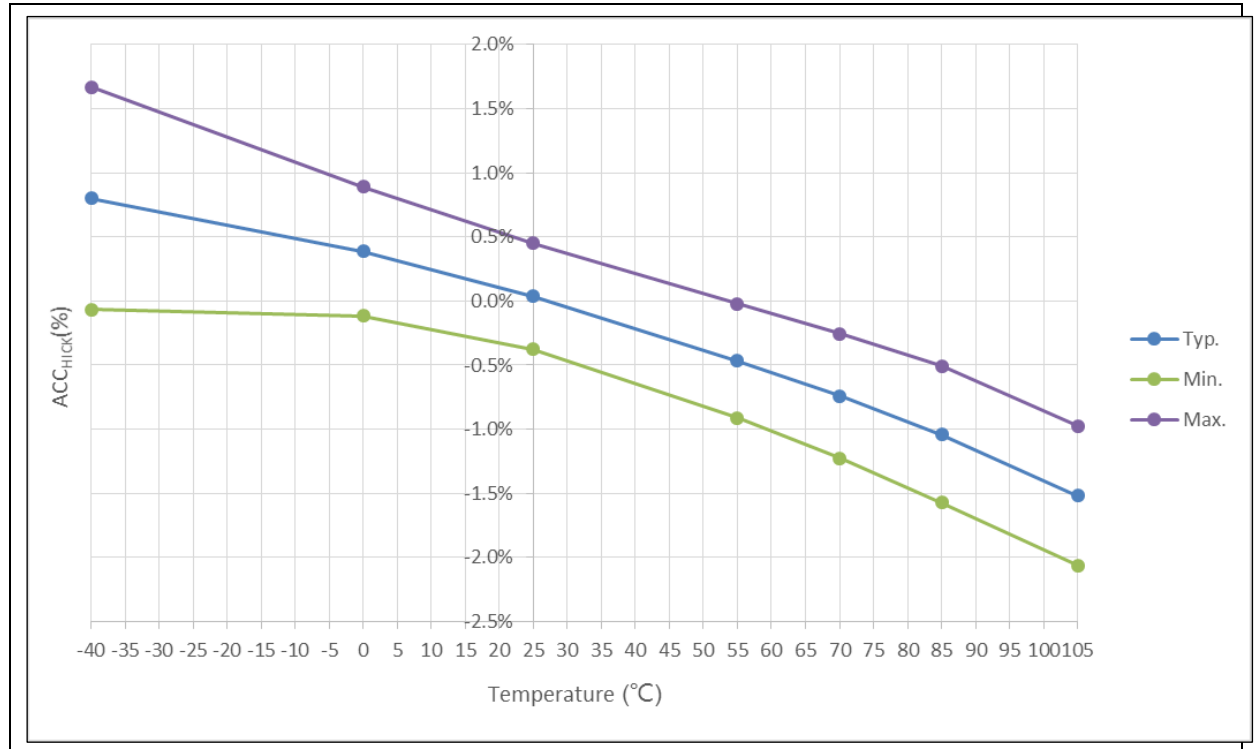
Low-speed internal clock (LICK)

Table 28. LICK clock characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{LICK}[1]	Frequency	-	25	35	45	kHz

(1) Guaranteed by characterization results, not tested in production.

4.3.8 PLL characteristics

Table 29. PLL characteristics

Symbol	Parameter	Min[1]	Typ	Max[1]	Unit
f_{PLL_IN}	PLL input clock [2]	2	8	16	MHz
	PLL input clock duty cycle	40	-	60	%
f_{PLL_OUT}[3]	PLL multiplier output clock	32	-	300	MHz
t_{LOCK}	PLL lock time	-	-	200	µs
Jitter	Cycle-to-cycle jitter	-	-	300	ps

(1) Guaranteed by design, not tested in production.
(2) Use the appropriate multiplier factor to ensure that PLL input clock values are compatible with the range defined by f_{PLL_OUT}.
(3) PLL/2 (divided by 2) is used as clock source of system clock. Refer to AT32F423 Reference Manual for details.

4.3.9 Wakeup time from low-power mode

The wakeup times given in the table below are measured on a wakeup phase with the HICK. The clock source used to wake up the device depends on the current operating mode:

● Sleep mode: The clock source is the clock that was configured before entering Sleep mode.

● Deepsleep or Standby mode: The clock source is the HICK.

Table 30. Low-power mode wakeup time

Symbol	Parameter	Conditions	Typ	Unit
$t_{WUSLEEP}$	Wakeup from Sleep mode	-	3.7	µs
$t_{WUDEEPSLEEP}$	Wakeup from Deepsleep mode	LDO in Run mode	450	µs
		LDO in low-power mode	500	
$t_{WUSTDBY}$	Wakeup from Standby mode	-	800	µs

4.3.10 EMC characteristics

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

Functional EMS (electromagnetic susceptibility)

- **EFT:** A burst of Fast Transient voltage (positive and negative) is applied to V_{DD} and V_{SS} through a coupling/decoupling network, until a functional error occurs. This test is compliant with the IEC 61000-4-4 standard.

Table 31. EMS characteristics

Symb	Parameter	Conditions	Level/Class
V_{EFT}	Fast transient voltage burst limits to be applied through coupling/decoupling network conforming to IEC 61000-4-4 on V_{DD} and V_{SS} pins to induce a functional error. Both V_{DD} and V_{SS} have a 47 µF capacitor on their entries. Each V_{DD} and V_{SS} pair has an 0.1 µF bypass capacitor.	V_{DD} = 3.3 V, LQFP100, T_A = +25 °C, f_{HCLK} = 150 MHz, LDO 1.3 V. Conform to IEC 61000-4-4	4A（±4 kV）
		V_{DD} = 3.3 V, LQFP100, T_A = +25 °C, f_{HCLK} = 120 MHz, LDO 1.2 V. Conform to IEC 61000-4-4	
		V_{DD} = 3.3 V, LQFP100, T_A = +25 °C, f_{HCLK} = 64 MHz, LDO 1.0 V Conform to IEC 61000-4-4	

EMC characterization and optimization are performed at component level with a typical application environment. 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 optimization and prequalification tests in relation with the EMC level.

4.3.11 GPIO port characteristics

General input/output characteristics

All GPIOs are CMOS and TTL compliant.

Table 32. GPIO static characteristics

Symb	Parameter	Conditions	Min	Typ	Max	Unit
V_{IL}	GPIO input low level voltage	-	-0.3	-	0.28 x V_{DD} + 0.1	V
V_{IH}	TC GPIO input high level voltage	-		-	V_{DD} + 0.3	V
	FTa GPIO input high level voltage	Analog mode				
	FT and FTf GPIO input high level voltage	-	0.31 x V_{DD} + 0.8		5.5	
	FTa GPIO input high level voltage	Input floating, input pull-up, or input pull-down mode		-	5.5	
V_{hys}	Schmitt trigger voltage hysteresis[1]	-	200	-	-	mV
			5% V_{DD}	-	-	-
I_{lkg}	Input leakage current [2]	V_{SS} ≤ V_{IN} ≤ V_{DD} TC GPIOs	-	-	±1	μA
		V_{SS} ≤ V_{IN} ≤ 5.5V FT, FTf and FTa GPIOs	-	-	±1	
R_{PU}	Weak pull-up equivalent resistor	V_{IN} = V_{SS}	65	80	130	kΩ
R_{PD}	Weak pull-down equivalent resistor [3]	V_{IN} = V_{DD}	65	70	130	kΩ
C_{IO}	GPIO pin capacitance	-	-	9	-	pF

(1) Hysteresis voltage between Schmitt trigger switching levels. Guaranteed by characterization results, not tested in production.
(2) Leakage could be higher than max if negative current is injected on adjacent pins.
(3) When the input is higher than V_{DD} + 0.3 V, the internal pull-up and pull-down resistors must be disabled for FT, FTf and FTa pins.
(4) The pull-down resistor of BOOT0 exists permanently.

All GPIOs are CMOS and TTL compliant (no software configuration required). Their characteristics take into account the strict CMOS-technology or TTL parameters.

Output driving current

In the user application, the number of GPIO pins that can drive current must be controlled to respect the absolute maximum rating defined in *Section 4.2.1*

● The sum of the currents sourced by all GPIOs on V_{DD}, plus the maximum Run consumption of the MCU sourced on V_{DD}, cannot exceed the absolute maximum rating I_{VDD} (see *Table 7*).

● The sum of the currents sunk by all GPIOs on V_{SS}, plus the maximum Run consumption of the MCU sunk on V_{SS}, cannot exceed the absolute maximum rating I_{VSS} (see *Table 7*).

Output voltage levels

All GPIOs are CMOS and TTL compliant.

Table 33. Output voltage characteristics[1]

Symbol	Parameter	Conditions	Min	Max	Unit
Normal sourcing/sinking strength					
V_{OL}	Output low level voltage	CMOS port, I_{IO} = 4 mA	-	0.4	V
V_{OH}	Output high level voltage	2.7 V ≤ V_{DD} ≤ 3.6 V	V_{DD}-0.4	-	
V_{OL}	Output low level voltage	TTL port, I_{IO} = 2 mA	-	0.4	V
V_{OH}	Output high level voltage	2.7 V ≤ V_{DD} ≤ 3.6 V	2.4	-	
V_{OL}	Output low level voltage	I_{IO} = 9 mA	-	1.3	V
V_{OH}	Output high level voltage	2.7 V ≤ V_{DD} ≤ 3.6 V	V_{DD}-1.3	-	
V_{OL}	Output low level voltage	I_{IO} = 2 mA	-	0.4	V
V_{OH}	Output high level voltage	2.4 V ≤ V_{DD} < 2.7 V	V_{DD}-0.4	-	
Large sourcing/sinking strength					
V_{OL}	Output low level voltage	CMOS port, I_{IO} = 6 mA	-	0.4	V
V_{OH}	Output high level voltage	2.7 V ≤ V_{DD} ≤ 3.6 V	V_{DD}-0.4	-	
V_{OL}	Output low level voltage	TTL port, I_{IO} = 5 mA	-	0.4	V
V_{OH}	Output high level voltage	2.7 V ≤ V_{DD} ≤ 3.6 V	2.4	-	
V_{OL}	Output low level voltage	I_{IO} = 18 mA	-	1.3	V
V_{OH}	Output high level voltage	2.7 V ≤ V_{DD} ≤ 3.6 V	V_{DD}-1.3	-	
V_{OL}	Output low level voltage	I_{IO} = 4 mA	-	0.4	V
V_{OH}	Output high level voltage	2.4 V ≤ V_{DD} < 2.7 V	V_{DD}-0.4	-	
Maximum sourcing/sinking strength					
V_{OL}	Output low level voltage	CMOS port, I_{IO} = 15 mA	-	0.4	V
V_{OH}	Output high level voltage	2.7 V ≤ V_{DD} ≤ 3.6 V	V_{DD}-0.4	-	
V_{OL}	Output low level voltage	TTL port, I_{IO} = 12 mA	-	0.4	V
V_{OH}	Output high level voltage	2.7 V ≤ V_{DD} ≤ 3.6 V	2.4	-	
V_{OL}	Output low level voltage	I_{IO} = 12 mA	-	0.4	V
V_{OH}	Output high level voltage	2.4 V ≤ V_{DD} < 2.7 V	V_{DD}-0.4	-	
Ultra high sinking strength [2]					
V_{OL}	Output low level voltage	I_{IO} = 25 mA, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	0.4	V
V_{OL}	Output high level voltage	I_{IO} = 18 mA, 2.4 V ≤ V_{DD} < 2.7 V			

(1) Guaranteed by characterization results, not tested in production.
(2) When GPIO ultra high sinking strength is enabled, its V_{OH} is the same as that of maximum sourcing strength.

Input AC characteristics

The definition and values of input AC characteristics are given as follows.

Table 34. Input AC characteristics

Symbol	Parameter	Min	Max	Unit
$t_{EXINTpw}$	Pulse width of external signals detected by EXINT controller	10	-	ns

4.3.12 NRST pin characteristics

The NRST pin input driver uses CMOS technology. It is connected to a permanent pull-up resistor, R_{PU} (see the table below).

Table 35. NRST pin characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{IL(NRST)}$[1]	NRST input low level voltage	-	-0.3	-	0.8	V
$V_{IH(NRST)}$[1]	NRST input high level voltage	-	2	-	V_{DD} + 0.3	
$V_{hys(NRST)}$[1]	NRST Schmitt trigger voltage hysteresis	-	-	500	-	mV
R_{PU}[2]	Weak pull-up equivalent resistor	$V_{IN} = V_{SS}$	30	40	50	kΩ
$t_{ILV(NRST)}$[1]	NRST input low level invalid time	-	-	-	40	μs
$t_{ILNV(NRST)}$[1]	NRST input low level valid time	-	80	-	-	μs

(1) Guaranteed by design, not tested in production.
(2) Guaranteed by characterization results, not tested in production.

Figure 17. Recommended NRST pin protection
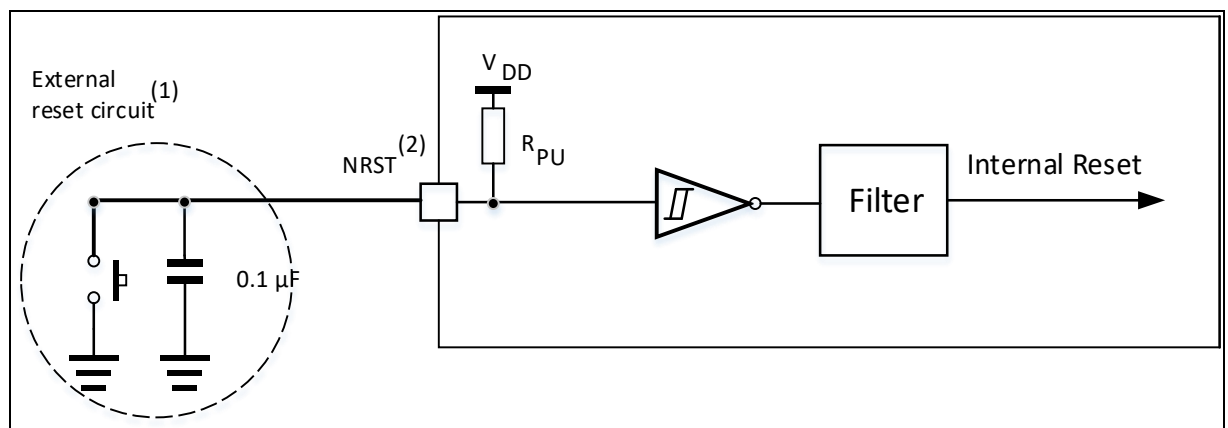
(1) The reset network protects the device against parasitic resets.
(2) The user must ensure that the level on the NRST pin can go below the $V_{IL\ (NRST)}$ max level specified in *Table 35*. Otherwise, the reset will not be performed by the device.

4.3.13 XMC characteristics

The parameters given in the table below are guaranteed by design and not tested in production.

Asynchronous waveforms and timings of SRAM/PSRAM/NOR

The results shown in these tables are obtained with the following XMC configuration:

● AddressSetupTime = 0

● AddressHoldTime = 1

● DataSetupTime = 1

Table 36. Asynchronous multiplexed PSRAM/NOR read timings

Symbol	Parameter	Min	Max	Unit
$t_{w(NE)}$	XMC_NE low time	$7t_{HCLK} - 2$	$7t_{HCLK} + 2$	ns
$t_{v(NOE\_NE)}$	XMC_NE low to XMC_NOE low	$3t_{HCLK} - 0.5$	$3t_{HCLK} + 1.5$	ns
$t_{w(NOE)}$	XMC_NOE low time	$4t_{HCLK} - 1$	$4t_{HCLK} + 2$	ns
$t_{h(NE\_NOE)}$	XMC_NOE high to XMC_NE high hold time	-1	-	ns
$t_{v(A\_NE)}$	XMC_NE low to XMC_A valid	-	0	ns
$t_{v(NADV\_NE)}$	XMC_NE low to XMC_NADV low	3	5	ns
$t_{w(NADV)}$	XMC_NADV low time	$t_{HCLK} - 1.5$	$t_{HCLK} + 1.5$	ns
$t_{h(AD\_NADV)}$	XMC_AD (address) valid hold time after XMC_NADV high	$t_{HCLK} + 3$	-	ns
$t_{h(A\_NOE)}$	Address hold time after XMC_NOE high	$t_{HCLK} + 3$	-	ns
$t_{h(UBLB\_NOE)}$	XMC_UB/LB hold time after XMC_NOE high	0	-	ns
$t_{v(UBLB\_NE)}$	XMC_NE low to XMC_UB/LB valid	-	0	ns
$t_{su(Data\_NE)}$	Data to XMC_NE high setup time	$2t_{HCLK} + 24$	-	ns
$t_{su(Data\_NOE)}$	Data to XMC_NOE high setup time	$2t_{HCLK} + 25$	-	ns
$t_{h(Data\_NE)}$	Data hold time after XMC_NE high	0	-	ns
$t_{h(Data\_NOE)}$	Data hold time after XMC_NOE high	0	-	ns

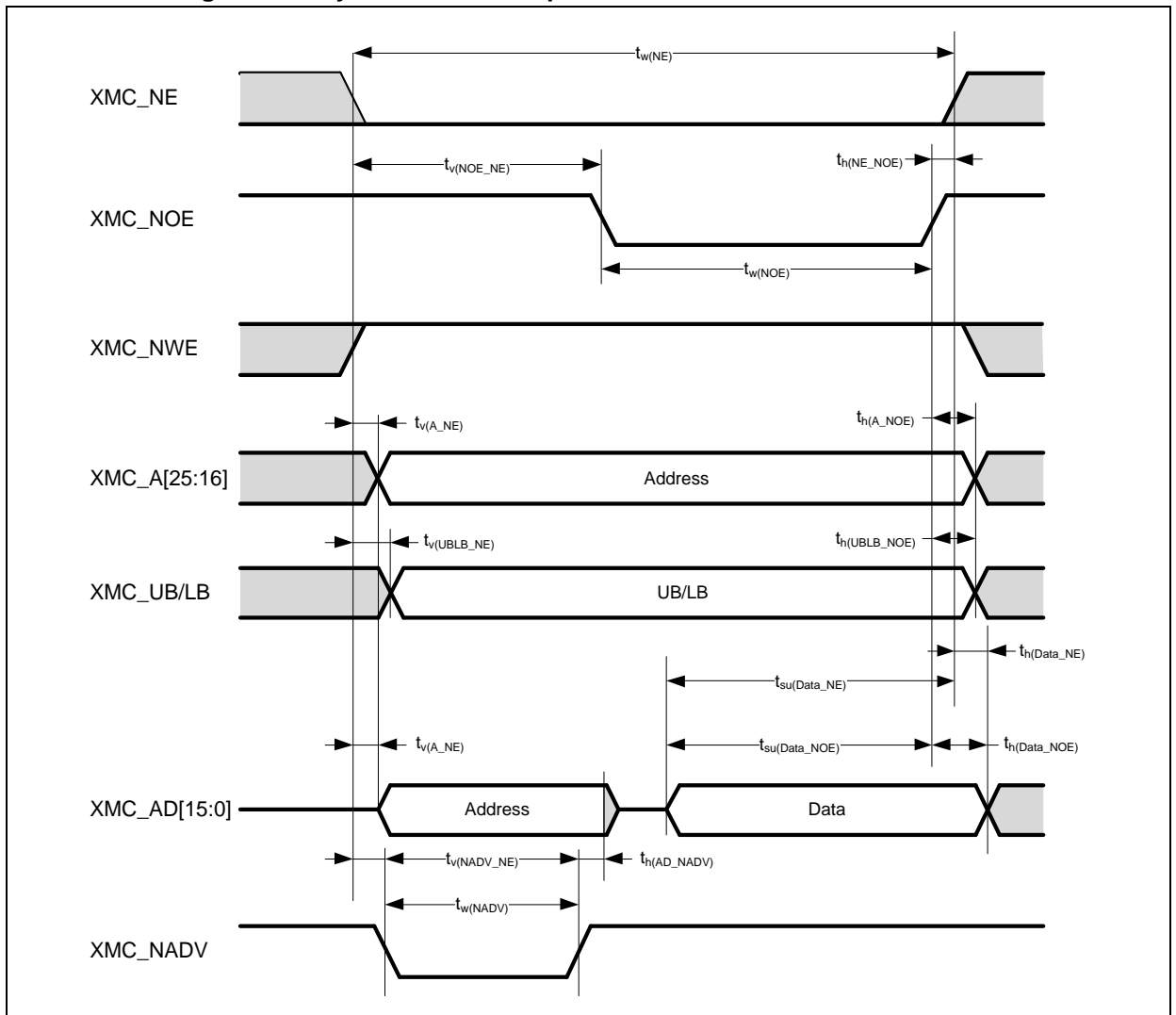**Figure 18. Asynchronous multiplexed PSRAM/NOR read waveforms**

Table 37. Asynchronous multiplexed PSRAM/NOR write timings

Symbol	Parameter	Min	Max	Unit
$t_{w(NE)}$	XMC_NE low time	$5t_{HCLK}$ - 1	$5t_{HCLK}$ + 2	ns
$t_{v(NWE\_NE)}$	XMC_NE low to XMC_NWE low	$2t_{HCLK}$	$2t_{HCLK}$ + 1	ns
$t_{w(NWE)}$	XMC_NWE low time	$2t_{HCLK}$ - 1	$2t_{HCLK}$ + 2	ns
$t_{h(NE\_NWE)}$	XMC_NWE high to XMC_NE high hold time	t_{HCLK} - 1	-	ns
$t_{v(A\_NE)}$	XMC_NE low to XMC_A valid	-	7	ns
$t_{v(NADV\_NE)}$	XMC_NE low to XMC_NADV low	3	5	ns
$t_{w(NADV)}$	XMC_NADV low time	t_{HCLK} - 1	t_{HCLK} + 1	ns
$t_{h(AD\_NADV)}$	XMC_AD (address) hold time after XMC_NADV high	t_{HCLK} - 3	-	ns
$t_{h(A\_NWE)}$	Address hold time after XMC_NWE high	$4t_{HCLK}$ + 2.5	-	ns
$t_{h(UBLB\_NWE)}$	XMC_UB/LB hold time after XMC_NWE high	t_{HCLK} - 1.5	-	ns
$t_{v(UBLB\_NE)}$	XMC_NE low to XMC_UB/LB valid	-	1.6	ns
$t_{v(Data\_NADV)}$	XMC_NADV high to data valid	-	t_{HCLK} + 1.5	ns
$t_{h(Data\_NWE)}$	Data hold time after XMC_NWE high	t_{HCLK} - 5	-	ns

Figure 19. Asynchronous multiplexed PSRAM/NOR write waveforms
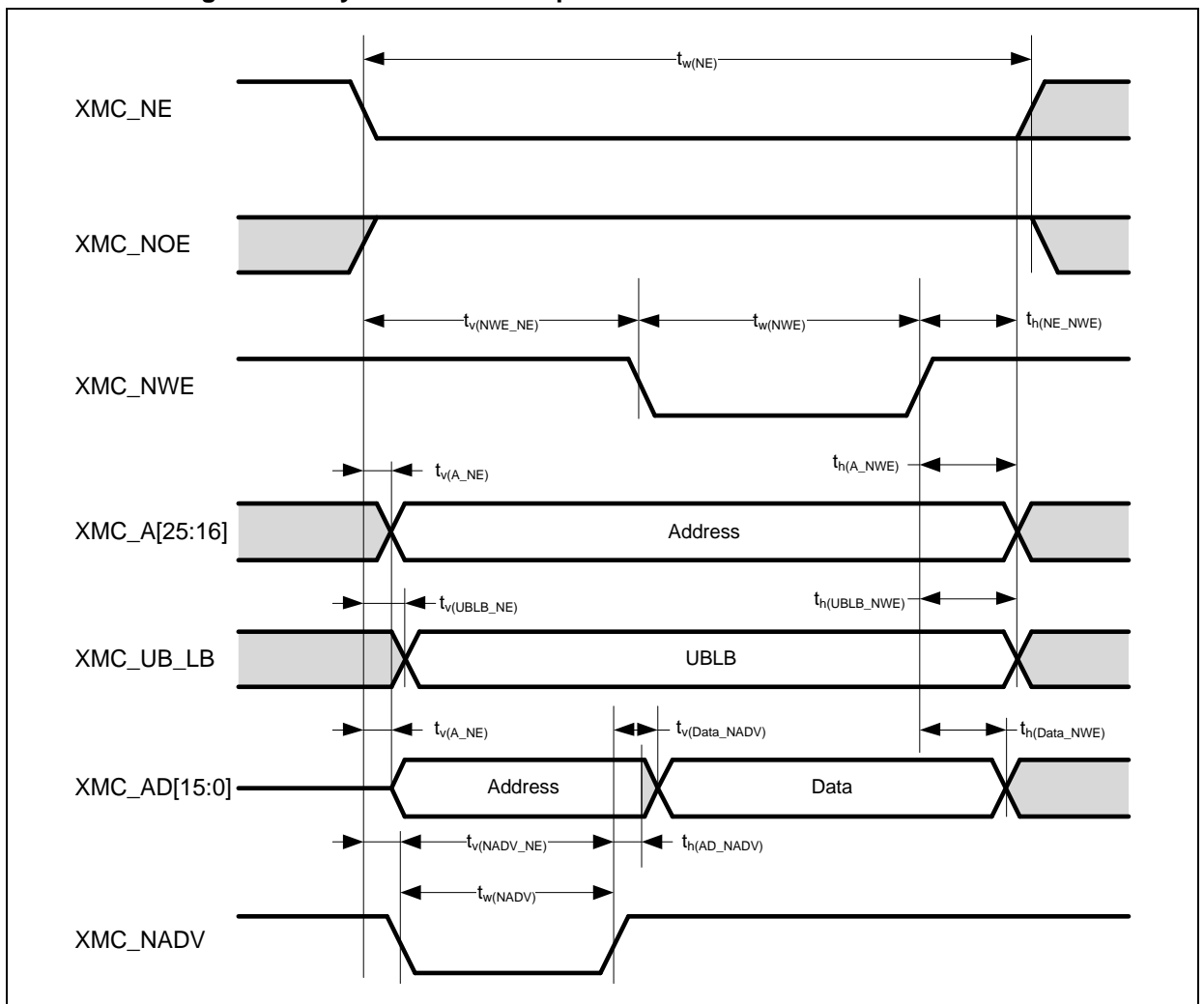
Synchronous waveforms and timings of PSRAM/NOR

The results given in these tables are obtained with the following XMC configuration:

- BurstAccessMode = XMC_BurstAccessMode_Enable; (Enable burst transfer mode)

- MemoryType = XMC_MemoryType_CRAM; (Memorty type is CRAM)

- WriteBurst = XMC_WriteBurst_Enable; (Enable write burst)

- CLKPrescale = 1 (1 memory cycle = 2 HCLK cycles) (Note: CLKPrescale is CLKPSC bit in XMC_BK1TMGx register. Refer to the AT32F423 reference manual.)

- DataLatency = 1 for NOR Flash; DataLatency = 0 for PSRAM (Note: DataLatency is DATLAT bit in XMC_BK1TMGx register. Refer to the AT32F423 reference manual.)

Table 38. Synchronous multiplexed PSRAM/NOR read timings

Symbol	Parameter	Min	Max	Unit
$t_{w(CLK)}$	XMC_CLK period	20	-	ns
$t_{d(CLKL-NEL)}$	XMC_CLK low to XMC_NE low	-	1.5	ns
$t_{d(CLKL-NEH)}$	XMC_CLK low to XMC_NE high	1	-	ns
$t_{d(CLKL-NADVL)}$	XMC_CLK low to XMC_NADV low	-	4	ns
$t_{d(CLKL-NADVH)}$	XMC_CLK low to XMC_NADV high	5	-	ns
$t_{d(CLKL-AV)}$	XMC_CLK low to XMC_A valid	-	0	ns
$t_{d(CLKL-AIV)}$	XMC_CLK low to XMC_A invalid	2	-	ns
$t_{d(CLKH-NOEL)}$	XMC_CLK high to XMC_NOE low		1	ns
$t_{d(CLKL-NOEH)}$	XMC_CLK low to XMC_NOE high	0.5	-	ns
$t_{d(CLKL-ADV)}$	XMC_CLK low to XMC_AD valid	-	12	ns
$t_{d(CLKL-ADIV)}$	XMC_CLK low to XMC_AD invalid	0	-	ns
$t_{su(ADV-CLKH)}$	XMC_AD valid data setup time before XMC_CLK high	6	-	ns
$t_{h(CLKH-ADV)}$	XMC_AD valid data hold time after XMC_CLK high	6	-	ns
$t_{su(NWAITV-CLKH)}$	XMC_NWAIT valid setup time before XMC_CLK high	8	-	ns
$t_{h(CLKH-NWAITV)}$	XMC_NWAIT valid hold time after XMC_CLK high	6	-	ns

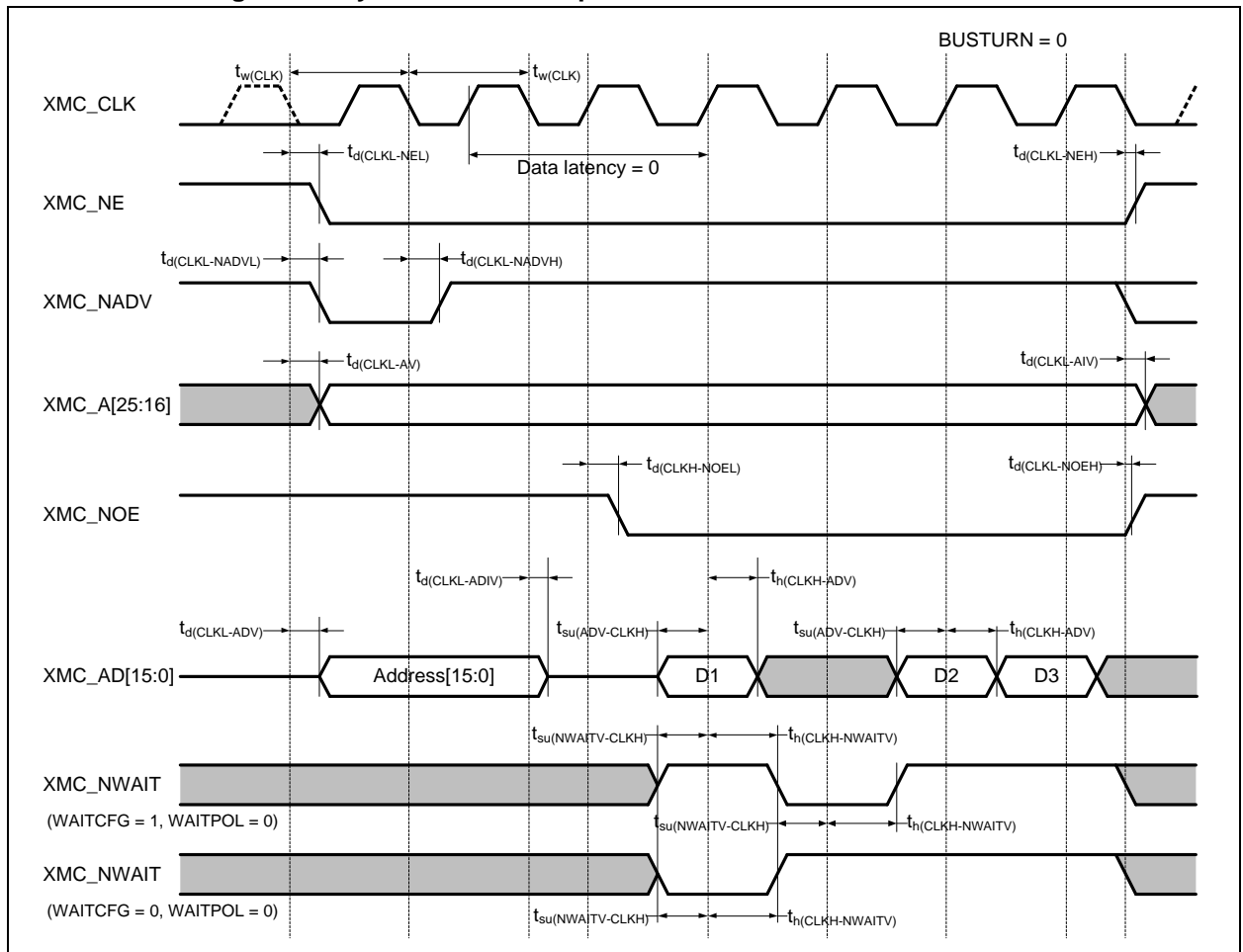**Figure 20. Synchronous multiplexed PSRAM/NOR read waveforms**

Table 39. Synchronous multiplexed PSRAM write timings

Symbol	Parameter	Min	Max	Unit
$t_{w(CLK)}$	XMC_CLK period	20	-	ns
$t_{d(CLKL-NEL)}$	XMC_CLK low to XMC_NE low	-	2	ns
$t_{d(CLKL-NEH)}$	XMC_CLK low to XMC_NE high	2	-	ns
$t_{d(CLKL-NADVL)}$	XMC_CLK low to XMC_NADV low	-	4	ns
$t_{d(CLKL-NADVH)}$	XMC_CLK low to XMC_NADV high	5	-	ns
$t_{d(CLKL-AV)}$	XMC_CLK low to XMC_A valid	-	0	ns
$t_{d(CLKL-AIV)}$	XMC_CLK low to XMC_A invalid	2	-	ns
$t_{d(CLKL-NWEL)}$	XMC_CLK low to XMC_NWE low	-	1	ns
$t_{d(CLKL-NWEH)}$	XMC_CLK low to XMC_NWE high	0.5	-	ns
$t_{d(CLKL-ADV)}$	XMC_CLK low to XMC_AD valid	-	12	ns
$t_{d(CLKL-ADIV)}$	XMC_CLK low to XMC_AD invalid	3	-	ns
$t_{d(CLKL-Data)}$	XMC_AD after XMC_CLK low	-	6	ns
$t_{d(CLKL-UBLBH)}$	XMC_CLK low to XMC_UB/LB high	1	-	ns
$t_{su(NWAITV-CLKH)}$	XMC_NWAIT valid setup time before XMC_CLK high	7	-	ns
$t_{h(CLKH-NWAITV)}$	XMC_NWAIT valid hold time after XMC_CLK high	2	-	ns

Figure 21. Synchronous multiplexed PSRAM write waveforms
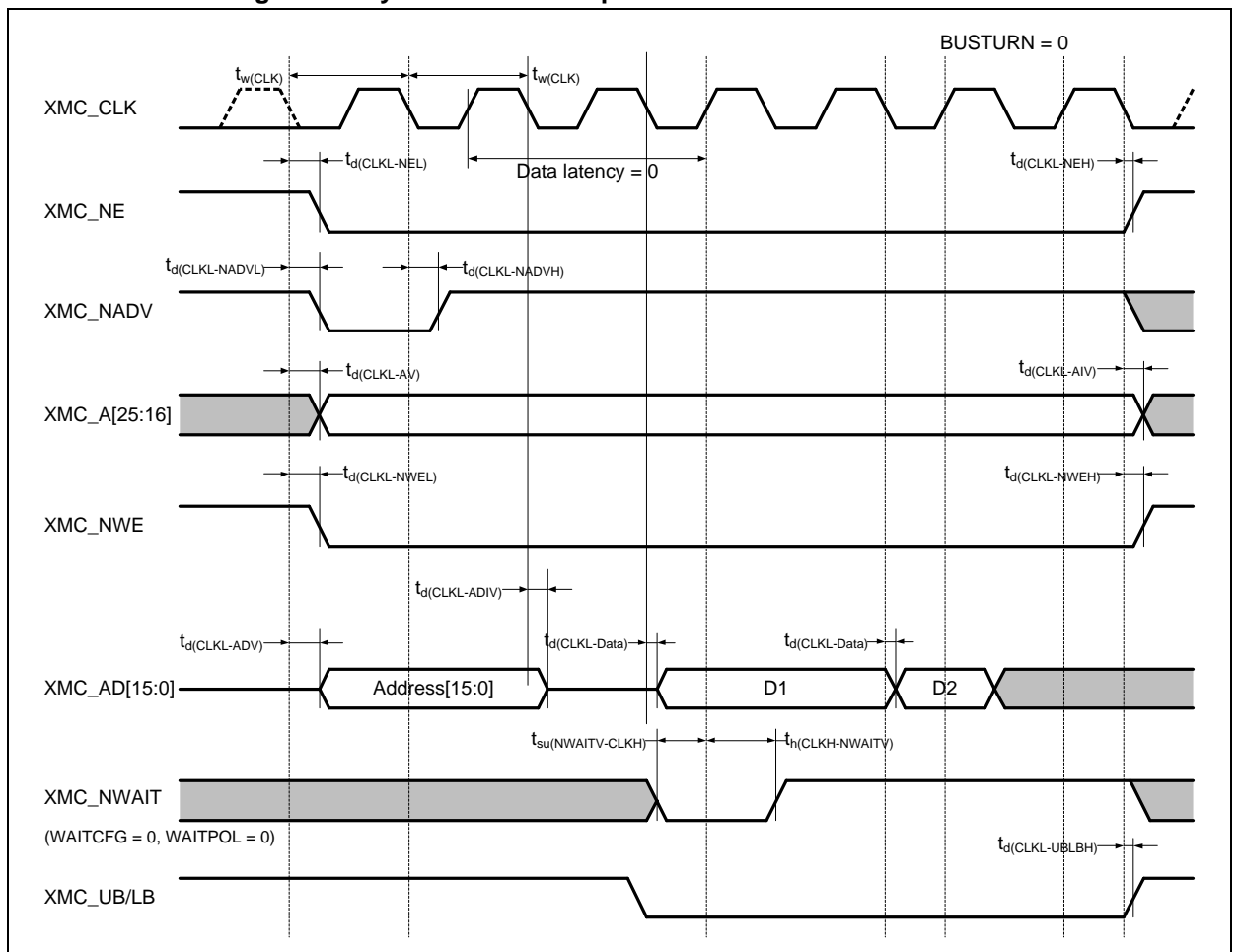
4.3.14 TMR timer characteristics

The parameters given in the table below are guaranteed by design and not tested in production.

Table 40. TMR timer characteristics

Symbol	Parameter	Conditions	Min	Max	Unit
$t_{res(TMR)}$	Timer resolution time	-	1	-	$t_{TMRxCLK}$
		$f_{TMRxCLK}$ = 150 MHz	6.66	-	ns
f_{EXT}	Timer external clock frequency on CH1 to CH4	-	0	$f_{TMRxCLK}/2$	MHz

4.3.15 SPI characteristics

Table 41. SPI characteristics

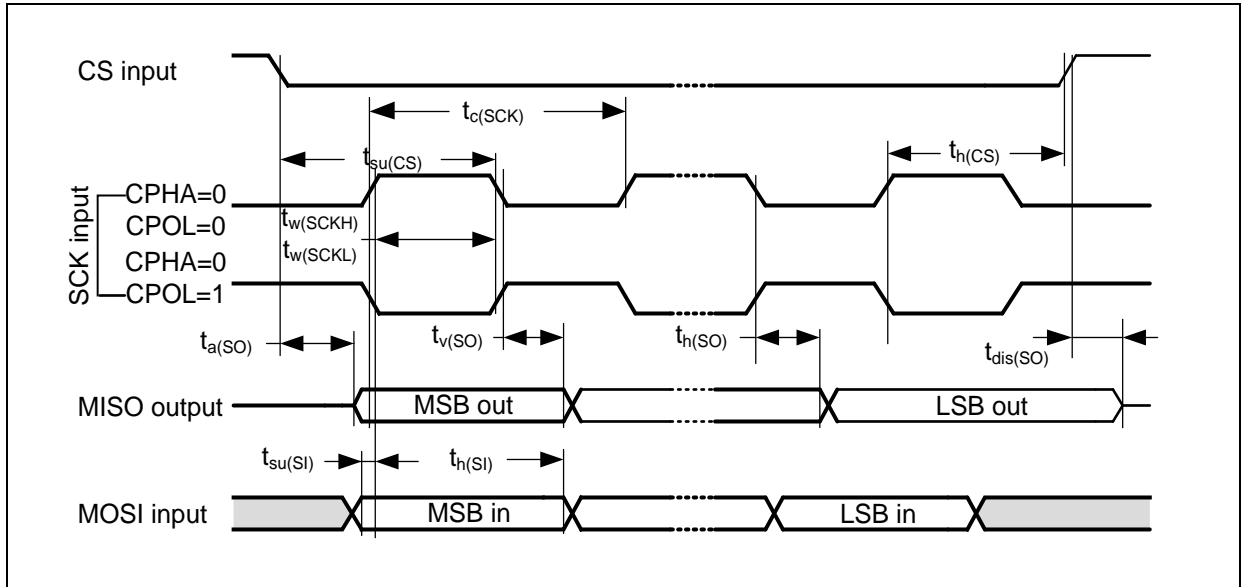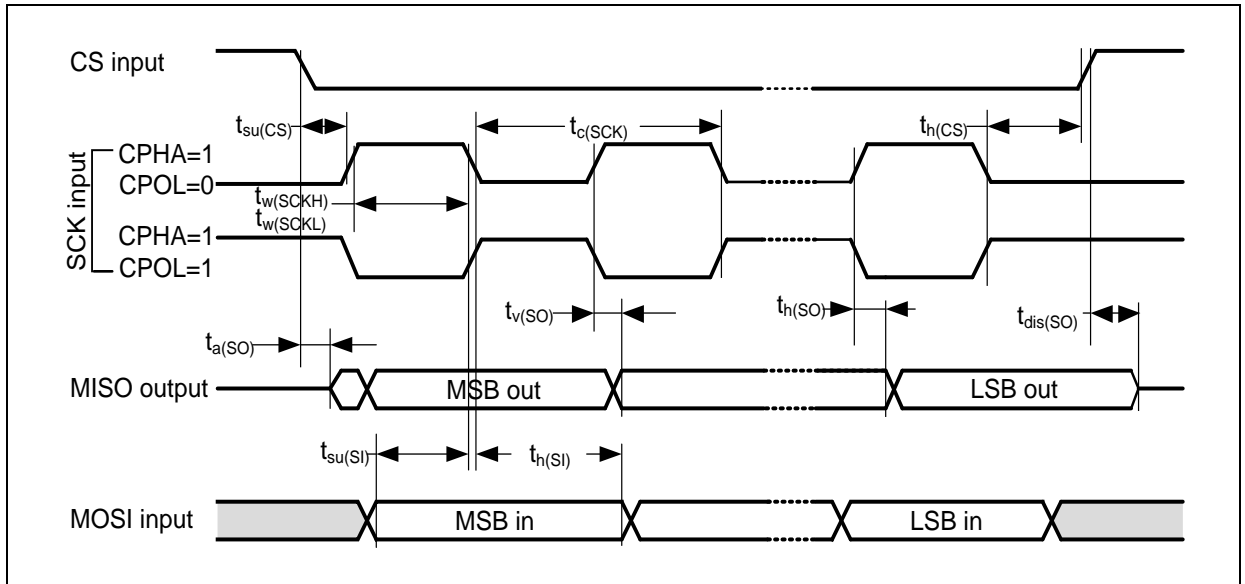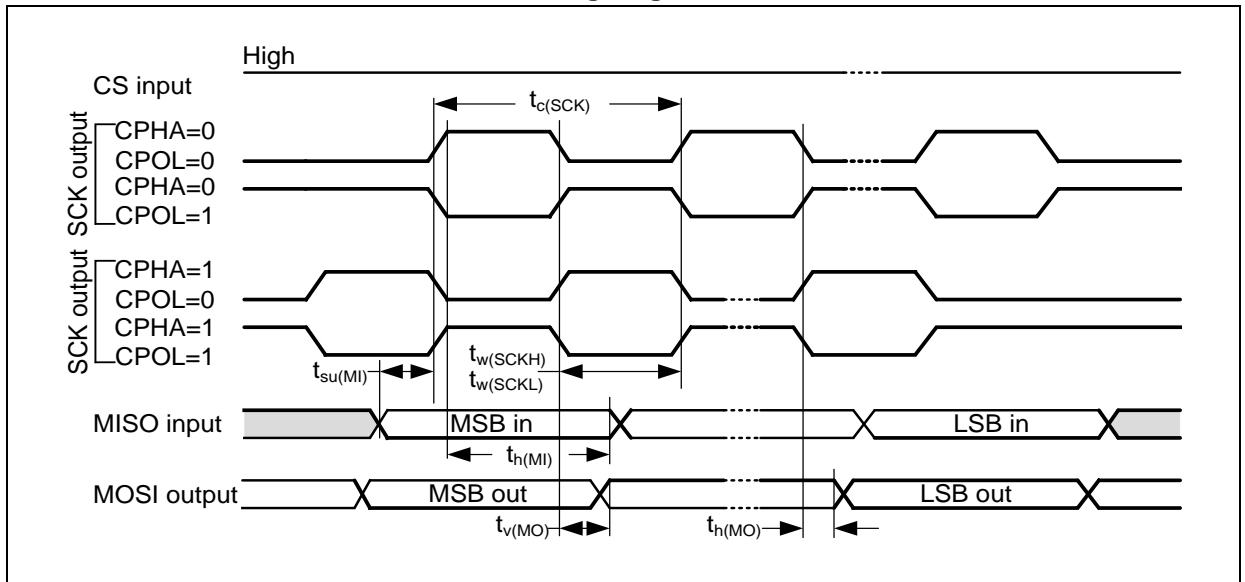| Symbol	Parameter	Conditions	Min	Max	Unit
f_{SCK} $(1/t_{c(SCK)})$[1]	SPI clock frequency[2][3]	Master mode	-	32	MHz
		Slave receive mode	-	32	
		Slave transmit mode	-	25	
$t_{su(CS)}$[1]	CS setup time	Slave mode	$4t_{PCLK}$	-	ns
$t_{h(CS)}$[1]	CS hold time	Slave mode	$2t_{PCLK}$	-	ns
$t_{w(SCKH)}$[1] $t_{w(SCKL)}$[1]	SCK high and low time	Master mode Prescaler factor = 4	$2t_{PCLK}$ - 3	$2t_{PCLK}$ + 3	ns
$t_{su(MI)}$[1]	Data input setup time	Master mode	6	-	ns
$t_{su(SI)}$[1]		Slave mode	5	-	
$t_{h(MI)}$[1]	Data input hold time	Master mode	4	-	ns
$t_{h(SI)}$[1]		Slave mode	5	-	
$t_{a(SO)}$[1][4]	Data output access time	Slave mode	t_{PCLK} - 2	$2t_{PCLK}$ + 2	ns
$t_{dis(SO)}$[1][5]	Data output disable time	Slave mode	t_{PCLK} - 2	$2t_{PCLK}$ + 2	ns
$t_{v(SO)}$[1]	Data output valid time	Slave mode (after enable edge)	-	25	ns
$t_{v(MO)}$[1]	Data output valid time	Master mode (after enable edge)	-	10	ns
$t_{h(SO)}$[1]	Data output hold time	Slave mode (after enable edge)	9	-	ns
$t_{h(MO)}$[1]		Master mode (after enable edge)	2	-	

(1) Guaranteed by design, not tested in production.
(2) The maximum SPI clock frequency should not exceed $f_{PCLK}/2$.
(3) The maximum SPI clock frequency is highly related with devices and the PCB layout. For more details about the complete solution, please contact your local Artery sales representative.
(4) Min time is the minimum time to drive the output and the max time is for the maximum time to validate the data.
(5) 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 22. SPI timing diagram – slave mode and CPHA = 0

Figure 23. SPI timing diagram – slave mode and CPHA = 1


Figure 24. SPI timing diagram – master mode

4.3.16 I²S characteristics

Table 42. I²S characteristics

Symbol	Parameter	Conditions	Min	Max	Unit
$t_{r(CK)}$ $t_{f(CK)}$	I²S clock rise and fall time	Capacitive load: C = 15 pF	-	12	ns
$t_{v(WS)}$[1]	WS valid time	Master mode	0	4	
$t_{h(WS)}$[1]	WS hold time	Master mode	0	4	
$t_{su(WS)}$[1]	WS setup time	Slave mode	9	-	
$t_{h(WS)}$[1]	WS hold time	Slave mode	0	-	
$t_{su(SD\_MR)}$[1]	Data input setup time	Master receiver	6	-	
$t_{su(SD\_SR)}$[1]		Slave receiver	2	-	
$t_{h(SD\_MR)}$[1][2]	Data input hold time	Master receiver	0.5	-	
$t_{h(SD\_SR)}$[1][2]		Slave receiver	0.5	-	
$t_{v(SD\_ST)}$[1][2]	Data output valid time	Slave transmitter (after enable edge)	-	20	
$t_{h(SD\_ST)}$[1]	Data output hold time	Slave transmitter (after enable edge)	9	-	
$t_{v(SD\_MT)}$[1][2]	Data output valid time	Master transmitter (after enable edge)	-	15	
$t_{h(SD\_MT)}$[1]	Data output hold time	Master transmitter (after enable edge)	0	-	

(1) Guaranteed by design, not tested in production.
(2) Depends on f_{PCLK}. For example, if f_{PCLK}=8 MHz, then T_{PCLK} = $1/f_{PCLK}$ =125 ns.

Figure 25. I²S slave timing diagram (Philips protocol)
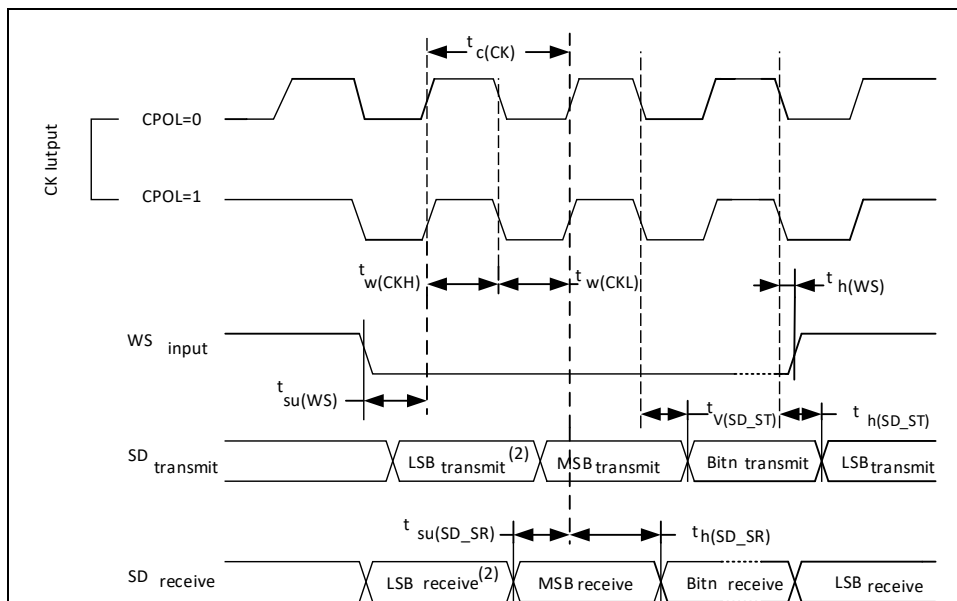
(1) LSB transmit/receive of the previously transmitted byte. No LSB transmit/receive is sent before the first byte.

Figure 26. I²S master timing diagram (Philips protocol)
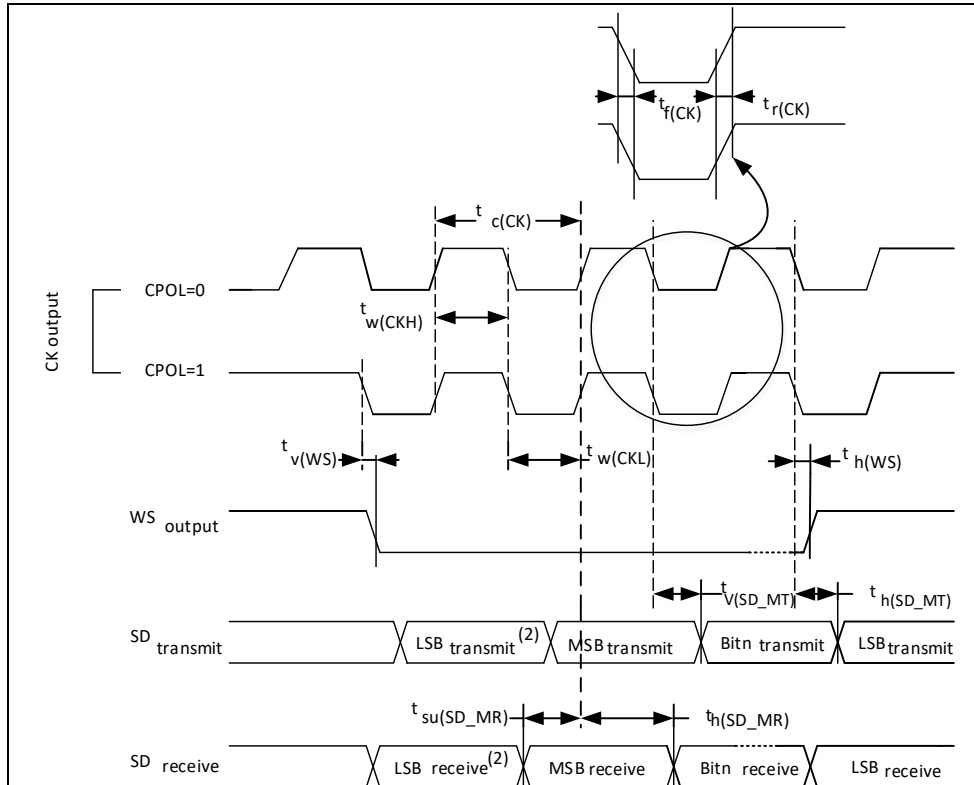
(1) LSB transmit/receive of the previously transmitted byte. No LSB transmit/receive is sent before the first byte.

4.3.17 I²C characteristics

GPIO pins SDA and SCL have limitation as follows: they are not "true" open-drain. When configured as open-drain, the PMOS connected between the GPIO pin and V_{DD} is disabled, but is still present.

I²C bus interface can support standard mode (max. 100 kHz), fast mode (max. 400 kHz), and fast mode plus (max. 1 MHz).

4.3.18 OTGFS characteristics

Table 43. OTGFS startup time

Symbol	Parameter	Max	Unit
$t_{STARTUP}$[1]	OTGFS transceiver startup time	1	µs

(1) Guaranteed by design, not tested in production.

Table 44. OTGFS DC electrical characteristics

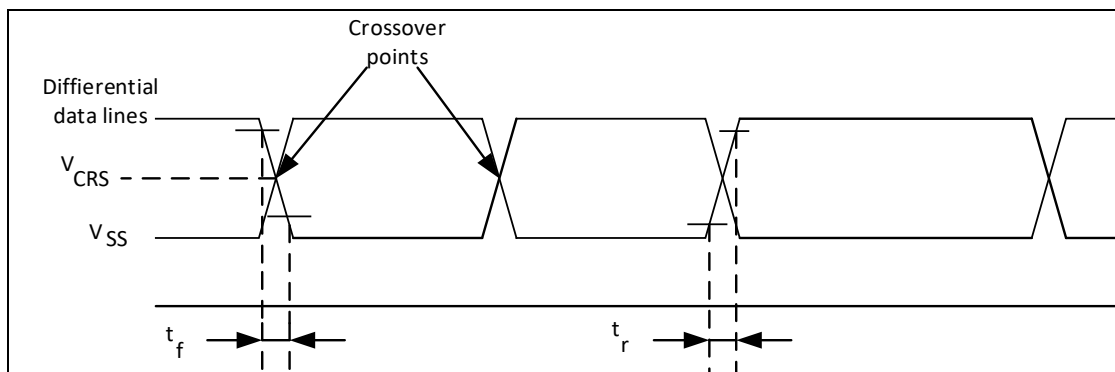| Symbol		Parameter	Conditions	Min[1]	Typ	Max[1]	Unit
Input levels	V_{DD}	OTGFS operating voltage	-	3.0[2]	-	3.6	V
	V_{DI}[3]	Differential input sensitivity	I (OTGFS_D+/D-)	0.2	-	-	V
	V_{CM}[3]	Differential common mode range	Include V_{DI} range	0.8	-	2.5	
	V_{SE}[3]	Single ended receiver threshold	-	1.3	-	2.0	
Output levels	V_{OL}	Static output level low	1.24 kΩ R_L to 3.6 V[4]	-	-	0.3	V
	V_{OH}	Static output level high	15 kΩ R_L to V_{SS}[4]	2.8	-	3.6	
R_{PU}		OTGFS_D+ internal pull-up	$V_{IN} = V_{SS}$	0.97	1.24	1.58	kΩ
R_{PD}		OTGFS_D+/D- internal pull-down	$V_{IN} = V_{DD}$	15	19	25	kΩ

(1) All the voltages are measured from the local ground potential.
(2) The AT32F423 USB functionality is ensured down to 2.7 V but not the full USB electrical characteristics that are degraded in the 2.7 to 3.0 V V_{DD} voltage range.
(3) Guaranteed by design, not tested in production.
(4) R_L is the load connected to the USB drivers.

Figure 27. OTGFS timings: definition of data signal rise and fall time

Table 45. OTGFS electrical characteristics

Symbol	Parameter	Conditions	Min[1]	Max[1]	Unit
t_r	Rise time [2]	$C_L ≤ 50$ pF	4	20	ns
t_f	Fall time [2]	$C_L ≤ 50$ pF	4	20	ns
t_{rfm}	Rise/fall time matching	t_r/t_f	90	110	%
V_{CRS}	Output signal crossover voltage	-	1.3	2.0	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 Chapter 7 (version 2.0).

4.3.19 12-bit ADC characteristics

Unless otherwise specified, the parameters given in the table below are preliminary values derived from tests performed under ambient temperature, f_{PCLK2} frequency and V_{DDA} supply voltage conditions summarized in *Table 11*.

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

Table 46. ADC characteristics

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
V_{DDA}	Power supply	-		2.4	-	3.6	V
V_{REF+}[1]	Positive reference voltage	-		2.0	-	V_{DDA}	V
I_{DDA}[2]	Current on the V_{DDA} input pin	f_{ADC} = 80 MHz		-	1000	1250	µA
I_{VREF+}[1][2]	Current on the V_{REF+} input pin	f_{ADC} = 80 MHz		-	470	510	µA
f_{ADC}	ADC clock frequency	$V_{REF+} \geq 3.0$ V		0.6	-	80	MHz
		$V_{REF+} < 3.0$ V		0.6	-	30	
f_S[3]	Sampling rate	12-bit resolution	Fast channel	0.04	-	5.33	MSPS
			Slow channel			4.21	
		10-bit resolution	Fast channel	0.047	-	6.15	
			Slow channel			4.71	
		8-bit resolution	Fast channel	0.055	-	7.27	
			Slow channel			5.33	
		6-bit resolution	Fast channel	0.067	-	8.88	
			Slow channel			6.15	
f_{TRIG}[3]	External trigger frequency	f_{ADC} = 80 MHz		-	-	4.44	MHz
		-		-	-	18	1/f_{ADC}
V_{AIN}[3]	Conversion voltage range [1]	-		0 (V_{REF-} internally connected to ground)	-	V_{REF+}	V
R_{AIN}[3]	External input impedance	-		See *Table 47*			Ω
C_{ADC}[3]	Internal sample and hold capacitor	-		-	10	-	pF
t_{CAL}[3]	Calibration time	f_{ADC} = 80 MHz		2.56			µs
		-		205			1/f_{ADC}
t_{lat}[3]	Preempted trigger conversion latency	f_{ADC} = 80 MHz		-	-	37.5	ns
		-		-	-	3[4]	1/f_{ADC}
t_{latr}[3]	Regular trigger conversion latency	f_{ADC} = 80 MHz		-	-	25	ns
		-		-	-	2[4]	1/f_{ADC}
t_S[3]	Sampling time	f_{ADC} = 80 MHz		0.031	-	8.006	µs
		-		2.5	-	640.5	1/f_{ADC}
t_{STAB}[3]	Power-up time	-		45			1/f_{ADC}
t_{CONV}[3]	Total conversion time (including sampling time)	f_{ADC} = 80 MHz in 12-bit resolution		0.188	-	8.163	µs
		12-bit resolution		15 ~ 653 (t_S for sampling + 12.5 for successive approximation)			1/f_{ADC}

(1) V_{REF+} may be connected to V_{DDA} internally, depending on packages.
(2) Guaranteed by characterization results, not tested in production.
(3) Guaranteed by design, not tested in production.
(4) For external triggers, a delay of $1/f_{PCLK2}$ must be added to the latency specified in *Table 46*.

Table 47 defines the maximum external impedance allowed for an error below 1 of LSB in 12-bit resolution.

Table 47. R_{AIN} max when f_{ADC} = 80 MHz [1]

T_S (cycle)	t_S (µs)	R_{AIN} max (Ω)[1]	
		Fast channel	**Slow channel**
2.5	0.031	30	Not support
6.5	0.081	200	50
12.5	0.156	400	350
24.5	0.306	800	700
47.5	0.594	1700	1500
92.5	1.156	3000	2600
247.5	3.094	9000	8500
640.5	8.006	20000	19000

(1) Guaranteed by design.

Table 48. ADC accuracy [1][2]

Symbol	Parameter	Test Conditions	Typ	Max	Unit
ET	Total unadjusted error	f_{ADC} = 80 MHz, R_{AIN} < 20 kΩ, V_{DDA} = 3.0 ~ 3.6 V, T_A =-40 ~ 105 °C, V_{REF+} = V_{DDA}	±3	±5	LSB
EO	Offset error		-1	+1/-2	
EG	Gain error		+2	+3.5	
ED	Differential linearity error		+2.5	+4/-1	
EL	Integral linearity error		+3	±4.5	
ET	Total unadjusted error	f_{ADC} = 30 MHz, R_{AIN} < 20 kΩ, V_{DDA} = 2.4 ~ 3.6 V, T_A = -40 ~ 105 °C, V_{REF+} = V_{DDA}	±2	±3.5	LSB
EO	Offset error		-0.5	+1/-2	
EG	Gain error		+2	+3	
ED	Differential linearity error		±0.75	±1	
EL	Integral linearity error		±1.5	±2	
ET	Total unadjusted error	f_{ADC} = 30 MHz, R_{AIN} < 20 kΩ, V_{DDA} = 2.4 ~ 3.6 V, T_A = -40 ~ 105 °C V_{REF+} = 2.0 ~ 2.4 V	±2.5	±4	LSB
EO	Offset error		-1.5	+1/-3.5	
EG	Gain error		+2	+3.5	
ED	Differential linearity error		±0.7	+1.2/-1	
EL	Integral linearity error		±1.2	±2	

(1) ADC DC accuracy values are measured after internal calibration.
(2) Guaranteed by characterization results, not tested in production.

Figure 28. ADC accuracy characteristics
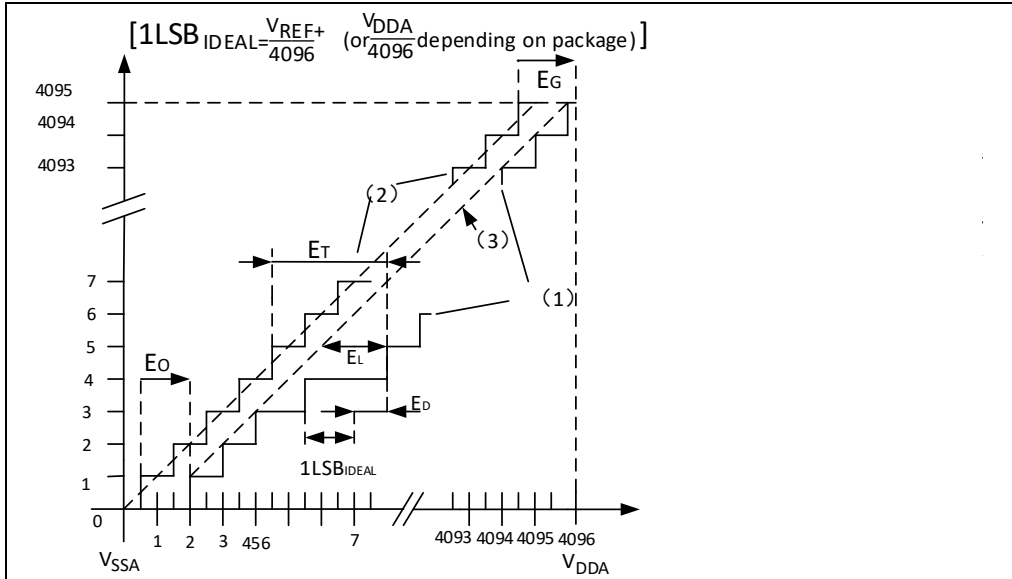
(1) Example of an actual transfer curve.
(2) Ideal transfer curve.
(3) End point correlation line.

E_T = Maximum deviation between the actual and the ideal transfer curves.
E_O = Deviation between the first actual transition and the first ideal one.
E_G = Deviation between the last ideal transition and the last actual one.
E_D = Maximum deviation between actual steps and the ideal one.
E_L = Maximum deviation between any actual transition and the end point correlation line.

Figure 29. Typical connection diagram using the ADC
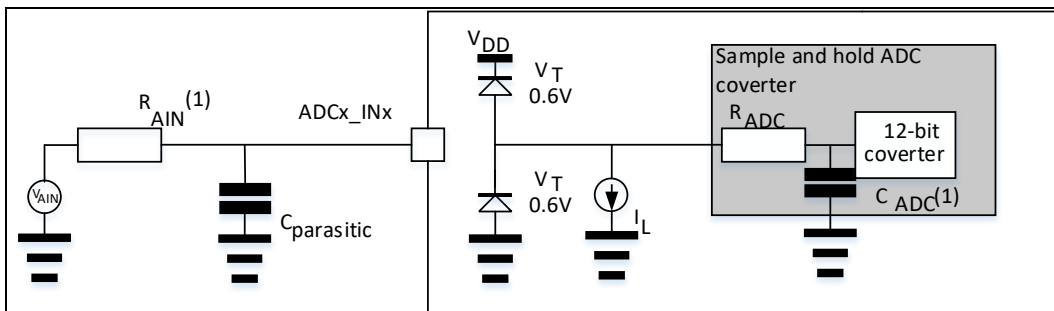
(1) Refer to *Table 46* for the values of R_{AIN} and C_{ADC}.
(2) $C_{parasitic}$ represents the capacitance of the PCB (dependent on soldering and PCB layout quality) plus the pad capacitance (roughly 7 pF). A high $C_{parasitic}$ value will downgrade conversion accuracy. To remedy this, f_{ADC} should be reduced.

General PCB design guidelines

Power supply decoupling should be performed as shown in *Figure 30 or Figure 31,* depending on whether V_{REF+} is connected to V_{DDA} or not. The 100 nF capacitors should be ceramic (good quality). They should be placed as close as possible to the chip.

Figure 30. Power supply and reference decoupling (for packages with external V_REF+ pin)
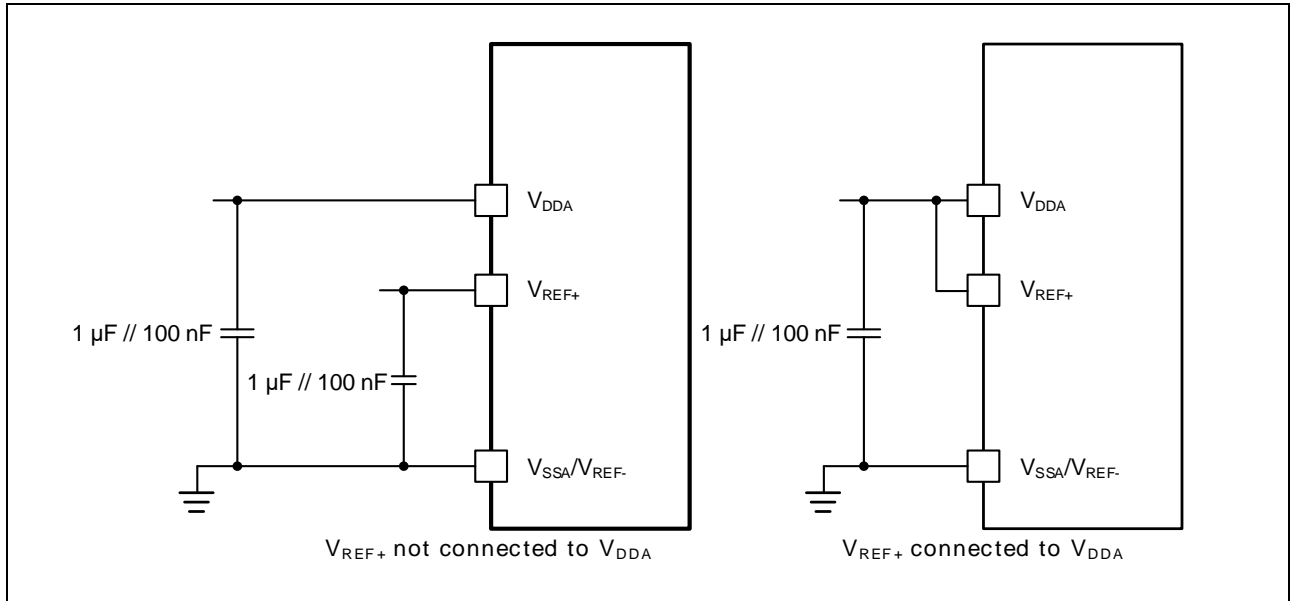
(1) V_REF+ input is available only on 100-pin package.

Figure 31. Power supply and reference decoupling (for packages without V_REF+ pin)
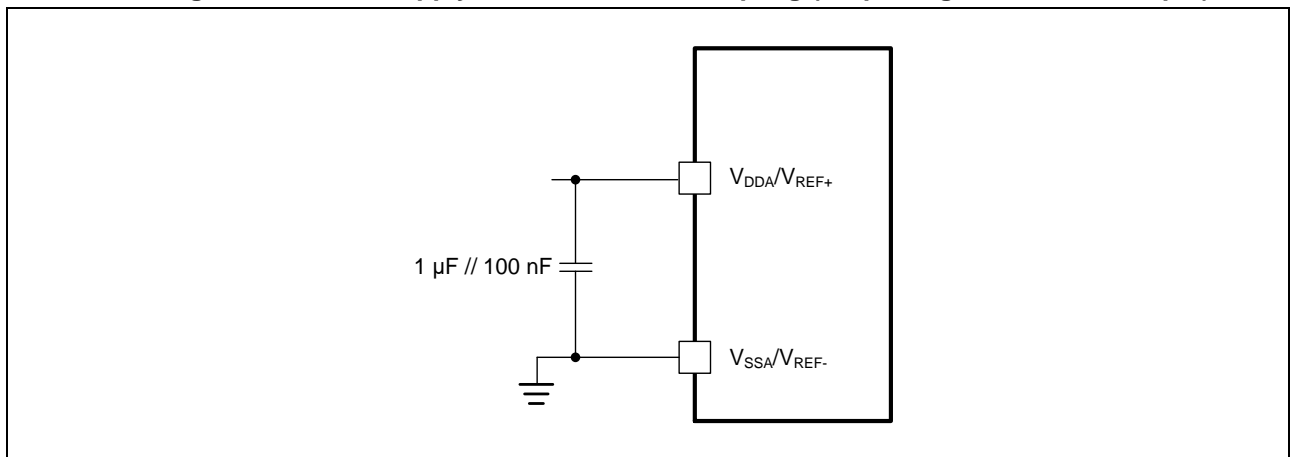
(1) V_REF+ input is available only on 100-pin package.

4.3.20 Internal reference voltage (V_INTRV) characteristics

Table 49. Internal reference voltage characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_INTRV[1]	Internal reference voltage	-	1.16	1.20	1.24	V
T_Coeff[1]	Temperature coefficient	-	-	50	100	ppm/°C
T_S_VINTRV[2]	ADC sampling time when reading the internal reference voltage	-	5	-	-	µs

(1) Guaranteed by characterization results, not tested in production.
(2) Guaranteed by design, not tested in production.

4.3.21 Temperature sensor (V$_{TS}$) characteristics

Table 50. Temperature sensor characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
T$_L$[1]	V$_{TS}$ linearity with temperature	T$_A$ = -20 ~ +85 °C	-	±1	±2	°C
		T$_A$ = -40 ~ +105 °C	-	-	±3	
Avg_Slope[1][2]	Average slope	-	-4.06	-4.26	-4.47	mV/°C
V$_{25}$[1][2]	Voltage at 25 °C	-	1.20	1.29	1.38	V
t$_{START}$[3]	Startup time	-	-	-	100	µs
T$_{S\_temp}$[3]	ADC sampling time when reading the temperature	-	5	-	-	µs

(1) Guaranteed by characterization results, not tested in production.
(2) The temperature sensor output voltage changes linearly with temperature. The offset of this line varies from chip to chip due to process variation (up to 50 °C from one chip to another). The internal temperature sensor is more suited to applications that detect temperature variations instead of absolute temperatures. If accurate temperature readings are needed, an external temperature sensor part should be used.
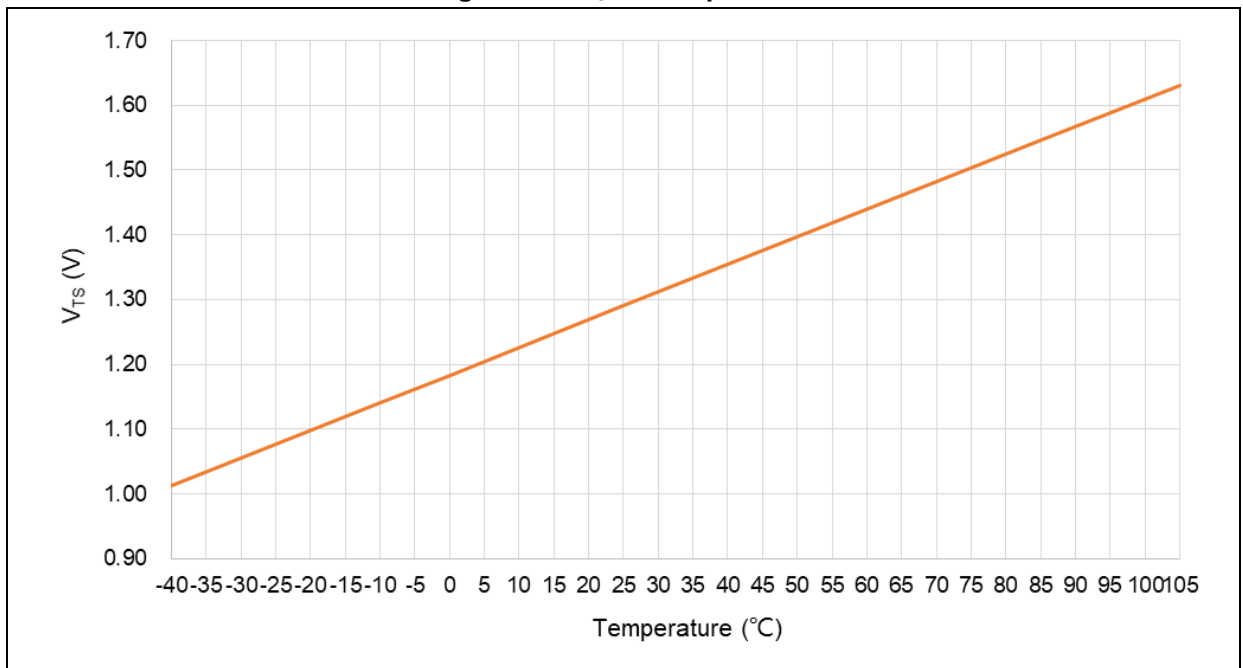(3) Guaranteed by design, not tested in production.

Obtain the temperature using the following formula:

Temperature (in °C) = {(V$_{25}$ - V$_{TS}$) / Avg_Slope} + 25.

Where,

V$_{25}$ = V$_{TS}$ value for 25° C and

Avg_Slope = Average Slope for curve between Temperature vs. V$_{TS}$ (given in mV/° C).

Figure 32. V$_{TS}$ vs. temperature

4.3.22 12-bit DAC specifications

Table 51. DAC characteristics

Symbol	Parameter	Comments	Min	Typ	Max	Unit
V_{DDA}	Analog supply voltage	-	2.4	-	3.6	V
V_{REF+}[1]	Reference supply voltage	-	2.0	-	3.6	V
V_{SSA}	Ground	-	0	-	0	V
R_{LOAD}[2]	Load resistance with buffer ON	-	5	-	-	kΩ
R_O[2]	Impedance output with buffer OFF	-	-	13.2	16	kΩ
C_{LOAD}[2]	Capacitive load (with buffer ON)	-	-	-	50	pF
DAC_OUT[2]	Lower DAC_OUT voltage with buffer ON	-	0.2	-	-	V
	Higher DAC_OUT voltage with buffer ON	-	-	-	V_{REF+} - 0.2	V
	Lower DAC_OUT voltage with buffer OFF	-	-	0.5	5	mV
	Higher DAC_OUT voltage with buffer OFF	-	-	-	V_{REF+} - 5 mV	V
I_{DDA}[3]	DAC DC current consumption in quiescent mode	With no load, at V_{REF+} = 3.6 V	-	450	515	µA
I_{VREF+}[1][3]	DAC DC current consumption in quiescent mode	With no load, at V_{REF+} = 3.6 V	-	380	390	µA
DNL[3]	Differential non linearity	-	-	±0.5	±1	LSB
INL[3]	Integral non linearity (difference between measured value at Code I and a line drawn between DAC_OUT min and DAC_OUT max)	-	-	±1	±2	LSB
Offset[3]	Offset error (difference between measured value at Code (0x800) and the ideal value = V_{REF+}/2)	-	-	10	15	mV
			-	10	20	LSB
Gain error[3]	Gain error	-	-	0.2	0.4	%
$t_{SETTLING}$[2]	Settling time	R_{LOAD} ≥ 5 kΩ C_{LOAD} ≤ 50 pF	-	1	4	µs
Update rate[2]	Max frequency for a correct DAC_OUT change when small variation in the input code (from code i to i+1 LSB)	R_{LOAD} ≥ 5 kΩ C_{LOAD} ≤ 50 pF	-	-	1	MSPS
t_{WAKEUP}[2]	Wakeup time from off state (setting the EN bit in the DAC Control register)	R_{LOAD} ≥ 5 kΩ C_{LOAD} ≤ 50 pF	-	1.2	4	µs

(1) V_{REF+} can be internally connected to V_{DDA} depending on the packages.
(2) Guaranteed by design, not tested in production.
(3) Guaranteed by characterization results, not tested in production.

5 Package information

5.1 LQFP100 – 14 x 14 mm

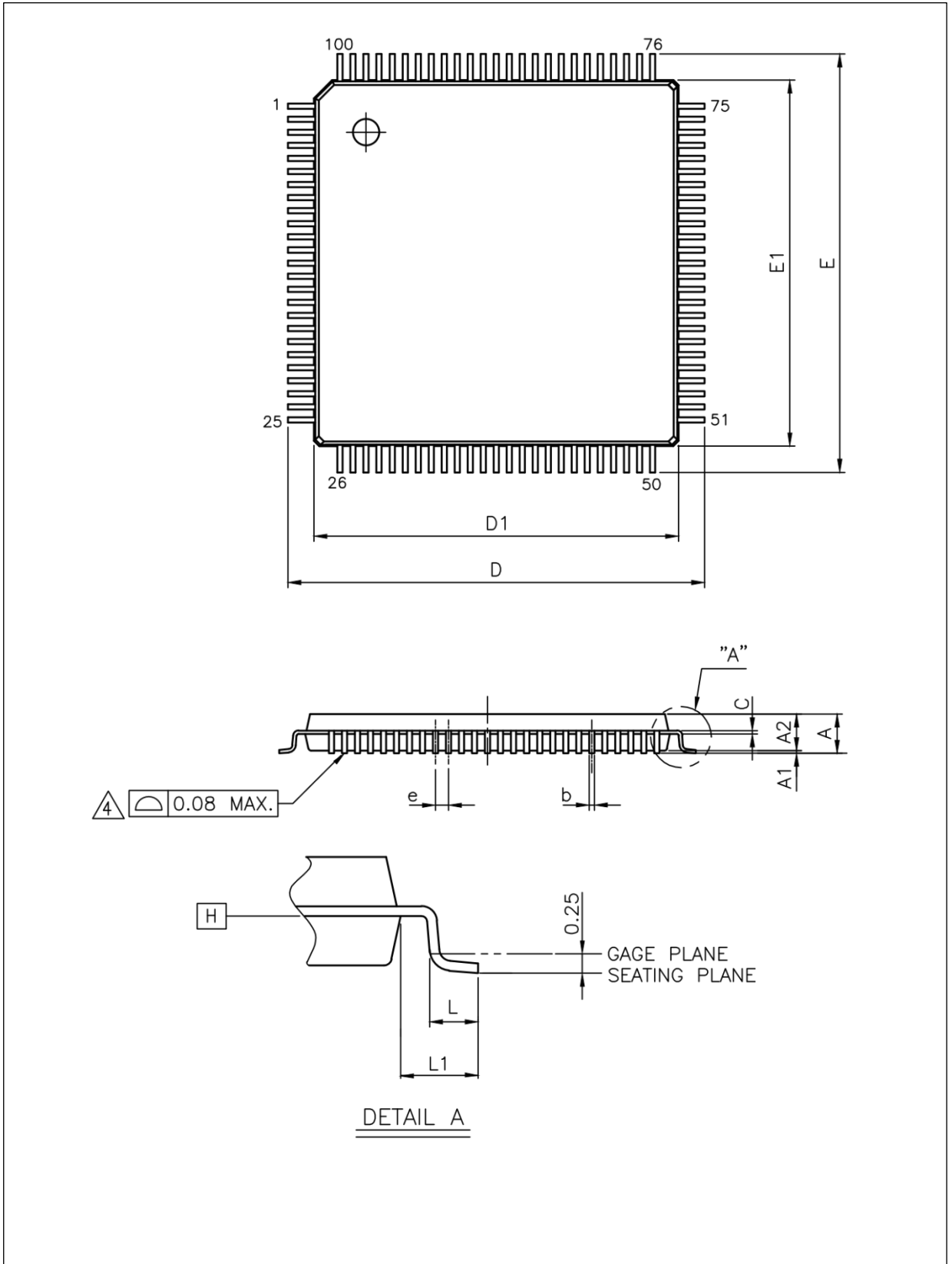**Figure 33. LQFP100 – 14 x 14 mm 100 pin low-profile quad flat package outline**

Table 52. LQFP100 – 14 x 14 mm 100 pin low-profile quad flat package mechanical data

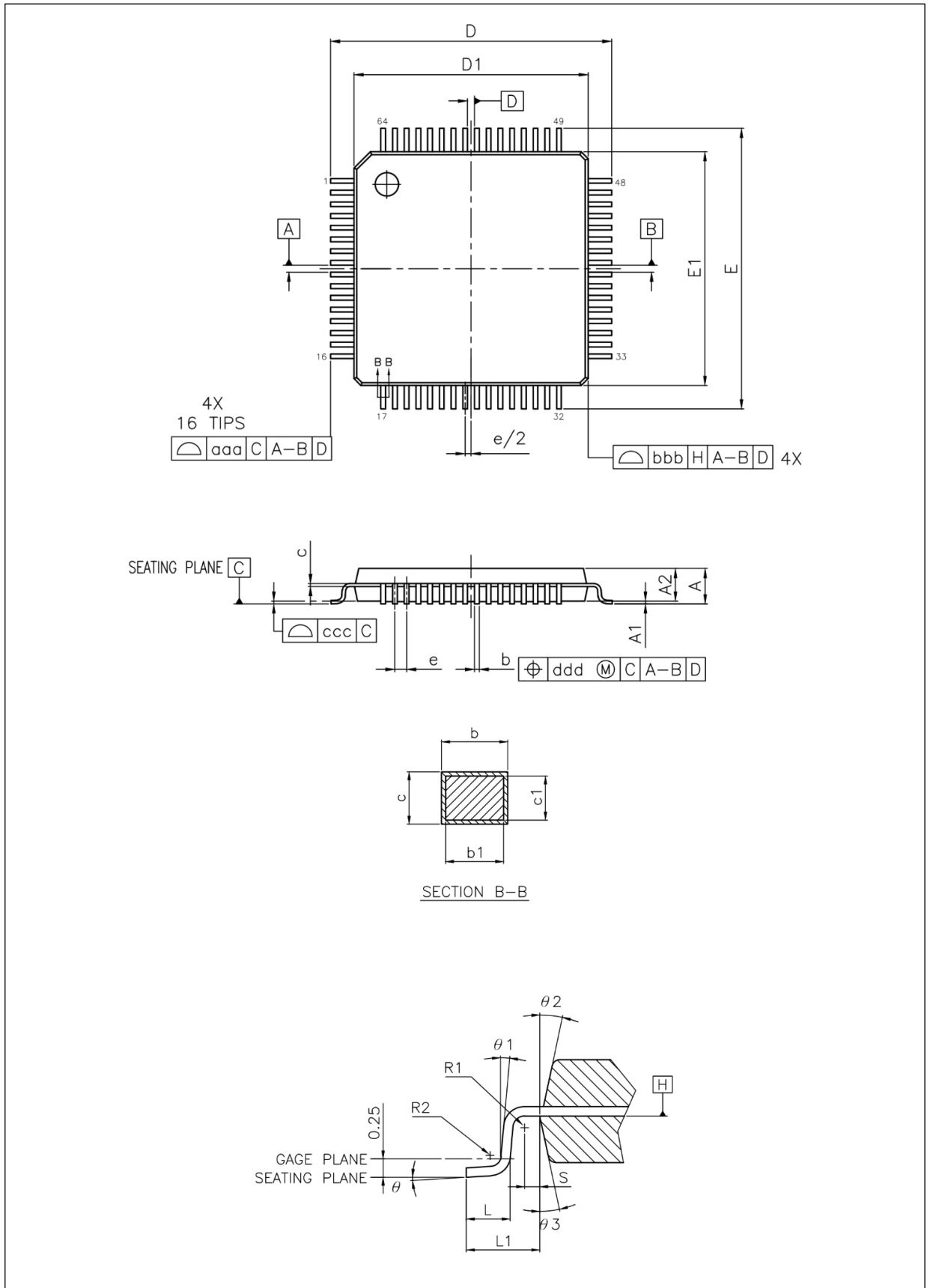| Symbol	Millimeters		
	Min	Typ	Max
A	-	-	1.60
A1	0.05	-	0.15
A2	1.35	1.40	1.45
b	0.17	0.20	0.26
c	0.10	0.127	0.20
D	15.75	16.00	16.25
D1	13.90	14.00	14.10
E	15.75	16.00	16.25
E1	13.90	14.00	14.10
e	0.50 BSC.		
L	0.45	0.60	0.75
L1	1.00 REF.		

5.2   LQFP64 – 10 x 10 mm

Figure 34. LQFP64 – 10 x 10 mm 64 pin low-profile quad flat package outline

Table 53. LQFP64 – 10 x 10 mm 64 pin low-profile quad flat package mechanical data

Symbol	Millimeters		
	Min	Typ	Max
A	-	-	1.60
A1	0.05	-	0.15
A2	1.35	1.40	1.45
b	0.17	0.20	0.27
c	0.09	-	0.20
D	11.75	12.00	12.25
D1	9.90	10.00	10.10
E	11.75	12.00	12.25
E1	9.90	10.00	10.10
e	0.50 BSC.		
Θ	3.5° REF.		
L	0.45	0.60	0.75
L1	1.00 REF.		
ccc	0.08		

5.3   LQFP64 – 7 x 7 mm

Figure 35. LQFP64 – 7 x 7 mm 64 pin low-profile quad flat package outline
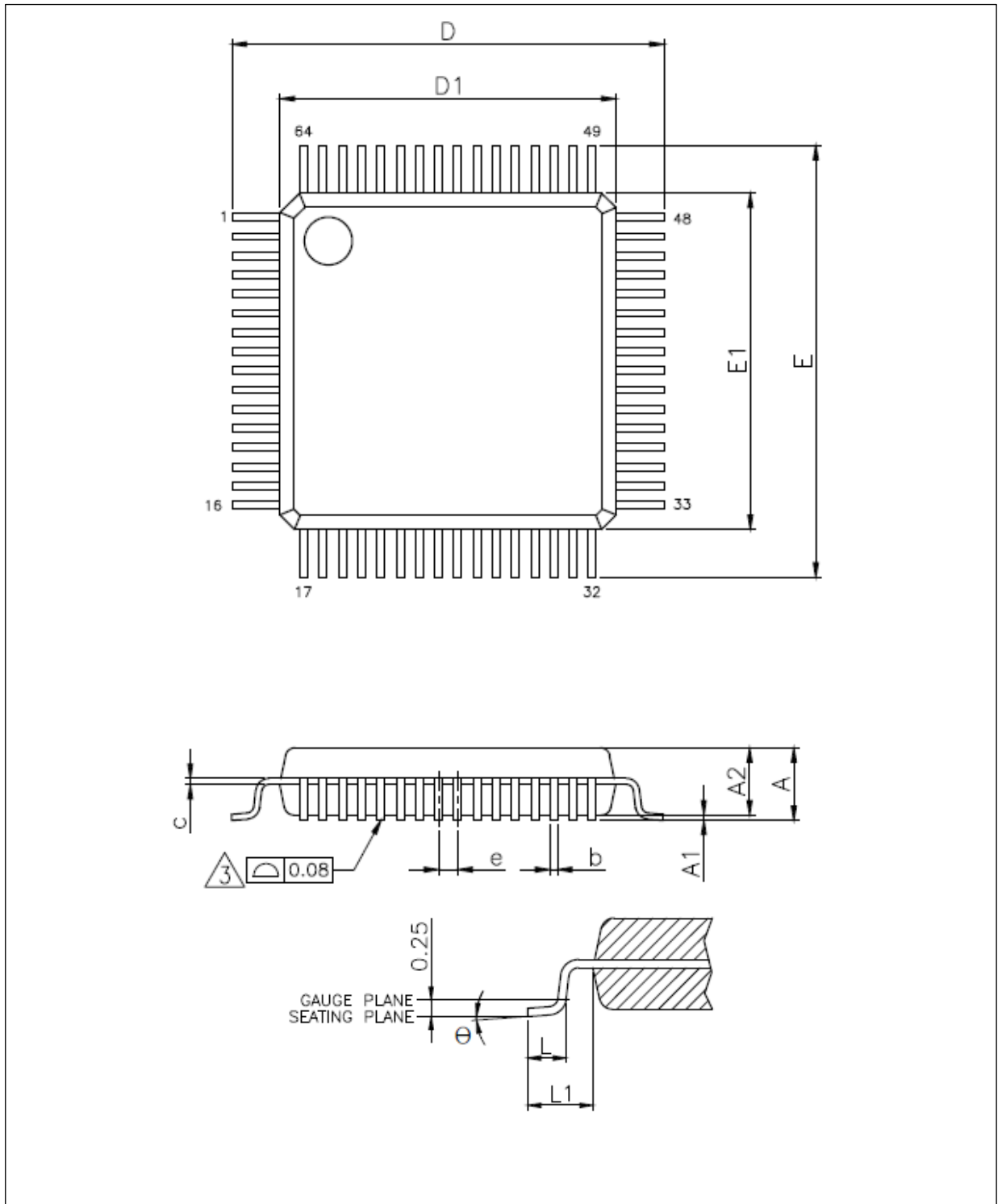
Table 54. LQFP64 – 7 x 7 mm 64 pin low-profile quad flat package mechanical data

Symbol	Millimeters		
	Min	Typ	Max
A	-	-	1.60
A1	0.05	-	0.15
A2	1.35	1.40	1.45
b	0.13	0.18	0.23
c	0.09	-	0.20
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	0.40 BSC.		
Θ	0°	3.5°	7°
L	0.45	0.60	0.75
L1	1.00 REF.		

5.4   LQFP48 – 7 x 7 mm

Figure 36. LQFP48 – 7 x 7 mm 64 pin low-profile quad flat package outline
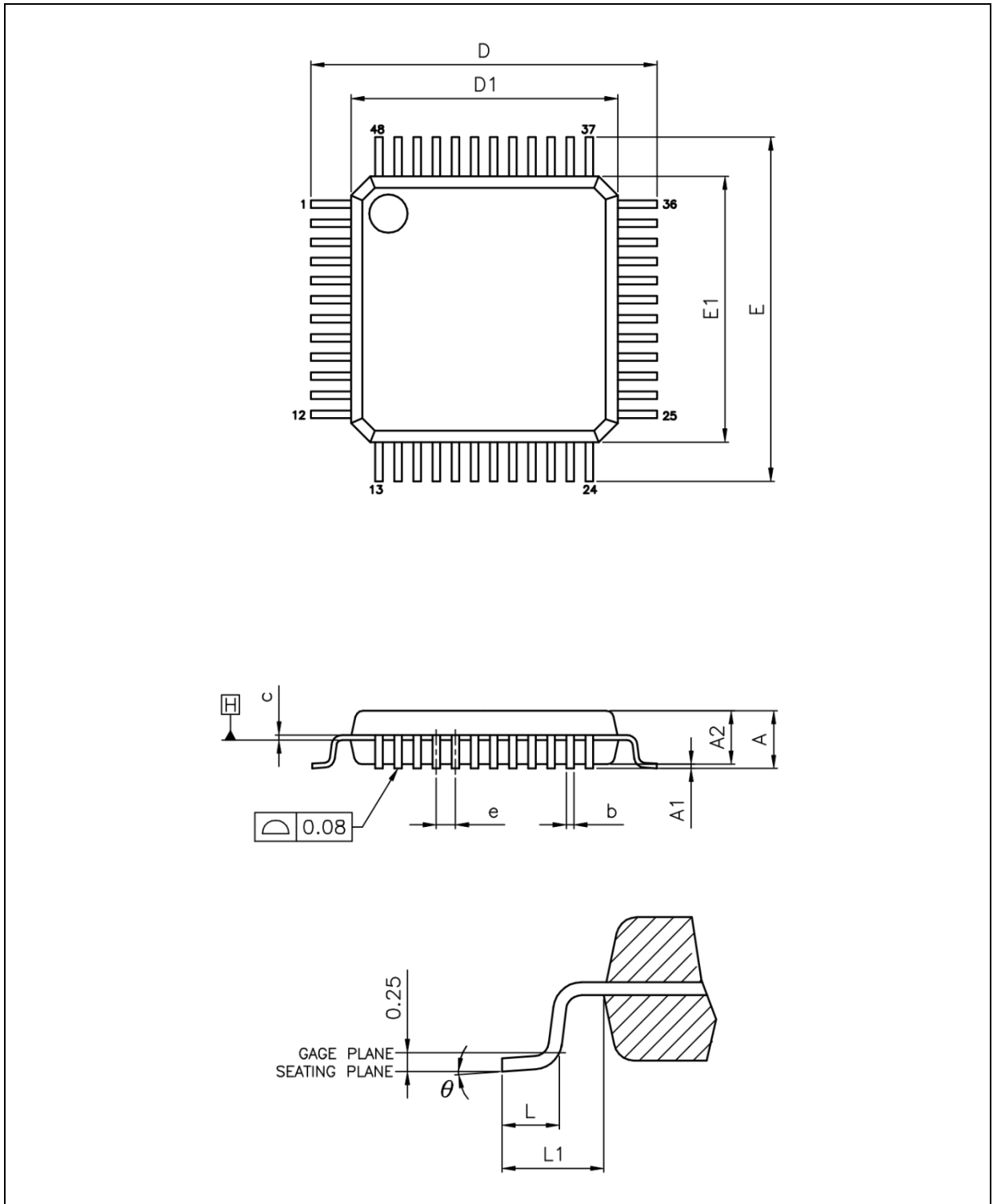
Table 55. LQFP48– 7 x 7 mm 48 pin low-profile quad flat package outline

Symbol	Millimeters		
	Min	**Typ**	**Max**
A	-	-	1.60
A1	0.05	-	0.15
A2	1.35	1.40	1.45
b	0.17	0.22	0.27
c	0.09	-	0.20
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 BSC.		
Θ	0°	3.5°	7°
L	0.45	0.60	0.75
L1	1.00 REF.		

5.5   QFN48 – 6 x 6 mm

Figure 37. QFN48 – 6 x 6 mm 48 pin quad flat no-leads package outline
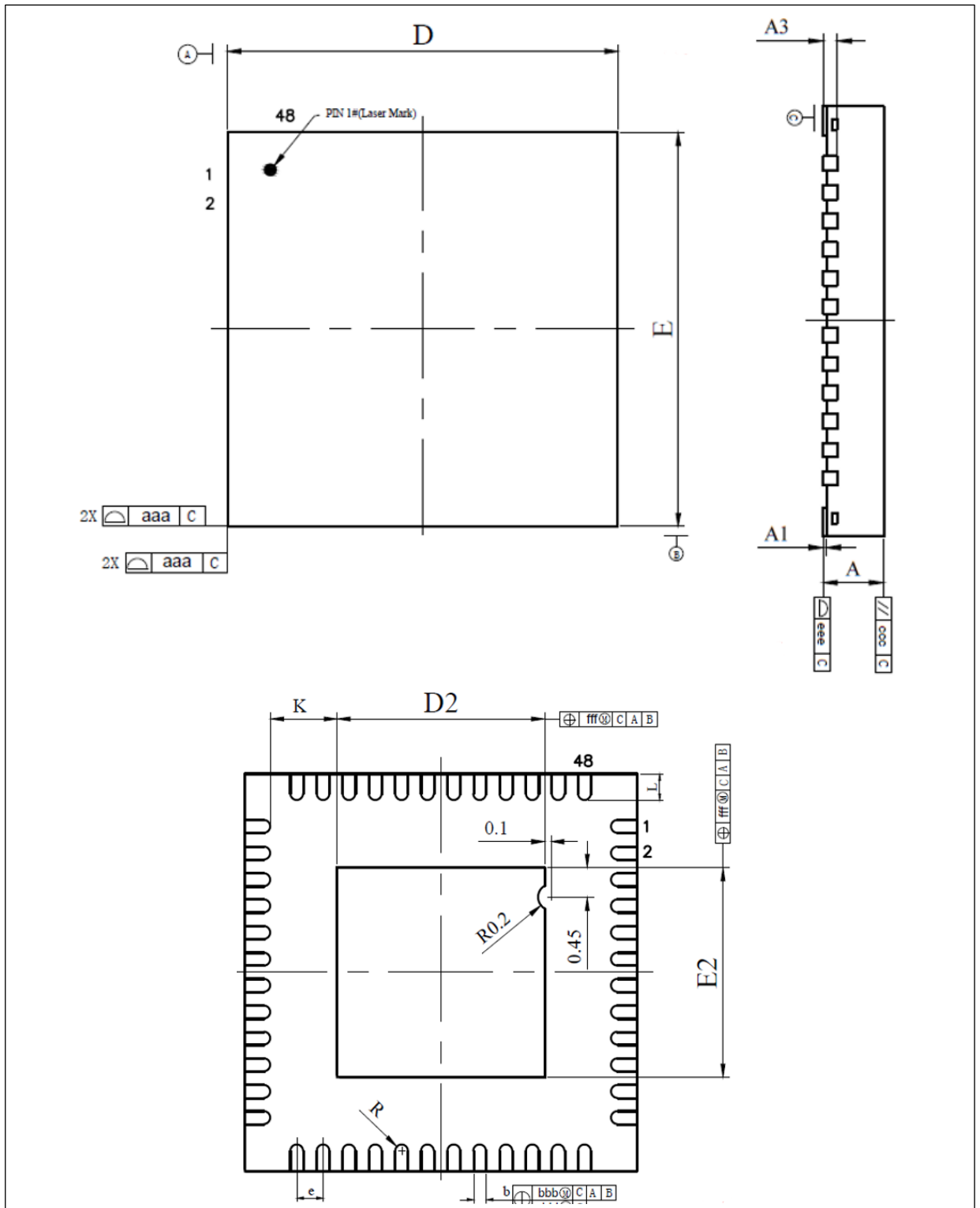
Table 56. QFN48 – 6 x 6 mm 48 pin quad flat no-leads package mechanical data

Symbol	Millimeters		
	Min	Typ	Max
A	0.80	0.85	0.90
A1	0.00	0.02	0.05
A3	0.203 REF.		
b	0.15	0.20	0.25
D	5.90	6.00	6.10
D2	3.07	3.17	3.27
E	5.90	6.00	6.10
E2	3.07	3.17	3.27
e	0.40 BSC.		
K	0.20	-	-
L	0.35	0.40	0.45

5.6 QFN36 – 6 x 6 mm

Figure 38. QFN36 – 6 x 6 mm 36 pin quad flat no-leads package outline

TOP VIEW

SIDE VIEW

BOTTOM VIEW
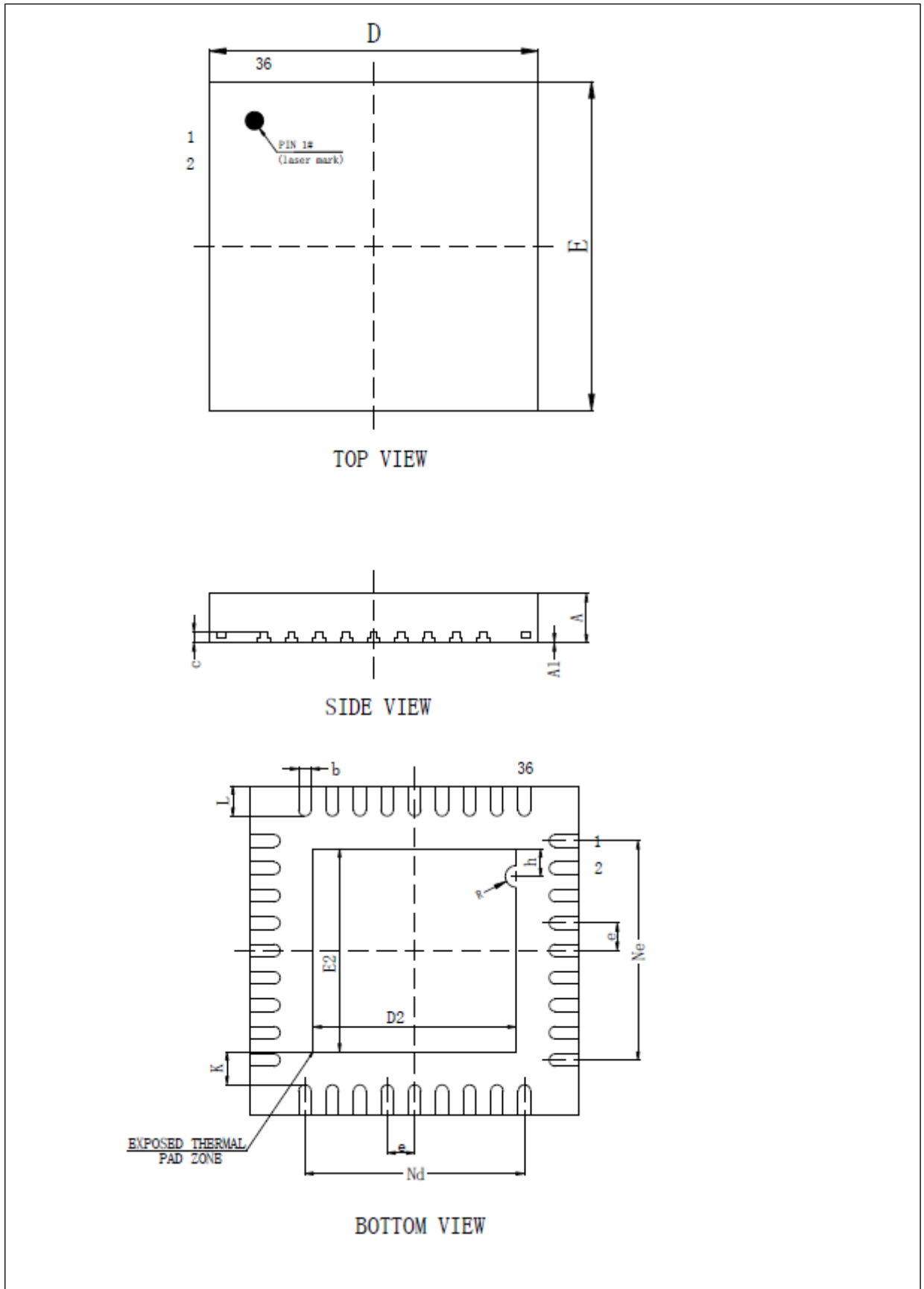
Table 57. QFN36 – 6 x 6 mm 36 pin quad flat no-leads package mechanical data

Symbol	Millimeters		
	Min	**Typ**	**Max**
A	0.85	0.90	0.95
A1	0.00	0.02	0.05
b	0.18	0.23	0.28
c	0.203 REF.		
D	5.90	6.00	6.10
D2	3.60	3.70	3.80
Nd	4.00 BSC.		
E	5.90	6.00	6.10
E2	3.60	3.70	3.80
Ne	4.00 BSC.		
e	0.50 BSC.		
L	0.50	0.55	0.60
K	0.60 REF.		

5.7 QFN32 – 4 x 4 mm

Figure 39. QFN32 – 4 x 4 mm 32 pin quad flat no-leads package outline
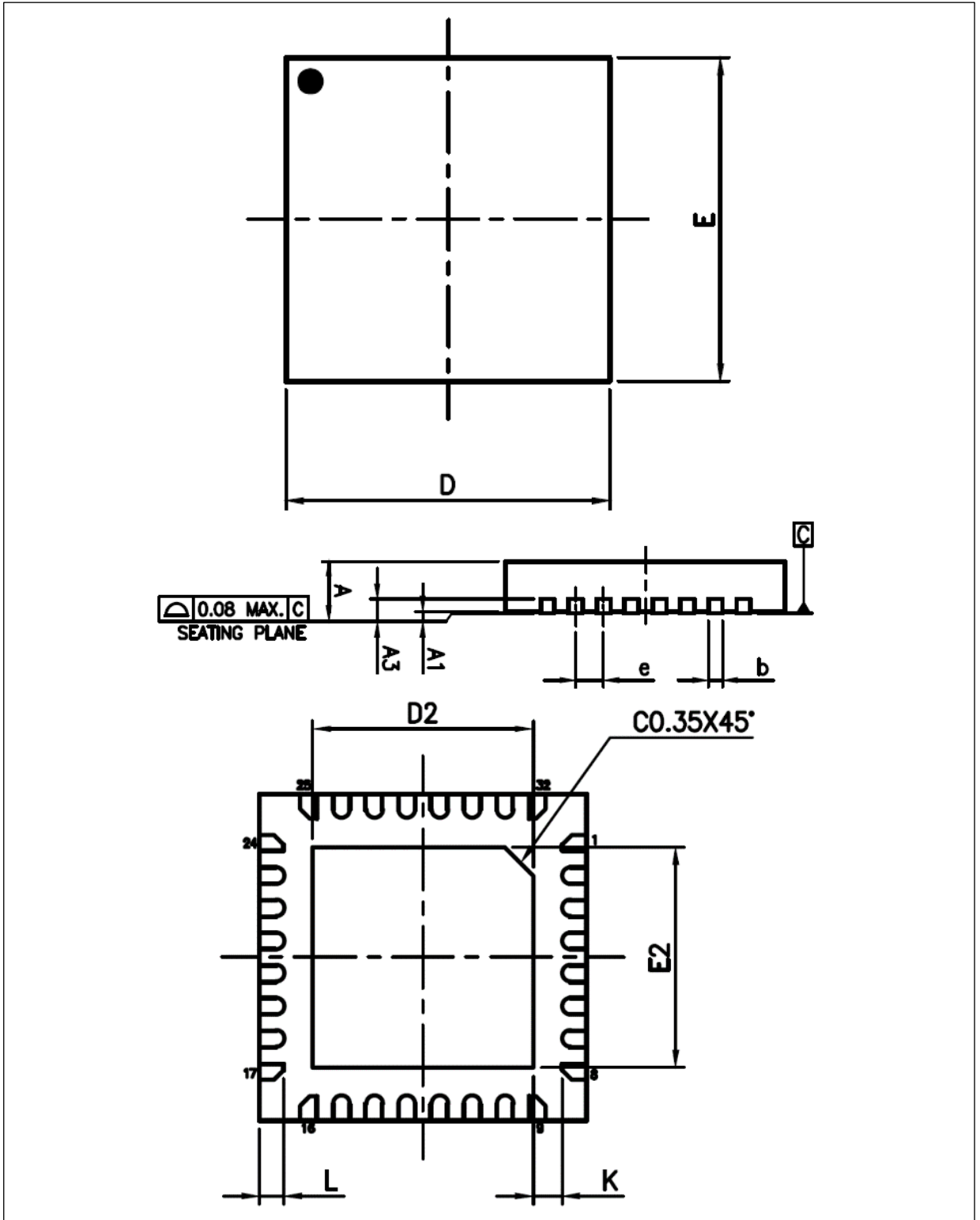
Table 58. QFN32 – 4 x 4 mm 32 pin quad flat no-leads package mechanical data

Symbol	Millimeters		
	Min	Typ	Max
A	0.80	0.85	0.90
A1	0.00	0.02	0.05
A3	0.203 REF.		
b	0.15	0.20	0.25
D	3.90	4.00	4.10
D2	2.65	2.70	2.75
E	3.90	4.00	4.10
E2	2.65	2.70	2.75
e	0.40 BSC.		
K	0.20	-	-
L	0.25	0.30	0.35

5.8   Device marking

Figure 40. Marking example

LQFP100, LQFP64, LQFP48, QFN48, QFN36

QFN32
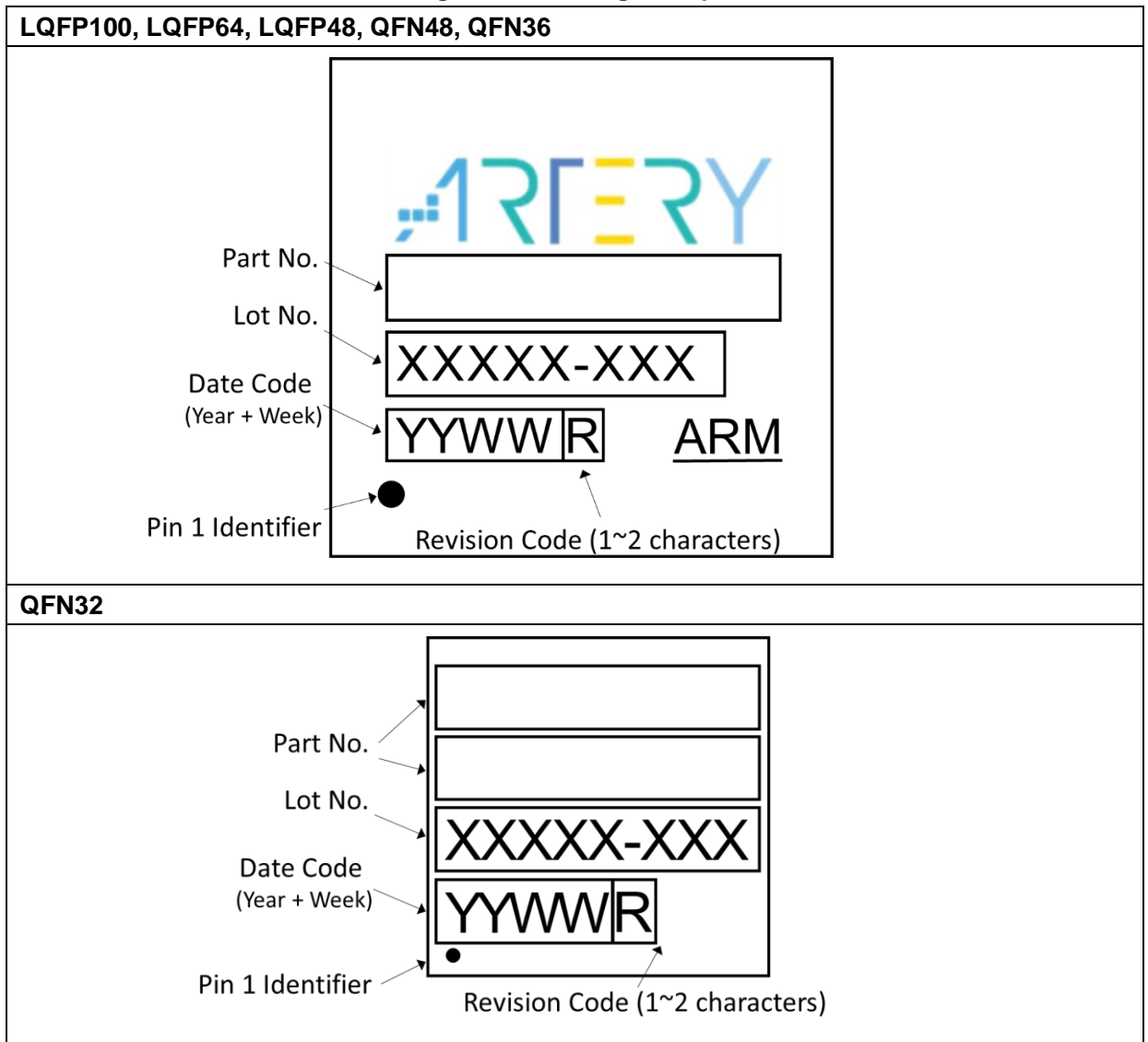
(1) Not to scale.

5.9   Thermal characteristics

Thermal characteristics are calculated based on two-layer board that uses FR-4 material in 1.6mm thickness. They are guaranteed by design, not tested in production.

Table 59. Package thermal characteristics

Symbol	Parameter	Value	Unit
Θ_{JA}	Thermal resistance junction-ambient LQFP100– 14 x 14 mm	75.6	°C/W
	Thermal resistance junction-ambient LQFP64 – 10 x 10 mm	84.0	
	Thermal resistance junction-ambient LQFP64 – 7 x 7 mm	92.4	
	Thermal resistance junction-ambient LQFP48 – 7 x 7 mm	92.4	
	Thermal resistance junction-ambient QFN48 – 6 x 6 mm	57.0	
	Thermal resistance junction-ambient QFN36 – 6 x 6 mm	57.0	
	Thermal resistance junction-ambient QFN32 – 4 x 4 mm	71.3	

6 Part numbering

Table 60. AT32F423 series part numbering

Examples: AT32 F 4 2 3 R C T 7 -7

Product family

AT32 = ARM®-based 32-bit microcontroller

Product type

F = general-purpose

Core

4 = Cortex®-M4

Product series

2 = Value line

Product application

3 = CAN+OTG series

Pin count

V = 100 pins   R = 64 pins

C = 48 pins   T = 36 pins

K = 32 pins

Internal Flash memory size

C = 256 Kbytes of Flash memory

B = 128 Kbytes of Flash memory

8 = 64 Kbytes of Flash memory

Package type

T = LQFP

U = QFN

Temperature range

7 = -40 °C to +105 °C

Package information

-7 = LQFP64 - 7 x 7 mm

-4 = QFN32 - 4 x 4 mm

None = other packages

For a list of available options (speed, package, etc.) or for more information concerning this device, please contact your local Artery sales office.

7 Document revision history

Table 61. Document revision history

Date	Version	Revision note
2023.3.20	2.00	Initial release.
2023.5.22	2.01	Added note (3) for Table 32.
2023.10.17	2.02	1. Modified Table 41 and Table 42. 2. Modified the fourth paragraph in "IMPORTANT NOTICE".

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