ARM®-based 32-bit Cortex®-M4 MCU+FPU with 256 to 1024 KB Flash, sLib, USBFS, Ethernet, 17 timers, 3 ADCs, 21 communication interfaces

Feature

- **Core: ARM® 32-bit Cortex®-M4 CPU with FPU**
  - 240 MHz maximum frequency, with a memory protection unit (MPU), single-cycle multiplication and hardware division
  - Floating point unit (FPU) and
  - DSP instructions
- **Memories**
  - 256 to 1024 KBytes of internal Flash memory
  - sLib: set any part of main Flash as a secure library that is code-excutable but non-readable
  - SPIM interface: interface up to 16 Mbytes of the external SPI Flash
  - Up to 96+128 KBytes of SRAM
  - External memory controller (XMC) with 16-bit data bus, supporting multiplexed PSRAM/NOR and NAND memories
- **XMC as LCD parallel interface, compatible with 8080/6800 modes**
- **Power control (PWC)**
  - 2.6 to 3.6 V power supply
  - Power on reset (POR), low voltage reset (LVR), and power voltage monitoring (PVM)
  - Low power modes: Sleep, Deepsleep, and Standby modes
  - V_{BAT} supply for LEXT, RTC, and forty-two 16-bit battery powered registers (BPR)
- **Clock and reset management (CRM)**
  - 4 to 25 MHz crystal oscillator (HEXT)
  - 48 MHz internal factory-trimmed high speed internal clock (HICK), offers 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 (LEXT)
  - Low speed internal clock (LICK)
- **Analog**
  - 3 x 12-bit 2 MSPS A/D converters, up to 16 input channels
  - Temperature sensor (V_{TS}) and internal reference voltage (V_{INTRV})
  - 2 x 12-bit D/A converters
- **DMA: 14-channel DMA controller**
- **Up to 80 fast GPIOs**
  - all mappable on 16 external interrupts (EXINT)
  - almost all 5 V-tolerant
- **Up to 17 timers (TMR)**
  - Up to 2 x 16-bit motor control PWM advanced timers with dead-time generator and emergency brake
  - Up to 8 x 16-bit + 2 x 32-bit timers, each with 4 IC/OC/PWM or pulse counter and quadrature encoder input
  - 2 x 16-bit basic timers to drive the DAC
  - 2 x watchdog timers (general WDT and windowed WWDT)
  - SysTick timer: a 24-bit downcounter
- **Up to 21 communication interfaces**
  - Up to 3 x I^2C interfaces (SMBus/PMBus)
  - Up to 8 x USARTs (ISO7816 interface, LIN, IrDA capability, modem control)
  - Up to 4 x SPIs (50 Mbit/s), all with I^2S interface multiplexed, I^2S2/I^2S3 support full-duplex
  - Up to 2 x CAN interfaces (2.0B Active)
  - USB 2.0 full speed interface supporting crystal-less
  - Up to 2 x SDIO interfaces
  - 10/100M Ethernet MAC with dedicated DMA and buffer (4 KBytes): IEEE1588 hardware support, MII/RMII available
- **CRC calculation unit, 96-bit unique ID (UID)**
- **Debug mode**
  - Serial wire debug (SWD) and JTAG interface
  - Cortex®-M4 Embedded Trace Macrocell (ETM)
- **Operating temperatures: -40 to +105 °C**
- **Packages**
  - LQFP100 14 x 14 mm
  - LQFP64 10 x 10 mm

Table 1. Device summary

Internal Flash	Part number
1024 KBytes	AT32F407RGT7, AT32F407VGT7
512 KBytes	AT32F407RET7, AT32F407VET7
256 KBytes	AT32F407RCT7, AT32F407VCT7

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1 Descriptions

The AT32F407 is based on the high-performance ARM®Cortex®-M4 32-bit RISC core operating at a frequency of up to 240 MHz. The Cortex®-M4 core features a single-precision Floating Point Unit (FPU) which supports 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) which enhances application security.

The AT32F407 incorporates high-speed embedded memories (up to 1024 KBytes of internal Flash memory, 96+128 KBytes of SRAM), the external SPI Flash (up to 16 MBytes addressing capability), and a wide range of enhanced GPIOs 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-excutable only.

The AT32F407 offers three 12-bit ADCs, two 12-bit DACs, eight general-purpose 16-bit timers plus two general-purpose 32-bit timers, and up to two PWM timers for motor control. It supports standard and advanced communication interfaces: up to three I^2Cs, four SPIs (all multiplexed as I^2Ss), two SDIOs, eight USARTs/UARTs, an USBFS, two CANs, and an Ethernet MAC.

The AT32F407 operates in the -40 to +105 °C temperature range, from a 2.6 to 3.6 V power supply. A comprehensive set of power-saving mode allows the design of low-power application.

The AT32F407 offers devices in different package types. They are fully pin-to-pin, software and functionality compatible among the AT32F407 series devices, except that the configurations of peripherals are not completely identical, depending on the package types.

Table 2. AT32F407 features and peripheral counts

Part Number		AT32F407xxT7					
		RC	RE	RG	VC	VE	VG
CPU frequency (MHz)		240					
Int. Flash(1)(2)	ZW (KBytes)	256	256	256	256	256	256
	NZW (KBytes)	0	256	768	0	256	768
	Total (KBytes)	256	512	1024	256	512	1024
SRAM(2) (KBytes)		96 + 128					
Timers	Advanced	2			2		
	32-bit general-purpose	2			2		
	16-bit general-purpose	8			8		
	Basic	2			2		
	SysTick	1			1		
	WDT	1			1		
	WWDT	1			1		
	RTC	1			1		
Communication	I^2C	3			3		
	SPI/I^2S	4/4 (2 full-duplex)			4/4 (2 full-duplex)		
	USART + UART	4 + 4			4 + 4		
	SDIO	2			2		
	USBFS device	1			1		
	CAN	2			2		
	Ethernet MAC	1			1		
Analog	12-bit ADC numbers/channels	3					
		16			16		
	12-bit DAC numbers	2					
XMC		1(3)			1		
SPIM(4)		1 ch / up to 16 MB					
GPIO		51			80		
Operating temperatures		-40 to +105 °C					
Packages		LQFP64 10 x 10 mm			LQFP100 14 x 14 mm		

(1) ZW = zero wait-state, up to SYSCLK 240 MHz
NZW = non-zero wait-state

(2) The internal Flash and SRAM sizes are configurable with User System Data. Take the AT32F407VGT7 as an example, on which the Flash/SRAM can be configured into two options below:
- ZW: 256 KBytes, NZW: 768 KBytes, SRAM: 96 KBytes;
- ZW: 128 KBytes, NZW: 896 KBytes, SRAM: 224 KBytes.

(3) For LQFP64 package, XMC only supports the LCD panel with 8-bit mode.

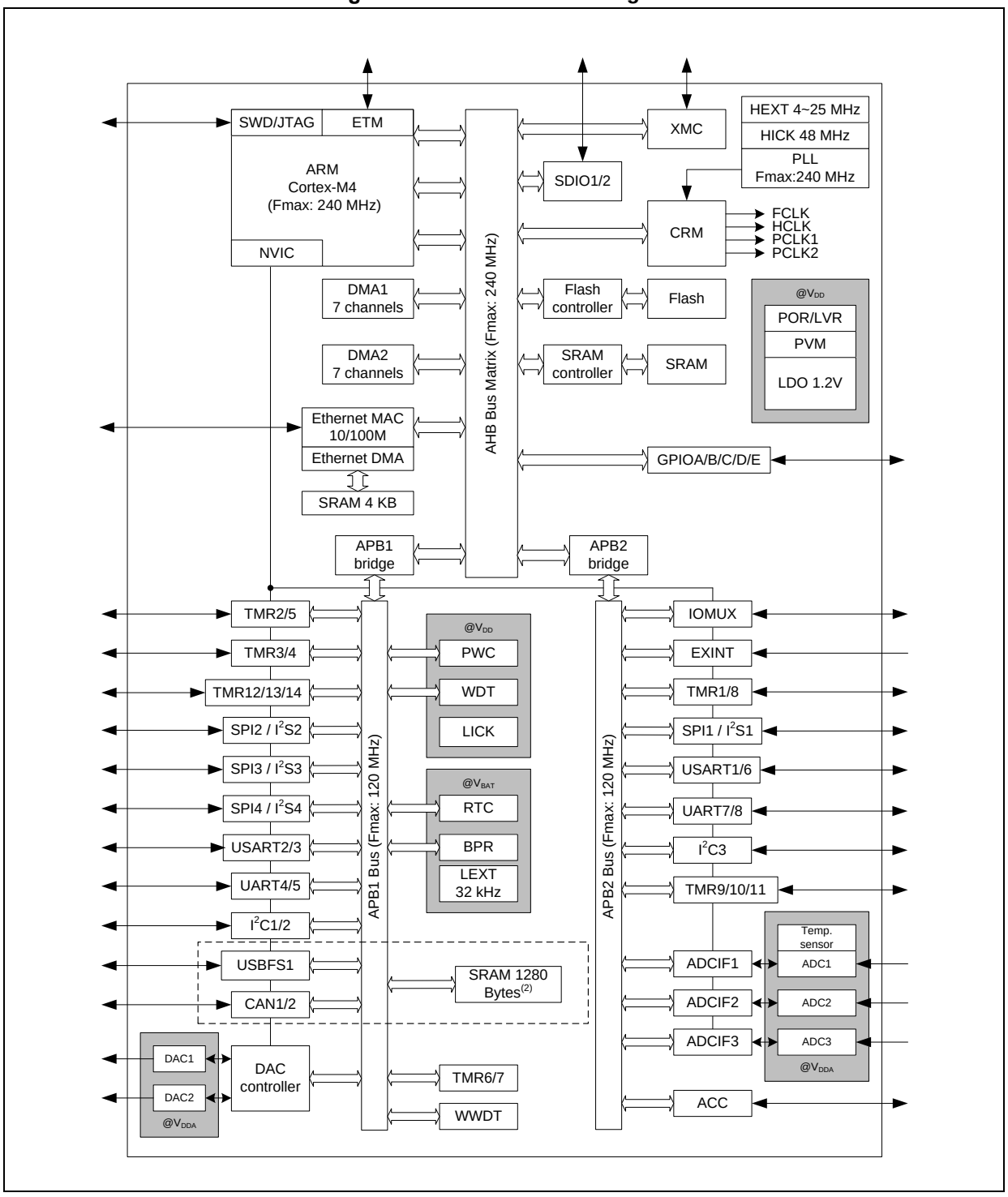
(4) SPIM = External SPI Flash memory extension, for both program execution and data storage with encryption capability.

2 Functionality overview

2.1 ARM® Cortex®-M4 with FPU

The ARM® Cortex®-M4 processor is the latest generation of ARM® processors for embedded systems. It is a 32-bit RISC processor featuring exceptional code efficiency, outstanding computational performance and advanced interrupt response mechanism. The processor supports a set of DSP instructions which enable efficient signal processing and complex algorithm execution. Its single-precision FPU (floating point unit) speeds up floating point calculation while avoiding saturation. *Figure 1* shows the general block diagram of the AT32F407.

Figure 1. AT32F407 block diagram



2.2 Memory

2.2.1 Internal Flash memory

Up to 1024 KBytes of embedded Flash is available for storing programs and data. Any part of the embedded Flash memory can be protected by the sLib (security library), a security area that is code-excutable only but non-readable. “sLib” is a mechanism designed to protect the intelligence of solution venders and facilitate the second-level development by customers.

The AT32F407 provides extra interface called SPIM (SPI memory), which interfaces the external SPI Flash memory for program and data storage. With up to16 MBytes addressing capability, SPIM can be used as an extensive Flash memory Bank 3. Besides, SPIM can be encrypted through the User System Data block to ensure data security, and the encryption range can be configured through the corresponding control register.

There is another 18-KByte boot code area in which the boodloader is stored.

A User System Data block is included, which is used to configure the hardware behaviors such as read/erase/write protection and watchdog self-enable. User System Data allows to set erase/write and read protection individually.

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 in turn be divided up into 8 subareas. The protection area sizes are between 32 bytes and the entire 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

The device offers up to 224 KBytes of embedded SRAM that is accessible (read/write) at CPU clock speed with 0 wait states.

2.2.4 External memory controller (XMC)

AT32F407 embeds an XMC block (external memory controller). It has two Chip Select outputs supporting the following modes: multiplexed PSRAM/NOR and 16-bit/8-bit NAND memory.

Main features:

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

The XMC can be configured to interface with most graphic LCD controllers. It supports the Intel 8080 and Motorola 6800 modes.

2.3 Interrupts

2.3.1 Nested vectored interrupt controller (NVIC)

The AT32F407 embed a nested vectored interrupt controller able to manage 16 priority levels and handle maskable interrupt channels plus the 16 interrupt lines of the Cortex®-M4 with FPU. 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 with NVIC, consists of 20 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} = 2.6～3.6 V: an external power supply for GPIOs and the internal block such as regulator (LDO), provided externally through V_{DD} pins.
- V_{DDA} = 2.6～3.6 V: an external analog power supply for ADC and DAC. V_{DDA} and V_{SSA} must be the same voltage potential as V_{DD} and V_{SS}, respectively.
- V_{BAT} = 1.8～3.6 V: power supply for V_{BAT} domain through the external battery or super capacitor, or from V_{DD} when the external battery or super capacitor is not present. V_{BAT} (through power switch) supplies for RTC, external crystal 32 kHz (LEXT), and battery powered registers (BPR) when V_{DD} is not present.

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

The device has an integrated power-on reset (POR)/low voltage reset (PDR) circuitry. It is always active, and allows proper operation starting from/down to 2.6 V. The device remains in reset mode when V_{DD} is 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 can be 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 operation modes: normal, low-power, and power down.

- Normal mode: It is used in Run/Sleep mode and in the Deepsleep mode;
- Low-power mode: It can be used in the Deepsleep mode;
- Power down mode: It is used in Standby mode: The 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 its normal mode after reset.

2.4.4 Low-power modes

The AT32F407 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 the lowest power consumption while retaining the content of SRAM and registers. All clocks in the LDO domain are stopped, disabling the PLL, the HICK clock, and the HEXT crystal. The voltage regulator 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, the RTC alarm, the USBFS or the Ethernet MAC wakeup.

- **Standby mode**

  The Standby mode is used to achieve the lowest power consumption. The internal voltage regulator is switched off so that the entire LDO 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 RTC register, the BPR domain register and Standby circuitry.

  The device leaves Standby mode when an external reset (NRST pin), a WDT reset, a rising edge on the WKUP pin, or an RTC alarm occurs.

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

2.5 Boot modes

At startup, boot pins are used to select one of three boot options:

- Boot from the internal Flash. For the AT32F407xG, user has an option to boot from any of two memory banks. By default, boot from Flash memory Bank 1 is selected. User can choose to boot from Flash memory Bank 2 by setting the User System Data area;
- Boot from boot code area;
- Boot from embedded SRAM.

The bootloader is stored in boot code area. It is used to reprogram the Flash memory through USART1, USART2, or USBFS1. If SPIM_IO0/1 pins are mapped on USBFS1 pins, the Flash memory Bank 3 cannot be reprogrammed through USBFS1. *Table 3* provides AT32F407 pin configurations related to the Bootloader.

Table 3. Bootloader pin configurations

Interface	Part number	Pin
USART1	All part numbers	PA9: USART1_TX PA10: USART1_RX
USART2	AT32F407VGT7	PD5: USART2_TX (remapped) PD6: USART2_RX (remapped)
	Part numbers except AT32F407VGT7	PA2: USART2_TX PA3: USART2_RX
USBFS1	All part numbers	PA11: USBFS1_D- PA12: USBFS1_D+

2.6 Clocks

On reset, the internal 48 MHz clock (HICK), aftering being divided by 6 (that is 8 MHz), is selected as the default CPU clock. The application can select an external 4 to 25 MHz clock (HEXT) as a system clock. This clock can be monitored for failure. If 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 take the same action once HEXT fails when it is used as the source of PLL.

Several prescalers are are available to allow the configuration of the AHB and the APB (APB1 and APB2) frequency. The maximum frequency of the AHB domain is 240 MHz. The maximum allowed frequency of the APB domains are 120 MHz.

The AT32F407 embeds an automatic clock calibration (ACC) block, which calibrates the internal 48 MHz HICK clock, assuring the most precise accuracy of the HICK over the full 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), as input (with or without pull-up or pull-down), or as mutilple function. Most of the GPIO pins are shared with digital or analog multiple functions. All GPIOs are high current-capable.

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

2.8 Remap capability

This feature allows the use of a maximum number of peripherals in a given application. Indeed, alternate functions are available not only on the default pins but also on other specific pins onto which they are remappable. This has the advantage of making board design and port usage much more flexible.

For details refer to *Table 6*; it shows the list of remappable multiple functions and the pins onto which they can be remapped. See the AT32F407 reference manual for software considerations.

2.9 Direct Memory Access Controller (DMA)

The device features two flexible 14-channel general-purpose DMAs (7 channels for DMA1 and 7 channels for DMA2). They are able to manage memory-to-memory, peripheral-to-memory, and memory-to-peripheral transfers. The two DMA controllers support 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 request logic, 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^2C, USART, advanced, general-purpose, and basic timers TMRx, DAC, I^2S, SDIO, and ADC.

2.10 Timers (TMR)

The AT32F407 device includes two advanced timers, ten 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

Timer	Counter resolution	Counter type	Prescaler factor	DMA request generation	Capture/compare channels	Complementary outputs
TMR1, TMR8	16-bit	Up, down, up/down	Any integer between 1 and 65536	Yes	4	Yes
TMR2, TMR5	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	Any integer between 1 and 65536	No	2	No
TMR10, TMR11 TMR13, TMR14	16-bit	Up	Any integer between 1 and 65536	No	1	No
TMR6, TMR7	16-bit	Up	Any integer between 1 and 65536	Yes	0	No

2.10.1 Advanced timers (TMR1 and TMR8)

The two advanced timers (TMR1 and TMR8) can each be seen three-phase PWM generators multiplexed on 6 channels. They have complementary PWM outputs with programmable dead-time insertion. They can also be seen as a complete general-purpose timer. Their 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 the TMRx timer. If configured as the 16-bit PWM generator, it has full modulation capability (0-100%).

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

Many features are shared with those of the general-purpose timers which have the same architecture. The advanced timers can therefore work together with the general-purpose timers via the timer link feature for synchronization or event chaining.

2.10.2 General-purpose timers (TMRx)

There are 10 synchronizable general-purpose timers embedded in the AT32F407.

- **TMR2, TMR3, TMR4, and TMR5**

  The AT32F407 has four full- featured general-purpose timers: TMR2, TMR3, TMR4, and TMR5.The TMR2 and TMR5 timers are based on a 32-bit auto-reload up/down counter and a 16-bit prescaler. The TMR3 and TMR4 timers are based on a 16- bit auto-reload up/down counter and a 16-bit prescaler. They can offer four independent channels on the largest package. Each channel can be used for input capture/output compare, PWM or one-cycle mode output.

  These general-purpose timers can work together, or with the advanced timers via the timer link feature for synchronization or event chaining. In debug mode, their counters can be frozen. Any of these general-purpose timers can be used to generate PWM outputs. Each timer has individual DMA request mechanism.

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

- **TMR9 and TMR12**

  TMR9 and TMR12 are based on a 16-bit auto-reload upcounter, a 16-bit prescaler, and two independent channels for input capture/output compare, PWM, or one-cycle mode output. They can be synchronized with the TMR2, TMR3, TMR4, and TMR5 full-featured general-purpose timers. They can also be used as simple time bases.

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

  These timers are based on a 16-bit auto-reload upcounter, a 16-bit prescaler, and one independent channels for input capture/output compare, PWM, or one-cycle mode output. They can be synchronized with the TMR2, TMR3, TMR4, and TMR5 full-featured general-purpose timers. They can also be used as simple time bases.

2.10.3 Basic timers (TMR6 and TMR7)

These two timers are mainly used for DAC trigger generation. Each of them can also be used as a generic 16-bit time base.

2.10.4 SysTick timer

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

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

2.11 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-enabling or not through the User System Data configuration. The counter can be frozen in debug mode.

2.12 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 a problem occurs. It is clocked from the main clock. It has an early warning interrupt capability and the counter can be frozen in debug mode.

2.13 Real-time clock (RTC) and battery powered registers (BPR)

The RTC and the battery powered registers (BPR) are supplied through a power switch that is powered either from V_{DD} When present or from the V_{BAT} pin. The battery powered registers are forty-two 16-bit registers used to store 84 bytes of user application data. RTC and BPR are not reset by a system or power reset, and they are not reset when the device wakes up from the Standby mode.

The real-time clock provides a continuous-running counter. The RTC provides lock calendar function, and provides an alarm interrupt and periodic interrupt functions through software. It is clocked by a 32.768 kHz external oscillator (LEXT), the internal low-power clock (LICK), or the high-speed external clock (HEXT) divided by 128. The RTC can be calibrated using a divided-by-64 output of TAMPER pin to compensate for any natural quartz deviation. The RTC features a 32-bit programmable counter that allows long time measurement with the help of the compare register. A 20-bit prescaler is used for the time base clock and is by default configured to generate a time base of 1 second from a clock at 32.768 kHz.

2.14 Communication interfaces

2.14.1 Serial peripheral interface (SPI) / Inter-integrated sound interface (I^2S)

There are up to four SPIs are able to communicate up to 50 Mbits/s in slave and master modes in full-duplex and simplex communication modes. The 3-bit prescaler generates eight master mode frequencies and 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.

Four standard I^2S interfaces (multiplexed with SPI) are available, that can be operated in master or slave mode in half-duplex mode and I^2S2 and I^2S3 also in full duplex mode. These interfaces can be configured to operate with 16/24/32 bit resolution, as input or output channels. Audio sampling frequencies from 8 kHz up to 192 kHz are supported. When I^2S configured in master mode, the master clock can be output to the external DAC/CODEC at 256 times the sampling frequency. All I^2Ss can be served by the DMA controller.

2.14.2 Universal synchronous / asynchronous receiver transmitters (USART)

The AT32F407 embeds four universal synchronous/asynchronous receiver transmitters (USART1, USART2, USART3, and USART6) and 4 universal asynchronous receiver transmitters (UART4, UART5, UART7, and UART8).

These eight interfaces provide asynchronous communication, IrDA SIR ENDEC support, multiprocessor communication mode, single-wire half-duplex communication mode, and have LIN Master/Slave capability.These eight interfaces are able to communicate at speeds of up to 7.5 Mbit/s.

USART1, USART2, and USART3 provide hardware management of the CTS and RTS signals. USART1, USART2, USART3, and USART6 also provide Smart Card mode (ISO 7816 compliant) and SPI-like communication capability. All interfaces can be served by the DMA controller.

Table 5. USART / UART feature comparison

USART/UART name	USART1	USART2	USART3	UART4	UART5	USART6	UART7	UART8
Hardware flow control for modem	Yes	Yes	Yes	-	-	-	-	-
Continuous communication using DMA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Multiprocessor communication	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Synchronous mode	Yes	Yes	Yes	-	-	Yes	-	-
Smartcard mode	Yes	Yes	Yes	-	-	Yes	-	-
Single-wire half-duplex communication	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IrDA SIR ENDEC blcok	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LIN mode	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

2.14.3 Inter-integrated-circuit interface (I^2C)

Up to three I^2C bus interfaces can operate in multi-master and slave modes. They support standard mode (max. 100 kHz) and fast mode (max. 400 kHz). The I^2C bus frequency can be increased up to 1 MHz. For more details, please contact your local Artery sales office for technical support.

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

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

2.14.4 Secure digital input / output interface (SDIO)

Two SD/SDIO/MMC host interfaces are available to support MultiMediaCard System Specification Version 4.2 in three different data bus modes: 1-bit (default), 4-bit and 8-bit. The interface allows data transfer at up to 48 MHz in 8-bit mode, and is compliant with SD Memory Card Specifications Version 2.0.

The two different data bus modes supported in the SDIO Card Specification Version 2.0 are: 1-bit (default) and 4-bit.

The current version supports only one SD/SDIO/MMC4.2 card at any one time and a stack of MMC4.1 or previous.

In addition to SD/SDIO/MMC/eMMC, this interface is fully compliant with the CE-ATA digital protocol Rev1.1.

2.14.5 Controller area network (CAN)

Two CANs are compliant with specifications 2.0A and B (active) with a bit rate up to 1 Mbit/s. It can receive and transmit standard frames with 11-bit identifiers as well as extended frames with 29-bit identifiers. Each CAN has three transmit mailboxes, two receive buffer areas with 3 stages, and 14 scalable filter banks.

2.14.6 Universal serial bus full-speed (USBFS)

AT32F407 embeds a USB device peripheral compatible with the USB full-speed 12 Mbit/s. It has software-configurable endpoint setting and suspend/resume support. The dedicated 48 MHz clock is generated from the internal main PLL or direct from the 48 MHz HICK.

2.14.7 Ethernet MAC interface (EMAC)

The AT32F407 devices provide an IEEE-802.3-2002-compliant media access controller (MAC) for Ethernet LAN communications through an industry-standard media-independent interface (MII) or a reduced media-independent interface (RMII). The AT32F407 requires an external physical interface device (PHY) to connect to the physical LAN bus (such as twisted-pair and fibers). The PHY is connected to the AT32F407 MAC port using as many as 17 signals (MII) or 9 signals (RMII) and can be clocked by the 25 MHz (MII) or 50 MHz (RMII) output from the AT32F407.

The EMAC includes the following features:

- 10 and 100 Mbit/s rates
- Dedicated DMA controller allowing high-speed transfers between the dedicated SRAM and the descriptors
- Tagged MAC frame (VLAN support)

- Half-duplex (CSMA/CD) and full-duplex operation
- MAC control sublayer (control frames)
- 32-bit CRC generation and removal
- Several address filtering modes for physical and multicast address (multicast and group addresses)
- 32-bit status code for each transmitted or received frame
- Internal FIFOs to buffer transmit and receive frames. The transmit FIFO and the receive FIFO are both 2 Kbytes each, that is 4 KBytes in total
- Hardware PTP (precision time protocol) in line with IEEE 1588, with the timestamp comparator connected to the TMR2 trigger input
- Interrupt trigger when system time becomes greater than target time

2.15 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 and a fixed generator polynomial. Among other applications, CRC-based techniques are used to verify data transmission or storage integrity.

2.16 Analog-to-digital converter (ADC)

Three 12-bit analog-to-digital converters are embedded into AT32F407 devices and they share up to 16 external channels, performing conversions in single or sequence modes. In sequence mode, automatic conversion is performed on a selected group of analog inputs.

Additional logic functions embedded in the ADC interface allow:

- Simultaneous sample and hold
- Interleaved sample and hole
- Single sample

The ADC can be served by the DMA controller.

The voltage monitoring 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 events generated by the general-purpose timers (TMRx) and the advanced timers (TMR1 and TMR8) can be internally connected to the ADC regular trigger and injection trigger, respectively, to allow the application to synchronize A/D conversion and timers.

2.16.1 Temperature sensor (V_{TS})

The temperature sensor has to generate 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.

2.16.2 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.

2.17 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.

The DAC has the following features:

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

Several DAC trigger inputs are availabel in the AT32F407. DAC outputs can be triggered through the timer update output. The timer update outpu can also be connected to different DMA channels.

2.18 Debug

2.18.1 Serial wire (SWD) / JTAG port

The ARM® SWJ-DP interface is embedded, consisting of a serial wire debug port and JTAG. It enables either a serial wire debug or a JTAG probe to be connected to the target for programming and debug operation. The JTAG TMS and TCK pins are shared respectively with SWDIO and SWCLK.

2.18.2 Embedded Trace Macrocell (ETM)

The ARM® Embedded Trace Macrocell (ETM) provides a greater visibility of the instruction and data flow inside the CPU core by streaming compressed data at a very high rate from the AT32F407 through a small number of ETM pins to an external hardware trace port analyzer (TPA) device. The TPA is connected to a host computer using USB or any other high-speed channel. Real-time instruction and data flow activity can be recorded and then formatted for display on the host computer that runs debugger software. TPA hardware is commercially available from common development tool vendors. It operates with third party debugger software tools.

3 Pin functional definitions

Figure 2. AT32F407 LQFP100 pinout

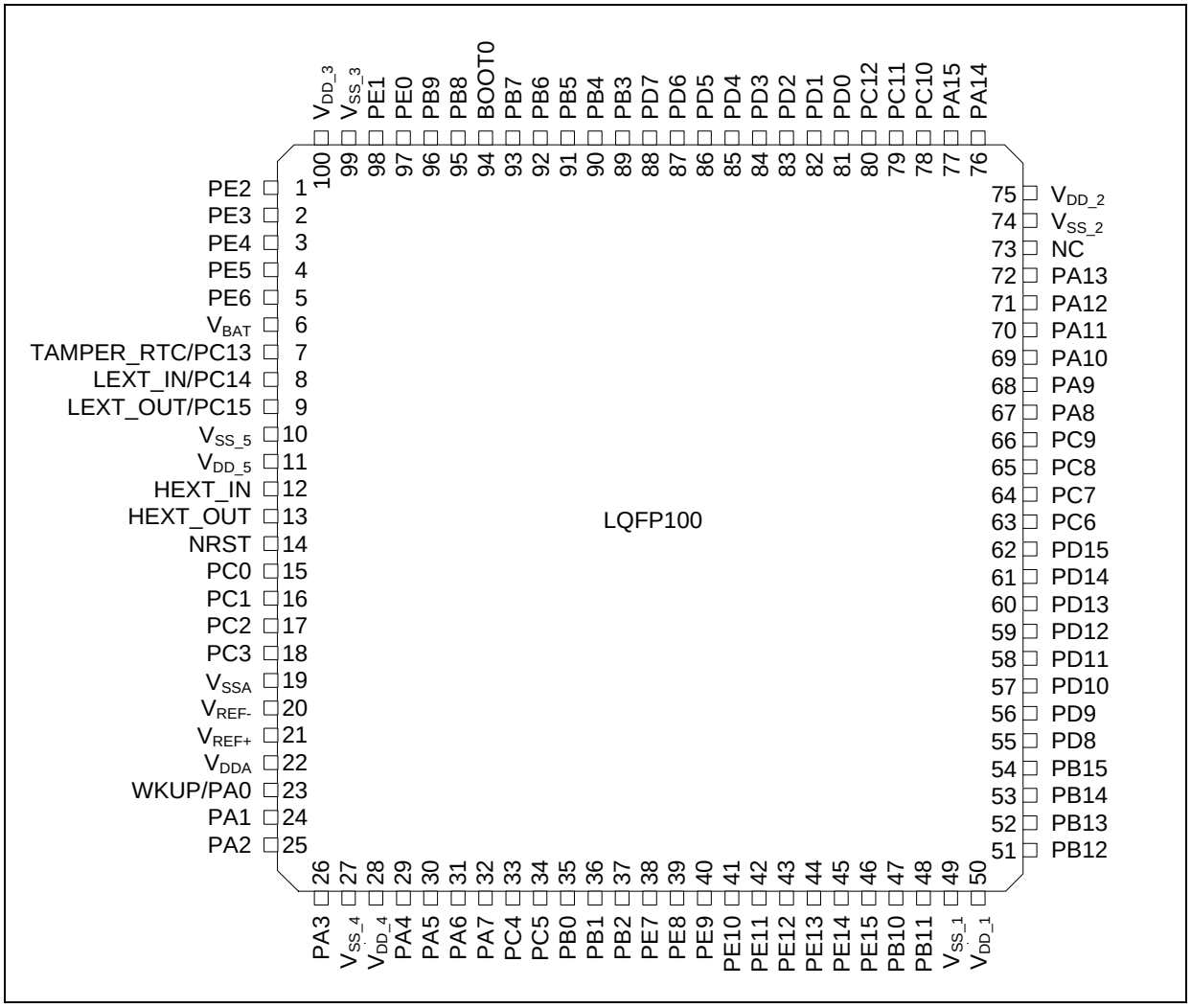
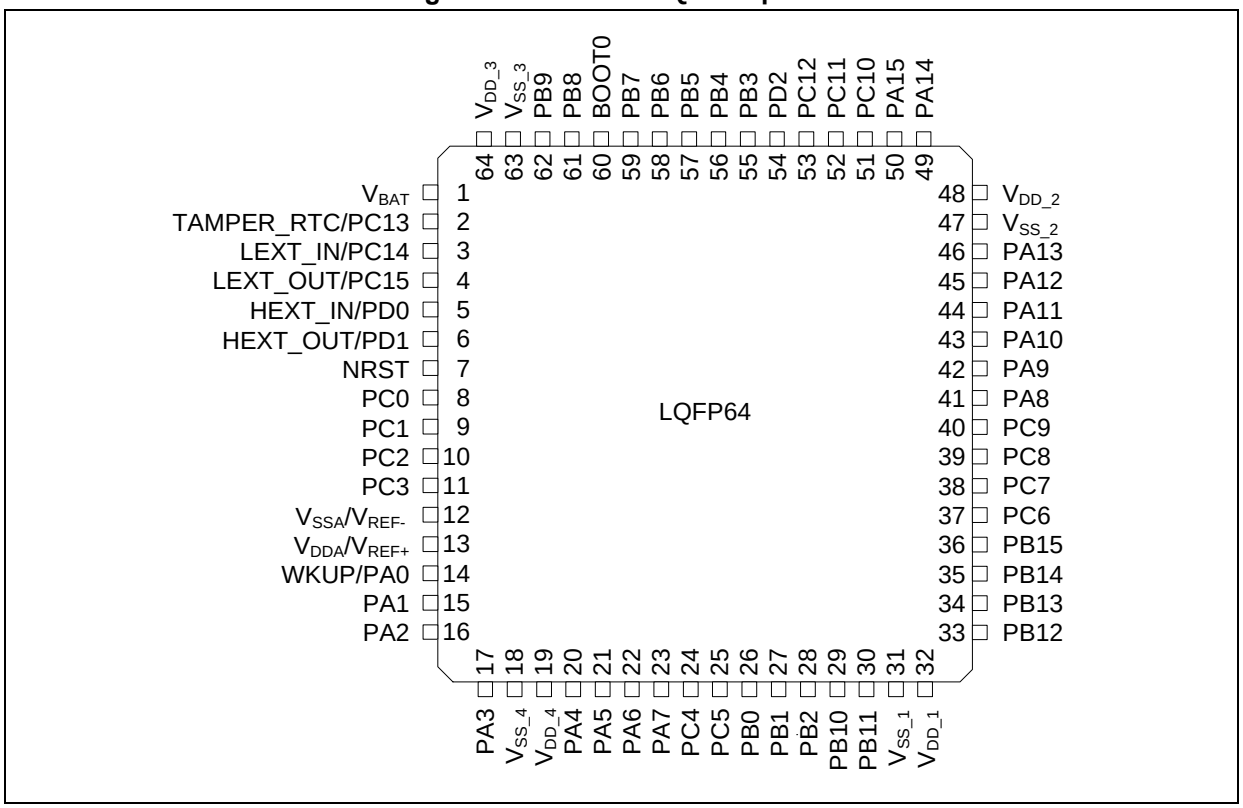


Figure 3. AT32F407 LQFP64 pinout



The table below is the pin definition of the AT32F407. ”-” presents there is no such pinout on the related package. The multi-functions list follows priority from high to low. In principle, the analog signals have priority over the digital signals, and the digital output signals have priority over the digital input signals.

Table 6. AT32F407 series pin definitions

Pin number		Pin name	Type(1)	IO level(2)	Main function(3)	Multi-functions(4)	
LQFP64	LQFP100					Default	Remap
-	1	PE2	I/O	FT	PE2	SPI4_SCK(7) / I2S4_CK(7) / XMC_A23 / TRACECK	-
-	2	PE3	I/O	FT	PE3	XMC_A19 / TRACED0	-
-	3	PE4	I/O	FT	PE4	SPI4_CS(7) / I2S4_WS(7) / XMC_A20 / TRACED1	-
-	4	PE5	I/O	FT	PE5	SPI4_MISO(7) / XMC_A21 / TRACED2	TMR9_CH1
-	5	PE6	I/O	FT	PE6	SPI4_MOSI(7) / I2S4_SD(7) / XMC_A22 / TRACED3	TMR9_CH2
1	6	V_{BAT}	S	-	V_{BAT}	-	-
2	7	TAMPER-RTC / PC13(5)	I/O	TC	PC13(6)	TAMPER-RTC	-
3	8	LEXT_IN / PC14(5)	I/O	TC	PC14(6)	LEXT_IN	-
4	9	LEXT_OUT / PC15(5)	I/O	TC	PC15(6)	LEXT_OUT	-
-	10	V_{SS_5}	S	-	V_{SS_5}	-	-
-	11	V_{DD_5}	S	-	V_{DD_5}	-	-
-	12	HEXT_IN	I	-	HEXT_IN	-	-
-	13	HEXT_OUT	O	-	HEXT_OUT	-	-
5	-	HEXT_IN / PD0(8)	I/O	TC	HEXT_IN	-	PD0(8)
6	-	HEXT_OUT / PD1(8)	I/O	TC	HEXT_OUT	-	PD1(8)
7	14	NRST	I/O	-	NRST	-	-
8	15	PC0	I/O	FTa	PC0	ADC123_IN10 / SDIO2_D0(7)	-
9	16	PC1	I/O	FTa	PC1	ADC123_IN11 / SDIO2_D1(7) / EMAC_MDC	-
10	17	PC2	I/O	FTa	PC2	ADC123_IN12 / SDIO2_D2(7) / EMAC_MII_TXD2	UART8_TX / XMC_NWE
11	18	PC3	I/O	FTa	PC3	ADC123_IN13 / SDIO2_D3(7) / XMC_A0 / EMAC_MII_TX_CLK	UART8_RX
12	19	V_{SSA}	S	-	V_{SSA}	-	-
-	20	V_{REF-}	S	-	V_{REF-}	-	-
-	21	V_{REF+}	S	-	V_{REF+}	-	-
13	22	V_{DDA}	S	-	V_{DDA}	-	-

Pin number		Pin name	Type(1)	IO level(2)	Main function(3)	Multi-functions(4)	
LQFP64	LQFP100					Default	Remap
14	23	PA0-WKUP	I/O	TC	PA0	ADC123_IN0 / WKUP / USART2_CTS(7) / EMAC_MII_CRS_WKUP / TMR2_CH1(7) / TMR2_EXT(7) / TMR5_CH1 / TMR8_EXT	UART4_TX
15	24	PA1	I/O	FTa	PA1	ADC123_IN1 / USART2_RTS(7) / EMAC_MII_RX_CLK / EMAC_RMII_REF_CLK / TMR2_CH2(7) / TMR5_CH2	UART4_RX
16	25	PA2	I/O	FTa	PA2	ADC123_IN2 / USART2_TX(7) / EMAC_MDIO / TMR2_CH3(7) / TMR5_CH3 / TMR9_CH1(7)	SDIO2_CK / XMC_D4
17	26	PA3	I/O	FTa	PA3	ADC123_IN3 / USART2_RX(7) / EMAC_MII_COL / TMR2_CH4(7) / TMR5_CH4 / TMR9_CH2(7)	I2S2_MCK / SDIO2_CMD / XMC_D5
18	27	V_{SS_4}	S	-	V_{SS_4}	-	-
19	28	V_{DD_4}	S	-	V_{DD_4}	-	-
20	29	PA4	I/O	FTa	PA4	DAC_OUT1 / ADC12_IN4 / USART2_CK(7) / SPI1_CS(7) / I2S1_WS(7) / SDIO2_D4	USART6_TX / SPI3_CS / I2S3_WS / SDIO2_D0 / XMC_D6
21	30	PA5	I/O	FTa	PA5	DAC_OUT2 / ADC12_IN5 / SPI1_SCK(7) / I2S1_CK(7) / SDIO2_D5	USART6_RX / SDIO2_D1 / XMC_D7
22	31	PA6	I/O	FTa	PA6	ADC12_IN6 / SPI1_MISO(7) / SDIO2_D6 / TMR3_CH1(7) / TMR8_BRK / TMR13_CH1	I2S2_MCK / SDIO2_D2 / TMR1_BRK
23	32	PA7	I/O	FTa	PA7	ADC12_IN7 / SPI1_MOSI(7) / I2S1_SD(7) / SDIO2_D7 / EMAC_MII_RX_DV(7) / EMAC_RMII_CRS_DV(7) / TMR3_CH2(7) / TMR8_CH1C / TMR14_CH1	SDIO2_D3 / TMR1_CH1C
24	33	PC4	I/O	FTa	PC4	ADC12_IN14 / SDIO2_CK(7) / XMC_NE4 / EMAC_MII_RXD0(7) / EMAC_RMII_RXD0(7)	-
25	34	PC5	I/O	FTa	PC5	ADC12_IN15 / SDIO2_CMD(7) / EMAC_MII_RXD1(7) / EMAC_RMII_RXD1(7)	XMC_NOE
26	35	PB0	I/O	FTa	PB0	ADC12_IN8 / I2S1_MCK(7) / EMAC_MII_RXD2(7) / TMR3_CH3(7) / TMR8_CH2C	TMR1_CH2C
27	36	PB1	I/O	FTa	PB1	ADC12_IN9 / SPIM_SCK / EMAC_MII_RXD3(7) / TMR3_CH4(7) / TMR8_CH3C	TMR1_CH3C
28	37	PB2	I/O	FT	PB2 / BOOT1(10)	-	-
-	38	PE7	I/O	FT	PE7	UART7_RX(7) / XMC_D4(7)	TMR1_EXT
-	39	PE8	I/O	FT	PE8	UART7_TX(7) / XMC_D5(7)	TMR1_CH1C
-	40	PE9	I/O	FT	PE9	XMC_D6(7)	TMR1_CH1
-	41	PE10	I/O	FT	PE10	XMC_D7(7)	TMR1_CH2C

Pin number		Pin name	Type(1)	IO level(2)	Main function(3)	Multi-functions(4)	
LQFP64	LQFP100					Default	Remap
-	42	PE11	I/O	FT	PE11	XMC_D8	SPI4_SCK / I2S4_CK / TMR1_CH2
-	43	PE12	I/O	FT	PE12	XMC_D9	SPI4_CS / I2S4_WS / TMR1_CH3C
-	44	PE13	I/O	FT	PE13	XMC_D10	SPI4_MISO / TMR1_CH3
-	45	PE14	I/O	FT	PE14	XMC_D11	SPI4_MOSI / I2S4_SD / TMR1_CH4
-	46	PE15	I/O	FT	PE15	XMC_D12	TMR1_BRK
29	47	PB10	I/O	FT	PB10	USART3_TX(7) / I2C2_SCL(9) / EMAC_MII_RX_ER	I2S3_MCK / SPIM_IO0 / TMR2_CH3
30	48	PB11	I/O	FT	PB11	USART3_RX(7) / I2C2_SDA(9) / EMAC_MII_TX_EN / EMAC_RMII_TX_EN	SPIM_IO1 / TMR2_CH4
31	49	V_{SS_1}	S	-	V_{SS_1}	-	-
32	50	V_{DD_1}	S	-	V_{DD_1}	-	-
33	51	PB12	I/O	FT	PB12	USART3_CK(7) / CAN2_RX(7) / I2C2_SMBA(9) / SPI2_CS(9) / I2S2_WS(9) / EMAC_MII_TXD0 / EMAC_RMII_TXD0 / TMR1_BRK(7)	XMC_D13
34	52	PB13	I/O	FT	PB13	USART3_CTS(7) / CAN2_TX(7) / SPI2_SCK(9) / I2S2_CK(9) / EMAC_MII_TXD1 / EMAC_RMII_TXD1 / TMR1_CH1C(7)	-
35	53	PB14	I/O	FT	PB14	USART3_RTS(7) / SPI2_MISO(9) / I2S2_SDEXT(9) / TMR1_CH2C(7) / TMR12_CH1	XMC_D0
36	54	PB15	I/O	FT	PB15	SPI2_MOSI(9) / I2S2_SD(9) / TMR1_CH3C(7) / TMR12_CH2	-
-	55	PD8	I/O	FT	PD8	XMC_D13(7)	USART3_TX / EMAC_MII_RX_DV / EMAC_RMII_CRS_DV
-	56	PD9	I/O	FT	PD9	XMC_D14	USART3_RX / EMAC_MII_RXD0 / EMAC_RMII_RXD0
-	57	PD10	I/O	FT	PD10	XMC_D15	USART3_CK / EMAC_MII_RXD1 / EMAC_RMII_RXD1
-	58	PD11	I/O	FT	PD11	XMC_A16	USART3_CTS / EMAC_MII_RXD2
-	59	PD12	I/O	FT	PD12	XMC_A17	USART3_RTS / EMAC_MII_RXD3 / TMR4_CH1
-	60	PD13	I/O	FT	PD13	XMC_A18	TMR4_CH2
-	61	PD14	I/O	FT	PD14	XMC_D0(7)	TMR4_CH3
-	62	PD15	I/O	FT	PD15	XMC_D1(7)	TMR4_CH4
37	63	PC6	I/O	FT	PC6	USART6_TX(7) / I2S2_MCK(7) / SDIO1_D6 / TMR8_CH1	XMC_D1 / TMR3_CH1

Pin number		Pin name	Type(1)	IO level(2)	Main function(3)	Multi-functions(4)	
LQFP64	LQFP100					Default	Remap
38	64	PC7	I/O	FT	PC7	USART6_RX(7) / I2S3_MCK(7) / SDIO1_D7 / TMR8_CH2	TMR3_CH2
39	65	PC8	I/O	FT	PC8	USART6_CK / I2S4_MCK(7) / SDIO1_D0 / TMR8_CH3	TMR3_CH3
40	66	PC9	I/O	FT	PC9	I2C3_SDA(7) / SDIO1_D1 / TMR8_CH4	TMR3_CH4
41	67	PA8	I/O	FT	PA8	CLKOUT / USART1_CK / I2C3_SCL / USBFS_SOF / SPIM_CS / TMR1_CH1(7)	-
42	68	PA9	I/O	FT	PA9	USART1_TX(7) / I2C3_SMBA / TMR1_CH2(7)	-
43	69	PA10	I/O	FT	PA10	USART1_RX(7) / TMR1_CH3(7)	I2S4_MCK
44	70	PA11	I/O	TC	PA11	USBFS1_D- / USART1_CTS / CAN1_RX(7) / SPIM_IO0(7) / TMR1_CH4(7)	-
45	71	PA12	I/O	TC	PA12	USBFS1_D+ / USART1_RTS / CAN1_TX(7) / SPIM_IO1(7) / TMR1_EXT(7)	-
46	72	PA13	I/O	FT	JTMS-SWDIO	-	PA13
-	73	Not connected					
47	74	V_{SS_2}	S	-	V_{SS_2}	-	-
48	75	V_{DD_2}	S	-	V_{DD_2}	-	-
49	76	PA14	I/O	FT	JTCK-SWCLK	-	PA14
50	77	PA15	I/O	FT	JTDI	SPI3_CS(7) / I2S3_WS(7)	PA15 / SPI1_CS / I2S1_WS / TMR2_CH1 / TMR2_EXT
51	78	PC10	I/O	FT	PC10	UART4_TX(7) / SDIO1_D2	USART3_TX / SPI3_SCK / I2S3_CK
52	79	PC11	I/O	FT	PC11	UART4_RX(7) / SDIO1_D3	USART3_RX / SPI3_MISO / I2S3_SDEXT / XMC_D2
53	80	PC12	I/O	FT	PC12	UART5_TX(7) / SDIO1_CK	USART3_CK / SPI3_MOSI / I2S3_SD / XMC_D3
-	81	PD0	I/O	FT	PD0	XMC_D2(7)	CAN1_RX
-	82	PD1	I/O	FT	PD1	XMC_D3(7)	CAN1_TX
54	83	PD2	I/O	FT	PD2	UART5_RX(7) / SDIO1_CMD / TMR3_EXT	XMC_NWE
-	84	PD3	I/O	FT	PD3	XMC_CLK	USART2_CTS
-	85	PD4	I/O	FT	PD4	XMC_NOE(7)	USART2_RTS
-	86	PD5	I/O	FT	PD5	XMC_NWE(7)	USART2_TX
-	87	PD6	I/O	FT	PD6	XMC_NWAIT	USART2_RX
-	88	PD7	I/O	FT	PD7	XMC_NE1 / XMC_NCE2	USART2_CK
55	89	PB3	I/O	FT	JTDO	SPI3_SCK(7) / I2S3_CK(7)	PB3 / UART7_RX / SPI1_SCK / I2S1_CK / SWO / TMR2_CH2

Pin number		Pin name	Type(1)	IO level(2)	Main function(3)	Multi-functions(4)	
LQFP64	LQFP100					Default	Remap
56	90	PB4	I/O	FT	NJTRST	SPI3_MISO(7) / I2S3_SDEXT(7)	PB4 / SPI1_MISO / I2C3_SDA / UART7_TX / TMR3_CH1
57	91	PB5	I/O	FT	PB5	SPI3_MOSI(7) / I2S3_SD(7) / I2C1_SMBA(7) / EMAC_PPS_OUT	SPI1_MOSI / I2S1_SD / CAN2_RX / TMR3_CH2
58	92	PB6	I/O	FT	PB6	I2C1_SCL(7) / SPIM_IO3 / TMR4_CH1(7)	USART1_TX / I2S1_MCK / SPI4_CS / I2S4_WS / CAN2_TX
59	93	PB7	I/O	FT	PB7	I2C1_SDA(7) / XMC_NADV / SPIM_IO2 / TMR4_CH2(7)	USART1_RX / SPI4_SCK / I2S4_CK
60	94	BOOT0	I	-	BOOT0	-	-
61	95	PB8	I/O	FT	PB8	SDIO1_D4 / EMAC_MII_TXD3 / TMR4_CH3(7) / TMR10_CH1	UART5_RX / SPI4_MISO / I2C1_SCL / CAN1_RX
62	96	PB9	I/O	FT	PB9	SDIO1_D5 / TMR4_CH4(7) / TMR11_CH1	UART5_TX / SPI4_MOSI / I2S4_SD / I2C1_SDA / CAN1_TX
-	97	PE0	I/O	FT	PE0	UART8_RX(7) / XMC_LB / TMR4_EXT	-
-	98	PE1	I/O	FT	PE1	UART8_TX(7) / XMC_UB	-
63	99	V_{SS_3}	S	-	V_{SS_3}	-	-
64	100	V_{DD_3}	S	-	V_{DD_3}	-	-

(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 functionalities. FTa pin is 5 V-tolerant when configured as input floating, input pull-up, or input pull-down mode. However, it cannot be 5 V-tolerant when configured as analog mode. Meanwhile, its input level should not higher than V_{DD} + 0.3 V.

(3) Function availability depends on the chosen device.

(4) If several peripherals share the same GPIO pin, to avoid conflict between these multiple functions only one peripheral should be enabled at a time through the peripheral clock enable bit (in the corresponding RCC peripheral clock enable register).

(5) PC13, PC14, and PC15 are supplied through the 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).

(6) Main function after the first battery powered domain power-up. Later on, it depends on the contents of the battery powered registers even after reset (because these registers are not reset by the main reset). For details on how to manage these GPIOs, refer to the battery powered domain and register description sections in the AT32F407 reference manual.

(7) This multiple function can be remapped by software to some other port pins (if available on the used package). For more details, refer to the multi-function GPIO and debug configuration section in the AT32F407 reference manual.

(8) For the LQFP64 package, the pins number 5 and 6 are configured as HEXT_IN and HEXT_OUT after reset, the functionality of PD0 and PD1 can be remapped by software on these pins. However, for the LQFP100 package, PD0 and PD1 are available by default, so there is no need for remapping. For more details, refer to multi-function GPIO and debug configuration section in the AT32F407 reference manual.

(9) SPI2, I^2S2, and I^2C2 are not available when the Ethernet MAC is being used.

(10) If the device boots from Flash and leaves PB2 not used, suggest to pull PB2/BOOT1 pin down to V_{SS}.

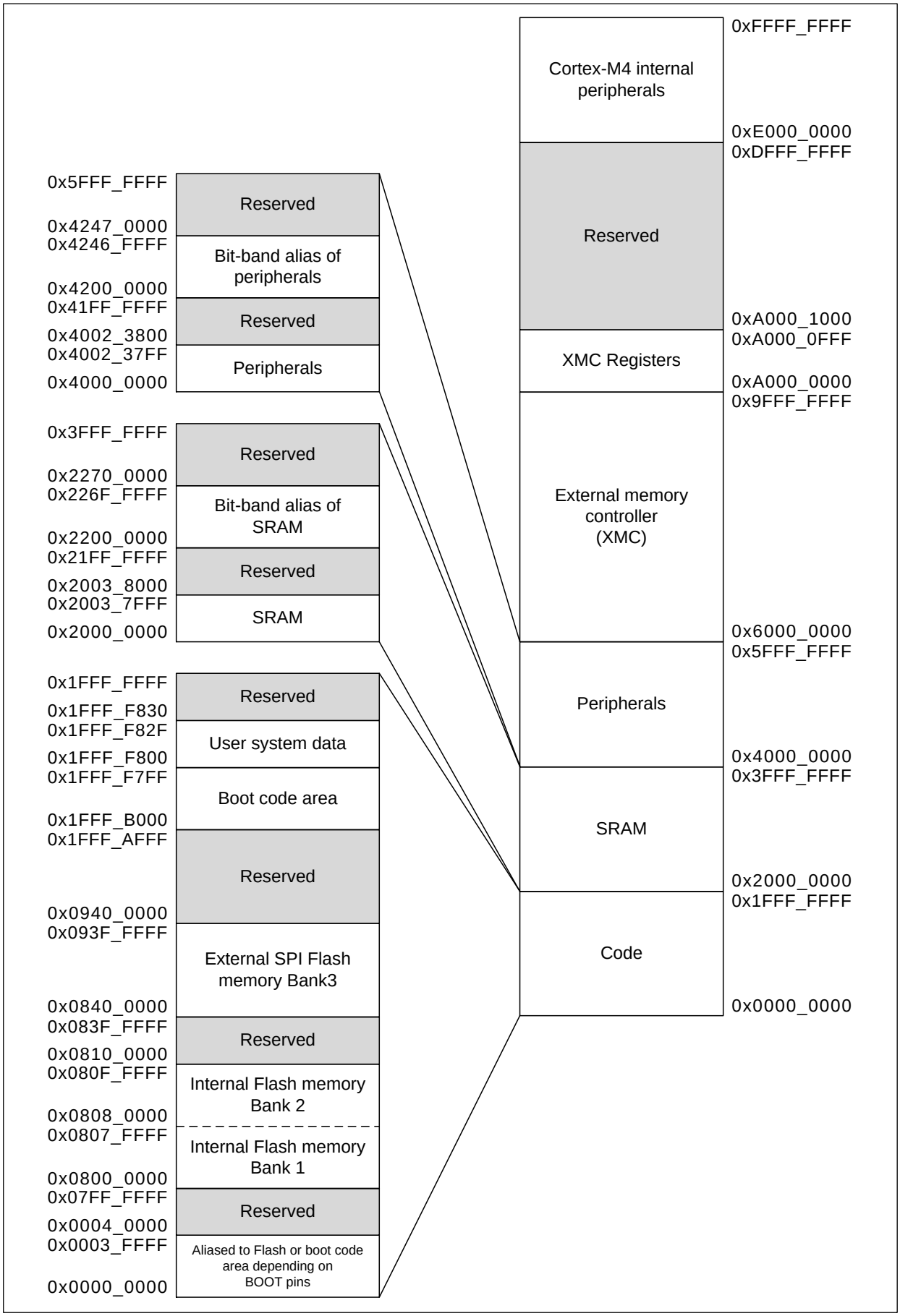
Table 7. XMC pin definition

Pins	XMC			LQFP64
	Multiplexed PSRAM/NOR	LCD	NAND	
PE2	A23	A23	-	-
PE3	A19	A19	-	-
PE4	A20	A20	-	-
PE5	A21	A21	-	-
PE6	A22	A22	-	-
PC2	NWE	NWE	NWE	Yes
PC3	-	A0	-	Yes
PA2	DA4	D4	D4	Yes
PA3	DA5	D5	D5	Yes
PA4	DA6	D6	D6	Yes
PA5	DA7	D7	D7	Yes
PC4	NE4	NE4	-	Yes
PC5	NOE	NOE	NOE	Yes
PE7	DA4	D4	D4	-
PE8	DA5	D5	D5	-
PE9	DA6	D6	D6	-
PE10	DA7	D7	D7	-
PE11	DA8	D8	D8	-
PE12	DA9	D9	D9	-
PE13	DA10	D10	D10	-
PE14	DA11	D11	D11	-
PE15	DA12	D12	D12	-
PB12	DA13	D13	D13	Yes
PB14	DA0	D0	D0	Yes
PD8	DA13	D13	D13	-
PD9	DA14	D14	D14	-
PD10	DA15	D15	D15	-
PD11	A16	A16	CLE	-
PD12	A17	A17	ALE	-
PD13	A18	A18	-	-
PD14	DA0	D0	D0	-
PD15	DA1	D1	D1	-
PC6	DA1	D1	D1	Yes
PC11	DA2	D2	D2	Yes
PC12	DA3	D3	D3	Yes
PD0	DA2	D2	D2	-
PD1	DA3	D3	D3	-

Pins	XMC			LQFP64
	Multiplexed PSRAM/NOR	LCD	NAND	
PD2	NWE	NWE	NWE	Yes
PD3	CLK	-	-	-
PD4	NOE	NOE	NOE	-
PD5	NWE	NWE	NWE	-
PD6	NWAIT	-	NWAIT	-
PD7	NE1	NE1	NCE2	-
PB7	NADV	-	-	Yes
PE0	LB	-	-	-
PE1	UB	-	-	-

4 Memory mapping

Figure 4. Memory map



5 Electrical characteristics

5.1 Parameter conditions

5.1.1 Minimum and maximum values

The minimum and maximum values are guaranteed 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.

5.1.2 Typical values

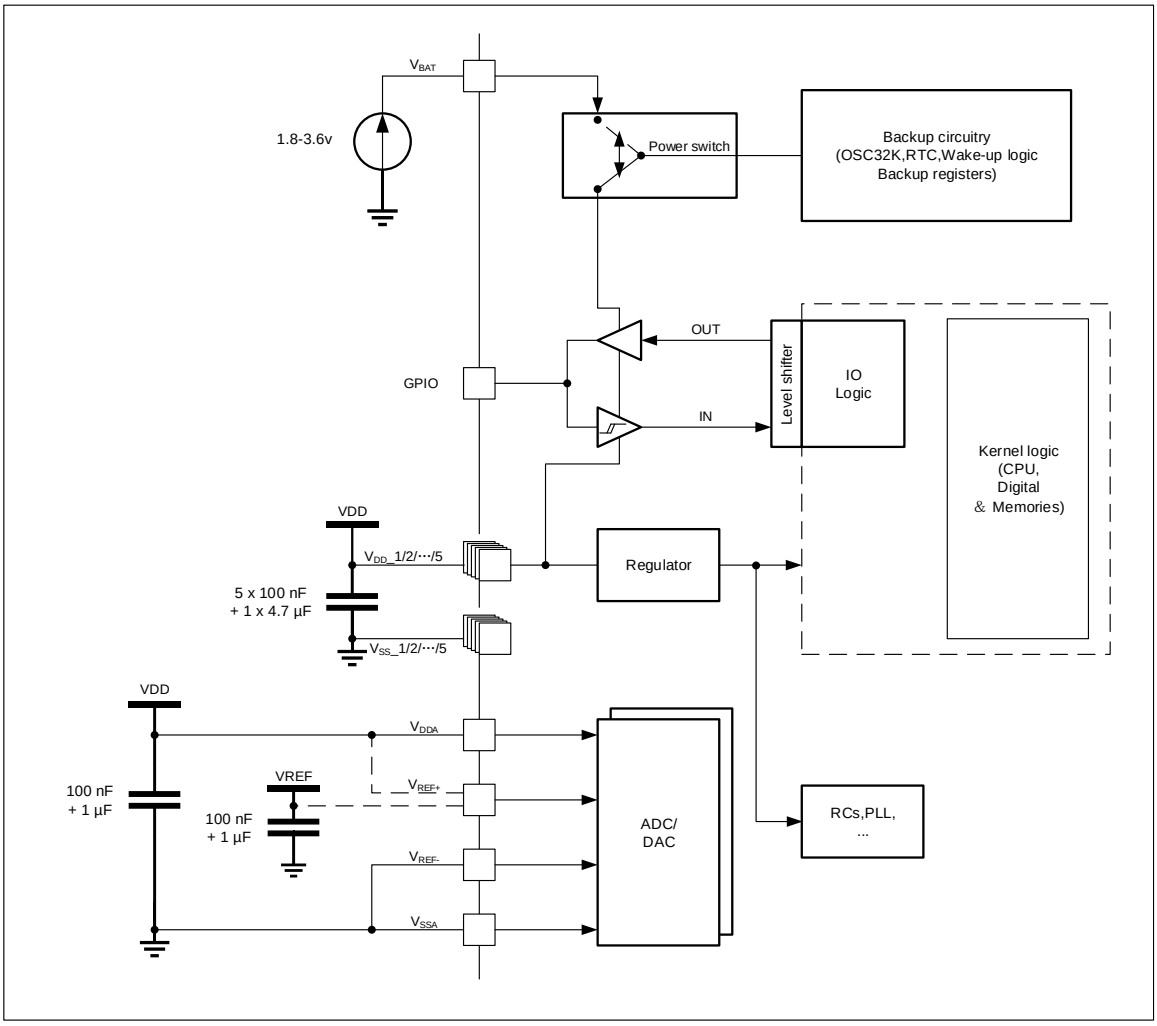
Typical data are based on T_A = 25 °C, V_{DD} = 3.3 V.

5.1.3 Typical curves

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

5.1.4 Power supply scheme

Figure 5. Power supply scheme



Caution: In this figure, the 4.7µF capacitor must be connected to V_{DD3}.

5.2 Absolute maximum values

5.2.1 Ratings

If stresses were out of the absolute maximum ratings listed in *Table 8*, *Table 9*, and *Table 10*, it may cause permanent damage to the device. These are maximum stress ratings only that the device could bear, 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 8. Voltage characteristics

Symbol	Ratings	Min	Max	Unit
V_{DD}-V_{SS}	External main supply voltage (including V_{DDA} and V_{DD})	-0.3	4.0	V
V_{IN}	Input voltage on FT 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 9. Current characteristics

Symbol	Ratings	Max	Unit
I_{VDD}	Total current into V_{DD}/V_{DDA} 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 GPIOs and control pin	-25	

Table 10. Thermal characteristics

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

5.2.2 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 conforms to the JS-001-2017/JS-002-2018 standard.

Table 11. ESD values

Symbol	Parameter	Conditions	Class	Max(1)	Unit
$V_{ESD(HBM)}$	Electrostatic discharge voltage (human body model)	T_A = +25 °C, conforming to JS-001-2017	3A	5000	V
$V_{ESD(CDM)}$	Electrostatic discharge voltage (charge device model)	T_A = +25 °C, conforming to JS-002-2018	III	1000	

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

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 12. Latch-up values

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

5.3 Specification

5.3.1 General operating conditions

Table 13. General operating conditions

Symbol	Parameter	Conditions		Min	Max	Unit
f_{HCLK}	Internal AHB clock frequency	Bank 3 not used	3.1 V ≤ V_{DD} ≤ 3.6 V	0	240	MHz
			2.6 V ≤ V_{DD} < 3.1 V	0	180	
		Bank 3 used	3.1 V ≤ V_{DD} ≤ 3.6 V	0	180	
			2.6 V ≤ V_{DD} < 3.1 V	0	160	
f_{PCLK1}	Internal APB1 clock frequency	-		0	120	MHz
f_{PCLK2}	Internal APB2 clock frequency	-		0	120	MHz
V_{DD}	Standard operating voltage	-		2.6	3.6	V
V_{DDA}	Analog operating voltage	Must be the same potential as V_{DD}(1)		2.6	3.6	V
V_{BAT}	Backup operating voltage	-		1.8	3.6	V
P_D	Power dissipation: T_A = 105 °C	LQFP100		-	326	mW
		LQFP64		-	309	
T_A	Ambient temperature	-		-40	105	°C

5.3.2 Operating conditions at power-up / power-down

Table 14. Operating conditions at power-up / power-down

Symbol	Parameter	Conditions	Min	Max	Unit
t_{VDD}	V_{DD} rise time rate	-	0	∞(1)	ms/V
	V_{DD} fall time rate		20	∞	μs/V

(1) If V_{DD} rising time rate is slower than 120 ms/V, the code should access the backup registers after V_{DD} higher than V_{POR} + 0.1V.

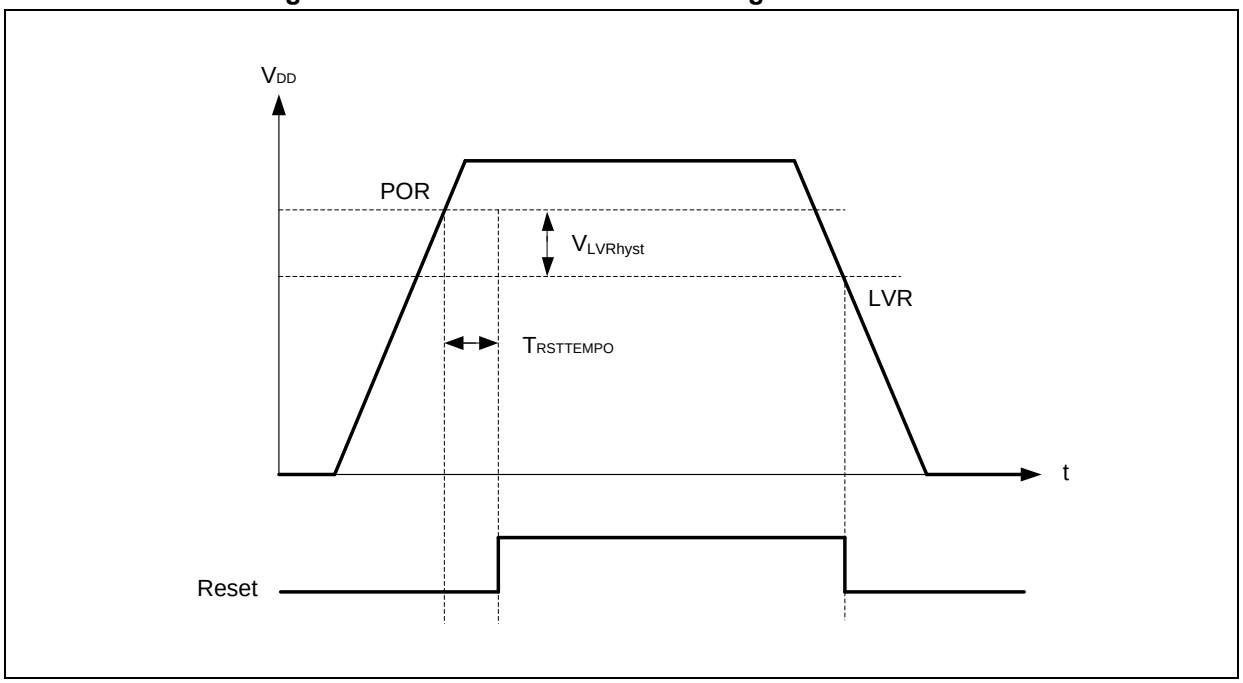
5.3.3 Embedded reset and power control block characteristics

Table 15. Embedded reset and power management block characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{PVM}	Power voltage monitoring level selection	PVMSEL[2:0] = 001 (rising edge)(1)	2.19	2.28	2.37	V
		PVMSEL[2:0] = 001 (falling edge)(1)	2.09	2.18	2.27	V
		PVMSEL[2:0] = 010 (rising edge)(2)	2.28	2.38	2.48	V
		PVMSEL[2:0] = 010 (falling edge)(2)	2.18	2.28	2.38	V
		PVMSEL [2:0] = 011 (rising edge)(2)	2.38	2.48	2.58	V
		PVMSEL [2:0] = 011 (falling edge)(2)	2.28	2.38	2.48	V
		PVMSEL [2:0] = 100 (rising edge)(2)	2.47	2.58	2.69	V
		PVMSEL[2:0] = 100 (falling edge)(2)	2.37	2.48	2.59	V
		PVMSEL[2:0] = 101 (rising edge)(2)	2.57	2.68	2.79	V
		PVMSEL[2:0] = 101 (falling edge)(2)	2.47	2.58	2.69	V
		PVMSEL[2:0] = 110 (rising edge)(2)	2.66	2.78	2.9	V
		PVMSEL[2:0] = 110 (falling edge)(2)	2.56	2.68	2.8	V
		PVMSEL[2:0] = 111 (rising edge)	2.76	2.88	3	V
		PVMSEL[2:0] = 111 (falling edge)	2.66	2.78	2.9	V
V_{HYS_P}(2)	PVM hysteresis	-	-	100	-	mV
V_{POR}(2)	Power on reset threshold	-	2.03	2.18	2.35	V
V_{LVR}(2)	Low voltage reset threshold	-	1.85(3)	2.02	2.2	V
$V_{LVRhyst}$(2)	LVR hysteresis	-	-	160	-	mV
$T_{RESTTEMPO}$(2)	Reset temporization: CPU starts execution after V_{DD} keeps higher than V_{POR} for $T_{RSTTEMPO}$	-	-	13	-	ms

(1) PVMSEL[2:0] = 001 may be not available for its voltage detector level may be lower than $V_{POR/PDR}$.
(2) Guaranteed by design, not tested in production.
(3) The product behavior is guaranteed by design down to the minimum V_{LVR} value.

Figure 6. Power on reset and low voltage reset waveform



5.3.4 Memory characteristics

Table 16. Internal Flash memory characteristics

Symbol	Parameter	Conditions	Typ(1) fHCLK						Unit
			240	200	144	72	48	8	MHz
TPROG	Programming time	-	50						µs
tERASE	Page (2 KB) erase time	-	50						ms
tME	Mass erase time	AT32F407xC	0.8						s
		AT32F407xE	1.4						
		AT32F407xG	1.4						
IDD	Supply current	Programming mode	35.5	29.9	22.5	13.4	9.9	3.7	mA
		Erase mode	57.4	49.2	38.8	25.4	20.6	11.4	

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

Table 17. Internal Flash memory endurance and data retention

Symbol	Parameter	Conditions	Min(1)	Typ	Max	Unit
NEND	Endurance	TA = -40 ~ 105 °C	100	-	-	kcycles
tRET	Data retention	TA = 105 °C	10	-	-	years

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

5.3.5 Supply current characteristics

The current consumption 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. The current consumption is obtained by characterization results, not tested in production.

Typical and maximum current consumption

The MCU is placed under the following conditions:

- All GPIO pins are in analog mode.
- Prefetch ON. (Reminder: this bit must be set before clock setting and bus prescaling.)
- When the peripherals are enabled:
  - If f_{HCLK} > 120 MHz, $f_{PCLK1} = f_{HCLK}/2$, $f_{PCLK2} = f_{HCLK}/2$, $f_{ADCCLK} = f_{PCLK2}/4$
  - If $f_{HCLK} \leq 120$ MHz, $f_{PCLK1} = f_{HCLK}$, $f_{PCLK2} = f_{HCLK}$, $f_{ADCCLK} = f_{PCLK2}/4$
- Code executes in ZW area.
- 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 18. Typical current consumption in Run mode

Symbol	Parameter	Conditions	f_{HCLK}	Typ		Unit
				All peripherals enabled	All peripherals disabled	
I_{DD}	Supply current in Run mode	High speed external crystal (HEXT)(1)(2)	240 MHz	100.7	41.0	mA
			200 MHz	84.7	34.6	
			144 MHz	62.0	25.7	
			120 MHz	62.5	23.3	
			108 MHz	56.7	21.3	
			72 MHz	39.2	15.4	
			48 MHz	27.1	11.1	
			36 MHz	21.0	8.99	
			24 MHz	14.9	6.86	
			16 MHz	10.8	5.44	
			8 MHz	6.25	3.58	
			4 MHz	4.29	2.95	
			2 MHz	3.31	2.63	
			1 MHz	2.83	2.47	
			500 kHz	2.59	2.39	
			125 kHz	2.40	2.34	
		High speed internal clock (HICK)(2)	240 MHz	100.5	41.0	mA
			200 MHz	84.6	34.6	
			144 MHz	61.9	25.6	
			120 MHz	62.5	23.2	
			108 MHz	56.6	21.2	
			72 MHz	39.2	15.4	
			48 MHz	27.0	11.1	
			36 MHz	20.9	8.91	
			24 MHz	14.8	6.78	
			16 MHz	10.7	5.36	
			8 MHz	6.16	3.49	
			4 MHz	4.20	2.86	
			2 MHz	3.22	2.54	
			1 MHz	2.74	2.39	
			500 kHz	2.50	2.31	
			125 kHz	2.32	2.25	

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

Table 19. Typical current consumption in Sleep mode

Symbol	Parameter	Conditions	f_{HCLK}	Typ		Unit
				All peripherals enabled	All peripherals disabled	
I_{DD}	Supply current in Sleep mode	High speed external crystal (HEXT)(1)(2)	240 MHz	85.3	12.5	mA
			200 MHz	71.7	10.8	
			144 MHz	52.5	8.52	
			120 MHz	53.7	8.07	
			108 MHz	48.7	7.54	
			72 MHz	33.9	6.29	
			48 MHz	23.5	5.07	
			36 MHz	18.3	4.45	
			24 MHz	13.1	3.83	
			16 MHz	9.59	3.42	
			8 MHz	5.66	2.57	
			4 MHz	4.00	2.45	
			2 MHz	3.17	2.39	
			1 MHz	2.76	2.36	
			500 kHz	2.55	2.34	
			125 kHz	2.40	2.33	
		High speed internal clock (HICK)(2)	240 MHz	85.3	12.4	mA
			200 MHz	71.7	10.8	
			144 MHz	52.6	8.44	
			120 MHz	53.7	7.99	
			108 MHz	48.7	7.45	
			72 MHz	33.8	6.20	
			48 MHz	23.4	4.97	
			36 MHz	18.2	4.35	
			24 MHz	13.0	3.74	
			16 MHz	9.51	3.33	
			8 MHz	5.57	2.48	
			4 MHz	3.91	2.36	
			2 MHz	3.08	2.30	
			1 MHz	2.67	2.27	
			500 kHz	2.47	2.25	
			125 kHz	2.31	2.24	

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

Table 20. Maximum current consumption in Run mode

Symbol	Parameter	Conditions	f_{HCLK}	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	240 MHz	115.5	126.5	mA
			200 MHz	99.2	110.2	
			144 MHz	75.9	87.4	
			120 MHz	76.7	86.5	
			108 MHz	70.7	81.3	
			72 MHz	52.5	62.8	
			48 MHz	39.9	50.0	
			36 MHz	33.5	43.5	
			24 MHz	27.1	37.0	
			16 MHz	22.8	32.6	
			8 MHz	18.0	27.8	
		High speed external crystal (HEXT)(1), all peripherals disabled	240 MHz	53.4	63.5	mA
			200 MHz	46.9	57.0	
			144 MHz	37.8	47.7	
			120 MHz	35.4	45.3	
			108 MHz	33.3	43.2	
			72 MHz	27.3	37.1	
			48 MHz	22.9	32.6	
			36 MHz	20.7	30.4	
			24 MHz	18.5	28.2	
			16 MHz	17.0	26.7	
			8 MHz	15.2	24.8	

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

Table 21. Maximum current consumption in Sleep mode

Symbol	Parameter	Conditions	f_{HCLK}	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	240 MHz	99.8	110.4	mA
			200 MHz	86.0	96.4	
			144 MHz	66.2	78.0	
			120 MHz	67.7	76.5	
			108 MHz	62.5	72.7	
			72 MHz	47.0	57.0	
			48 MHz	36.1	46.0	
			36 MHz	30.6	40.4	
			24 MHz	25.1	34.8	
			16 MHz	21.5	31.1	
			8 MHz	17.3	26.9	
		High speed external crystal (HEXT)(1), all peripherals disabled	240 MHz	23.9	33.5	mA
			200 MHz	22.3	31.8	
			144 MHz	20.0	29.4	
			120 MHz	19.6	29.0	
			108 MHz	19.0	28.4	
			72 MHz	17.7	27.1	
			48 MHz	16.4	25.8	
			36 MHz	15.8	25.2	
			24 MHz	15.2	24.6	
			16 MHz	14.8	24.2	
			8 MHz	13.9	23.3	

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

Table 22. Typical and maximum current consumptions in Deepsleep and Standby modes

Symbol	Parameter	Conditions	Typ(1)		Max(2)			Unit
			V_{DD}/V_{BAT} = 2.6 V	V_{DD}/V_{BAT} = 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 (no WDT)	1.35	1.36	Refer to note (3)	13.6	23.7	mA
		LDO in low-power mode, HICK and HEXT OFF (no WDT)	1.33	1.34		13.1	22.8	
	Supply current in Standby mode	LEXT and RTC OFF	3.93	5.72	7.49	10.4	14.9	µA
		LEXT and RTC ON	4.55	6.48	8.34	11.5	16.5	

(1) Typical values are measured at T_A = 25 °C.
(2) Guaranteed by characterization results, not tested in production.
(3) The value may be several times the typical values due to process variation.

Figure 7. Typical current consumption in Deepsleep mode vs. temperature at different V_{DD}

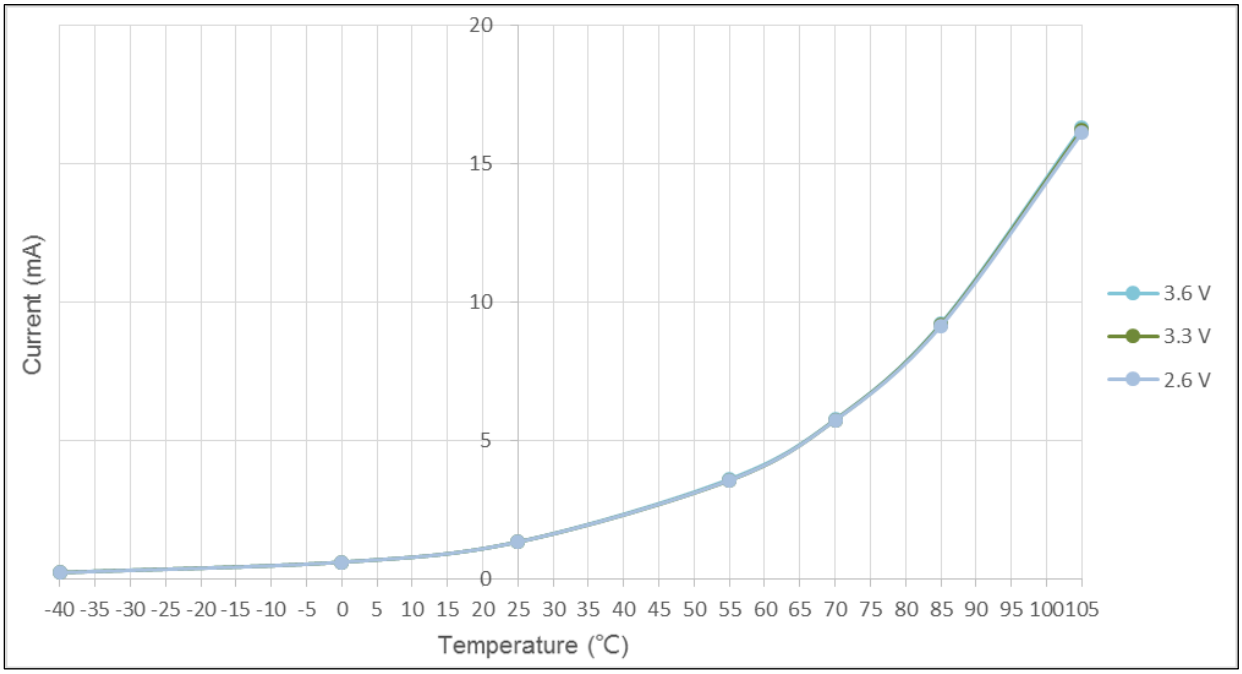


Figure 8. Typical current consumption in Standby mode vs. temperature at different V_{DD}

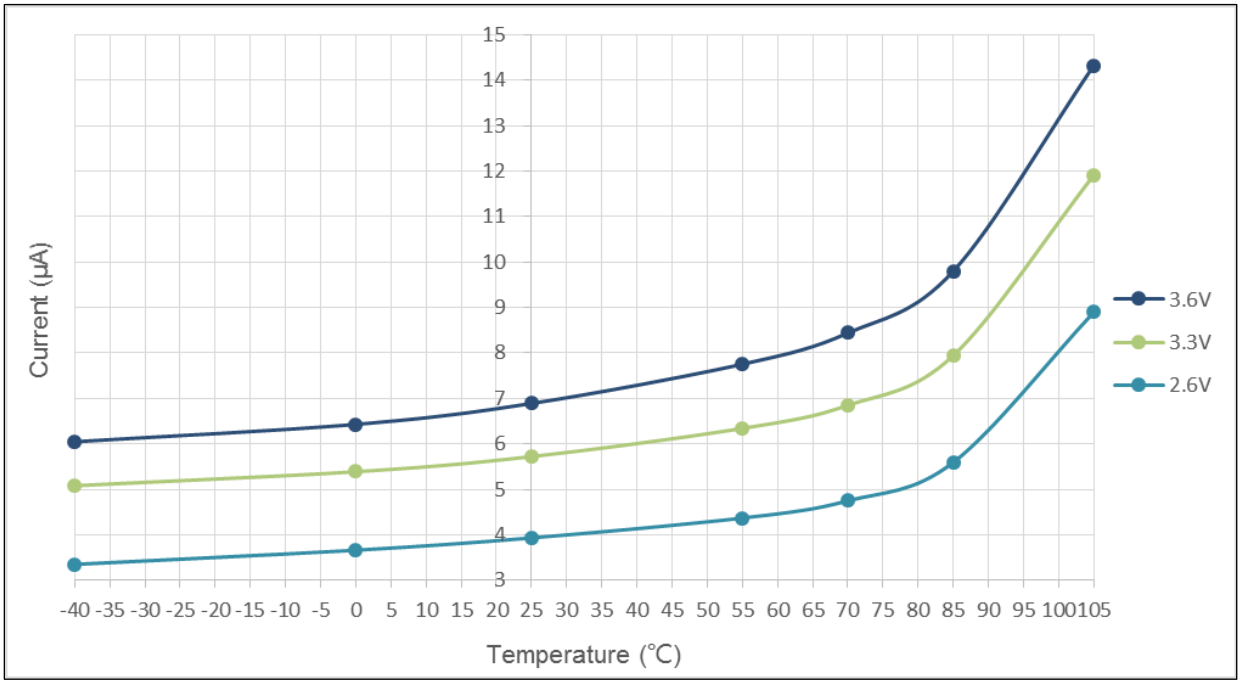
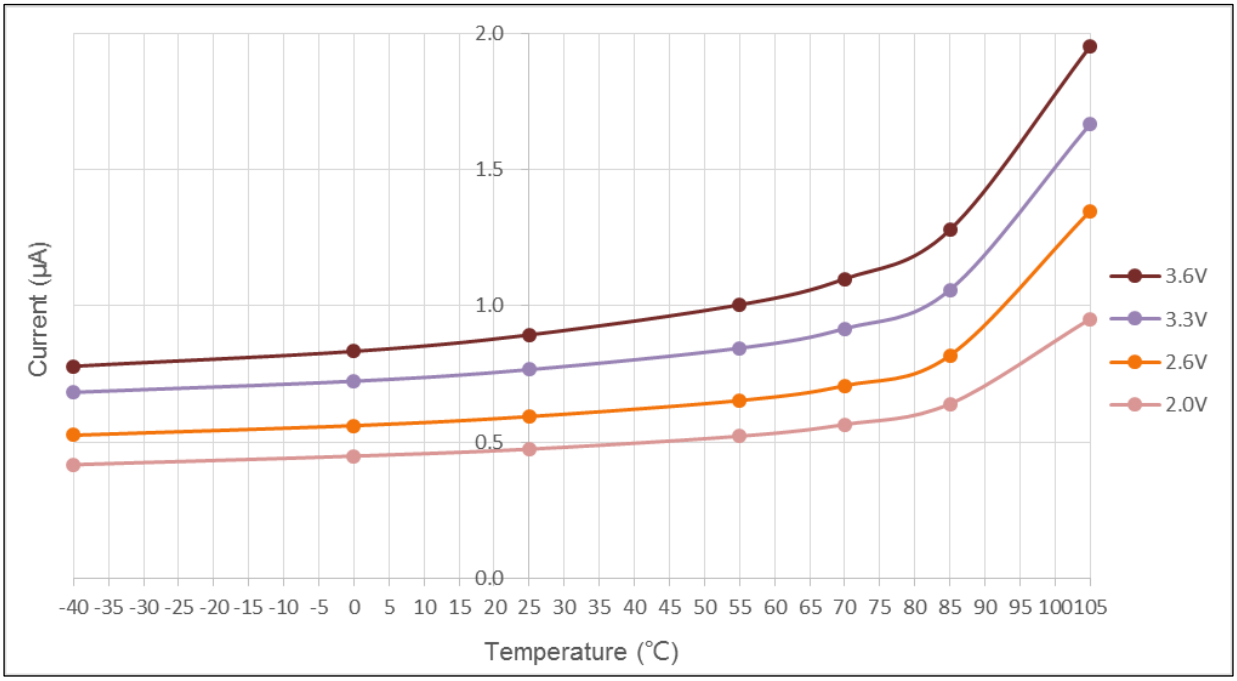


Table 23. Typical and maximum current consumptions on V_{BAT}

Symbol	Parameter	Conditions	Typ(1)			Max(2)			Unit
			V_{BAT} = 2.0 V	V_{BAT} = 2.6 V	V_{BAT} = 3.3 V	T_A = 25 °C	T_A = 85 °C	T_A = 105 °C	
I_{DD_VBAT}	Supply current of V_{BAT}	LEXT and RTC ON, $V_{DD} < V_{LVR}$	0.47	0.59	0.77	0.92	1.34	2.04	µA

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

Figure 9. Typical current consumption on V_{BAT} with LEXT and RTC ON vs. temperature at different V_{BAT}



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 24. Peripheral current consumption

Peripheral		Typ	Unit
AHB	DMA1	9.34	μA/MHz
	DMA2	9.39	
	GPIOA	1.41	
	GPIOB	1.41	
	GPIOC	1.47	
	GPIOD	1.43	
	GPIOE	1.44	
	XMC	26.89	
	CRC	1.53	
	SDIO1	19.62	
	SDIO2	20.40	
	EMAC EMAC_TX EMAC_RX EMAC_PTP	30.78	
APB1	TMR2	9.11	
	TMR3	6.52	
	TMR4	6.54	
	TMR5	8.82	
	TMR6	0.77	
	TMR7	0.75	
	TMR12	3.89	
	TMR13	2.45	
	TMR14	2.48	
	SPI2/I^2S2	5.19	
	SPI3/I^2S3	4.95	
	SPI4/I^2S4	2.62	
	USART2	2.60	
	USART3	2.57	
	UART4	2.60	
	UART5	2.63	

Peripheral		Typ	Unit
APB1	I^2C1	2.47	μA/MHz
	I^2C2	2.54	
	USBFS	6.40	
	CAN1	3.77	
	CAN2	3.77	
	DAC1/2	2.30	
	WWDT	0.34	
	PWC	0.34	
	BPR	68.36	
APB2	IOMUX	2.32	
	SPI1/I^2S1	2.82	
	USART1	2.53	
	USART6	2.64	
	UART7	2.80	
	UART8	2.85	
	I^2C3	2.48	
	TMR1	8.99	
	TMR8	8.72	
	TMR9	3.78	
	TMR10	2.62	
	TMR11	2.56	
	ADC1	5.17	
	ADC2	5.24	
	ADC3	5.18	
	ACC	0.95	

5.3.6 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).

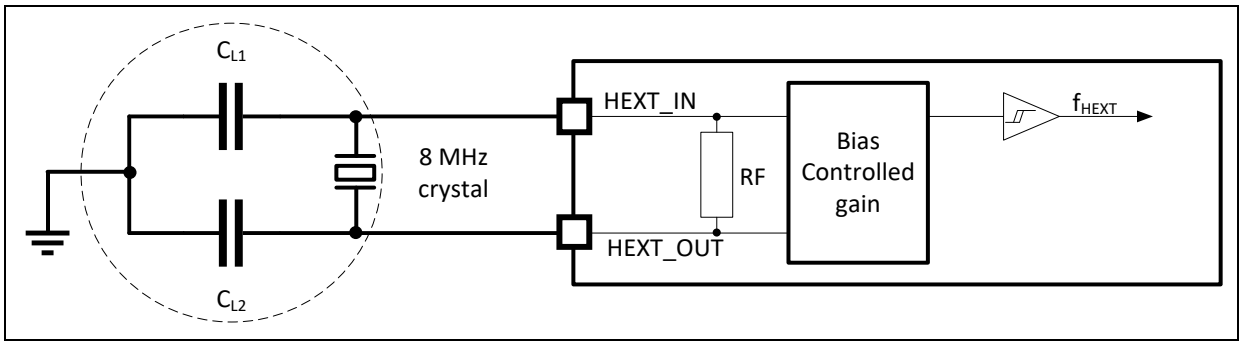
Table 25. HEXT 4-25 MHz crystal characteristics(1)(2)

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 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 25 pF range (typ.), designed for high-frequency applications, and selected to match the requirements of the crystal or resonator. C_{L1} and C_{L2} are usually the same size. The crystal manufacturer typically specifies a load capacitance which is the series combination of C_{L1} and C_{L2}. PCB and MCU pin capacitance must be included (10 pF can be used as a rough estimate of the combined pin and board capacitance) when sizing C_{L1} and C_{L2}.

Figure 10. HEXT typical application with an 8 MHz crystal



High-speed external clock generated from an external source

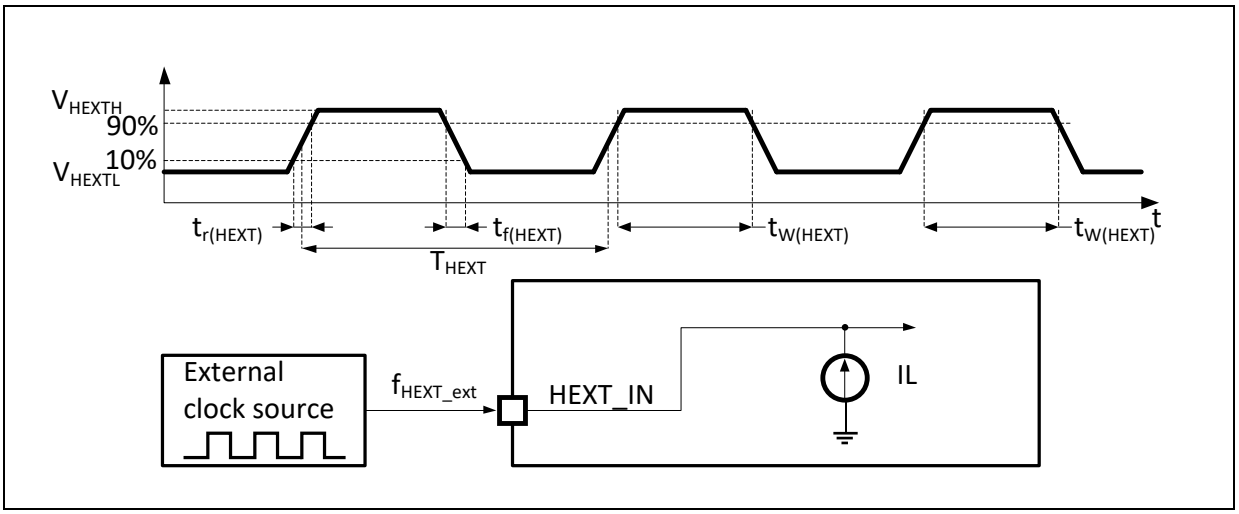
The characteristics given in the table below result from tests performed using a high-speed external clock source.

Table 26. 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
DuCy(HEXT)	Duty cycle	-	45	-	55	%
I_L	HEXT_IN Input leakage current	$V_{SS} \le V_{IN} \le V_{DD}$	-	-	±1	μA

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

Figure 11. HEXT 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 27. LEXT 32.768 kHz crystal characteristics(1)(2)

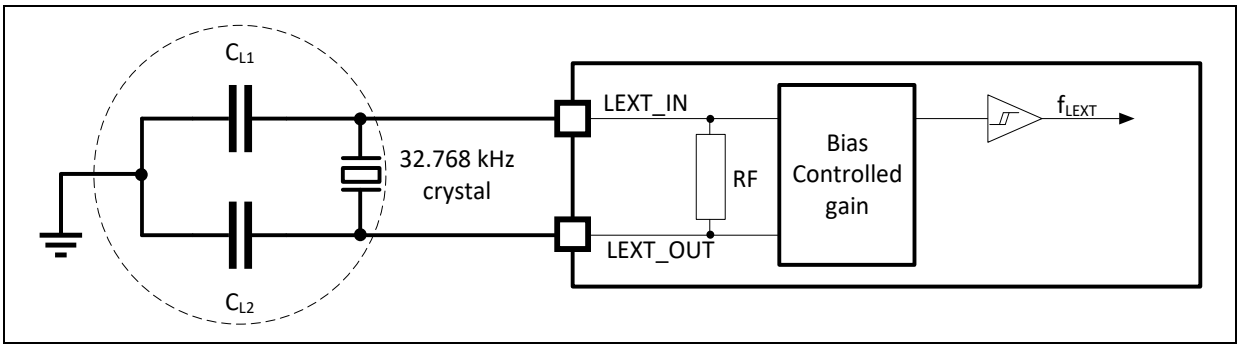
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$t_{SU(LEXT)}$	Startup time	V_{DD} is stabilized	-	150	-	ms

(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 selected to match the requirements of the crystal or resonator. C_{L1} and C_{L2}, are usually the same size. The crystal manufacturer typically specifies a load capacitance which is the series combination of C_{L1} and C_{L2}.

Load capacitance C_L has 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 trace PCB-related capacitance. Typically, it is between 2 pF and 7 pF.

Figure 12. 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

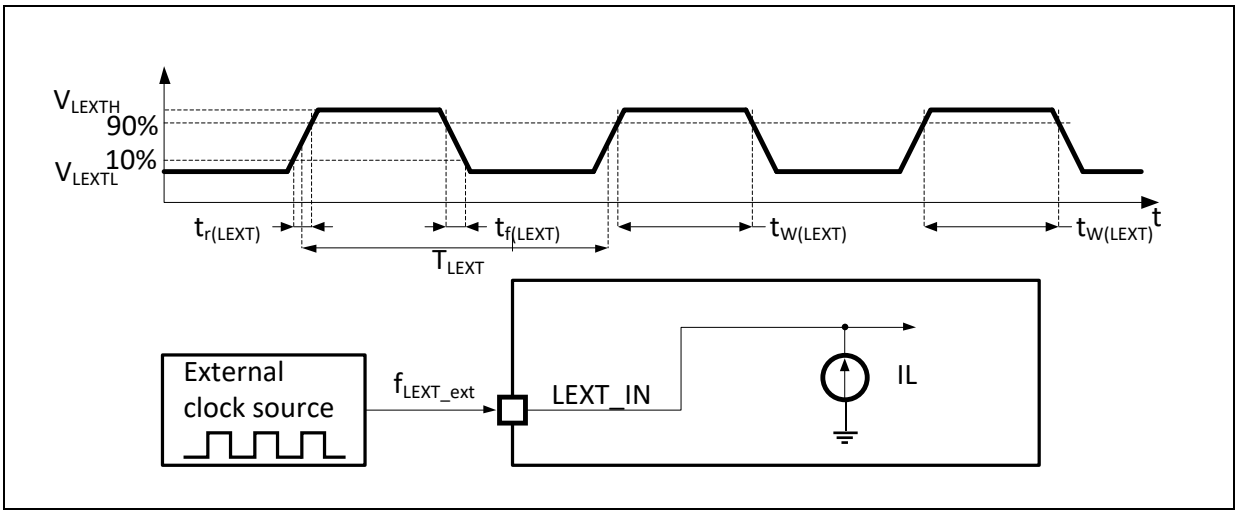
The characteristics given in the table below result from tests performed using a low-speed external clock source.

Table 28. 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
$DuCy_{(LEXT)}$	Duty cycle	-	30	-	70	%
I_L	LEXT_IN input leakage current	$V_{SS} \le V_{IN} \le V_{DD}$	-	-	±1	μA

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

Figure 13. LEXT external source AC timing diagram



5.3.7 Internal clock source characteristics

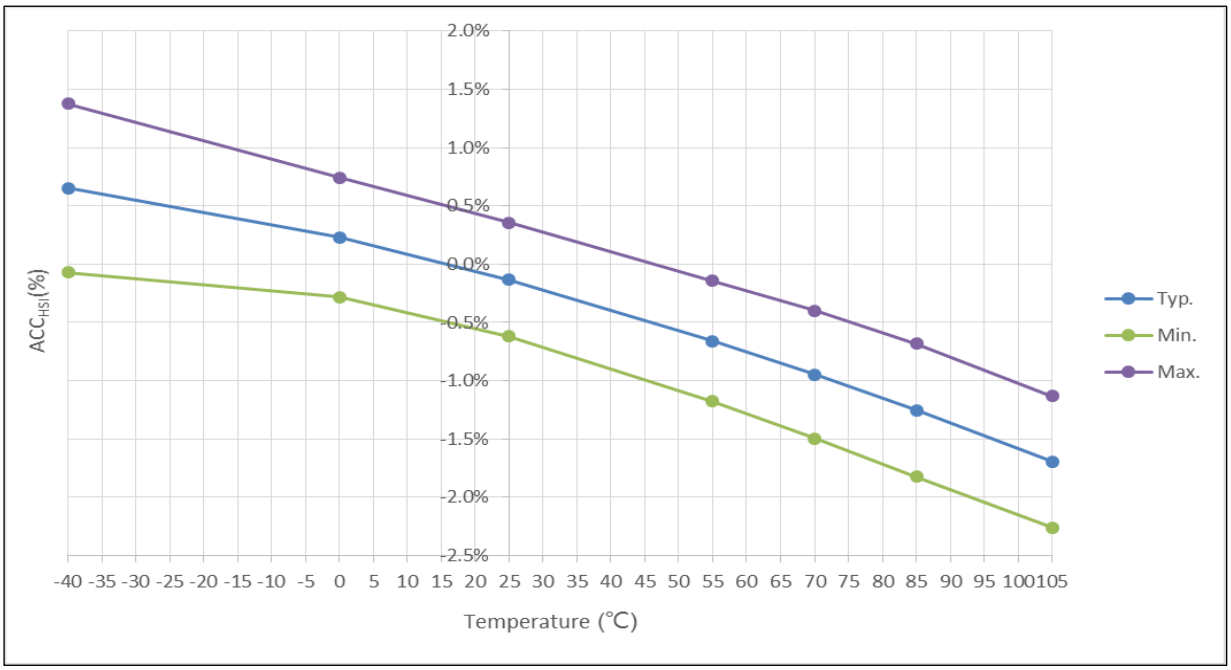
High-speed internal clock (HICK)

Table 29. HICK clock characteristics

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
f_{HICK}	Frequency	-		-	48	-	MHz
$DuCy_{(HICK)}$	Duty cycle	-		45	-	55	%
ACC_{HICK}	Accuracy of the HICK oscillator	User-trimmed with the RCC_CTRL register		-	-	1(1)	%
		ACC-trimmed		-	-	0.25(1)	
		Factory-calibrated(2)	T_A = -40 ~ 105 °C	-2.5		2	%
			T_A = -40 ~ 85 °C	-2.5	-	2	
			T_A = 0 ~ 70 °C	-1.5	-	1.5	
			T_A = 25 °C	-1	-	1	
$t_{SU(HICK)}$(2)	HICK oscillator startup time	-		-	-	10	µs
$I_{DD(HICK)}$(2)	HICK oscillator power consumption	-		-	240	290	µA

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

Figure 14. HICK clock frequency accuracy vs. temperature



Low-speed internal clock (LICK)

Table 30. LICK clock characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{LICK}(1)	Frequency	-	30	40	60	kHz

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

5.3.8 PLL characteristics

Table 31. PLL characteristics

Symbol	Parameter	Min	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}	PLL multiplier output clock	16	-	240	MHz
t_{LOCK}	PLL lock time	-	-	200	μs
Jitter	Cycle-to-cycle jitter	-	-	300	ps

(1) Guaranteed by characterization results, not tested in production.
(2) Take care of using the appropriate multiplier factors so as to have PLL input clock values compatible with the range defined by f_{PLL_OUT}.

5.3.9 Wakeup time from low-power mode

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

- Sleep mode: the clock source is the clock that was set before entering Sleep mode.
- Deepsleep or Standby mode: the clock source is the HICK.

Table 32. Low-power mode wakeup time

Symbol	Parameter	Typ	Unit
$t_{WUSLEEP}$(1)	Wakeup from Sleep mode	3.3	μs
$t_{WUDEEPSLEEP}$(1)	Wakeup from Deepsleep mode (regulator in normal mode)	280	μs
	Wakeup from Deepsleep mode (regulator in low-power mode)	320	
$t_{WUSTDBY}$(1)	Wakeup from Standby mode	8	ms

(1) The wakeup times are measured from the wakeup event to the point in which the user application code reads the first instruction.

5.3.10 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 disturbance occurs. This test is compliant with the IEC 61000-4-4 standard.

Table 33. EMS characteristics

Symb	Parameter	Conditions	Level/Class
V_{EFT}	Fast transient voltage burst limits to be applied through coupling/decoupling network conforms to IEC 61000-4-4 on V_{DD} and V_{SS} pins to induce a functional disturbance, V_{DD} and V_{SS} input has one 47 µF capacitor and each V_{DD} and V_{SS} pin pair 0.1 µF	V_{DD} = 3.3 V, LQFP100, T_A = +25 °C, f_{HCLK} = 240 MHz, conforms to IEC 61000-4-4	4A (4kV)
		V_{DD} = 3.3 V, LQFP100, T_A = +25 °C, f_{HCLK} = 72 MHz, conforms 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 software optimization and prequalification tests in relation with the EMC level requested for his application.

5.3.11 GPIO port characteristics

General input / output characteristics

All GPIOs are CMOS and TTL compliant.

Table 34. GPIO static characteristics

Symb	Parameter	Conditions	Min	Typ	Max	Unit
V_{IL}	GPIO input low level voltage	-	–0.3	-	0.28 * V_{DD} + 0.1	V
V_{IH}	TC GPIO input high level voltage	-	0.31 * V_{DD} + 0.8	-	V_{DD} + 0.3	V
	FTa GPIO input high level voltage	Analog mode				
	FT GPIO input high level voltage	-		-	5.5	
	FTa GPIO input high level voltage	Input floating, input pull-up, or input pull-down mode				
V_{hys}	TC GPIO Schmitt trigger voltage hysteresis(1)	-	200	-	-	mV
	FT and FTa GPIO Schmitt trigger voltage hysteresis(1)		5% V_{DD}	-	-	-
I_{lkg}	Input leakage current(2)	$V_{SS} \le V_{IN} \le V_{DD}$ TC GPIOs	-	-	±1	µA
		$V_{SS} \le V_{IN} \le 5.5V$ FT and FTa GPIO	-	-	±1	
R_{PU}	Weak pull-up equivalent resistor	$V_{IN} = V_{SS}$	60	70	100	kΩ
R_{PD}	Weak pull-down equivalent resistor(3)	$V_{IN} = V_{DD}$	60	70	100	kΩ
C_{IO}	GPIO pin capacitance	-	-	9	-	pF

(1) Hysteresis voltage between Schmitt trigger switching levels. Guaranteed by characterization results.
(2) Leakage could be higher than max if negative current is injected on adjacent pins.
(3) The pull-down resistor of BOOT0 exists permanently.

All GPIOs are CMOS and TTL compliant (no software configuration required). Their characteristics cover more than the strict CMOS-technology or TTL parameters.

Output driving current

In the user application, the number of GPIO pins which can drive current must be controlled to respect the absolute maximum rating defined in *Section 5.2.1*:

- 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 9*).
- 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 9*).

Output voltage levels

All GPIOs are CMOS and TTL compliant.

Table 35. Output voltage characteristics

Symbol	Parameter	Conditions	Min	Max	Unit
Maximum sourcing/sinking strength					
V_{OL}	Output low level voltage	CMOS standard, I_{IO} = 15 mA	-	0.4	V
V_{OH}	Output high level voltage		V_{DD}-0.4	-	
V_{OL}	Output low level voltage	TTL standard, I_{IO} = 6 mA	-	0.4	V
V_{OH}	Output high level voltage		2.4	-	
Large sourcing/sinking strength					
V_{OL}	Output low level voltage	CMOS standard, I_{IO} = 6 mA	-	0.4	V
V_{OH}	Output high level voltage		V_{DD}-0.4	-	
V_{OL}	Output low level voltage	TTL standard, I_{IO} = 3 mA	-	0.4	V
V_{OH}	Output high level voltage		2.4	-	
V_{OL}(1)	Output low level voltage	I_{IO} = 20 mA	-	1.3	V
V_{OH}(1)	Output high level voltage		V_{DD}-1.3	-	
Normal sourcing/sinking strength					
V_{OL}	Output low level voltage	CMOS standard, I_{IO} = 4 mA	-	0.4	V
V_{OH}	Output high level voltage		V_{DD}-0.4	-	
V_{OL}	Output low level voltage	TTL standard, I_{IO} = 2 mA	-	0.4	V
V_{OH}	Output high level voltage		2.4	-	
V_{OL}(1)	Output low level voltage	I_{IO} = 10 mA	-	1.3	V
V_{OH}(1)	Output high level voltage		V_{DD}-1.3	-	

(1) Guaranteed by characterization results.

Input AC characteristics

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

Table 36. Input AC characteristics

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

5.3.12 NRST pin characteristics

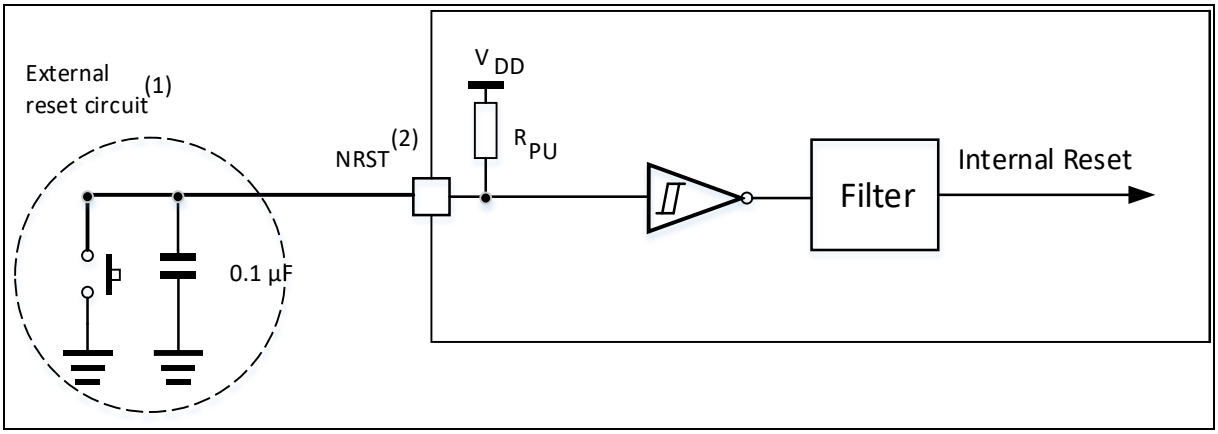
The NRST pin input driver uses CMOS technology. It is connected to a permanent pull-up resistor, R_{PU} (see the table below).

Table 37. NRST pin characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{IL(NRST)}$(1)	NRST input low level voltage	-	-0.5	-	0.8	V
$V_{IH(NRST)}$(1)	NRST input high level voltage	-	2	-	V_{DD} + 0.3	
$V_{hys(NRST)}$	NRST Schmitt trigger voltage hysteresis	-	-	500	-	mV
R_{PU}	Weak pull-up equivalent resistor	V_{IN} = V_{SS}	30	40	50	kΩ
$V_{F(NRST)}$(1)	NRST input filtered puLEXT	-	-	-	33.3	μs
$V_{NF(NRST)}$(1)	NRST input not filtered puLEXT	-	66.7	-	-	μs

(1) Guaranteed by design.

Figure 15. 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 37*. Otherwise the reset will not be taken into account by the device.

5.3.13 XMC characteristics

Asynchronous waveforms and timings of PSRAM / NOR

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

- AddressSetupTime = 0
- AddressHoldTime = 1
- DataSetupTime = 1

Table 38. 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 16. Asynchronous multiplexed PSRAM / NOR read waveforms

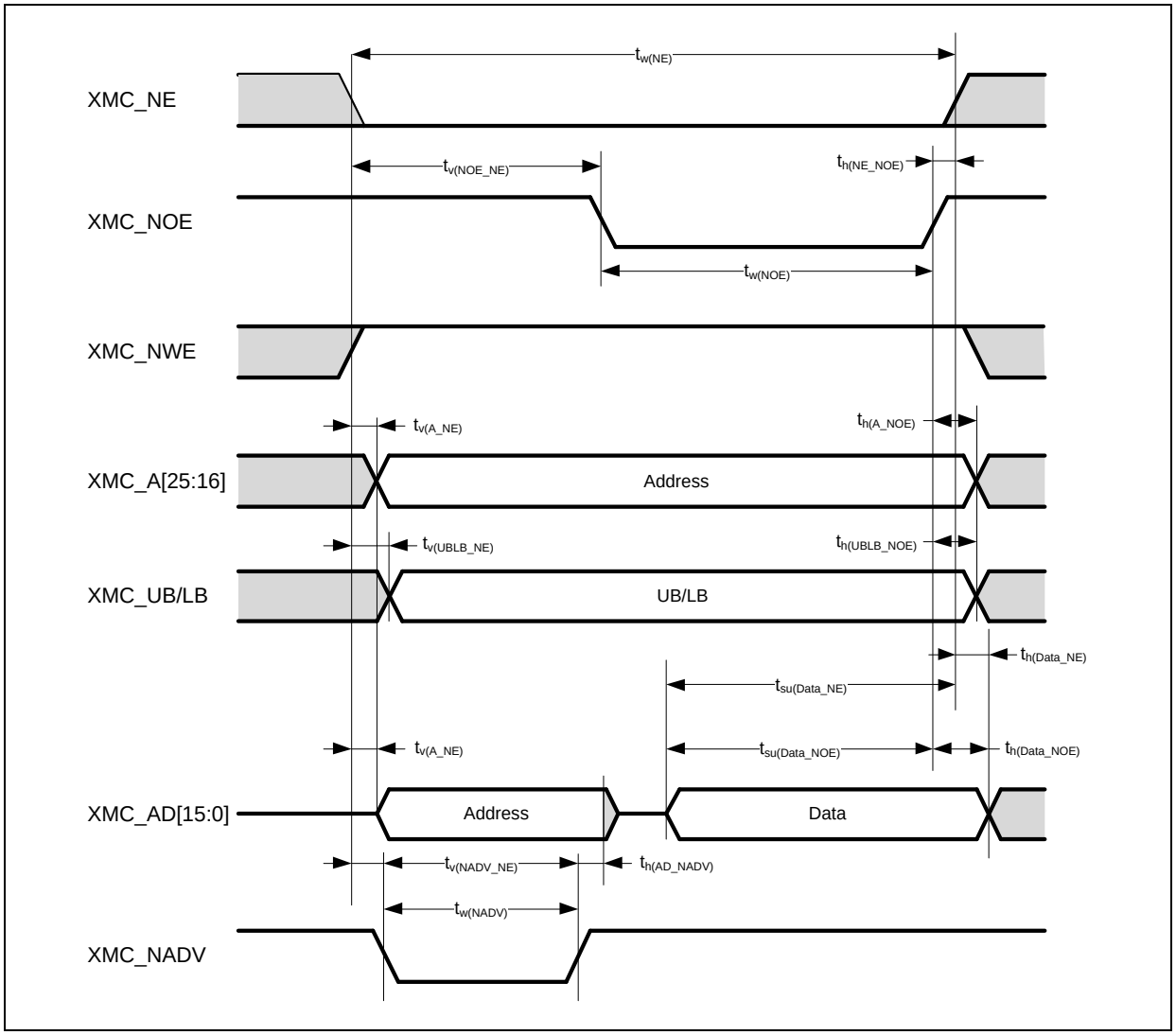
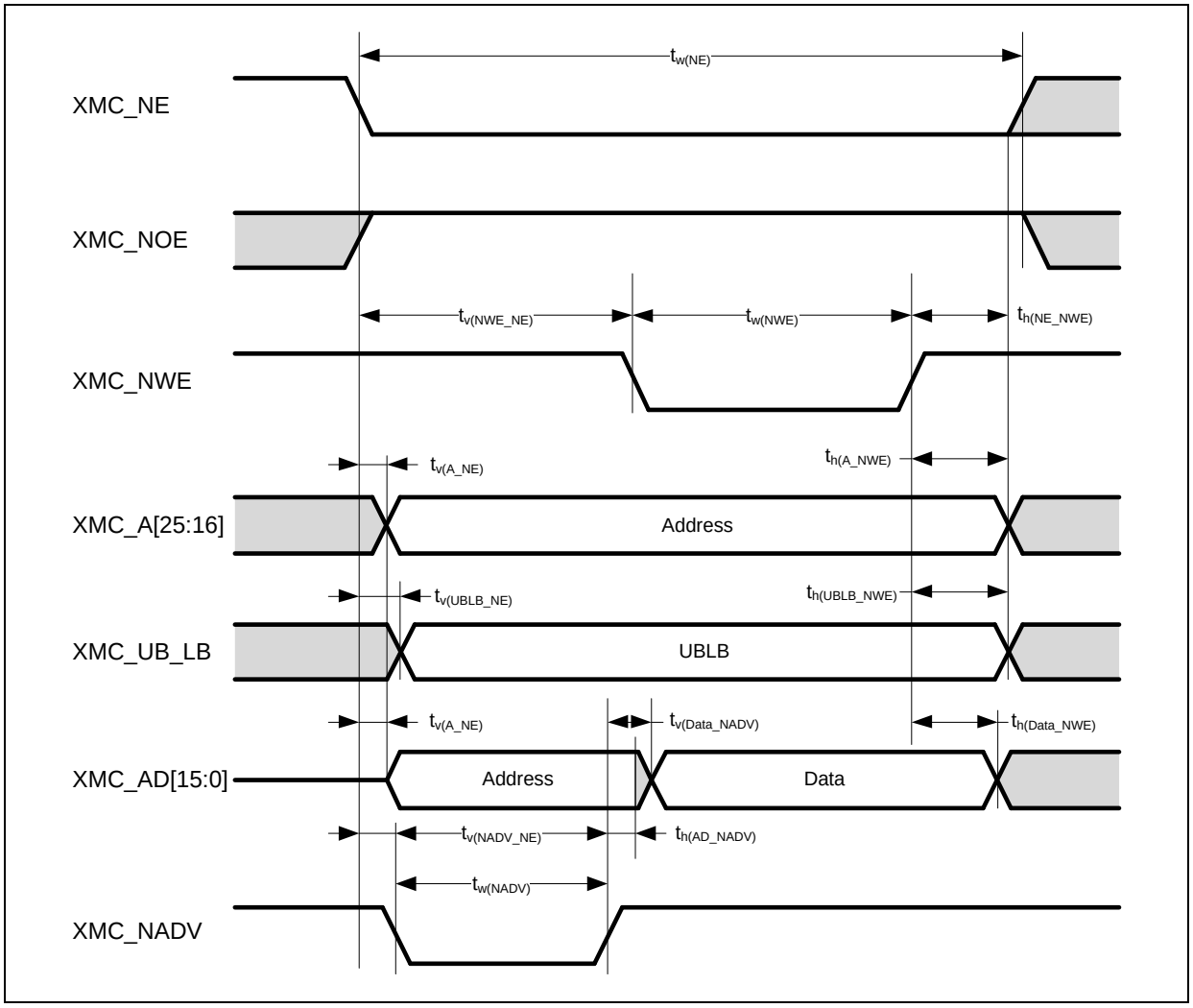


Table 39. Asynchronous multiplexed PSRAM / NOR write timings

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) valid 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 17. Asynchronous multiplexed PSRAM / NOR write waveforms



Synchronous waveforms and timings of PSRAM / NOR

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

- BurstAccessMode = XMC_BurstAccessMode_Enable;
- MemoryType = XMC_MemoryType_CRAM;
- WriteBurst = XMC_WriteBurst_Enable;
- CLKPrescale = 1; (1 memory cycle= 2 HCLK cycles) (Note: CLKPrescale refers to the CLKPSC bit in XMC_BK1TMGx register. Refer to the AT32F407 reference manual.)
- DataLatency = 1 for NOR Flash; DataLatency = 0 for PSRAM (Note: DataLatency refers to the DATLAT bit in XMC_BK1TMGx register. Refer to the AT32F407 reference manual.)

Table 40. 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
$t_{d(CLKH-NEH)}$	XMC_CLK low to XMC_NE high	t_{HCLK} + 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
$t_{d(CLKH-AIV)}$	XMC_CLK low to XMC_A invalid	t_{HCLK} + 2	-	ns
$t_{d(CLKL-NOEL)}$	XMC_CLK high to XMC_NOE low		t_{HCLK} + 1	ns
$t_{d(CLKH-NOEH)}$	XMC_CLK low to XMC_NOE high	t_{HCLK} + 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 before XMC_CLK high	6	-	ns
$t_{h(CLKH-ADV)}$	XMC_AD valid data after XMC_CLK high	t_{HCLK} - 10	-	ns
$t_{su(NWAITV-CLKH)}$	XMC_NWAIT valid before XMC_CLK high	8	-	ns
$t_{h(CLKH-NWAITV)}$	XMC_NWAIT valid after XMC_CLK high	6	-	ns

Figure 18. Synchronous multiplexed PSRAM / NOR read timings

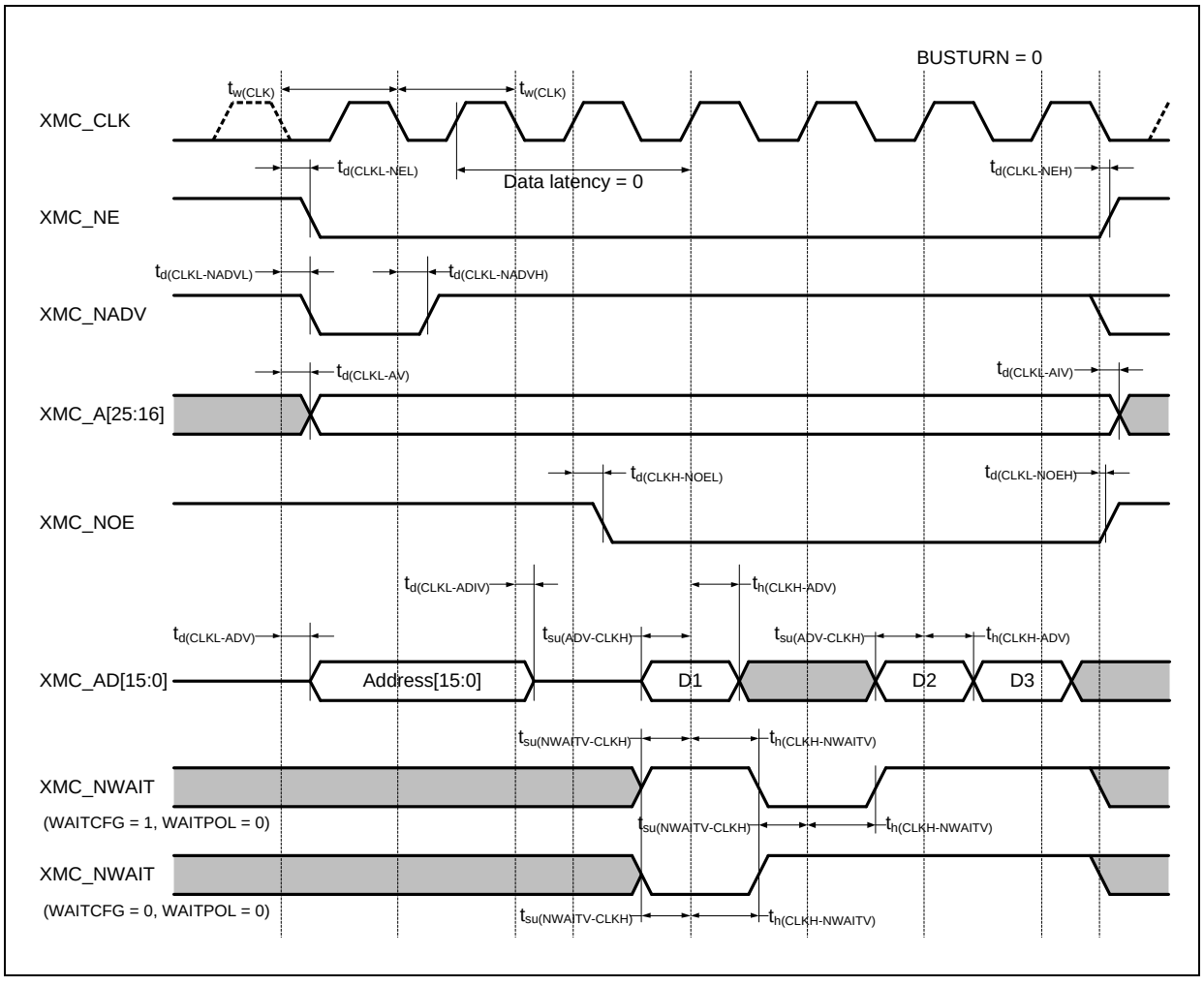
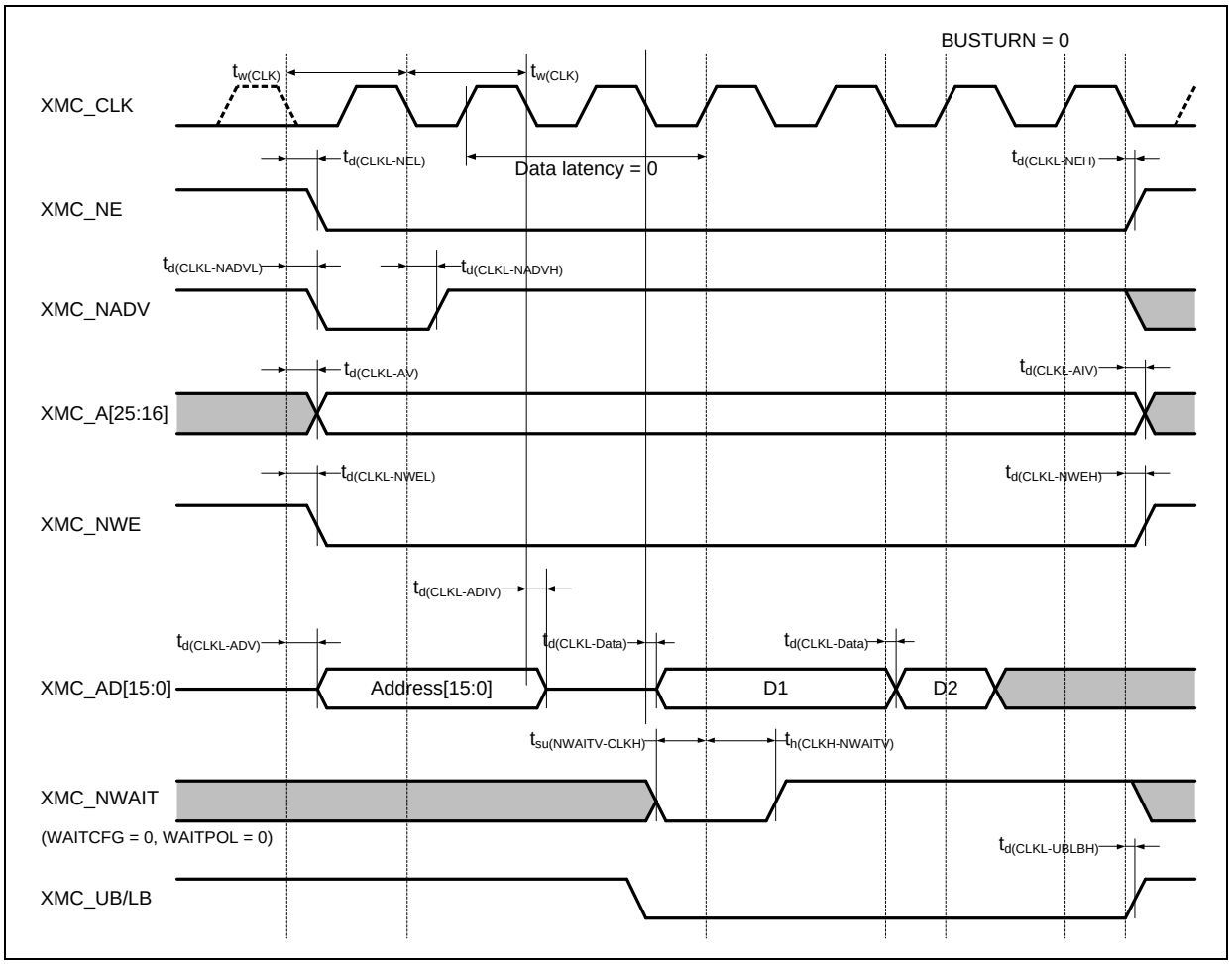


Table 41. Synchronous multiplexed PSRAM write timings

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
$t_{d(CLKH-NEH)}$	XMC_CLK low to XMC_NE high	t_{HCLK} + 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
$t_{d(CLKH-AIV)}$	XMC_CLK low to XMC_A invalid	t_{HCLK} + 2	-	ns
$t_{d(CLKL-NWEL)}$	XMC_CLK low to XMC_NWE low	-	1	ns
$t_{d(CLKH-NWEH)}$	XMC_CLK low to XMC_NWE high	t_{HCLK} + 1	-	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 valid after XMC_CLK low	-	6	ns
$t_{d(CLKL-UBLBH)}$	XMC_CLK low to XMC_UB/LB high	t_{HCLK} + 1	-	ns
$t_{su(NWAITV-CLKH)}$	XMC_NWAIT valid before XMC_CLK high	7	-	ns
$t_{h(CLKH-NWAITV)}$	XMC_NWAIT valid after XMC_CLK high	2	-	ns

Figure 19. Synchronous multiplexed PSRAM write timings



NAND controller waveforms and timings

he results shown in this table are obtained with the following XMC configuration:

- COM.XMC_SetupTime = 0x01; (Note: STP in XMC_BKxTMGMEM)
- COM.XMC_WaitSetupTime = 0x03; (Note: OP in XMC_BKxTMGMEM)
- COM.XMC_HoldSetupTime = 0x02; (Note: HLD in XMC_BKxTMGMEM)
- COM.XMC_HiZSetupTime = 0x01; (Note: WRSTP in XMC_BKxTMGMEM)
- ATT.XMC_SetupTime = 0x01; (Note: STP in XMC_BKxTMGATT)
- ATT.XMC_WaitSetupTime = 0x03; (Note: OP in XMC_BKxTMGATT)
- ATT.XMC_HoldSetupTime = 0x02; (Note: HLD in XMC_BKxTMGATT)
- ATT.XMC_HiZSetupTime = 0x01; (Note: WRSTP in XMC_BKxTMGATT)
- Bank = XMC_Bank_NAND;
- MemoryDataWidth = XMC_MemoryDataWidth_16b; (Note: Memory data width = 16 bits)
- ECC = XMC_ECC_Enable; (Note: enable ECC calculation)
- ECCPageSize = XMC_ECCPageSize_512Bytes; (Note: ECC page size = 512 Bytes)
- DLYCRSetupTime = 0; (Note: DLYCR in XMC_BKxCTRL)
- DLYARSetupTime = 0; (Note: DLYAR in XMC_BKxCTRL)

Table 42. NAND Flash read and write timings

Symbol	Parameter	Min	Max	Unit
$t_{w(NOE)}$	XMC_NWE low width	$4T_{HCLK}$ - 1.5	$4T_{HCLK}$ + 1.5	ns
$t_{su(D-NOE)}$	XMC_D valid data before XMC_NOE high	25	-	ns
$t_{h(NOE-D)}$	XMC_D valid data after XMC_NOE high	14	-	ns
$t_{d(ALE-NOE)}$	XMC_ALE valid before XMC_NOE low	-	$3T_{HCLK}$ + 2	ns
$t_{h(NOE-ALE)}$	XMC_NOE high to XMC_ALE invalid	$3T_{HCLK}$ + 4.5	-	ns
$t_{w(NWE)}$	XMC_NWE low width	$4T_{HCLK}$ - 1	$4T_{HCLK}$ + 2.5	ns
$t_{v(NWE-D)}$	XMC_NWE low to XMC_D valid	-	0	ns
$t_{h(NWE-D)}$	XMC_NWE high to XMC_D invalid	$10T_{HCLK}$ + 4	-	ns
$t_{d(D-NWE)}$	XMC_D valid before XMC_NWE high	$6T_{HCLK}$ + 12	-	ns
$t_{d(ALE-NWE)}$	XMC_ALE valid before XMC_NWE low	-	$3T_{HCLK}$ + 1.5	ns
$t_{h(NWE-ALE)}$	XMC_NWE high to XMC_ALE invalid	$3T_{HCLK}$ + 4.5	-	ns

Figure 20. NAND controller read waveforms

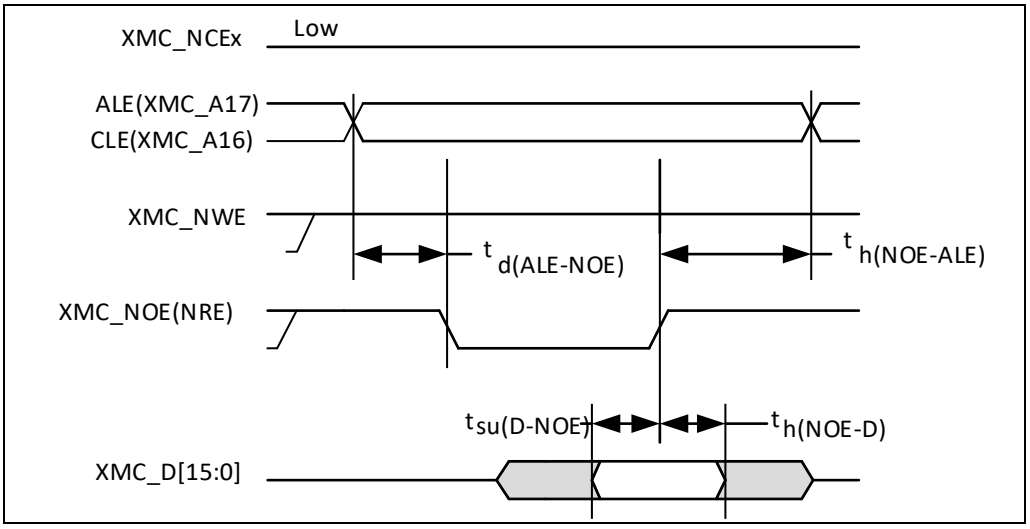


Figure 21. NAND controller write waveforms

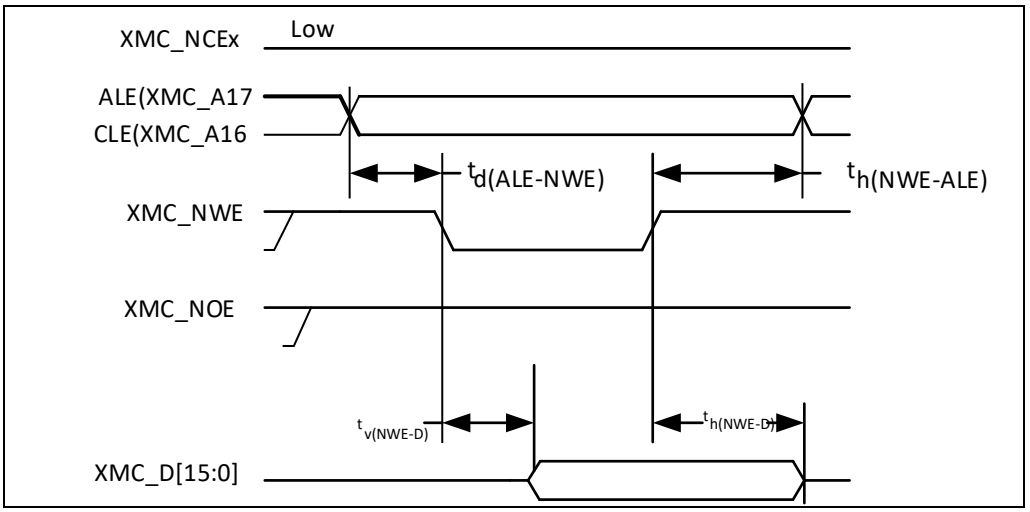


Figure 22. NAND controller common memory read waveforms

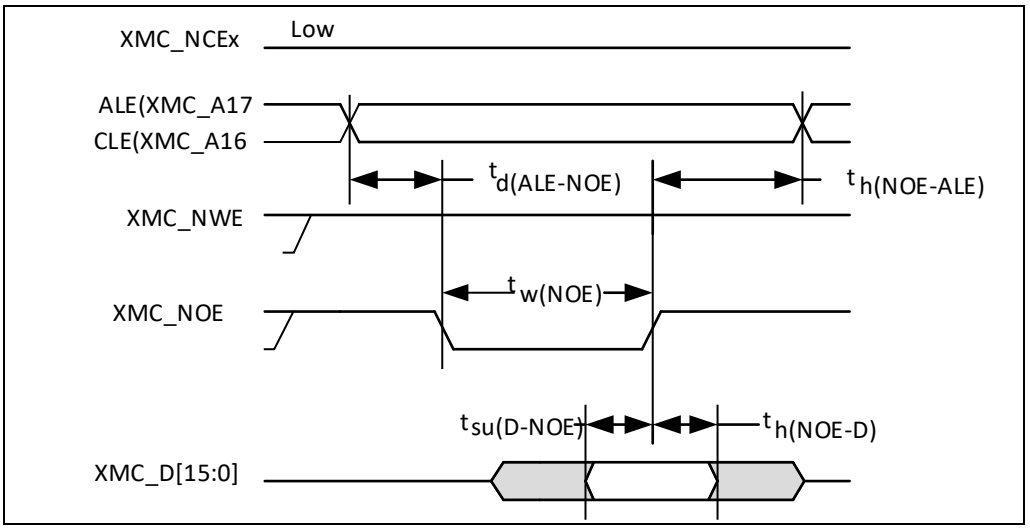
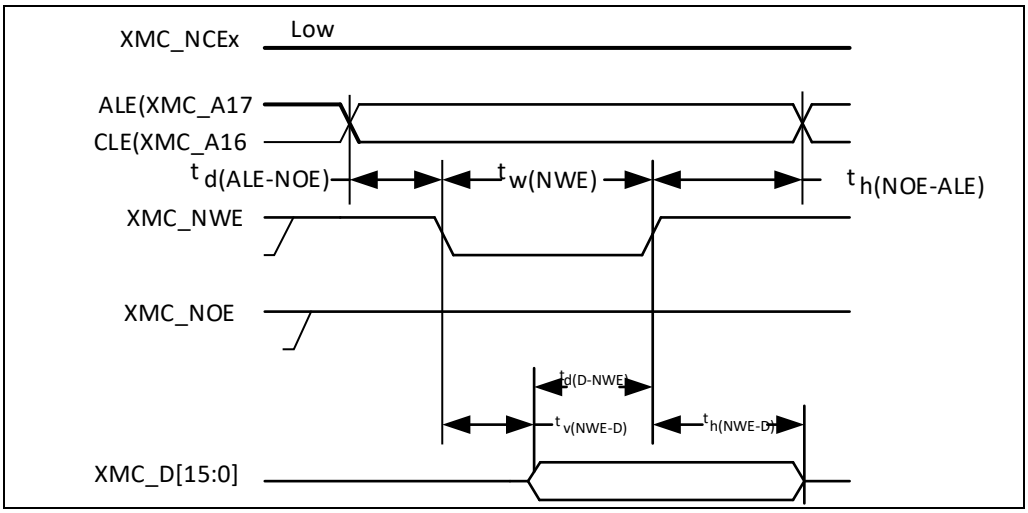


Figure 23. NAND controller for common memory write waveforms



5.3.14 TMR timer characteristics

The parameters given in the table below are guaranteed by design.

Table 43. TMR characteristics

Symbol	Parameter	Conditions	Min	Max	Unit
$t_{res(TMR)}$	Timer resolution time	-	1	-	$t_{TMRxCLK}$
		$f_{TMRxCLK}$ = 240 MHz	4.17	-	ns
f_{EXT}	Timer external clock frequency on CH1 to CH4	-	0	$f_{TMRxCLK}/2$	MHz
				50	MHz

5.3.15 SPI / I²S characteristics

The parameters are listed in *Table 44* for SPI and in *Table 45* for I²S.

Table 44. SPI characteristics

Symbol	Parameter	Conditions	Min	Max	Unit
f_{SCK} $(1/t_{c(SCK)})^{(1)}$	SPI clock frequency$^{(2)(3)}$	V_{DD} = 3.3 V, T_A = 25 °C	-	50	MHz
		V_{DD} = 3.3 V, T_A = 105 °C	-	36	
		V_{DD} = 2.6 V, T_A = 105 °C	-	30	
$t_{r(SCK)}$ $t_{f(SCK)}$	SPI clock rise and fall time	Capacitive load: C = 30 pF	-	8	ns
$t_{su(CS)}^{(1)}$	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, f_{PCLK} = 100 MHz, prescaler = 4	15	25	ns
$t_{su(MI)}^{(1)}$	Data input setup time	Master mode	5	-	ns
$t_{su(SI)}^{(1)}$		Slave mode	5	-	
$t_{h(MI)}^{(1)}$	Data input setup time	Master mode	5	-	ns
$t_{h(SI)}^{(1)}$		Slave mode	4	-	
$t_{a(SO)}^{(1)(4)}$	Data output access time	Slave mode, f_{PCLK} = 20 MHz	0	$3t_{PCLK}$	ns
$t_{dis(SO)}^{(1)(5)}$	Data output disable time	Slave mode	2	10	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)	-	5	ns
$t_{h(SO)}^{(1)}$	Data output hold time	Slave mode (after enable edge)	15	-	ns
$t_{h(MO)}^{(1)}$		Master mode (after enable edge)	2	-	

(1) Guaranteed by characterization results, 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 for 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 24. SPI timing diagram - slave mode and CPHA = 0

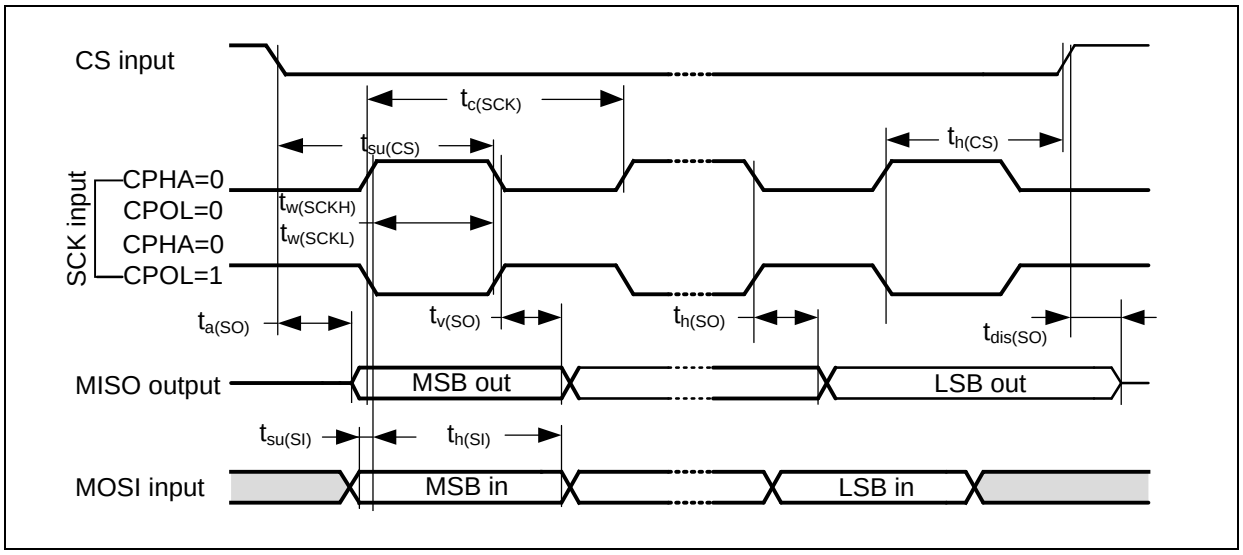


Figure 25. SPI timing diagram - slave mode and CPHA = 1

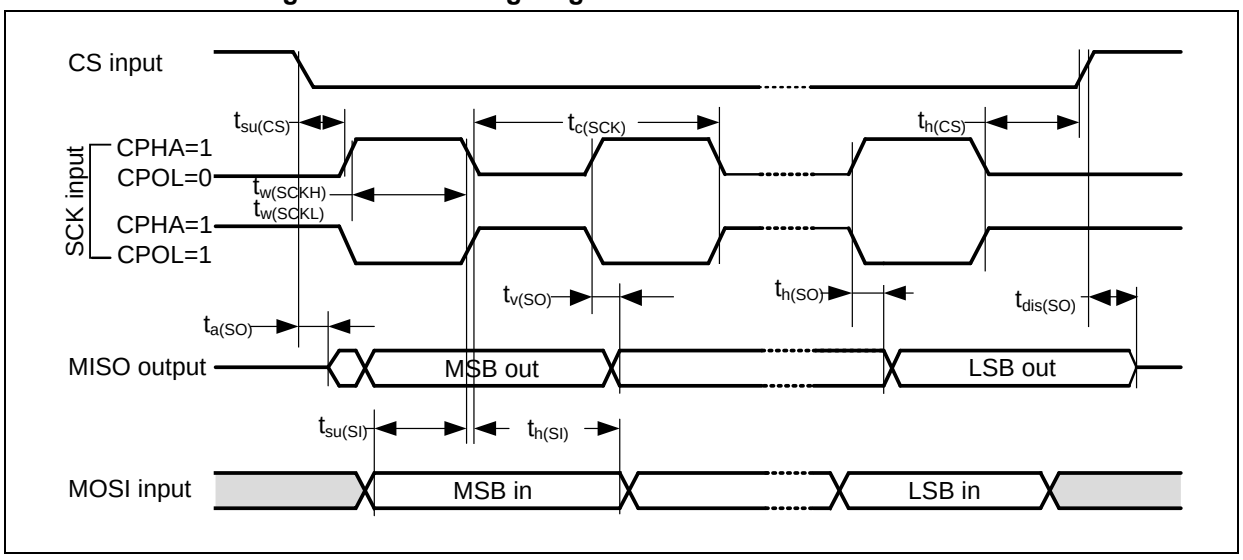


Figure 26. SPI timing diagram - master mode

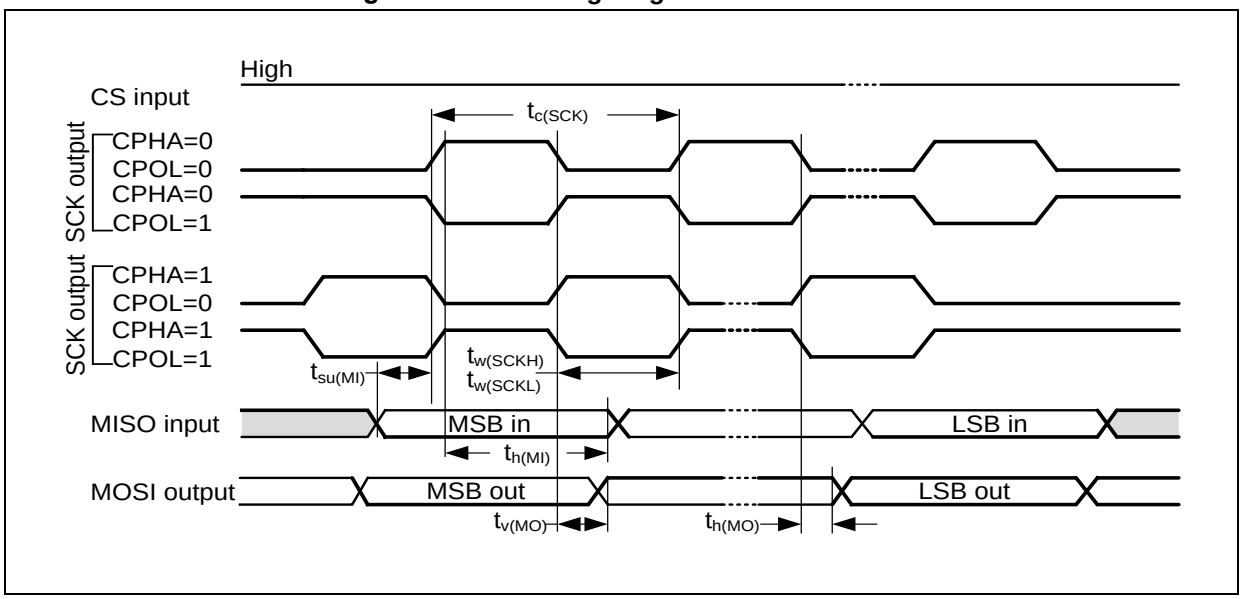
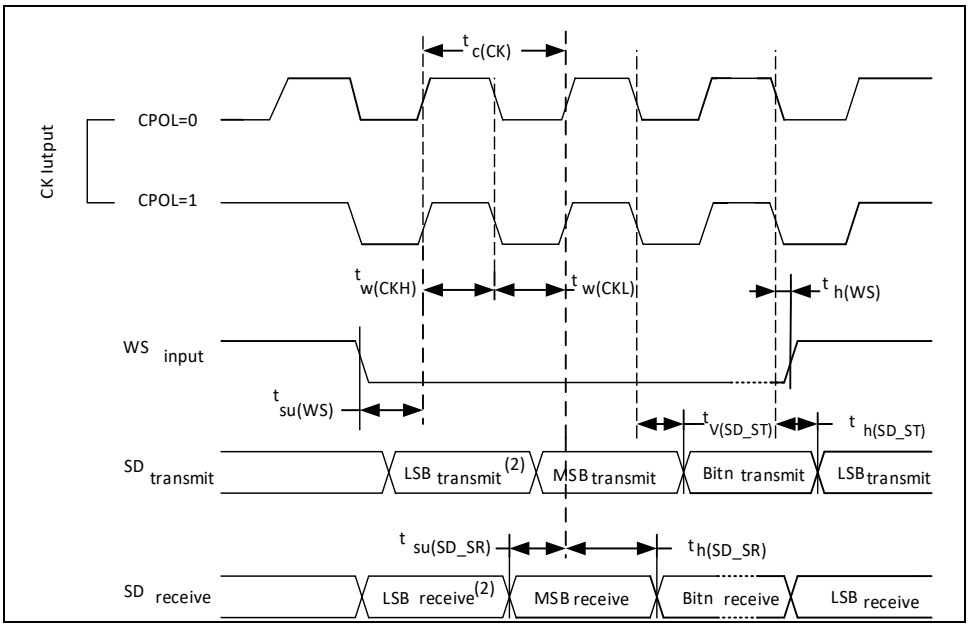


Table 45. I²S characteristics

Symbol	Parameter	Conditions	Min	Max	Unit
f_{CK} $1/t_{c(CK)}$	I²S clock frequency	Master mode (data: 16 bits, audio frequency = 48 kHz)	1.522	1.525	MHz
		Slave mode	0	6.5	
$t_{r(CK)}$ $t_{f(CK)}$	I²S clock rise and fall time	Capacitive load: C = 50 pF	-	8	ns
$t_{v(WS)}$(1)	WS valid time	Master mode	3	-	
$t_{h(WS)}$(1)	WS hold time	Master mode	2	-	
$t_{su(WS)}$(1)	WS setup time	Slave mode	4	-	
$t_{h(WS)}$(1)	WS hold time	Slave mode	0	-	
$t_{w(CKH)}$(1)	CK high and low time	Master f_{PCLK} = 16 MHz, audio frequency = 48 kHz	312.5	-	
$t_{w(CKL)}$(1)			345	-	
$t_{su(SD_MR)}$(1)	Data input setup time	Master receiver	6.5	-	
$t_{su(SD_SR)}$(1)		Slave receiver	1.5	-	
$t_{h(SD_MR)}$(1)(2)	Data input hold time	Master receiver	0	-	
$t_{h(SD_SR)}$(1)(2)		Slave receiver	0.5	-	
$t_{v(SD_ST)}$(1)(2)	Data output valid time	Slave transmitter (after enable edge)	-	18	
$t_{h(SD_ST)}$(1)	Data output hold time	Slave transmitter (after enable edge)	11	-	
$t_{v(SD_MT)}$(1)(2)	Data output valid time	Master transmitter (after enable edge)	-	3	
$t_{h(SD_MT)}$(1)	Data output hold time	Master transmitter (after enable edge)	0	-	

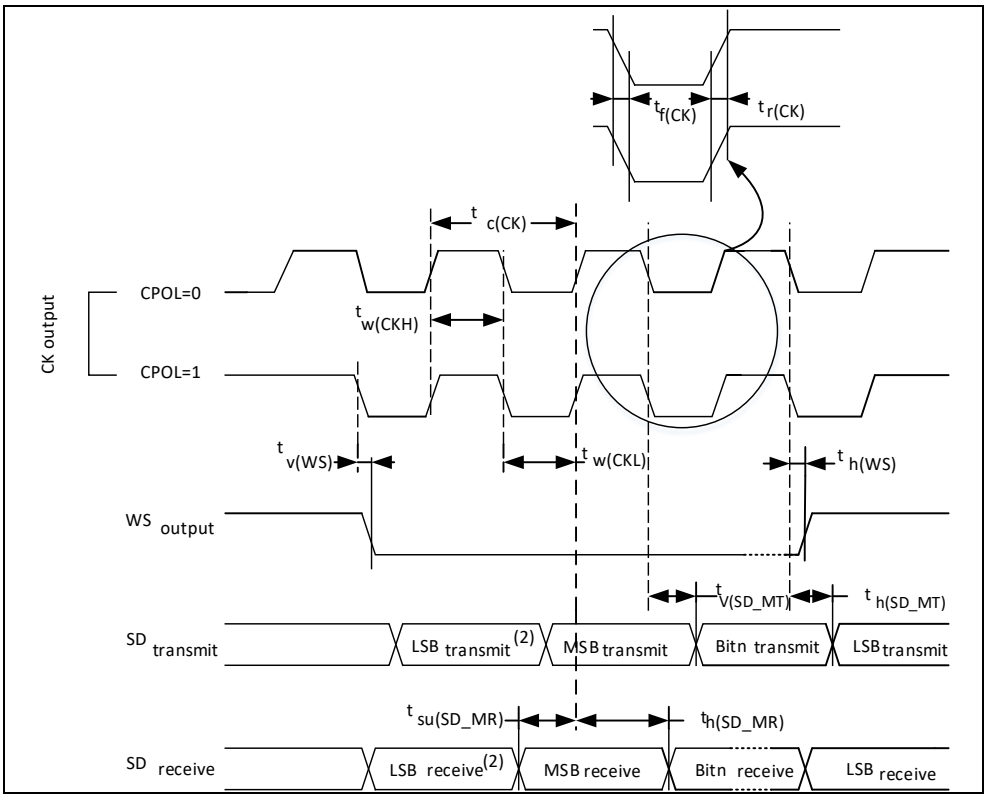
(1) Guaranteed by design and/or characterization results.
(2) Depends on f_{PCLK}. For example, if f_{PCLK}=8 MHz, then T_{PCLK} = 1/f_{PCLK} =125 ns.

Figure 27. 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 28. 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.

5.3.16 I²C interface 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) and fast mode (max. 400 kHz). The I²C bus frequency can be increased up to 1 MHz. For more complete information, please contact your local Artery sales office for technical support.

5.3.17 SDIO characteristics

Figure 29. SDIO high-speed mode

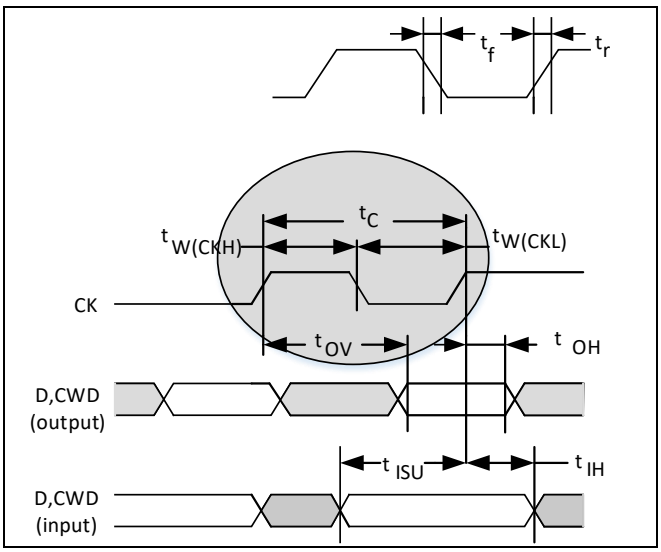


Figure 30. SD default mode

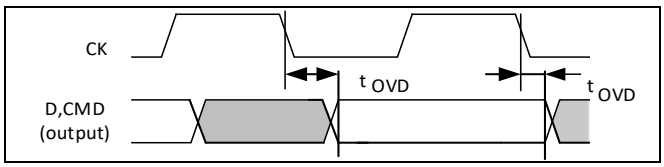


Table 46. SD / MMC characteristics

Symbol	Parameter	Conditions	Min	Max	Unit
f_{PP}	Clock frequency in data transfer mode	-	0	48	MHz
$t_{W(CKL)}$	Clock low time, f_{PP} = 16 MHz	-	32	-	ns
$t_{W(CKH)}$	Clock high time, f_{PP} = 16 MHz	-	30	-	
t_r	Clock rise time	-	-	4	
t_f	Clock fall time	-	-	5	
CMD, D inputs (referenced to CK)					
t_{ISU}	Input setup time	-	2	-	ns
t_{IH}	Input hold time	-	0	-	
CMD, D outputs (referenced to CK) in MMC and SD HS mode					
t_{OV}	Output valid time	-	-	6	ns
t_{OH}	Output hold time	-	0	-	
CMD, D outputs (referenced to CK) in SD default mode(1)					
t_{OVD}	Output valid default time	-	-	7	ns
t_{OHD}	Output hold default time	-	0.5	-	

(1) Refer to SDIO_CLKCTRL, the SDIO clock control register to control the CK output.

5.3.18 USBFS characteristics

Table 47. USBFS startup time

Symbol	Parameter	Max	Unit
$t_{STARTUP}$(1)	USBFS transceiver startup time	1	µs

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

Table 48. USBFS DC electrical characteristics

Symbol		Parameter	Conditions	Min(1)	Typ	Max(1)	Unit
Input levels	V_{DD}	USBFS operating voltage	-	3.0(2)		3.6	V
	V_{DI}(3)	Differential input sensitivity	I (USBFS_D+, USBFS_D-)	0.2		-	V
	V_{CM}(3)	Differential common mode range	Includes 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	R_L of 1.24 kΩ to 3.6 V(4)	-		0.3	V
	V_{OH}	Static output level high	R_L of 15 kΩ to V_{SS}(4)	2.8		3.6	
R_{PU}		USBFS_D+ internal pull-up	V_{IN} = V_{SS}	0.97	1.24	1.58	kΩ

(1) All the voltages are measured from the local ground potential.
(2) The AT32F407 USB functionality is ensured down to 2.7 V but not the full USB electrical characteristics which are degraded in the 2.7 to 3.0 V V_{DD} voltage range.
(3) Guaranteed by characterization results, not tested in production.
(4) R_L is the load connected on the USB drivers.

Figure 31. USBFS timings: definition of data signal rise and fall time

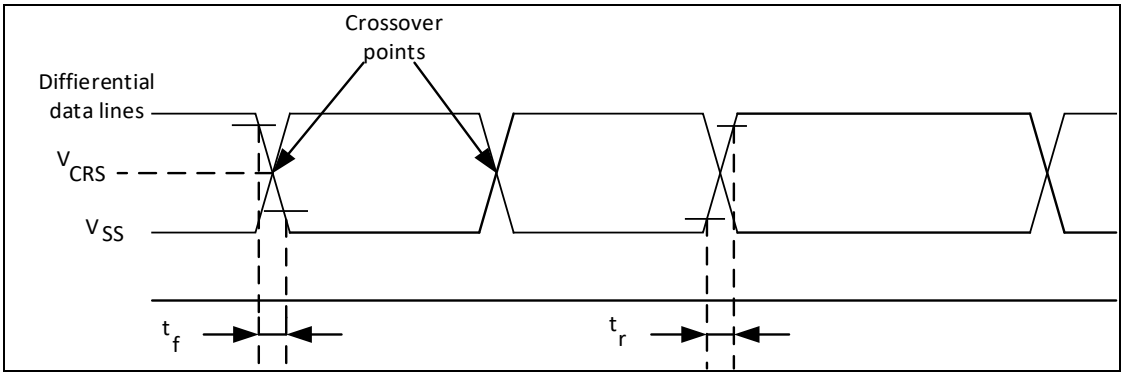


Table 49. USBFS electrical characteristics

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).

5.3.19 EMAC characteristics

Operating voltage

Table 50. EMAC DC electrical characteristics

Symbol	Parameter	Min(1)	Max(1)	Unit
V_{DD}	Ethernet operating voltage	3.0	3.6	V

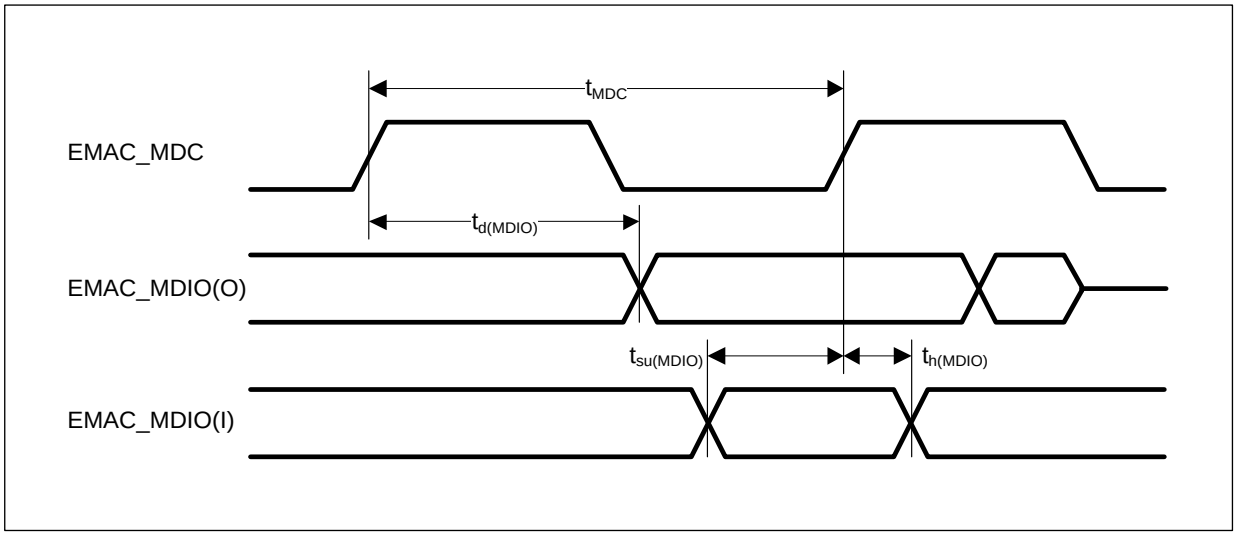
(1) All the voltages are measured from the local ground potential.

SMI (station management interface)

Table 51. Dynamic characteristics: EMAC signals for SMI

Symbol	Parameter	Min	Typ	Max	Unit
t_{MDC}	MDC cycle time (1.96 MHz, f_{AHB} = 200 MHz)	509	510	511	ns
$t_{d(MDIO)}$	MDIO write data valid time	13.5	14.5	15.5	
$t_{su(MDIO)}$	Read data setup time	35	-	-	
$t_{h(MDIO)}$	Read data hold time	0	-	-	

Figure 32. EMAC SMI timing diagram

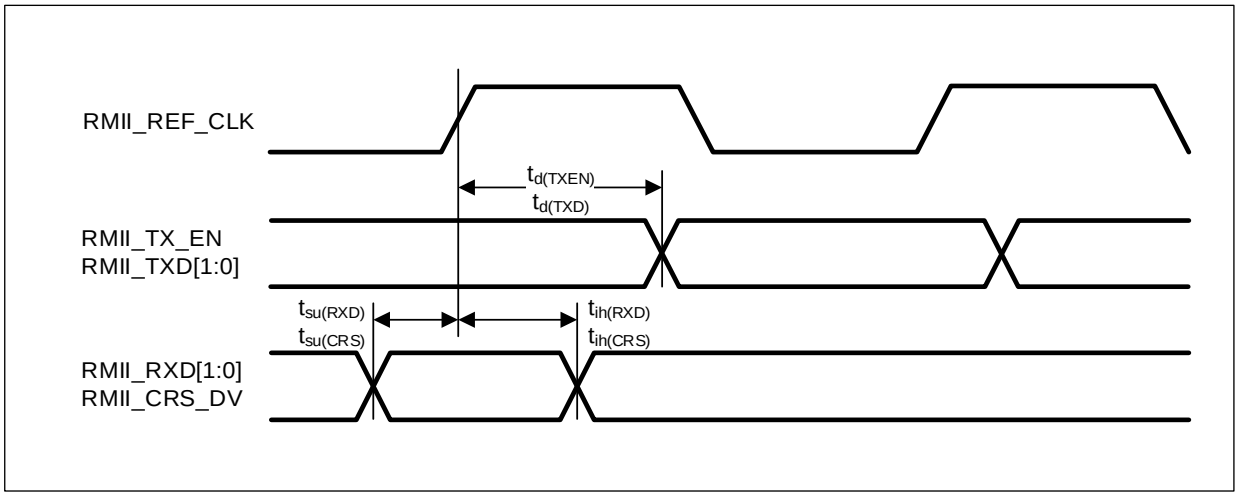


RMII

Table 52. Dynamic characteristics: EMAC signals for RMII

Symbol	Parameter	Min	Typ	Max	Unit
$t_{su(RXD)}$	Receive data setup time	4	-	-	ns
$t_{ih(RXD)}$	Receive data hold time	2	-	-	
$t_{su(DV)}$	Carrier sense set-up time	4	-	-	
$t_{ih(DV)}$	Carrier sense hold time	2	-	-	
$t_{d(TXEN)}$	Transmit enable valid delay time	8	10	16	
$t_{d(TXD)}$	Transmit data valid delay time	7	10	16	

Figure 33. EMAC RMII timing diagram

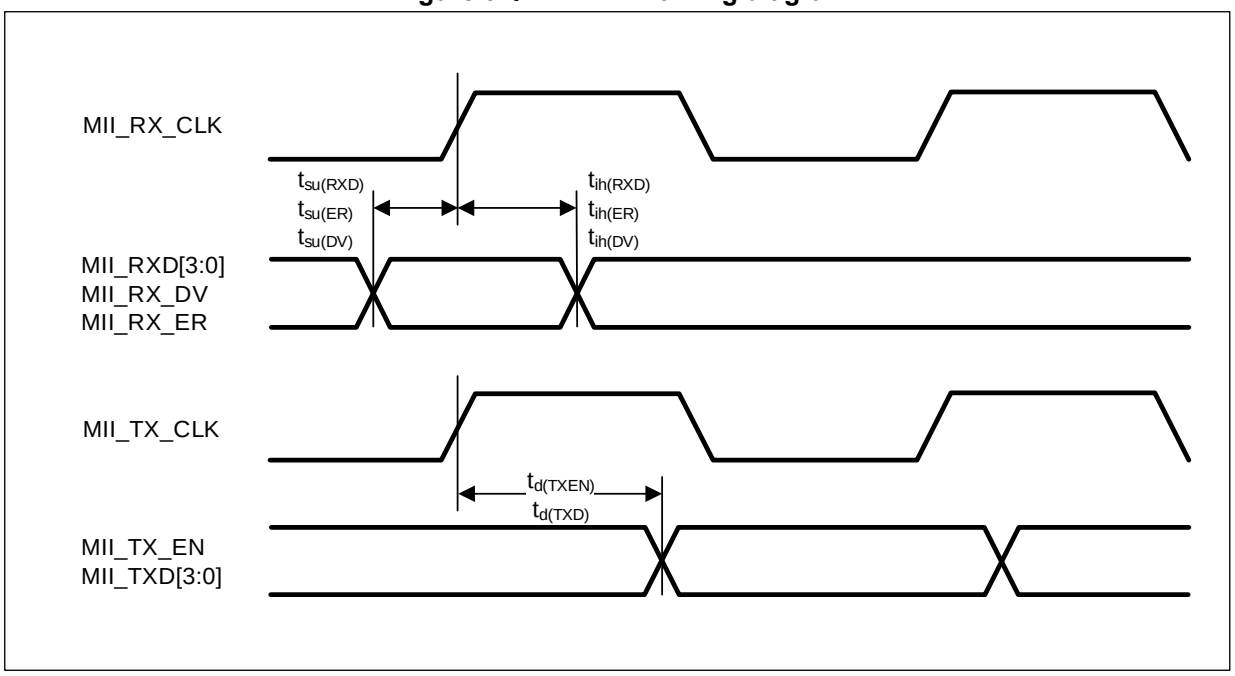


MII

Table 53. Dynamic characteristics: EMAC signals for MII

Symbol	Parameter	Min	Typ	Max	Unit
$t_{su(RXD)}$	Receive data setup time	10	-	-	ns
$t_{ih(RXD)}$	Receive data hold time	10	-	-	
$t_{su(DV)}$	Data valid setup time	10	-	-	
$t_{ih(DV)}$	Data valid hold time	10	-	-	
$t_{su(ER)}$	Error setup time	10	-	-	
$t_{ih(ER)}$	Error hold time	10	-	-	
$t_{d(TXEN)}$	Transmit enable valid delay time	14	16	18	
$t_{d(TXD)}$	Transmit data valid delay time	13	16	20	

Figure 34. EMAC MII timing diagram



5.3.20 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 13*.

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

Table 54. ADC characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{DDA}	Power supply	-	2.6	-	3.6	V
V_{REF+}	Positive reference voltage(3)	-	2.0	-	V_{DDA}	V
I_{DDA}	Current on the V_{DDA} input pin	-	-	380(1)	445	μA
I_{VREF}	Current on the V_{REF+} input pin(3)	-	-	200(1)	220	μA
f_{ADC}	ADC clock frequency	-	0.6	-	28	MHz
f_S(2)	Sampling rate	-	0.05	-	2	MHz
f_{TRIG}(2)	External trigger frequency	f_{ADC} = 28 MHz	-	-	1.65	MHz
		-	-	-	17	$1/f_{ADC}$
V_{AIN}	Conversion voltage range(3)	-	0 (V_{SSA} or V_{REF-} tied to ground))	-	V_{REF+}	V
R_{AIN}(2)	External input impedance	-	See *Table 55* and *Table 56* for details			Ω
C_{ADC}(2)	Internal sample and hold capacitor	-	-	10	-	pF
t_{CAL}(2)	Calibration time	f_{ADC} = 28 MHz	6.61			μs
		-	185			$1/f_{ADC}$
t_{lat}(2)	Injection trigger conversion latency	f_{ADC} = 28 MHz	-	-	107	ns
		-	-	-	3(4)	$1/f_{ADC}$
t_{latr}(2)	Regular trigger conversion latency	f_{ADC} = 28 MHz	-	-	71.4	μs
		-	-	-	2(4)	$1/f_{ADC}$
t_S(2)	Sampling time	f_{ADC} = 28 MHz	0.053	-	8.55	μs
		-	1.5	-	239.5	$1/f_{ADC}$
t_{STAB}(2)	Power-up time	-	42			$1/f_{ADC}$
t_{CONV}(2)	Total conversion time (including sampling time)	f_{ADC} = 28 MHz	0.5	-	9	μs
		-	14 to 252 (t_S for sampling + 12.5 for successive approximation)			$1/f_{ADC}$

(1) Guaranteed by characterization results, not tested in production.
(2) Guaranteed by design, not tested in production.
(3) V_{REF+} can be internally connected to V_{DDA} and V_{REF-} can be internally connected to V_{SSA}, depending on the package.
(4) For external triggers, a delay of $1/f_{PCLK2}$ must be added to the latency specified in *Table 54*.

Table 55 and *Table 56* are used to determine the maximum external impedance allowed for an error below 1/4 of LSB.

Table 55. R_{AIN} max for f_{ADC} = 14 MHz

T_S (Cycle)	t_S (µs)	R_{AIN} max (kΩ)(1)
1.5	0.11	0.25
7.5	0.54	1.3
13.5	0.96	2.5
28.5	2.04	5.0
41.5	2.96	8.0
55.5	3.96	10.5
71.5	5.11	13.5
239.5	17.11	40

(1) Guaranteed by design.

Table 56. R_{AIN} max for f_{ADC} = 28 MHz

T_S (Cycle)	t_S (µs)	R_{AIN} max (kΩ)(1)
1.5	0.05	0.1
7.5	0.27	0.6
13.5	0.48	1.2
28.5	1.02	2.5
41.5	1.48	4.0
55.5	1.98	5.2
71.5	2.55	7.0
239.5	8.55	20

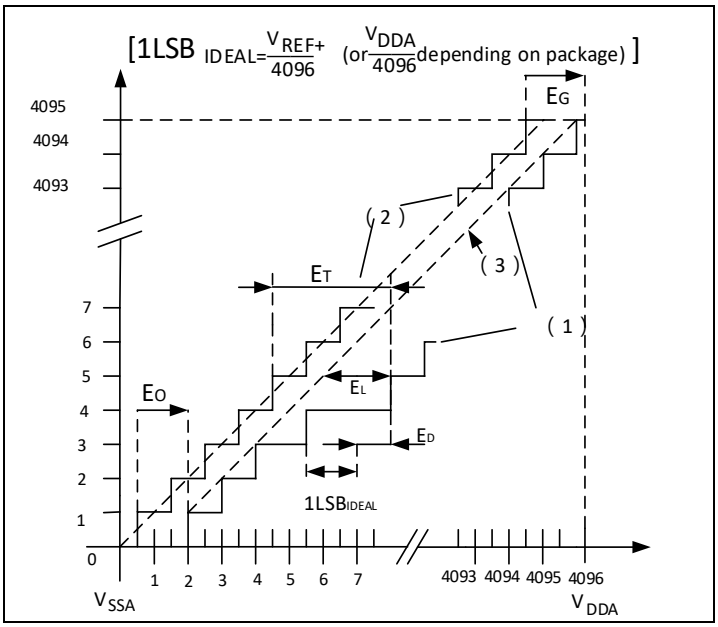
(1) Guaranteed by design.

Table 57. ADC accuracy(1)

Symbol	Parameter	Test Conditions	Typ(2)	Max(2)	Unit
ET	Total unadjusted error	f_{PCLK2} = 56 MHz,	±1.5	±2.5	LSB
EO	Offset error	f_{ADC} = 28 MHz, R_{AIN} < 10 kΩ,	+0.5	±1.5	
EG	Gain error	V_{DDA} = 3.0 to 3.6 V, T_A = 25 °C	+1	+2/-0.5	
ED	Differential linearity error	Measurements made after ADC calibration	±0.6	±0.9	
EL	Integral linearity error	V_{REF+} = V_{DDA}	±0.8	±1.5	
ET	Total unadjusted error	f_{PCLK2} = 56 MHz,	±2	±4	LSB
EO	Offset error	f_{ADC} = 28 MHz, R_{AIN} < 10 kΩ,	+0.5	±2	
EG	Gain error	V_{DDA} = 2.6 to 3.6 V	+1	+2.5/-1.5	
ED	Differential linearity error	Measurements made after ADC calibration	±0.6	±1.2	
EL	Integral linearity error		±1	±2	

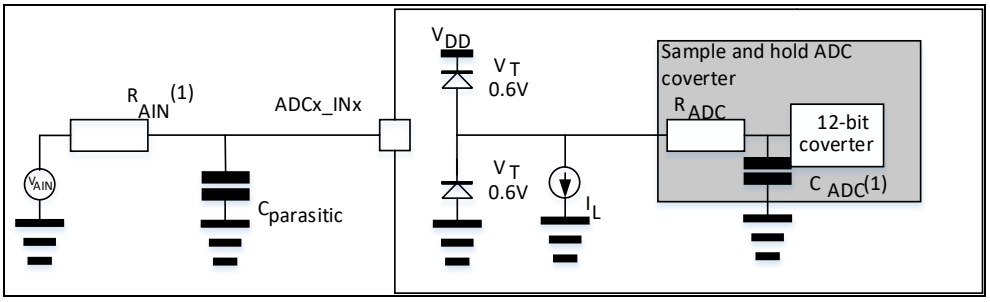
(1) ADC DC accuracy values are measured after internal calibration.
(2) Guaranteed by characterization results, not tested in production.

Figure 35. ADC accuracy characteristics



(1) Example of an actual transfer curve.
(2) Ideal transfer curve.
(3) End point correlation line.
(4) ET = Maximum deviation between the actual and the ideal transfer curves.
EO = Deviation between the first actual transition and the first ideal one.
EG = Deviation between the last ideal transition and the last actual one.
ED = Maximum deviation between actual steps and the ideal one.
EL = Maximum deviation between any actual transition and the end point correlation line.

Figure 36. Typical connection diagram using the ADC



(1) Refer to *Table 54* 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.

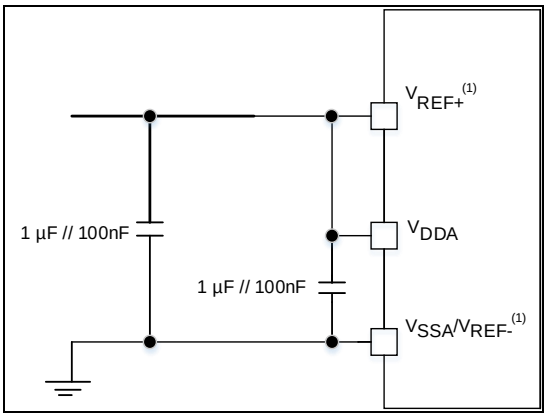
General PCB design guidelines

Power supply decoupling should be performed as shown in *Figure 37* or *Figure 38*.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 them as close as possible to the chip.

If HEXT is enabled while ADC uses any input channel of ADC123_IN10~13, following PCB layout guide line below benefits to isolate the high frequency interference from HEXT emitting to ADC input signals nearby.

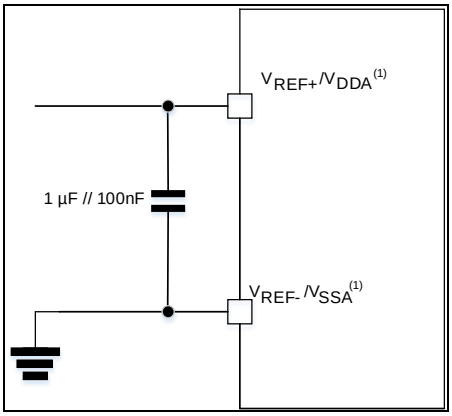
- Use different PCB layers to route ADC_IN signal apart from HEXT path
- Do not route ADC_IN signals and HEXT path parallel

Figure 37. Power supply and reference decoupling (V_{REF+} not connected to V_{DDA})



(1) V_{REF+} and V_{REF-} inputs are available only on 100-pin package.

Figure 38. Power supply and reference decoupling (V_{REF+} connected to V_{DDA})



(1) V_{REF+} and V_{REF-} inputs are available only on 100-pin package

5.3.21 Internal reference voltage (V_{INTRV}) characteristics

Table 58. Internal reference voltage characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{INTRV}	Internal reference voltage	-	1.16	1.20	1.24	V
T_{Coeff}(1)	Temperature coefficient	-	-	-	120	ppm/°C
T_{S_VINTRV}	ADC sampling time when reading the internal reference voltage	-	-	5.1	17.1	µs

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

5.3.22 Temperature sensor (V_{TS}) characteristics

Table 59. Temperature sensor characteristics

Symbol	Parameter	Min	Typ	Max	Unit
T_L(1)	V_{TS} linearity with temperature	-	±2	±4	ºC
Avg_Slope(1(2))	Average slope	-4.11	-4.26	-4.41	mV/ºC
V_{25}(1)(2)	Voltage at 25 ºC	1.19	1.28	1.37	V
t_{START}(3)	Startup time	-	-	100	µs
T_{S_temp}(3)	ADC sampling time when reading the temperature	-	8.6	17.1	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:

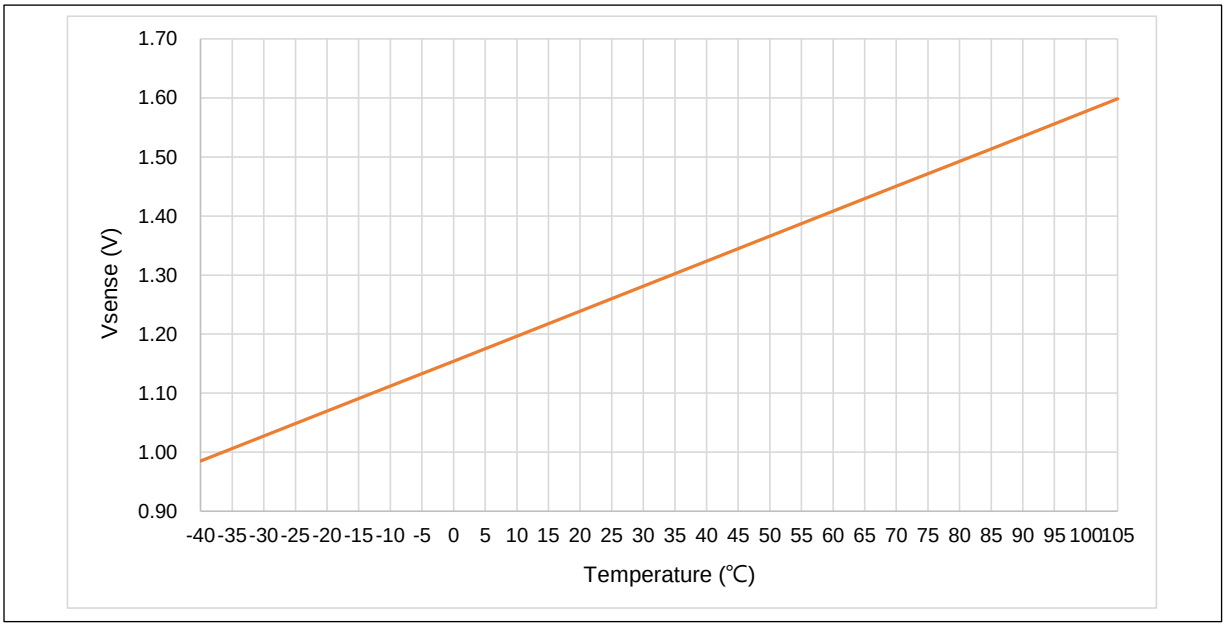
Temperature (in °C) = {(V_{25} - V_{TS}) / Avg_Slope} + 25.

Where,

V_{25} = V_{TS} value for 25° C and

Avg_Slope = Average Slope for curve between Temperature vs. V_{SENSE} (given in mV/° C).

Figure 39. V_{TS} vs. temperature



5.3.23 12-bit DAC specifications

Table 60. DAC characteristics

Symbol	Parameter	Comments	Min	Typ	Max	Unit
V_{DDA}	Analog supply voltage	-	2.6	-	3.6	V
V_{REF+}(3)	Reference supply voltage	-	2.0	-	3.6	V
V_{SSA}	Ground	-	0	-	0	V
R_{LOAD}(1)	Resistive load with buffer ON	-	5	-	-	kΩ
R_O(2)	Impedance output with buffer OFF	-	-	13.2	16	kΩ
C_{LOAD}(1)	Capacitive load	-	-	-	50	pF
DAC_OUT(1)	Lower DAC_OUT voltage with buffer ON	-	0.15	-	-	V
	Higher DAC_OUT voltage with buffer ON	-	-	-	V_{REF+} - 0.2	V
	Lower DAC_OUT voltage with buffer OFF	-	-	0.5	3.5	mV
	Higher DAC_OUT voltage with buffer OFF	-	-	-	V_{REF+} - 1.5 mV	V
I_{DDA}	DC current consumption in quiescent mode	With no load, V_{REF+} = 3.6 V	-	480	625	μA
I_{VREF}(3)	DC current consumption in quiescent mode	With no load, V_{REF+} = 3.6 V	-	330	340	μA
DNL(2)	Differential non linearity	-	-	±0.4	±0.8	LSB
INL(2)	Integral non linearity (difference between measured value and a line drawn between DAC_OUT min and DAC_OUT max)	-	-	±0.8	±1.5	LSB
Offset(2)	Offset error (difference between measured value at Code (0x800) and the ideal value = V_{REF+}/2)	-	-	15	30	mV
			-	20	35	LSB
Gain error(2)	Gain error	-	-	0.1	0.25	%
$t_{SETTLING}$	Settling time	C_{LOAD} ≤ 50 pF, R_{LOAD} ≥ 5 kΩ	-	1	4	μs
Update rate	Max frequency for a correct DAC_OUT change when small variation in the input code (from code i to i+1 LSB)	C_{LOAD} ≤ 50 pF, R_{LOAD} ≥ 5 kΩ	-	-	1	MSPS
t_{WAKEUP}	Wakeup time from off state (setting the EN bit in the DAC Control register)	C_{LOAD} ≤ 50 pF, R_{LOAD} ≥ 5 kΩ	-	1.2	4	μs

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

6 Package information

6.1 LQFP100 package information

Figure 40. LQFP100 – 14 x 14 mm 100 pin low-profile quad flat package outline

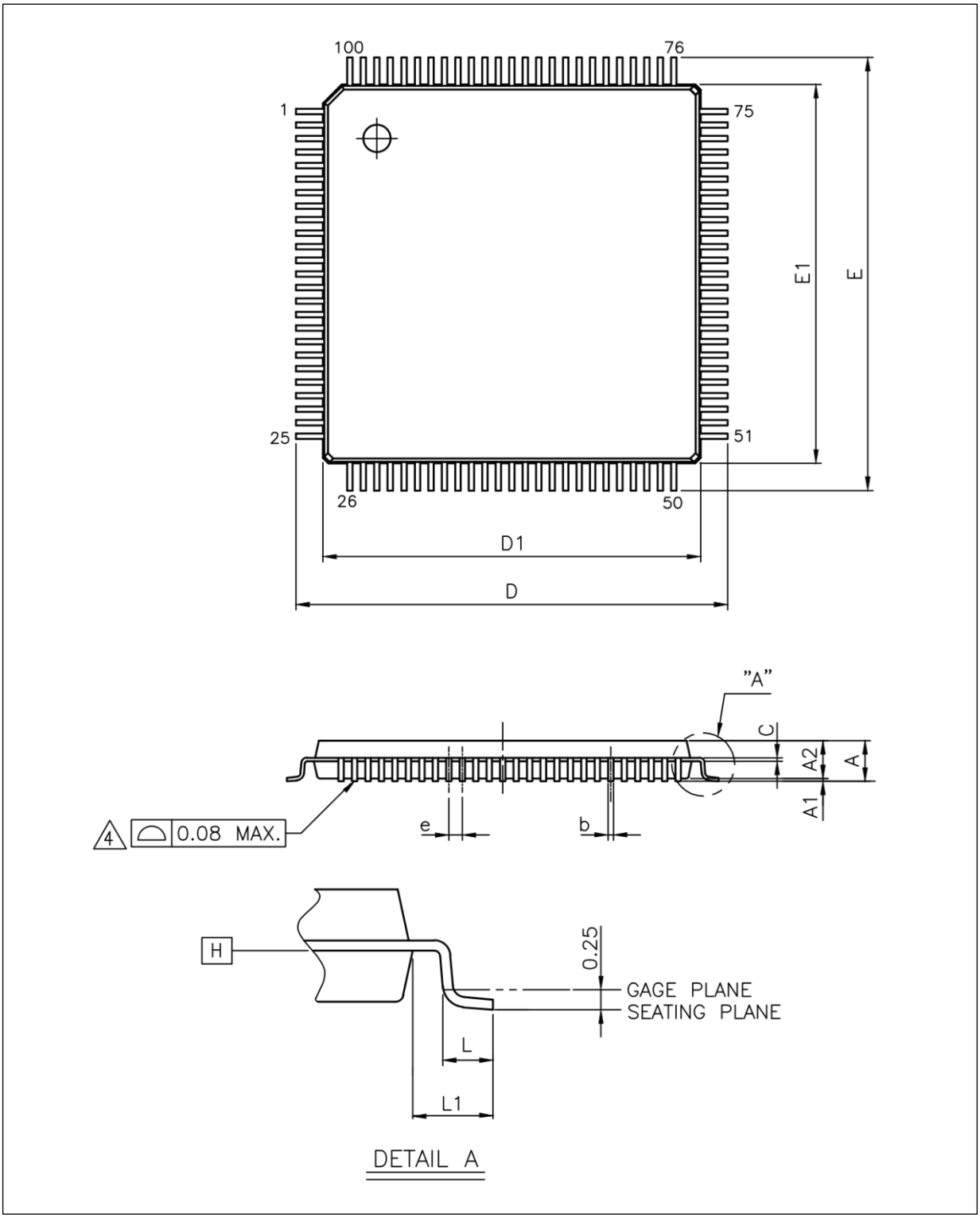


Table 61. LQFP100 – 14 x 14 mm 100 pin low-profile quad flat package mechanical data

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.		

6.2 LQFP64 package information

Figure 41. LQFP64 – 10 x 10 mm 64 pin low-profile quad flat package outline

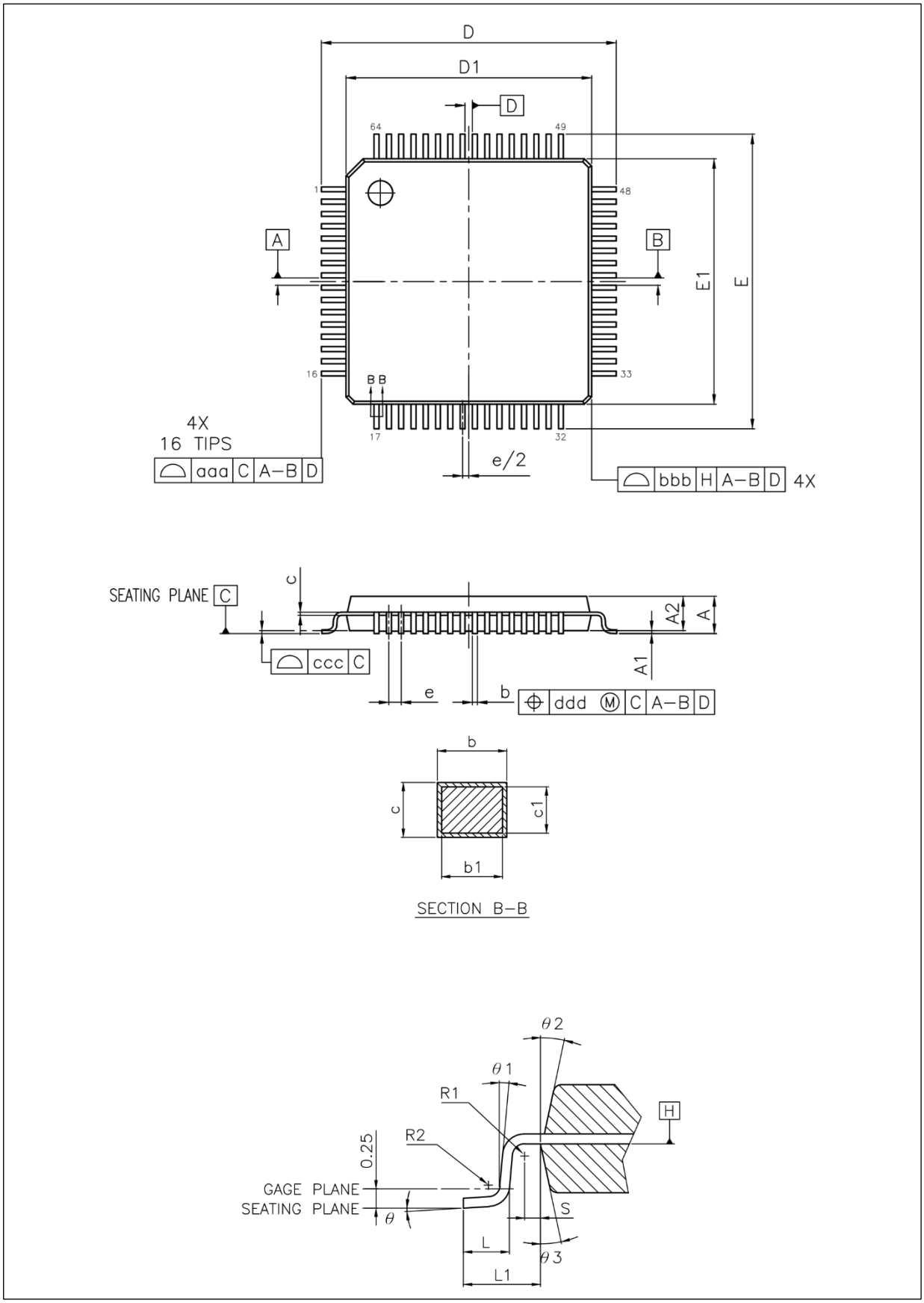
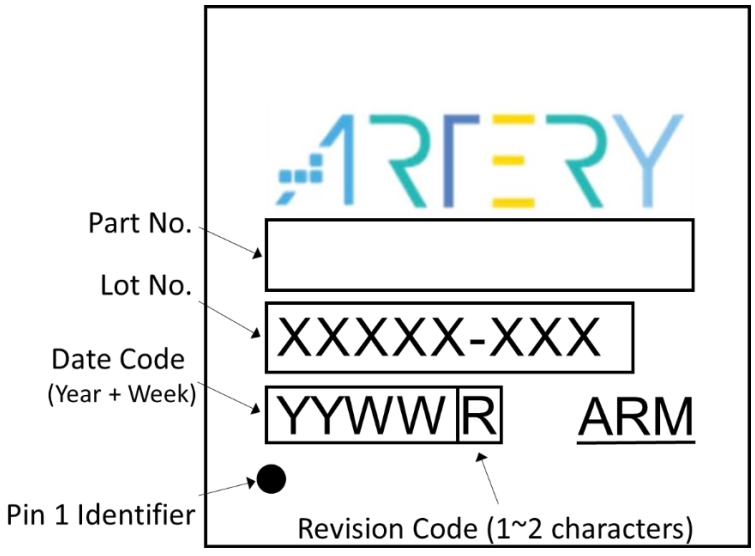


Table 62. LQFP64 – 10 x 10 mm 64 pin low-profile quad flat package mechanical data

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		

6.3 Device marking

Figure 42. Marking example



(1) Not In Scale.

6.4 Thermal characteristics

Table 63. Package thermal characteristics

Symbol	Parameter	Value	Unit
Θ_{JA}	Thermal resistance junction-ambient LQFP100 – 14 × 14 mm/0.5 mm pitch	61.2	°C/W
	Thermal resistance junction-ambient LQFP64 – 10 × 10 mm/0.5 mm pitch	64.6	

7 Part numbering

Table 64. AT32F407 series part numbering

Example: AT32 F 4 0 7 V G T 7

Product family

AT32 = ARM®-based 32-bit microcontroller

Product type

F = General-purpose

Core

4 = Cortex®-M4

Product series

0 = Main Stream

Product application

7 = Ethernet MAC series

Pin count

R = 64 pins

V = 100 pins

Internal Flash memory size

C = 256 KBytes of the internal Flash memory

E = 512 KBytes of the internal Flash memory

G = 1 MBytes of the internal Flash memory

Package

T = LQFP

Temperature range

7 = -40 °C to +105 °C

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

8 Document revision history

Table 65. Document revision history

Date	Version	Change
2020.1.8	1.00	Initial release
2020.2.10	1.01	Modified the max. frequency of the system and the internal AHB clock as 240 MHz; and the internal APB clock as 120 MHz
2020.4.22	1.02	1. Modified the minimum value of V_{REF+} of ADC and DAC as 2.0 V 2. Modified conditions and max. frequencies of the internal AHB clock in *Table 13* 3. Updated current values in sector *5.3.4* 4. Removed the original note (9) of *Table 6* 5. Modified the parameter descriptions, conditions, and the maximum values of the SPI clock frequency in *Table 44*
2020.8.7	1.03	Corrected values in *Table 59*
2021.7.20	2.00	1. Modified paragraph orders and descriptions of the whole document 2. Added *Table 6* note (10)
2022.1.27	2.01	Added *Section 6.3* device marking example
2022.6.10	2.02	1. Added max value and notes (at T_A = 25 °C) in *Table 22* and *Table 23* 2. Added min and max values in D, D1, E and E1 lines of all package mechanic data tables.

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