STM32H5Exxx

Arm® Cortex®-M33 32-bit MCU, TrustZone®, FPU, 1023 CoreMark®, 250 MHz, 4 MB flash, 1.5 MB RAM, Ethernet, USB, graphic

Datasheet - production data

Features

Includes ST state-of-the-art patented technology

Core

- Arm® Cortex®-M33 CPU with TrustZone®, FPU, frequency up to 250 MHz, MPU,1023 CoreMark®

ART Accelerator

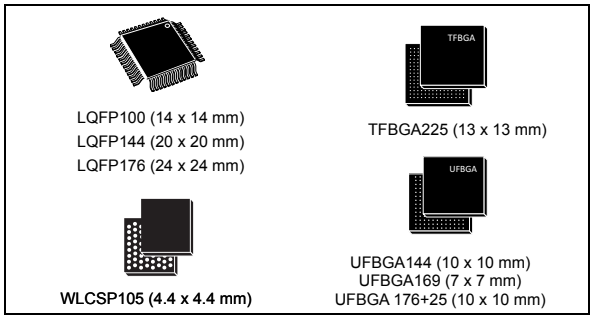
- 16-Kbyte instruction cache for 0-wait-state execution from flash and external memories
- 8-Kbyte data cache for external memories

Benchmarks

- 1023 CoreMark® (4.092 CoreMark®/MHz)

Memories

- Up to 4 Mbytes of embedded flash memory with ECC, two banks read-while-write
- Up to 96-Kbyte per bank with high-cycling capability (100 K cycles) for data flash
- 2-Kbyte OTP (one-time programmable)
- 1536 Kbytes of contiguous SRAM (384-Kbyte with ECC)
- 4 Kbytes of backup SRAM available in the lowest power modes
- Flexible external memory controller with up to 32-bit: SRAM, PSRAM, SDRAM/LPSDR SDRAM, FRAM, NOR/NAND memories
- Two Octo-SPI interfaces with support for serial PSRAM/NAND/NOR, hyper RAM/flash
- Two SD/SDIO/MMC interfaces



Clock management

- Internal oscillators: 64 MHz HSI, 48 MHz HSI48, 4 MHz CSI, 32 kHz LSI
- External oscillators: 4-50 MHz HSE, 32.768 kHz LSE

Rich graphic features

- Chrom-ART2 Accelerator (DMA2D) for enhanced graphic content creation
- Hardware JPEG codec
- LCD-TFT controller (LTDC)
- Dedicated graphic timer and digital camera interface

General-purpose inputs/outputs

- Up to 178 fast I/Os with interrupt capability (most of them 5 V-tolerant)
- Up to ten I/Os with independent supply down to 1.08 V

Low-power consumption

- Sleep, Stop, and Standby modes
- V_{BAT} supply for RTC, 32 backup registers (32-bit)

Security

- Arm® TrustZone® with Armv8-M mainline security extension
- Up to eight configurable SAU regions
- TrustZone® aware and securable peripherals

- Flexible life cycle scheme with secure debug authentication
- SFI (secure firmware installation)
- Root of trust thanks to unique boot entry and secure hide protection area (HDP)
- Secure firmware upgrade support with TF-M
- Public key accelerator, ECDSA signature verification
- HASH (SHA-1, SHA-2, SHA-3)
- True random number generator, NIST SP800-90B compliant
- 96-bit unique ID
- Active tampers

Two DMA controllers to offload the CPU

- Two dual-port DMAs with FIFO

Mathematical acceleration

- CORDIC for trigonometric functions acceleration
- FMAC (filter mathematical accelerator)

Reset and supply management

- 1.71 V to 3.6 V application supply and I/O
- POR, PDR, PVD, and BOR
- Embedded (LDO) or SMPS step-down converter regulator

Up to 24 timers

- 18 16-bit timers (including six low-power available in Stop mode)
- Two 32-bit timers with up to four IC/OC/PWM or pulse counters and quadrature (incremental) encoder input
- Two watchdogs and two SysTick timers

Up to 37 communication interfaces

- Up to four I2Cs Fm+ (SMBus/PMBus®)
- Two I3Cs
- Up to 12 U(S)ARTs (ISO7816 interface, LIN, IrDA, modem control) and one LPUART
- Up to six SPIs, three muxed in full-duplex I2S, and up to seven additional SPIs (from five USARTs and two OctoSPIs)
- Two SAIs
- Three FDCANs
- One 8- to 14-bit camera interface
- 16-bit parallel slave synchronous interface
- One HDMI-CEC
- Ethernet MAC interface with DMA controller
- One USB OTG full-speed, one USB OTG high-speed with embedded PHY
- One USB Type-C®/USB Power Delivery r3.1

Analog

- Three 12-bit ADCs with up to 5 Msps in 12-bit
- Two 12-bit DACs
- Digital temperature sensor
- Two ultra-low-power comparators
- One operational amplifier (7 MHz bandwidth)

Programmable logic array (PLAY)

- PLAY interface with 128 inputs and 16 outputs

Debug

- Authenticated debug, flexible device life cycle
- Serial wire-debug (SWD), JTAG, Embedded Trace Macrocell™ (ETM)

ECOPACK2 compliant packages

Table 1. Device summary

Reference	Part numbers
STM32H5E4xx	STM32H5E4VJ, STM32H5E4VK, STM32H5E4ZJ, STM32H5E4ZK, STM32H5E4IJ, STM32H5E4IK, STM32H5E4AJ, STM32H5E4AK
STM32H5E5xx	STM32H5E5VJ, STM32H5E5VK, STM32H5E5ZJ, STM32H5E5ZK, STM32H5E5IJ, STM32H5E5IK, STM32H5E5LJ, STM32H5E5LK

Contents

List of tables

List of figures

1 Introduction

This document provides the ordering information and mechanical device characteristics of the STM32H5Exxx microcontrollers.

For information on the device errata with respect to the datasheet and reference manual, refer to the STM32H5Exxx errata sheet (ES0639).

For information on the Arm® Cortex®-M33 core, refer to the Cortex®-M33 Technical Reference Manual, available from the www.arm.com website.

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2 Description

The STM32H5Exxx devices are high-performance microcontrollers of the STM32H5 series, based on the high-performance Arm® Cortex®-M33 32-bit RISC core. They operate at a frequency of up to 250 MHz.

The Cortex®-M33 core features a single-precision floating-point unit (FPU), which supports all the Arm® single-precision data-processing instructions and all the data types.

This core implements a full set of DSP (digital signal processing) instructions and a memory protection unit (MPU) that enhances the application security.

The devices embed high-speed memories (up to 4 Mbytes of dual bank flash memory and 1536 Kbytes of SRAM), a flexible external memory controller (FMC) for devices with packages of 100 pins and more, two OCTOSPI memory interfaces, and an extensive range of enhanced I/Os and peripherals connected to three APB buses, three AHB buses, and a 32-bit multi-AHB bus matrix.

The devices offer security foundation compliant with the trusted-based security architecture (TBSA) requirements from Arm®. They embed the necessary security features to implement a secure boot, secure data storage and secure firmware update. Besides these capabilities, the devices incorporate a secure firmware installation that allows the customer to secure the provisioning of the code during its production. A flexible life cycle is managed thanks to multiple levels of protection and secure debug authentication. Firmware hardware isolation is supported thanks to securable peripherals, memories, and I/Os, and to privilege configuration of peripherals and memories.

The devices feature several protection mechanisms for embedded flash memory and SRAM: readout protection, write protection, secure, and hide protection areas.

Dedicated peripherals reinforce security: an HASH hardware accelerator, and a true random number generator.

The devices offer active tamper detection and protection against transient and environmental perturbation attacks, thanks to several internal monitoring, generating secret data erase in case of attack. This helps to fit the PCI requirements for point of sales applications.

The devices offer three fast 12-bit ADCs, two DACs, an internal voltage reference buffer, a low-power RTC, two 32-bit general-purpose timers, two 16-bit PWM timers dedicated to motor control, eight 16-bit general-purpose timers, two 16-bit basic timers, and six 16-bit low-power timers.

The devices also feature standard and advanced communication interfaces, namely: four I^2Cs, two I3Cs, six SPIs, six USARTs, six UARTs and one low-power UART, two SAIs, one digital camera interface (DCMI), up to two SDMMC, three FDCANs, one USB OTG high-speed with embedded PHY, one USB full-speed, one USB Type-C®/USB power delivery controller, one programmable logic array PLAY.

The devices support a MDF (multi-function digital filter) with six filters dedicated to the connection of external sigma-delta modulators. Another low-power digital filter dedicated to audio signals is embedded (ADF), with one filter supporting sound-activity detection.

The devices offer a rich set of graphic features: Chrom-ART2 (DMA2D) for smooth motion and transparency effects, dedicated graphic timer (GFXTIM) for smart management of graphical events for frame or line counting, MJPEG, and LCD-TFT controller (LTDC).

The devices operate in the -40 to +85 °C/105 °C, and up to 125 °C at low dissipation (+130 °C junction) temperature ranges from a 1.71 to 3.6 V power supply.

A comprehensive set of power-saving modes allows the design of low-power applications.

Independent power supplies are supported: an analog independent supply input for ADC, DACs, a 3.3 V dedicated supply input for USB, and a dedicated supply input for some GPIOs and SDMMC. A VBAT input is available to connect a backup battery, to preserve the RTC functionality, and to backup 32 32-bit registers and a 4-Kbyte SRAM.

The devices offer eight packages, from 100 to 225 pins.

Table 2. STM32H5Exxx features and peripheral counts

Peripherals		STM32H5E4VJ/ STM32H5E4VK	STM32H5E5VJ/ STM32H5E5VK	STM32H5E4ZJ/ STM32H5E4ZK	STM32H5E5ZJ/ STM32H5E5ZK	STM32H5E4AJ/ STM32H5E4AK	STM32H5E4IJ/ STM32H5E4IK	STM32H5E5IJ/ STM32H5E5IK	STM32H5E5LJ/ STM32H5E5LK
Flash memory (Kbytes)		4096/3072							
SRAM	System (Mbytes)	1.5							
	Backup (Kbytes)	4							
Flexible memory controller for external memories (FMC)	NOR/RAM/ SDRAM	Yes(1)		Yes(2)		Yes			
	NAND flash memory	Yes							
	TFT-RGB controller	Yes							
OCTOSPI		2							
Timers	Advanced-control	2 (16 bits)							
	General-purpose	2 (32 bits) and 8 (16 bits)							
	Basic	2 (16 bits)							
	Low-power	6 (16 bits)							
	SysTick timer	2							
	Watchdog timers (independent, window)	2							

Table 2. STM32H5Exxx features and peripheral counts (continued)

Peripherals		STM32H5E4VJ/ STM32H5E4VK	STM32H5E5VJ/ STM32H5E5VK	STM32H5E4ZJ/ STM32H5E4ZK	STM32H5E5ZJ/ STM32H5E5ZK	STM32H5E4AJ/ STM32H5E4AK	STM32H5E4IJ/ STM32H5E4IK	STM32H5E5IJ/ STM32H5E5IK	STM32H5E5LJ/ STM32H5E5LK
Communication interfaces	SPI/I2S	5/3		6/3					
	I2C	4							
	I3C	2(3)							
	USART/UART /LPUART	6/6/1							
	SAI	2							
	FDCAN	3							
	OTG_FS	Yes							
	OTG_HS	-	Yes	-	Yes	-	-	Yes	
	UCPD	Yes							
	SDMMC	2							
	Digital camera interface (DCMI) / PSSI	Yes							
	Ethernet	Yes							
Graphic accelerators	LTDC	Yes							
	JPEG	Yes							
	Chrom-ART2 Accelerator (DMA2D)	Yes							
	GFXTIM	Yes							
Programmable logic array (PLAY)		Yes							
HDMI CEC		Yes							
Audio digital filter (ADF)		Yes							
Multi-function digital filter (MDF)		Yes							
CORDIC coprocessor		Yes							
Filter mathematical accelerator (FMAC)		Yes							
Real-time clock (RTC)		Yes							
Tamper pins	Passive	8							
	Active (shared output)	8							
	Active (independent output)	4				5			

Table 2. STM32H5Exxx features and peripheral counts (continued)

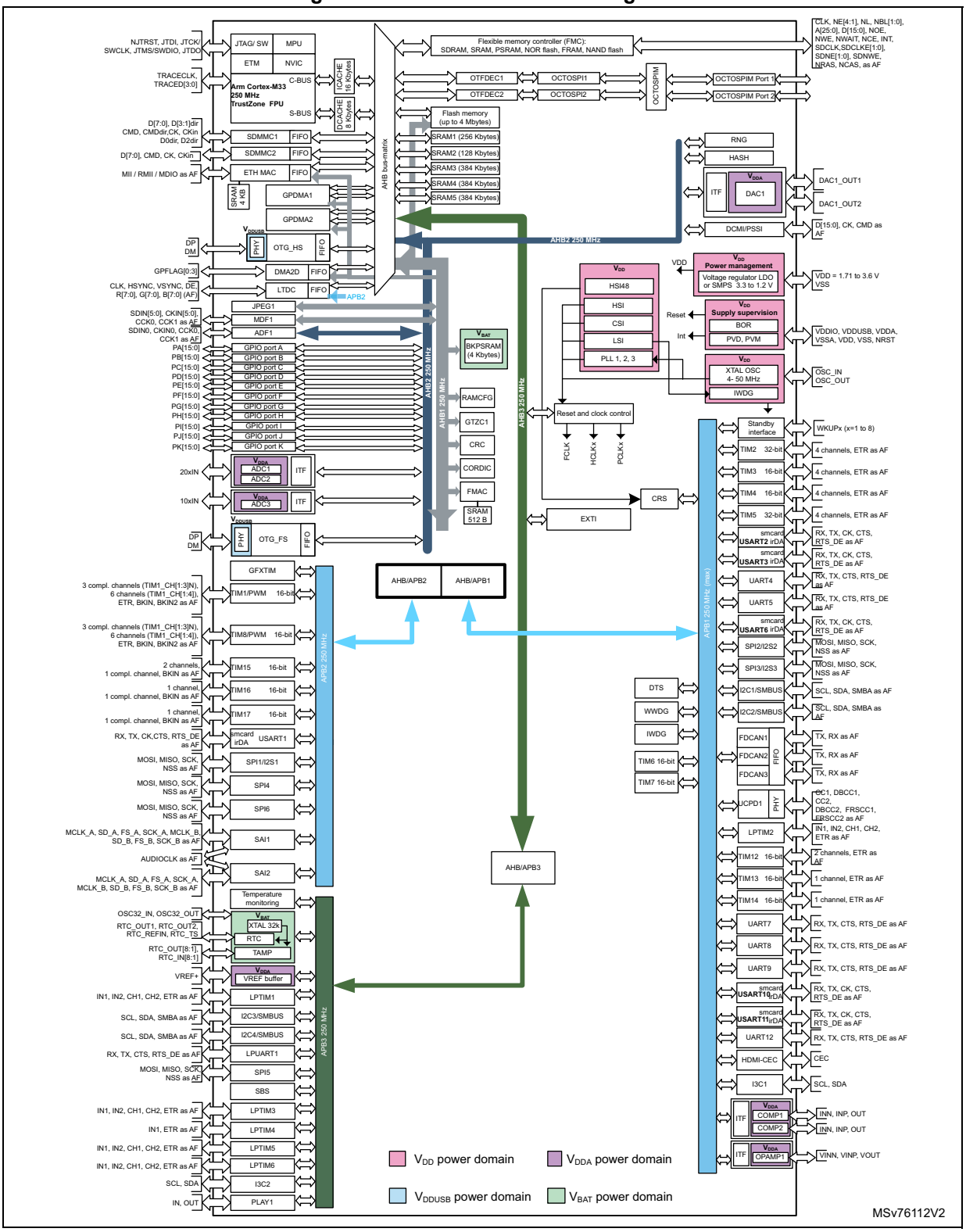
Peripherals		STM32H5E4VJ/ STM32H5E4VK	STM32H5E5VJ/ STM32H5E5VK	STM32H5E4ZJ/ STM32H5E4ZK	STM32H5E5ZJ/ STM32H5E5ZK	STM32H5E4AJ/ STM32H5E4AK	STM32H5E4IJ/ STM32H5E4IK		STM32H5E5IJ/ STM32H5E5IK		STM32H5E5LJ/ STM32H5E5LK
True random number generator (RNG)		Yes									
HASH (SHA2-512)		Yes									
PKA (ECDSA signature verification)		Yes									
GPIOs	GPIOs (LDO / SMPS)	80/ 78	NA/ 78	112/ 110	113/ 111	108/ NA	136/ 134	140/ 136	140/ 139	NA/ 132	NA/ 139	NA/ 176
	GPIOs supplied by V_{DDIO2} (LDO / SMPS)	NA/NA	NA/NA	10/9	10/9	10/NA	10/7	10/10		NA/10		
	Wake-up pins	7					8					
ADC	12-bit ADCs	3										
	Number of channels (LDO / SMPS)	26/24	NA/24	30/28	30/30	30/NA	30/30			NA/30		
DAC	12-bit DAC controller	1										
	Number of channels	2										
COMP		2										
OPAMP		1										
Maximum CPU frequency (MHz)		250										
Internal voltage reference buffer		Yes										
LDO		Yes	No	Yes						No		
Step-down converter (SMPS)		Yes			No	Yes						
Operating voltage		1.71 to 3.6 V										
V_{DDIO2} separate supply pin(4)		No		Yes								

Table 2. STM32H5Exxx features and peripheral counts (continued)

Peripherals	STM32H5E4VJ/ STM32H5E4VK	STM32H5E5VJ/ STM32H5E5VK	STM32H5E4ZJ/ STM32H5E4ZK	STM32H5E5ZJ/ STM32H5E5ZK	STM32H5E4AJ/ STM32H5E4AK	STM32H5E4IJ/ STM32H5E4IK	STM32H5E5IJ/ STM32H5E5IK	STM32H5E5LJ/ STM32H5E5LK
Operating temperature	Ambient operating temperature: T_A: -40 to 85 °C / -40 to 105 °C Junction temperature: T_j: (Voltage range VOS0, up to 250 MHz): -40 to 105 °C T_j: (Voltage range VOS1, up to 200 MHz): -40 to 130 °C							
Packages	LQFP100	WLCSP105	LQFP144	UFBGA144	LQFP144	UFBGA169	LQFP176	UFBGA176+25	LQFP176	UFBGA176+25	TFBGA225

1. Only multiplexed NOR/PSRAM memory is supported.
2. SDRAM is available up to 16 bits.
3. I3C1 and I3C2 share the same I/Os than I2C4 and I2C2 respectively.
4. The dedicated V_{DDIO2} represents the external power supply for 10 I/Os (PD6, PD7, PG9:14, PB8, and PB9).

Figure 1. STM32H5Exxx block diagram



Note: PC[15:13] are in the V_{BAT} domain.
USB HS is only available on STM32H5E5xx.

3 Functional overview

3.1 Arm Cortex-M33 core with TrustZone and FPU

The Cortex-M33 with TrustZone and FPU is a highly energy-efficient processor designed for microcontrollers and deeply embedded applications, especially those requiring efficient security. This processor delivers a high computational performance with low-power consumption and an advanced response to interrupts. It features:

- Arm TrustZone technology, using the Armv8-M main extension supporting secure and nonsecure states
- Memory protection units (MPUs), supporting up to 16 regions for secure and nonsecure applications
- Configurable secure attribute unit (SAU) supporting up to eight memory regions as secure or nonsecure
- Floating-point arithmetic functionality with support for single precision arithmetic

The processor supports a set of DSP instructions that allows an efficient signal processing and a complex algorithm execution.

The Cortex-M33 processor supports the following bus interfaces:

- System AHB bus:

  The system AHB (S-AHB) bus interface is used for any instruction fetch and data access to the memory-mapped SRAM, peripheral, external RAM and external device, or Vendor_SYS regions of the Armv8-M memory map.
- Code AHB bus:

  The code AHB (C-AHB) bus interface is used for any instruction fetch and data access to the code region of the Armv8-M memory map.

Figure 1 shows the general block diagram of the STM32H5Exxx devices.

3.2 ART Accelerator (ICACHE and DCACHE)

3.2.1 Instruction cache (ICACHE)

The instruction cache (ICACHE) is introduced on C-AHB code bus of Cortex-M33 processor to improve performance when fetching instruction (or data) from both internal and external memories.

ICACHE offers the following features:

- Multi-bus interface:
  - Slave port receiving the memory requests from the Cortex-M33 C-AHB code execution port
  - Master1 port performing refill requests to internal memories (flash memory and SRAMs)
  - Master2 port performing refill requests to external memories (external flash memory and RAMs through Octo-SPI and FMC interfaces)
  - Second slave port dedicated to ICACHE registers access

- Close to 0 wait-states instructions/data access performance:
  - 0 wait-states on cache hit
  - Hit-under-miss capability, allowing to serve new processor requests while a line refill (due to a previous cache miss) is still ongoing
  - Critical-word-first refill policy, minimizing processor stalls on cache miss
  - Hit ratio improved by two-way set-associative architecture and pLRU-t replacement policy (pseudo-least-recently-used, based on binary tree), algorithm with best complexity/performance balance
  - Dual master ports to decouple internal and external memory traffic, respectively, on fast and slow buses, minimizing impact on interrupt latency
  - Optimal cache line refill thanks to AHB burst transactions (of the cache line size)
  - Performance monitoring by means of a hit counter and a miss counter
- Extension of cacheable region beyond the code memory space, by means of address remapping logic that allows four cacheable external regions to be defined
- Power consumption reduced intrinsically (more accesses to cache memory rather than to bigger main memories); even improved by configuring ICACHE as direct mapped (rather than the default two-way set-associative mode)
- TrustZone security support
- Maintenance operation for software management of cache coherency
- Error management: detection of unexpected cacheable write access, with optional interrupt raising

3.2.2 Data cache (DCACHE)

The data cache (DCACHE) is introduced on S-AHB system bus of Cortex-M33 processor to improve the performance of data traffic to/from external memories. DCACHE offers the following features:

- Multi-bus interface:
  - Slave port receiving the memory requests from the Cortex-M33 S-AHB system port
  - Master port performing refill requests to external memories (external flash memory and RAMs through Octo-SPI and FMC interfaces)
  - A second slave port dedicated to DCACHE registers access
- Close to 0 wait-states external data access performance:
  - 0 wait-states on cache hit
  - Hit-under-miss capability, allowing to serve new processor requests to cached data, while a line refill (due to a previous cache miss) is still ongoing
  - Critical-word-first refill policy for read transactions, minimizing processor stalls on cache miss
  - Hit ratio improved by two-way set-associative architecture and pLRU-t replacement policy (pseudo-least-recently-used, based on binary tree), algorithm with best complexity/performance balance
  - Optimal cache line refill thanks to AHB burst transactions (of the cache line size)
  - Performance monitoring by means of two hit counters (for read and write) and two miss counters (for read and write)

- Supported cache accesses:
  - Supports both write-back and write-through policies (selectable with AHB bufferable attribute)
  - Read and write-back always allocated
  - Write-through always non-allocated (write-around)
  - Supports byte, half-word, and word writes
- TrustZone security support
- Maintenance operations for software management of cache coherency:
  - Full cache invalidation (non interruptible)
  - Address range clean and/or invalidate operations (background task, interruptible)
- Error management: detection of error for master port request initiated by DCACHE (line eviction or clean operation), with optional interrupt raising

3.3 Memory protection unit

The memory protection unit (MPU) is used to manage the CPU accesses to the memory and to prevent one task to accidentally corrupt the memory or the resources used by other active tasks. This memory area is organized into up to 20 protected areas (12 secure and 8 nonsecure). The MPU regions and registers are banked across secure and nonsecure states.

The MPU is especially helpful for applications where critical or certified code must be protected against the misbehavior of other tasks. It is usually managed by an RTOS (real-time operating system).

If a program accesses a memory location prohibited by the MPU, the RTOS can detect it and take action. In an RTOS environment, the kernel can dynamically update the MPU area settings based on the process to be executed.

3.4 Embedded flash memory

The devices feature 4 Mbytes of embedded flash memory for storing programs and data. The flash memory supports a high-cycle data area of up to 100 K cycles.

The flash memory interface features dual-bank operating modes, and read-while-write (RWW). A read operation can be performed on one bank, while an erase or program operation is performed on the other bank. Each bank contains 256 8-Kbyte pages.

The flash memory embeds a 2-Kbyte OTP (one-time programmable) for user data, and up to 192 Kbytes supporting high cycling capability (100 K cycles), to use for data (EEPROM emulation).

Option bytes are available to set the flash memory protection mechanisms:

- Different product states for protecting memory content from debug access
- Write protection (WRP) to protect areas against erasing and programming. Two areas per bank can be selected with 8-Kbyte granularity.
- Sector group write-protection (WRPSG), protecting up to 32 groups of four sectors (32 Kbytes) per bank
- Two secure-only areas (one per user flash memory bank). When enabled, this area is accessible only if the device operates in Secure-access mode

- One HDP area per bank providing temporal isolation for startup code

The whole non-volatile memory embeds the error correction code (ECC) feature supporting:

- Single-error detection and correction
- Double-error detection
- ECC fail address report

3.4.1 FLASH security and protections

Sensitive information is stored in the flash memory and it is important to protect the memory against unwanted operations such as reading confidential areas, illegal programming of immutable sectors, or malicious flash memory erasing.

For that purpose the following protection mechanisms are implemented:

- TrustZone backed watermark and block security protection
- Temporal isolation protection (HDP)
- Configuration protection
- User flash memory write protection
- Device non-volatile security life cycle and application boot state management
- OTP locking

Refer to the product reference manual for a detailed description of the security mechanisms.

3.4.2 FLASH privilege protection

Each flash memory sector can be programmed on the fly as privileged or unprivileged.

3.5 Embedded SRAMs

Six SRAMs are embedded in the STM32H5Exxx devices, each with specific features. SRAM1, SRAM2, SRAM3, SRAM4, and SRAM5 are the main ones. SRAM1 to SRAM5 are contiguous.

These SRAMs are made of several blocks that can be powered down in Stop mode to reduce consumption:

- SRAM1: 256 Kbytes
- SRAM2: 128 Kbytes with ECC
- SRAM3: 384 Kbytes (320 Kbytes when ECC is enabled: 256 Kbytes with ECC and 64 Kbytes without ECC)
- SRAM4: 384 Kbytes
- SRAM5: 384 Kbytes
- BKPSRAM (backup SRAM): 4 Kbytes with ECC, can be retained in all low-power modes and when V_{DD} is off in VBAT mode

Note: The ECC is supported by SRAM2, and BKPSRAM when enabled with the SRAM2_ECC, SRAM3_ECC, and BKPRAM_ECC user option bits.

3.5.1 SRAMs TrustZone security

When the TrustZone security is enabled, all SRAMs are secure after reset. The SRAM1, SRAM2, SRAM3, SRAM4, and SRAM5 can be programmed as secure or nonsecure by blocks, using the MPCBB (block-based memory protection controller).

The granularity of SRAM secure block based is a page of 512 bytes. Backup SRAM regions can be programmed as secure or nonsecure with watermark, using the TZSC (TrustZone security controller) in the GTZC (global TrustZone controller).

3.5.2 SRAMs privilege protection

SRAM1, SRAM2, SRAM3, SRAM4, and SRAM5 can be programmed as privileged or non-privileged by blocks, using the MPCBB. The granularity of SRAM privilege block based is a page of 512 bytes. Backup SRAM regions can be programmed as privileged or non-privileged with watermark, using the TZSC (TrustZone security controller) in the GTZC (global TrustZone controller).

3.6 Security overview

The STM32H5Exxx security enables the possibility to reopen the debug mode even if the product is in secure state.

The reopening of the debug mode is controlled with a debug authentication procedure which permits the authentication of the host.

Sensible assets (such as keys or secret codes) must be protected when opening the debug mode. The protection is made via code protection and hardware keys storage solutions where all *root of trust* can be protected thanks to hardware mechanisms.

In cases where sensitive information cannot be protected, a partial or a full regression can be launched to start a debug. Regressions are enabled by a debug authentication method.

Developers can introduce their own root of trust solution (OEM-iROT), including their installation in a non-trusted environment, thanks to a secure firmware install (SFI) solution.

The boot stages are isolated via a hardware mechanism called HDPL (temporal isolation level). The HDPL guarantees isolation of the different boot stages: ST assets, iROT (immutable root of trust), uROT (updatable root of trust), secure operating system and nonsecure applications.

The devices are powered by an Arm Cortex-M33 core, associated with all the TrustZone isolation infrastructure. This design permits to benefit from a run time isolation to run secure applications.

3.7 Boot modes

At startup, a BOOT0 pin and NSBOOTADD[31:8]/SECBOOTADD[31:8] option bytes are used to select the boot memory address that includes:

- Boot from any address in user flash memory
- Boot from system memory
  - Bootloader
  - Root security service (RSS)
  - Debug authentication library (RSS-DA)

Embedded bootloader

The embedded bootloader is located in the system memory, programmed by ST during production. It is used to reprogram the flash memory by using USART, I2C, I3C OTG_FS, or OTG_HS in device mode through the DFU (device firmware upgrade).

Refer to AN2606 "*Introduction to system memory boot mode on STM32 MCUs*".

Embedded root security services (RSS)

The embedded RSS are located in the secure information block, programmed by ST during production.

Refer to AN4992 "*Introduction to secure firmware install (SFI) for STM32 MCUs"*.

Embedded debug authentication (ST-DA)

The embedded ST-DA in the system memory is programmed by ST during production. ST-DA is the library that manages the debug authentication protocol, making it possible to securely reopen the debug or to launch regressions on secured products in the field.

3.8 Global TrustZone controller (GTZC)

GTZC is used to configure TrustZone and privileged attributes within the full system.

The GTZC includes three different sub-blocks:

- TZSC: TrustZone security controller

  This sub-block defines the secure/privilege state of slave/master peripherals. It also controls the nonsecure area size for the watermark memory peripheral controller (MPCWM). The TZSC block informs some peripherals (such as RCC or GPIOs) about the secure status of each securable peripheral, by sharing with RCC and I/O logic.
- TZIC: TrustZone illegal access controller

  This sub-block gathers all security illegal access events in the system and generates a secure interrupt towards NVIC.
- MPCBB: MPCBB: block-based memory protection controller

  This sub-block controls secure states of all memory blocks (512-byte pages) of the associated SRAM. This peripheral aims at configuring the internal RAM in a TrustZone system product having segmented SRAM with programmable-security and privileged attributes.

The GTZC main features are:

- Three independent 32-bit AHB interfaces for TZSC, TZIC and MPCBB

- MPCBB and TZIC accessible only with secure transactions
  - Enable illegal access events that may trigger a secure interrupt
- Secure and nonsecure access supported for privileged/non-privileged part of TZSC
- Set of registers to define product security settings:
  - Secure/privilege regions for external memories
  - Secure/privilege access mode for securable peripherals
  - Secure/privilege access mode for securable legacy masters

3.9 TrustZone security architecture

The security architecture is based on Arm TrustZone with the Armv8-M main extension.

The TrustZone security is activated by the TZEN option bit in the FLASH_OPTR register.

When the TrustZone is enabled, the SAU (security attribution unit) and IDAU (implementation defined attribution unit) define the access permissions based on secure and nonsecure state.

- SAU: up to eight SAU configurable regions are available for security attribution.
- IDAU: It provides a first memory partition as nonsecure or nonsecure callable attributes. It is then combined with the results from the SAU security attribution and the higher security state is selected.

Based on IDAU security attribution, the flash memory, system SRAMs and peripherals memory space is aliased twice for secure and nonsecure states. However, the external memories space is not aliased.

3.9.1 TrustZone peripheral classification

When the TrustZone security is active, a peripheral can be either securable or TrustZone-aware type as follows:

- securable: peripheral protected by an AHB/APB firewall gate controlled from TZSC to define security properties
- TrustZone-aware: peripheral connected directly to AHB or APB bus and implementing a specific TrustZone behavior such as a subset of registers being secure

3.9.2 Default TrustZone security state

The default system security state is detailed below:

- CPU:
  - Cortex-M33 is in secure state after reset. The boot address must be in secure address.
- Memory map:
  - SAU is fully secure after reset. Consequently, all memory map is fully secure. Up to eight SAU configurable regions are available for security attribution.
- Flash memory:
  - Flash memory security area is defined by watermark user options.
  - Flash memory block based area is nonsecure after reset.
- SRAMs:

  - All SRAMs are secure after reset. MPCBB (memory protection block based controller) is secure.
- External memories:
  - FMC, OCTOSPI banks are secure after reset. MPCWMx (memory protection watermark based controller) is secure.
- Peripherals
  - Securable peripherals are nonsecure after reset.
  - TrustZone-aware peripherals are nonsecure after reset. Their secure configuration registers are secure.
- All GPIOs are secure after reset.
- Interrupts:
  - NVIC: All interrupts are secure after reset. NVIC is banked for secure and nonsecure state.
- TZIC: All illegal access interrupts are disabled after reset.

3.10 Power supply management

The power controller (PWR) main features are:

- Power supplies and supply domains
  - Core domain (V_{CORE})
  - V_{DD} domain
  - Backup domain (V_{BAT})
  - Analog domain (V_{DDA})
  - V_{DDIO2} domain
  - V_{DDUSB} and optional $V_{DD11USB}$ for USB transceiver
- System supply voltage regulation
  - SMPS step down converter
  - Voltage regulator (LDO)
- Power supply supervision
  - POR/PDR monitor
  - BOR monitor
  - PVD monitor
- Power management
  - Operating modes
  - Voltage scaling control
  - Low-power modes
- VBAT battery charging
- TrustZone security and privileged protection

3.10.1 Power supply schemes

The devices require a 1.71 to 3.6 V V_{DD} operating voltage supply. Several independent supplies can be provided for specific peripherals:

- V_{DD} = 1.71 V to 3.6 V

V_{DD} is the external power supply for the I/Os, the internal regulator and the system analog such as reset, power management and internal clocks. It is provided externally through the VDD pins.

- V_{DDA} = 1.62 V (ADCs, COMP), 1.8 V (DAC), 2.0 V (OPAMP), or 2.1 V (VREFBUF) to 3.6 V

  V_{DDA} is the external analog power supply for ADCs, DACs and voltage reference buffer. This voltage level is independent from V_{DD}, and must preferably be connected to V_{DD} when these peripherals are not used.
- V_{DDSMPS} = 1.71 V to 3.6 V

  V_{DDSMPS} is the external power supply for the SMPS step down converter. It is provided externally through VDDSMPS supply pin and must be connected to the same supply than VDD.
- V_{LXSMPS} is the switched SMPS step down converter output. The SMPS power supply pins are available only on packages with SMPS step down converter option.
- V_{DDUSB} = 3.0 V to 3.6 V

  V_{DDUSB} is the external independent power supply for USB/OTG_FS/OTG_HS transceivers. It is independent from V_{DD}, and must preferably be connected to VDD when the USB is not used.
- $V_{DD11USB}$ = 0.95 V to 1.40 V (only available on STM32H5E5x devices) $V_{DD11USB}$ is the dedicated digital power supply for the OTG_HS transceiver. This should be connected to VCAP when used, and to GND when not used.
- V_{DDIO2} = 1.08 V to 3.6 V

  V_{DDIO2} is the external power supply for ten I/Os (PD6, PD7, PG9:14, PB8, PB9). This voltage level is independent from V_{DD}, voltage and must preferably be connected to VDD when those pins are not used.
- V_{BAT} = 1.2 V to 3.6 V

  V_{BAT} is the power supply for RTC, external clock 32 kHz oscillator and backup registers (through power switch) when V_{DD} is not present.
- V_{REF-}, V_{REF+}

  V_{REF+} is the input reference voltage for ADCs and DACs. It is also the output of the internal voltage reference buffer when enabled.

  V_{REF+} can be grounded when ADC and DAC are not active.

  VREF- and VREF+ pins are not available on all packages. When not available, they are bonded to VSSA and VDDA, respectively.

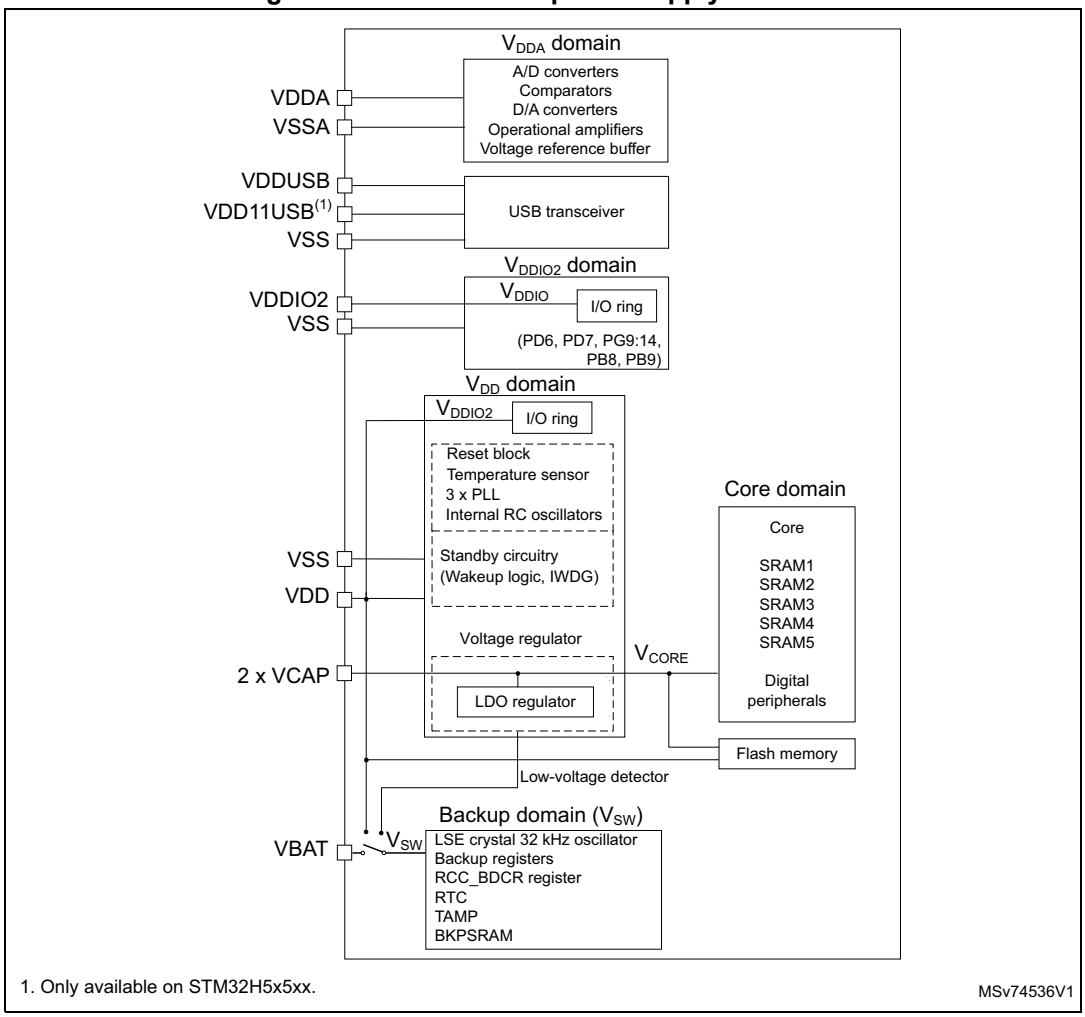
  When the VREF+ is double-bonded with VDDA in a package, the internal voltage reference buffer is not available and must be kept disabled.

  V_{REF-} must always be equal to V_{SSA}.

Depending upon the package, the devices embed an LDO and/or an SMPS regulator, to provide the V_{CORE} supply for digital peripherals, SRAM1, SRAM2, SRAM3, and embedded flash memory. The SMPS generates this voltage on VCAP (two pins), with a total external capacitor of 10 µF (typical). The SMPS requires an external coil. The LDO generates this voltage on VCAP pin connected to an external capacitor of 2x 2.2 µF (typical).

Both regulators can provide four different voltages (voltage scaling), and can operate in Stop modes.

Figure 2. STM32H5Exxx power supply overview



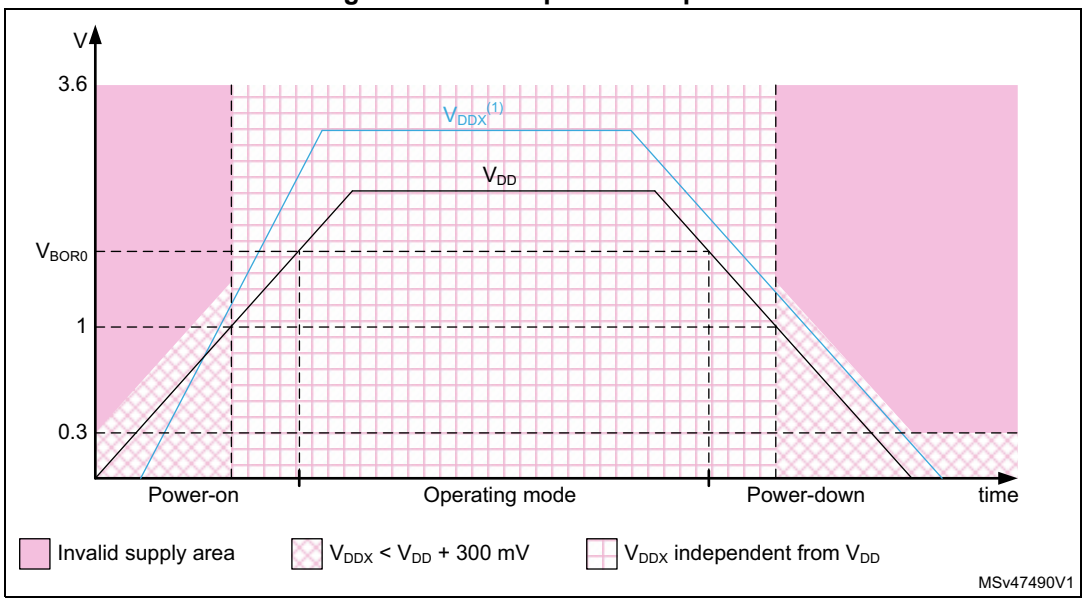
1. Only available on STM32H5x5xx.

MSv74536V1

During power-up and power-down phases, the following power sequence requirements must be respected:

- When V_{DD} is below 1 V, other power supplies (V_{DDA}, V_{DDIO2}, V_{DDUSB}) must remain below V_{DD} + 300 mV.
- When V_{DD} is above 1 V, all power supplies are independent.
- During the power-down phase, V_{DD} can temporarily become lower than other supplies only if the energy provided to the MCU remains below 1 mJ. This allows external decoupling capacitors to be discharged with different time constants during the power-down transient phase.

Figure 3. Power-up/down sequence



1. V_{DDX} refers to any power supply among V_{DDA}, V_{DDUSB}, and V_{DDIO2}.

3.10.2 Power supply supervisor

The devices have an integrated ultra-low-power brownout reset (BOR) active in all modes; The BOR ensures proper operation of the devices after power on and during power down. The devices remain in reset mode when the monitored supply voltage V_{DD} is below a specified threshold, without the need for an external reset circuit.

The lowest BOR level is 1.71 V at power on, and other higher thresholds can be selected through option bytes.The devices feature an embedded programmable voltage detector (PVD) that monitors the V_{DD} power supply and compares it to the V_{PVD} threshold.

An interrupt can be generated when V_{DD} drops below the V_{PVD} threshold and/or when V_{DD} is higher than the V_{PVD} threshold. The interrupt service routine can then generate a warning message and/or put the MCU into a safe state. The PVD is enabled by software.

In addition, the devices embed a peripheral voltage monitor that compares the independent supply voltages V_{DDA}, V_{DDUSB} and V_{DDIO2} to ensure that the peripheral is in its functional supply range.

The devices support dynamic voltage scaling to optimize power consumption in Run mode. The voltage from the main regulator that supplies the logic (V_{CORE}) can be adjusted according to the system maximum operating frequency.

The main regulator operates in the following ranges:

- VOS0 (V_{CORE} = 1.35 V) with CPU and peripherals running at up to 250 MHz
- VOS1 (V_{CORE} = 1.2 V) with CPU and peripherals running at up to 200 MHz
- VOS2 (V_{CORE} = 1.1 V) with CPU and peripherals running at up to 150 MHz
- VOS3 (V_{CORE} = 1.0 V) with CPU and peripherals running at up to 100 MHz

Low-power modes

By default, the microcontroller is in Run mode after a system or a power reset. It is up to the user to select one of the low-power modes described below:

- **Sleep** mode

  Only the CPU is stopped. All peripherals continue to operate and can wake up the CPU when an interrupt/event occurs.

- **Stop** mode

  This mode achieves the lowest power consumption while retaining the content of SRAM and registers. All clocks in the V_{CORE} domain are stopped, the PLL, the CSI, the HSI, the HSI48, and the HSE crystal oscillators are disabled. The LSE or LSI is still running.

  The RTC can remain active (Stop mode with RTC, Stop mode without RTC).

  The system clock when exiting from Stop mode can be either HSI up to 64 MHz, or CSI (4 MHz), depending on software configuration.

- **Standby** mode

  This mode is used to achieve the lowest power consumption with BOR. The PLL, the HSI, the CSI, the HSI48, and the HSE crystal oscillators are also switched off.

  The RTC can remain active (Standby mode with RTC, Standby mode without RTC).

  The BOR always remains active.

  The I/Os state during Standby mode can be retained.

  After entering Standby mode, SRAMs and register contents are lost, except for registers and backup SRAM in the Backup domain and Standby circuitry.

  The device exits Standby mode when an external reset (NRST pin), an IWDG reset, a WKUP pin event (configurable rising or falling edge), an RTC event (alarm, periodic wake-up, timestamp), or a tamper detection occurs. The tamper detection can be due to external pins or to an internal failure detection.

  The system clock after wake-up is HSI at 32 MHz.

3.10.3 Reset mode

To improve the consumption under reset, the I/Os state under and after reset is “analog state” (the I/O Schmitt trigger is disabled).

3.10.4 VBAT operation

The VBAT pin allows the device VBAT domain to be powered from an external battery or by an external super-capacitor.

The VBAT pin supplies the RTC with LSE, anti-tamper detection (TAMP), backup registers, and 4-Kbyte backup SRAM. Eight anti-tamper detection pins are available in VBAT mode.

The VBAT operation is automatically activated when V_{DD} is not present. An internal VBAT battery charging circuit is embedded and can be activated when V_{DD} is present.

Note: When the microcontroller is supplied from V_{BAT}, neither external interrupts nor RTC alarm/events exit it from the VBAT operation.

3.10.5 PWR TrustZone security

When the TrustZone security is activated by the TZEN option bit, the PWR is switched in TrustZone security mode.

The PWR TrustZone security secures the following configuration:

- Low-power mode
- Wake-up (WKUP) pins
- Voltage detection and monitoring
- VBAT mode

Some of the PWR configuration bits security are defined by the security of other peripherals:

- The voltage scaling (VOS) configuration is secure when the system clock selection is secure in RCC.
- The I/O pull-up/pull-down in Standby mode configuration is secure when the corresponding GPIO is secure.
- The backup domain write protection is secure when the RTC is secure.

3.11 Peripheral interconnect matrix

Several peripherals have direct connections between them, for autonomous communication, and to support the saving of CPU resources (thus power supply consumption). In addition, these hardware connections allow fast and predictable latency.

Depending on the peripherals, these interconnections can operate in Run and Sleep modes.

3.12 Reset and clock controller (RCC)

The clock controller distributes the clocks coming from the different oscillators to the core and to the peripherals. It also manages the clock gating for low-power modes and ensures the clock robustness. It features:

- **Clock prescaler:** to get the best trade-off between speed and current consumption, the clock frequency to the CPU and peripherals can be adjusted by a programmable prescaler.
- **Clock security system:** clock sources can be changed safely on the fly in Run mode through a configuration register.
- **Clock management:** to reduce the power consumption, the clock controller can stop the clock to the core, individual peripherals, or memory.
- **System clock source:** four different clock sources can be used to drive the master clock SYSCLK:
  - 4 to 50 MHz high-speed external crystal or ceramic resonator (HSE), can supply a PLL. The HSE can also be configured in bypass mode for an external clock.
  - 64 MHz high-speed internal RC oscillator (HSI), trimmable by software, can supply a PLL.
  - 4 MHz low-power internal oscillator (CSI), trimmable by software, can supply a PLL.
  - System PLL, which can be fed by HSE, HSI, or CSI, with a maximum frequency at 250 MHz.

- **RC48 with clock recovery system (HSI48):** internal 48 MHz clock source (HSI48), can be used to drive the USB.
- **UCPD kernel clock**, derived from HSI clock. The HSI RC oscillator must be enabled prior to the UCPD kernel clock use.
- **Auxiliary clock source:** two ultra-low power clock sources that can be used to drive the real-time clock:
  - 32.768 kHz low-speed external crystal (LSE), supporting four drive capability modes. The LSE can also be configured in bypass mode for an external clock.
  - 32 kHz low-speed internal RC (LSI), also used to drive the independent watchdog.
- **Peripheral clock sources:** several peripherals have their own independent clock, whatever the system clock. Three PLLs, each having three independent outputs allowing the highest flexibility, can generate independent clocks for the ADC, USB, SDMMC, RNG, FDCAN1, OCTOSPI.
- **Startup clock:** after reset, the microcontroller restarts by default with an internal 32 MHz clock (HSI/2). The prescaler ratio and clock source can be changed by the application program as soon as the code execution starts.
- **Clock security system (CSS):** this feature can be enabled by software. If a HSE clock failure occurs, the master clock automatically switches to HSI and a software interrupt is generated if enabled. LSE failure can also be detected and generates an interrupt.
- Clock-out capability:
  - **MCO (microcontroller clock output):** outputs one of the internal clocks for external use by the application.
  - **LSCO (low-speed clock output):** outputs LSI or LSE in all low-power modes (except VBAT mode).

Several prescalers allow AHB and APB frequencies configuration. The maximum frequency of the AHB and the APB clock domains is 250 MHz.

3.12.1 RCC TrustZone security

When the TrustZone security is activated by the TZEN option bit, the RCC is switched in TrustZone security mode.

The RCC TrustZone security secures some RCC system configuration and peripheral configuration clock from being read or modified by nonsecure accesses: when a peripheral is secure, the related peripheral clock, reset, clock source selection and clock enable during low-power modes control bits are secure.

A peripheral is in secure state:

- when its corresponding SEC security bit is set in the TZSC (TrustZone security controller), for securable peripherals.
- when a security feature of this peripheral is enabled through its dedicated bits, for TrustZone-aware peripherals.

3.13 Clock recovery system (CRS)

The devices embed a special block that allows automatic trimming of the internal 48 MHz oscillator to guarantee its optimal accuracy over the whole device operational range. The trimming is based on the external synchronization signal, derived from USB SOF (OTG_FS_SOF or OTG_HS_SOF) signalization, from LSE oscillator, from an external

signal on CRS_SYNC pin, or generated by user software. For faster lock-in during startup, automatic and manual trimming actions can be combined.

3.14 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 peripheral alternate function. Most of the GPIO pins are shared with digital or analog alternate functions.

After reset, all GPIOs are in analog mode to reduce power consumption.

If needed, the I/Os alternate function configuration can be locked following a specific sequence, to avoid spurious writing to the I/Os registers.

Ten I/Os (PD6, PD7, PG9:14, PB8, PB9) can be independently supplied by a dedicated V_{DDIO} supply.

3.14.1 GPIOs TrustZone security

Each I/O pin of GPIO port can be individually configured as secure. When the selected I/O pin is configured as secure, its corresponding configuration bits for alternate function, mode selection, I/O data are secure against a nonsecure access. The associated registers bit access is restricted to a secure software only. After reset, all GPIO ports are secure.

3.15 Multi-AHB bus matrix

A 32-bit multi-AHB bus matrix interconnects all the masters (CPU, GPDMA1, GPDMA2, SDMMC1, Ethernet, OTG_HS, DMA2D, LTDC) and the slaves (flash memory, FMC, OCTOSPI, SRAMs, AHB and APB) peripherals. It ensures seamless and efficient operation, even when several high-speed peripherals work simultaneously.

3.16 General purpose direct memory access controller (GPDMA)

The GPDMA controller is a bus master and system peripheral. It used to perform programmable data transfers between memory-mapped peripherals and/or memories via linked-lists, upon the control of an off-loaded CPU. The GPDMA main features are:

- Dual bidirectional AHB master
- Memory-mapped data transfers from a source to a destination:
  - Peripheral-to-memory
  - Memory-to-peripheral
  - Memory-to-memory
  - Peripheral-to-peripheral
- Autonomous data transfers during Sleep mode
- Transfers arbitration based on a four-grade programmed priority at a channel level:
  - One high-priority traffic class, for time-sensitive channels (queue 3)
  - Three low-priority traffic classes, with a weighted round-robin allocation for non time-sensitive channels (queues 0, 1, 2)

- Per channel event generation, on any of the following events: transfer complete or half transfer complete or data transfer error or user setting error, and/or update linked-list item error or completed suspension
- Per channel interrupt generation, with separately programmed interrupt enable per event
- 12 concurrent DMA channels:
  - Per channel FIFO for queuing source and destination transfers
  - Intra-channel DMA transfers chaining via programmable linked-list into memory, supporting two execution modes: run-to-completion and link step mode
  - Intra-channel and inter-channel DMA transfers chaining via programmable DMA input triggers connection to DMA task completion events
- Per linked-list item within a channel:
  - Separately programmed source and destination transfers
  - Programmable data handling between source and destination: byte-based reordering, packing or unpacking, padding or truncation, sign extension and left/right realignment
  - Programmable number of data bytes to be transferred from the source, defining the block level
  - channels with linear source and destination addressing: either fixed or contiguously incremented addressing, programmed at a block level, between successive single transfers
  - Four channels with 2D source and destination addressing: programmable signed address offsets between successive burst transfers (non-contiguous addressing within a block, combined with programmable signed address offsets between successive blocks, at a second 2D/repeated block level)
  - Support for scatter-gather (multi-buffer transfers), data interleaving and de-interleaving via 2D addressing
  - Programmable DMA request and trigger selection
  - Programmable DMA half-transfer and transfer complete events generation
  - Pointer to the next linked-list item and its data structure in memory, with automatic update of the DMA linked-list control registers
- Debug:
  - Channel suspend and resume support
  - Channel status reporting including FIFO level and event flags
- TrustZone support:
  - Support for secure and nonsecure DMA transfers, independently at a first channel level, and independently at a source/destination and link sub-levels
  - Secure and nonsecure interrupts reporting, resulting from any of the respectively secure and nonsecure channels
  - TrustZone-aware AHB slave port, protecting any DMA secure resource (register, register field) from a nonsecure access
- Privileged/unprivileged support:
  - Support for privileged and unprivileged DMA transfers, independently at a channel level
  - Privileged-aware AHB slave port

3.17 Chrom-ART2 Accelerator controller (DMA2D)

The Chrom-ART2 Accelerator (DMA2D) is a specialized DMA dedicated to image manipulation. It can perform the following operations:

- Filling a part or the whole of a destination image with a specific color
- Copying a part or the whole of a source image into a part or the whole of a destination image
- Copying a part or the whole of a source image into a part or the whole of a destination image with a pixel format conversion
- Blending a part and/or two complete source images with different pixel format and copy the result into a part or the whole of a destination image with a different color format.
- 90°/180°/270° rotation and mirroring
- Downscaling
- Stenciling
- Command list support

3.18 Graphic timer (GFXTIM)

The graphic timer (GFXTIM) is a graphic oriented timer allowing smart management of graphical events for frame or line counting. The GFXTIM main features are:

- Integrated frame and line clock generation
- One absolute frame counter with one compare channel
- Two auto-reload relative frame counters
- One line timer with two compare channels
- External tearing-effect line management and synchronization
- Four programmable event generators with external trigger generation
- One watchdog counter

3.19 Programmable logic array (PLAY)

The programmable logic array enables the user to create custom logic and state machines without the need for external programmable logic devices, such as FPGAs.

It enables the following features:

- Glitch-free programmable logic elements each comprising a 4-input look-up table and a register
- Configurable input and output interconnects
- Optional synchronization of inputs, with programmable glitch filters and edge detection/pulse extension feature.
- Software programmable inputs
- Flags with interrupt capability for communication with software
- Simple register-based configuration interface, protected by software lock
- Arm® TrustZone®-aware
- Privilege-aware

3.20 Interrupts and events

3.20.1 Nested vectored interrupt controller (NVIC)

The devices embed a nested vectored interrupt controller able to manage 16 priority levels and to handle up to 162 maskable interrupt channels plus the 16 interrupt lines of the Cortex-M33.

The NVIC benefits are the following:

- closely coupled NVIC giving low-latency interrupt processing
- interrupt entry vector table address passed directly to the core
- early processing of interrupts
- processing of late arriving higher priority interrupts
- support for tail chaining
- processor state automatically saved
- interrupt entry restored on interrupt exit with no instruction overhead
- TrustZone support: NVIC registers banked across secure and nonsecure states

The NVIC hardware block provides flexible interrupt management features with minimal interrupt latency.

3.20.2 Extended interrupt/event controller (EXTI)

The extended interrupts and event controller (EXTI) manages the individual CPU and system wake-up through configurable event inputs. It provides wake-up requests to the power control, and generates an interrupt request to the CPU NVIC and events to the CPU event input. For the CPU an additional event generation block (EVG) is needed to generate the CPU event signal.

The EXTI wake-up requests allow the system to be woken up from Stop modes.

The interrupt request and event request generation can also be used in Run modes. The EXTI also includes the EXTI multiplexer IO port selection.

The EXTI main features are the following:

- All event inputs allowed to wake up the system
- Configurable events (signals from I/Os or peripherals able to generate a pulse)
  - Selectable active trigger edge
  - Interrupt pending status register bit independent for the rising and falling edge
  - Individual interrupt and event generation mask, used for conditioning the CPU wake-up, interrupt and event generation
  - Software trigger possibility
- TrustZone secure events
  - The access to control and configuration bits of secure input events can be made secure
- EXTI IO port selection

3.21 Cyclic redundancy check calculation unit (CRC)

The CRC is used to get a CRC code using a configurable generator with polynomial value and size.

Among other applications, the CRC-based techniques are used to verify data transmission or storage integrity. In the scope of the EN/IEC 60335-1 standard, they offer a mean to verify the flash memory integrity.

The CRC calculation unit helps to compute a signature of the software during runtime, which can be ulteriorly compared with a reference signature generated at link-time and that can be stored at a given memory location.

3.22 CORDIC coprocessor (CORDIC)

The CORDIC coprocessor provides hardware acceleration of certain mathematical functions, notably trigonometric, commonly used in motor control, metering, signal processing and many other applications. It speeds up the calculation of these functions compared to a software implementation, allowing a lower operating frequency, or freeing up processor cycles in order to perform other tasks.

The CORDIC main features are:

- 24-bit CORDIC rotation engine
- Circular and hyperbolic modes
- Rotation and vectoring modes
- Functions: sine, cosine, sinh, cosh, atan, atan2, atanh, modulus, square root, natural logarithm
- Programmable precision
- Low-latency AHB slave interface
- Results can be read as soon as ready without polling or interrupt
- DMA read and write channels
- Multiple register read/write by DMA

3.23 Filter math accelerator (FMAC)

The FMAC performs arithmetic operations on vectors. It comprises a multiplier/accumulator (MAC) unit, together with address generation logic that allows it to index vector elements held in local memory.

The unit includes support for circular buffers on input and output, which allows digital filters to be implemented. Both finite and infinite impulse response filters can be done.

The unit allows frequent or lengthy filtering operations to be offloaded from the CPU, freeing up the processor for other tasks. In many cases it can accelerate such calculations compared to a software implementation, resulting in a speed-up of time critical tasks.

The FMAC main features are:

- 16 x 16-bit multiplier
- 24 + 2-bit accumulator with addition and subtraction
- 16-bit input and output data

- 256 x 16-bit local memory
- Up to three areas can be defined in memory for data buffers (two input, one output), defined by programmable base address pointers and associated size registers
- Input and output buffers can be circular
- Filter functions: FIR, IIR (direct form 1)
- Vector functions: dot product, convolution, correlation
- AHB slave interface
- DMA read and write data channels

3.24 Flexible memory controller (FMC)

The FMC includes three memory controllers:

- NOR/PSRAM memory controller
- NAND memory controller

The main features of the FMC controller are the following:

- Interface with static-memory mapped devices including:
  - Static random access memory (SRAM)
  - NOR flash memory/OneNAND flash memory
  - PSRAM (four memory banks)
  - NAND flash memory with ECC hardware to check up to 8 Kbytes of data
  - Ferroelectric RAM (FRAM, FeRAM)
- 8-,16-, and 32- bit data bus width
- Independent chip select control for each memory bank
- Independent configuration for each memory bank
- Write FIFO

3.24.1 LCD parallel interface

The FMC can be configured to interface seamlessly with most graphic LCD controllers. It supports the Intel® 8080 and Motorola® 6800 modes, and is flexible enough to adapt to specific LCD interfaces.

This LCD parallel interface capability makes it easy to build cost effective graphic applications using LCD modules with embedded controllers or high-performance solutions using external controllers with dedicated acceleration.

3.24.2 FMC TrustZone security

When the TrustZone security is enabled, the whole FMC banks are secure after reset. Nonsecure area can be configured using the TZSC MPCWMx controller.

- The FMC NOR/PSRAM bank:
  - Up to two nonsecure area can be configured thought the TZSC MPCWM2 controller with a 64-Kbyte granularity
- The FMC NAND bank:
  - Can be either configured as fully secure or fully nonsecure using the TZSC MPCWM3 controller

The FMC registers can be configured as secure through the TZSC controller.

3.25 Octo-SPI interface (OCTOSPI)

The OCTOSPI supports external memories such as serial PSRAMs, serial NAND/NOR flash memories, HyperRAMs™ and HyperFlash™ memories, with the following functional modes:

- Indirect mode: all the operations are performed using the OCTOSPI registers.
- Status-polling mode: the external memory status register is periodically read and an interrupt can be generated in case of flag setting.
- Memory-mapped mode: the external memory is memory mapped and is seen by the system as if it were an internal memory supporting read and write operation.

The OCTOSPI supports the following protocols with associated frame formats:

- Standard frame format with the command, address, alternate byte, dummy cycles and data phase
- HyperBus™ frame format

The OCTOSPI offers the following features:

- Three functional modes: Indirect, Status-polling, and Memory-mapped
- Read and write support in Memory-mapped mode
- Supports for single, dual, quad and octal communication
- Dual-quad mode, where eight bits can be sent/received simultaneously by accessing two quad memories in parallel.
- SDR (single-data rate) and DTR (double-transfer rate) support
- Data strobe support
- Fully programmable opcode
- Fully programmable frame format
- HyperBus support
- Integrated FIFO for reception and transmission
- 8-, 16-, and 32-bit data accesses allowed
- DMA channel for Indirect mode operations
- Interrupt generation on FIFO threshold, timeout, operation complete, and access error

3.25.1 OCTOSPI TrustZone security

When the TrustZone security is enabled, the whole OCTOSPI bank is secure after reset.

Up to two nonsecure area can be configured thought the TZSC MPCWM1 controller with a granularity of 64 Kbytes.

The OCTOSPI registers can be configured as secure through the TZSC controller.

3.26 OCTOSPI I/O manager (OCTOSPIM)

The OCTOSPI I/O manager is a low-level interface enabling:

- Efficient OCTOSPI pin assignment with a full I/O matrix (before alternate function map)
- Multiplex of Single-, Dual-, Quad-, Octal-SPI interfaces over the same bus and hence support memories embedded in a multichip package.

The OCTOSPIM main features are:

- Supports up to two single-, dual-, quad-, octal-SPI interfaces
- Supports up to two ports for pin assignment • Fully programmable I/O matrix for pin assignment by function (data/control/clock)

3.27 Delay block (DLYB)

The delay block (DLYB) is used to generate an output clock dephased from the input clock. The phase of the output clock must be programmed by the user application. The output clock is then used to clock the data received by another peripheral such as an SDMMC or Octo-SPI interface. The delay is voltage and temperature dependent, that may require the application to re-configure and recenter the output clock phase with the received data.

The delay block main features are:

- Input clock frequency ranging from 25 to 250 MHz
- Up to 12 oversampling phases

3.28 Analog-to-digital converters (ADC1, ADC2, and ADC3)

The devices embed three successive approximation analog-to-digital converters.

Table 3. ADC features

Mode/feature	ADC1	ADC2	ADC3
Resolution	12 bit		
Maximum sampling speed	5 Msps (12-bit resolution)		
Dual mode operation	X		-
Hardware offset calibration	X		
Hardware linearity calibration	-		
Single-end input	X		
Differential input	X		-
Injected channel conversion	X		
Oversampling	Up to x256		
Data register	16 bits		
Data register FIFO depth	3 stages		
DMA support	X		
Parallel data output to ADF	MDF		ADF
Offset compensation	X		
Gain compensation	-		
Number of analog watchdogs	3		

3.28.1 Analog temperature sensor

This sensor generates a voltage (V_{SENSE}) that varies linearly with temperature. It is internally connected to a comparator or to an ADC input channel used to convert the output voltage into a digital value.

The sensor provides good linearity but it must be calibrated to obtain a good accuracy of the temperature measurement. As the offset depends upon process variation, the uncalibrated internal temperature sensor is suitable for applications that detect only temperature changes.

To improve the measurement accuracy, each device is individually factory-calibrated by ST. The calibration data are stored in the system memory area, accessible in read-only mode.

3.28.2 Internal voltage reference (V_{REFINT})

The internal voltage reference (V_{REFINT}) provides a stable (bandgap) voltage output for the ADC. The V_{REFINT} is internally connected to ADC input channel.

The precise voltage of V_{REFINT} is individually measured for each part during manufacturing, and stored in the system memory area. It is accessible in read-only mode.

3.28.3 V_{BAT} battery voltage monitoring

This embedded hardware enables the application to measure the V_{BAT} battery voltage using ADC or input channel. As the V_{BAT} voltage may be higher than the V_{DDA}, and thus outside the ADC input range, the VBAT pin is internally connected to a bridge divider by four. As a consequence, the converted digital value is a quarter of the V_{BAT} voltage.

3.29 Digital temperature sensor (DTS)

The devices embeds a sensor that converts the temperature into a square wave, whose frequency is proportional to the temperature. The PCLK or the LSE clock can be used as reference clock for the measurements. Use the formula given in the product reference manual to calculate the temperature according to the measured frequency stored in the DTS_DR register.

3.30 Digital to analog converter (DAC)

The DAC module is a 12-bit voltage output digital-to-analog converter. The DAC can be configured in 8- or 12-bit mode, and can be used in conjunction with the DMA controller. In 12-bit mode, the data can be left- or right-aligned.

The DAC features two output channels, each with its own converter. In dual DAC channel mode, conversions can be done independently or simultaneously when both channels are grouped together for synchronous update operations. An input reference pin, VREF+ (shared with others analog peripherals), is available for better resolution. An internal reference can also be set on the same input.

The DAC_OUTx pin can be used as general purpose input/output (GPIO) when the DAC output is disconnected from output pad and connected to on chip peripheral. The DAC output buffer can be optionally enabled to allow a high drive output current. An individual calibration can be applied on each DAC output channel. The DAC output channels support a low power mode, the Sample and hold mode.

The digital interface supports the following features:

- One DAC interface, maximum two output channels
- Left or right data alignment in 12-bit mode
- Synchronized update capability
- Noise-wave and triangular-wave generation
- Sawtooth wave generation
- Dual DAC channel for independent or simultaneous conversions
- DMA capability for each channel including DMA underrun error detection
- Double data DMA capability to reduce the bus activity
- External triggers for conversion
- DAC output channel buffered/unbuffered modes
- Buffer offset calibration

- Each DAC output can be disconnected from the DAC_OUTx output pin
- DAC output connection to on chip peripherals
- Sample and Hold mode for low-power operation in Stop mode. The DAC voltage can be changed autonomously with the DMA while the device is in Stop mode.
- Voltage reference input

3.31 Voltage reference buffer (VREFBUF)

The devices embed a voltage reference buffer that can be used as reference for ADCs and DACs, and also as reference for external components through the VREF+ pin.

The internal voltage reference buffer supports voltages: 1.8, 2.048, and 2.5 V.

An external voltage reference can be provided through the VREF+ pin when the internal voltage reference buffer is off.

The VREF+ pin is double-bonded with VDDA on some packages. In these packages the internal voltage reference buffer is not available.

3.32 Comparators (COMP)

The devices embed two rail-to-rail comparators with programmable reference voltage (internal or external), hysteresis and speed (low speed for low power) and with selectable output polarity. The reference voltage can be one of the following:

- External I/O
- DAC output channels
- Internal reference voltage or submultiple (1/4, 1/2, 3/4)
- The analog temperature sensor
- The VBAT/4 supply.

All comparators can wake up from Stop mode, generate interrupts and breaks for the timers and can also be combined into a window comparator.

3.33 Operational amplifiers (OPAMP)

The devices embed an operational amplifier OPAMP1 with external or internal follower routing and PGA capability, and two inputs and one output. These three I/Os can be connected to the external pins, thus enabling any type of external interconnections. The operational amplifier can be configured internally as a follower, as an amplifier with a noninverting gain ranging from 2 to 16 or with an inverting gain ranging from -1 to -15.

The main features of the operational amplifier are:

- PGA with a noninverting gain ranging of 2, 4, 8 or 16 or inverting gain ranging of -1, -3, -7 or -15
- One positive input connected to the DAC
- Output connected to internal ADC
- Low input bias current down to 1 nA
- Low input offset voltage down to 1.5 mV
- Gain bandwidth up to 7 MHz

3.34 Multi-function digital filter (MDF) and audio digital filter (ADF)

The table below lists the set of features implemented into the MDF and the ADF.

Table 4. MDF features

MDF modes/features(1)	ADF1	MDF1
Number of filters (DFLTx) and serial interfaces (SITFx)	1	6
ADF_CKI0 / MDF_CKIy connected to pins	-	X
Sound activity detection (SAD)	X	-
RXFIFO depth (number of 24-bit words)	4	4
ADC connected to ADCITF1	ADC3	ADC1
ADC connected to ADCITF2	-	ADC2
Motor dedicated features (SCD, OLD, OEC, INT, snapshot, break)	-	X
Main path with CIC4, CIC5	X	X
Main path with CIC1,2, 3 or FastSinc	-	X
RSFLT, HPF, SAT, SCALE, DLY, Discard functions	X	X
Autonomous in Stop mode	-	-

1. X = supported.

3.34.1 Multi-function digital filter (MDF)

The MDF is a high-performance module dedicated to the connection of external sigma-delta ($\sum\Delta$) modulators. It is mainly targeted for the following applications:

- audio capture signals
- motor control
- metering

The MDF features six digital serial interfaces (SITFx) and digital filters (DFLTx) with flexible digital processing options to offer up to 24-bit final resolution.

The DFLTx of the MDF also include the filters of the ADF (audio digital filter).

The MDF can receive, via its serial interfaces, streams coming from various digital sensors.

The MDF supports the following standards allowing the connection of various ΣΔ modulator sensors:

- SPI interface
- Manchester coded 1-wire interface
- PDM interface

The MDF main features are:

- AHB interface
- Six serial digital inputs:
  - configurable SPI interface to connect various digital sensors
  - configurable Manchester coded interface support
  - compatible with PDM interface to support digital microphones
- Two common clock input/output for ∑Δ modulators
- Flexible BSMX for connection between filters and digital inputs
- Two inputs to connect the internal ADCs
- Six flexible digital filter paths, including:
  - A configurable CIC filter:
    - Can be split into two CIC filters: high-resolution filter and out-off limit detector
    - Can be configured in $Sinc^4$ filter
    - Can be configured in $Sinc^5$ filter
    - Adjustable decimation ratio
  - A reshape filter to improve the out-off band rejection and in-band ripple
  - A high-pass filter to cancel the DC offset
  - An offset error cancellation
  - Gain control
  - Saturation blocks
  - An out-off limit detector
- Short-circuit detector
- Clock absence detector
- 16- or 24-bit signed output data resolution
- Continuous or single conversion
- Possibility to delay independently each bitstream
- Various trigger possibilities
- Break generation on out-of limit or short-circuit detector events
- Autonomous functionality in Stop modes
- DMA can be used to read the conversion data
- Interrupts services

3.34.2 Audio digital filter (ADF)

The ADF is a high-performance module dedicated to the connection of external ∑Δ modulators. It is mainly targeted for the following applications:

- audio capture signals
- metering

The ADF features one digital serial interface (SITF0) and one digital filter (DFLT0) with flexible digital processing options to offer up to 24-bit final resolution.

The DLFT0 of the ADF is a subset of the digital filters included into the MDF.

The ADF serial interface supports several standards allowing the connection of various ∑Δ modulator sensors:

- SPI interface
- Manchester coded 1-wire interface
- PDM interface

The ADF main features are:

- AHB interface
- One serial digital input:
  - Configurable SPI interface to connect various digital sensors
  - Configurable Manchester coded interface support
  - Compatible with PDM interface to support digital microphones
- Two common clocks input/output for ∑Δ modulators
- Flexible BSMX for connection between filters and digital inputs
- One flexible digital filter path, including:
  - A configurable CIC filter:
    - Can be configured in $Sinc^4$ filter
    - Can be configured in $Sinc^5$ filter
    - Adjustable decimation ratio
  - A reshape filter to improve the out-off band rejection and in-band ripple
  - A high-pass filter to cancel the DC offset
  - Gain control
  - Saturation blocks
- Clock absence detector
- Sound activity detector
- 16- or 24-bit signed output data resolution
- Continuous or single conversion
- Possibility to delay independently each bitstream
- Various trigger possibilities
- Autonomous mode in Stop 0, Stop 1 and Stop 2 modes
- Wake-up from Stop with all interrupts
- DMA can be used to read the conversion data
- Interrupts services

3.35 Digital camera interface (DCMI)

The digital camera is a synchronous parallel interface able to receive a high-speed data flow from an external 8-, 10-, 12- or 14-bit CMOS camera module. It supports different data formats: YCbCr4:2:2/RGB565 progressive video and compressed data (JPEG). It can be used with black and white cameras, X24 and X5 cameras (it is assumed that all preprocessing such as resizing is performed in the camera module).

Main features:

- 8-, 10-, 12-, or 14-bit parallel interface
- Embedded/external line and frame synchronization
- Continuous or snapshot mode
- Crop feature
- Support of the following data formats:
  - 8/10/12/14-bit progressive video: monochrome or raw Bayer
  - YCbCr 4:2:2 progressive video
  - RGB 565 progressive video
  - Compressed data: JPEG

3.36 Parallel synchronous slave interface (PSSI)

The PSSI peripheral and the DCMI (digital camera interface) use the same circuitry. As a result, these two peripherals cannot be used at the same time: when using the PSSI, the DCMI registers cannot be accessed, and vice versa. In addition, the PSSI and the DCMI share the same alternate functions and the same interrupt vector.

The PSSI is a generic synchronous 8-/16-bit parallel data input/output slave interface. It enables the transmitter to send a data valid signal that indicates when the data is valid, and the receiver to output a flow control signal that indicates when it is ready to sample the data.

The PSSI peripheral main features are the following:

- Slave mode operation
- 8-bit or 16-bit parallel data input or output
- 4-word (16-byte) FIFO
- Data enable (PSSI_DE) alternate function input and ready (PSSI_RDY) alternate function output

When selected, these inputs can either enable the transmitter to indicate when the data is valid, or allow the receiver to indicate when it is ready to sample the data, or both.

3.37 LCD-TFT display controller (LTDC)

The LCD-TFT (liquid crystal display - thin film transistor) display controller provides a parallel digital RGB (Red, Green, Blue) and signals for horizontal/vertical synchronization, pixel clock and data enable as output to interface directly to a variety of LCD and TFT panels.

The LTDC main features are:

- 24-bit RGB parallel pixel output; 8 bits-per-pixel (RGB888)

- 2 display layers with dedicated FIFO (64x32-bit)
- Color look-up table (CLUT) up to 256 color (256x24-bit) per layer
- Programmable timings for different display panels
- Programmable background color
- Programmable polarity for HSYNC, VSYNC and data enable
- Up to 8 input color formats selectable per layer: – ARGB8888 – RGB888 – RGB565 – ARGB1555 – ARGB4444 – L8 (8-bit luminance or CLUT) – AL44 (4-bit alpha + 4-bit luminance) – AL88 (8-bit alpha + 8-bit luminance)
- Pseudo-random dithering output for low bits per channel – Dither width 2 bits for Red, Green, Blue
- Flexible blending between two layers using alpha value (per pixel or constant)
- Color keying (transparency color)
- Programmable window position and size
- Supports thin film transistor (TFT) color displays
- AHB master interface with burst of 16 words
- Up to 4 programmable interrupt events

3.38 JPEG codec (JPEG)

The hardware 8-bit JPEG codec encodes uncompressed image data stream or decodes JPEG-compressed image data stream. It also fully manages JPEG headers.

The JPEG codec main features are as follows:

- High-speed fully-synchronous operation
- Configurable as encoder or decoder
- Single-clock-per-pixel encode/decode
- RGB, YCbCr, YCMK and BW (grayscale) image color space support
- 8-bit depth per image component at encode/decode
- JPEG header generator/parser with enable/disable
- Four programmable quantization tables
- Single-clock Huffman coding and decoding
- Fully-programmable Huffman tables (two AC and two DC)
- Fully-programmable minimum coded unit (MCU)
- Concurrent input and output data stream interfaces

3.39 True random number generator (RNG)

The RNG is a true random number generator that provides full entropy outputs to the application as 32-bit samples. It is composed of a live entropy source (analog) and an internal conditioning component.

The RNG is a NIST SP 800-90B compliant entropy source that can be used to construct a non-deterministic random bit generator (NDRBG). It can be certified NIST SP800-90B.

The true random generator:

- delivers 32-bit true random numbers, produced by an analog entropy source conditioned by a NIST SP800-90B approved conditioning stage
- can be used as entropy source to construct a non-deterministic random bit generator (NDRBG)
- produces four 32-bit random samples every 412 AHB clock cycles if f_{AHB} < 77 MHz (256 RNG clock cycles otherwise)
- embeds start-up and NIST SP800-90B approved continuous health tests (repetition count and adaptive proportion tests), associated with specific error management
- can be disabled to reduce power consumption, or enabled with an automatic low-power mode (default configuration)
- has an AMBA AHB slave peripheral, accessible through 32-bit word single accesses only (else an AHB bus error is generated, and the write accesses are ignored)

3.40 HASH hardware accelerator (HASH)

The HASH is a fully compliant implementation of the secure hash (SHA-1, SHA-2 family, SHA-3 family) and the HMAC (keyed-hash message authentication code) algorithms. HMAC is suitable for applications requiring message authentication.

The HASH computes FIPS (Federal information processing standards) approved digests of length of 160, 224, 256, 512 bits, for messages of any length less than 2^{64} bits (SHA-1, SHA-224, and SHA-256) or less than 2^{128} bits (SHA-384, SHA-512).

The HASH main features are:

- Suitable for data authentication applications, compliant with:
  - FIPS PUB 180-4, *Secure Hash Standard* (SHA-1 and SHA-2 family)
  - FIPS PUB 186-4, *Digital* Signature Standard (DSS)
  - Internet Engineering Task Force (IETF) Request For Comments RFC 2104, *HMAC: Keyed-Hashing for Message Authentication* and Federal Information Processing Standards Publication FIPS PUB 198-1, *The Keyed-Hash Message* Authentication Code (HMAC)
  - Federal Information Processing Standards Publication FIPS PUB 202, Secure Hash Standard (SHA-3 family)
- Fast computation of SHA-1, SHA-224, SHA-256, SHA-512
  - 82 (respectively 66) clock cycles for processing one 512-bit block of data using SHA-1 (respectively SHA-256) algorithm
  - 98 clock cycles for processing one 1024-bit block of data using either SHA-384 or SHA-512 algorithm
  - Support for SHA-2 truncated outputs (SHA2-512/224, SHA2-512/256)
- Support for the six Keccak-based functions defined in FIPS 202 standard
  - Fixed output length: SHA3-224, SHA3-256, SHA3-384 and SHA3-512
  - Extendable-output functions: SHAKE128 and SHAKE256
  - One cycle per Keccak round, hence 58 cycles per 1088-bit block for SHA3-256
- Corresponding 32-bit words of the digest from consecutive message blocks are added to each other to form the digest of the whole message

  - Automatic 32-bit words swapping to comply with the internal little-endian representation of the input bit string
  - Word swapping supported: bits, bytes, half-words and 32-bit words
- Automatic padding to complete the input bit string to fit digest minimum block size
- Single 32-bit input register associated to an internal input FIFO of sixteen 32-bit words, corresponding to a 64-byte block size (16 x 32 bits)
- AHB slave peripheral, accessible through 32-bit word accesses only (else an AHB error is generated)
- 50 × 32-bit words (H0 to H41) for output message digest and general purpose SHA-3 outputs
- Automatic data flow control with support of direct memory access (DMA) using one channel. Single or fixed burst of 4 supported.
- Interruptible message digest computation, on a per-block word basis
  - Re-loadable digest registers
  - Hashing computation suspend/resume mechanism, including using DMA
- Support for HMAC mode with all supported algorithms

3.41 Public key accelerator (PKA)

The public key accelerator (PKA) can verify ECDSA signatures, with all needed computation performed within the accelerator. Application CPU is only needed to manage the inputs and the outputs of the operation.

The PKA main features are:

- ECDSA signature generation and verification
- Capability to handle operands up to 640 bits
- AMBA AHB slave peripheral, accessible through 32-bit word single accesses only (otherwise an AHB bus error is generated, and write accesses are ignored)

3.42 Timers and watchdogs

The devices include two advanced control timers, up to seven general-purpose timers, two basic timers, six low-power timers, two watchdog timers, and two SysTick timers.

Table 5 compares the features of the advanced control, general-purpose, and basic timers.

Table 5. Timer features

Type	Timer	Counter resolution	Counter type	Prescaler factor	DMA request generation	Capture/ compare channels	Complementary outputs
Advanced control	TIM1, TIM8	16 bits	Up, down, up/down	Any integer between 1 and 65536	Yes	4	4
General purpose	TIM2, TIM5	32 bits				4	No
	TIM3, TIM4	16 bits				4	No
General purpose	TIM12, TIM15	16 bits	Up			2	1
	TIM13, TIM14, TIM16, TIM17					1	1
Basic	TIM6, TIM7	16 bits	Up			0	No

3.42.1 Advanced-control timers (TIM1, TIM8)

These timers can be seen as a three-phase PWM multiplexed on six channels. They have complementary PWM outputs with programmable inserted dead-times. They can also be seen as complete general-purpose timers.

The four independent channels can be used for:

- Input capture
- Output compare
- PWM generation (edge or center-aligned modes) with full modulation capability (0 - 100 %)
- One-pulse mode output

In Debug mode, the advanced-control timer counter can be frozen and the PWM outputs disabled to turn off any power switches driven by these outputs.

Many features are shared with the general-purpose TIMx timers (described in the next section) using the same architecture, so the advanced-control timers can work together with the TIMx timers via the *Timer Link* feature for synchronization or event chaining.

3.42.2 General-purpose timers (TIM2, TIM3, TIM4, TIM5, TIM15, TIM16, TIM17)

The devices embed up to seven synchronizable general-purpose timers (see *Table 5*), each of them can be used to generate PWM outputs, or act as a simple time base.

- TIM2 and TIM5

  Full-featured general-purpose timers with 32-bit auto-reload up/down counter and 32-bit prescaler.

  These timers feature four independent channels for input capture/output compare, PWM or one-pulse mode output. They can work together, or with the other general-purpose timers via the Timer Link feature for synchronization or event chaining.

  The counters can be frozen in Debug mode. All have independent DMA request generation and support quadrature encoders.

- TIM3 and TIM4

  Full-featured general-purpose timers, with 16-bit auto-reload up/down counter and 16-bit prescaler.

  These timers feature four independent channels for input capture/output compare, PWM or one-pulse mode output.

  They can work together, or with the other general-purpose timers via the *Timer Link* feature for synchronization or event chaining.

  The counters can be frozen in Debug mode. All have independent DMA request generation and support quadrature encoders.
- TIM12, TIM13, TIM14, TIM15, TIM16, and TIM17

  General-purpose timers with mid-range features, with 16-bit auto-reload up counter and 16-bit prescaler.
  - TIM12 and TIM15 have two channels and one complementary channel
  - TIM13, TIM14, TIM16, and TIM17 have one channel and one complementary channel

  All channels can be used for input capture/output compare, PWM, or one-pulse mode output.

  These timers can work together via the Timer Link feature for synchronization or event chaining. The timers have independent DMA request generation.

  The counters can be frozen in Debug mode.

3.42.3 Basic timers (TIM6, TIM7)

These timers are mainly used for DAC trigger generation. They can also be used as generic 16-bit timebase.

3.42.4 Low-power timers (LPTIM1, LPTIM2, LPTIM3, LPTIM4, LPTIM5, LPTIM6)

The devices embed six low-power timers. These timers have an independent clock and are running in Stop mode if they are clocked by LSE, LSI or an external clock. They are able to wake up the system from Stop mode.

The low-power timers support the following features:

- 16-bit up counter with 16-bit autoreload register
- 3-bit prescaler with eight possible dividing factors (1, 2, 4, 8, 16, 32, 64, 128)
- Selectable clock
  - Internal clock sources: LSE, LSI, HSI or APB clock
  - External clock source over LPTIM input (working with no LP oscillator running, used by *Pulse Counter* application)
- 16-bit ARR autoreload register
- 16-bit capture/compare register
- Continuous/One-shot mode
- Selectable software/hardware input trigger
- Programmable digital glitch filter
- Configurable output: pulse, PWM
- Configurable I/O polarity

- Encoder mode
- Repetition counter
- Up to two independent channels for:
  - Input capture
  - PWM generation (edge-aligned mode)
  - One-pulse mode output
- Interrupt generation on ten events
- DMA request generation on the following events:
  - Update event
  - Input capture

3.42.5 Independent watchdog (IWDG)

The independent watchdog is based on a 12-bit downcounter and an 8-bit prescaler. It is clocked from an independent 32 kHz internal RC (LSI) and, as it operates independently from the main clock, it can operate in Stop and Standby modes. It can be used either as a watchdog to reset the device when a problem occurs, or as a free running timer for application timeout management. It is hardware or software configurable through the option bytes. The counter can be frozen in Debug mode.

3.42.6 Window watchdog (WWDG)

The window watchdog is based on a 7-bit downcounter that can be set as free running. It can be used as a watchdog to reset the device when a problem occurs. It is clocked from the main clock. It has an early warning interrupt capability and the counter can be frozen in Debug mode.

3.42.7 SysTick timer

The Cortex-M33 with TrustZone embeds two SysTick timers.

When TrustZone is activated, two SysTick timer are available:

- SysTick, secure instance
- SysTick, nonsecure instance

When TrustZone is disabled, only one SysTick timer is available. This timer (secure or nonsecure) is dedicated to real-time operating systems, but can also be used as a standard down counter. It features:

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

3.43 Real-time clock (RTC), tamper and backup registers

3.43.1 Real-time clock (RTC)

The RTC supports the following features:

- Calendar with subsecond, seconds, minutes, hours (12 or 24 format), weekday, date, month, year, in BCD (binary-coded decimal) format
- Binary mode with 32-bit free-running counter
- Automatic correction for 28, 29 (leap year), 30, and 31 days of the month
- Two programmable alarms
- On-the-fly correction from 1 to 32767 RTC clock pulses. This can be used to synchronize it with a master clock
- Reference clock detection: a more precise second source clock (50 or 60 Hz) can be used to enhance the calendar precision
- Digital calibration circuit with 0.95 ppm resolution, to compensate for quartz crystal inaccuracy
- Timestamp feature that can be used to save the calendar content. This function can be triggered by an event on the timestamp pin, or by a tamper event, or by a switch to VBAT mode
- 17-bit auto-reload wake-up timer (WUT) for periodic events with programmable resolution and period
- TrustZone support:
  - RTC fully securable
  - Alarm A, alarm B, wake-up timer and timestamp individual secure or nonsecure configuration
  - Alarm A, alarm B, wake-up timer and timestamp individual privileged protection

The RTC is supplied through a switch that takes power either from the V_{DD} supply when present or from the VBAT pin.

The RTC clock sources can be one of the following:

- 32.768 kHz external crystal (LSE)
- external resonator or oscillator (LSE)
- internal low-power RC oscillator (LSI, with typical frequency of 32 kHz)
- high-speed external clock (HSE), divided by a prescaler in the RCC.

The RTC is functional in VBAT mode and in all low-power modes when it is clocked by the LSE. When clocked by the LSI, the RTC is not functional in VBAT mode, but is functional in all low-power modes.

All RTC events (alarm, wake-up timer, timestamp) can generate an interrupt and wake up the device from the low-power modes.

3.43.2 Tamper and backup registers (TAMP)

The anti-tamper detection circuit is used to protect sensitive data from external attacks. 32 32-bit backup registers are retained in all low-power modes and in VBAT mode. The backup registers, as well as other secrets in the device, are protected by this anti-tamper detection circuit with eight tamper pins and nine internal tampers. The external tamper pins can be configured for edge detection, or level detection with or without filtering, or active

tamper that increases the security level by auto checking that the tamper pins are not externally opened or shorted.

TAMP main features:

- A tamper detection can erase the backup registers, backup SRAM, SRAM2, caches and cryptographic peripherals.
- 32 32-bit backup registers:
  - The backup registers (TAMP_BKPxR) are implemented in the Backup domain that remains powered-on by V_{BAT} when the V_{DD} power is switched off.
- Up to 8 tamper pins for 8 external tamper detection events:
  - Active tamper mode: continuous comparison between tamper output and input to protect from physical open-short attacks
  - Flexible active tamper I/O management: from 4 meshes (each input associated to its own exclusive output) to 7 meshes (single output shared for up to 7 tamper inputs)
  - Passive tampers: ultra-low power edge or level detection with internal pull-up hardware management
  - Configurable digital filter

Note: As input, only PC13, PA0, PA1, and PA2 are functional in Standby and VBAT modes. As output, only PC13 and PA1 are functional in Standby and VBAT modes.

- Internal tamper events to protect against transient or environmental perturbation attacks
- Each tamper can be configured in two modes:
  - Hardware mode: immediate erase of secrets on tamper detection, including backup registers erase
  - Software mode: erase of secrets following a tamper detection launched by software
- Any tamper detection can generate an RTC time stamp event.
- TrustZone support:
  - Tamper secure or nonsecure configuration.
  - Backup registers configuration in three configurable-size areas:
    - 1 read/write secure area
    - 1 write secure/read nonsecure area
    - 1 read/write nonsecure area
- Tamper configuration and backup registers privilege protection
- Monotonic counter

3.44 Inter-integrated circuit interface (I2C)

The devices embed four I2Cs. Refer to *Table 6* for the implemented features.

The I^2C bus interface handles communications between the microcontroller and the serial I^2C bus. It controls all I^2C bus-specific sequencing, protocol, arbitration and timing.

The I2C peripheral supports:

- I^2C-bus specification and user manual rev. 5 compatibility:
  - Target and controller modes, multicontroller capability

  - Standard-mode (Sm), with a bit rate up to 100 Kbit/s
  - Fast-mode (Fm), with a bit rate up to 400 Kbit/s
  - Fast-mode Plus (Fm+), with a bit rate up to 1 Mbit/s and 20 mA output drive I/Os
  - 7- and 10-bit addressing modes, multiple 7-bit target addresses
  - Programmable setup and hold times
  - Optional clock stretching
- System management bus (SMBus) specification rev 3.0 compatibility:
  - Hardware PEC (packet error checking) generation and verification with ACK control
  - Address resolution protocol (ARP) support
  - SMBus alert
- Power system management protocol (PMBus) specification rev 1.3 compatibility
- Independent clock: a choice of independent clock sources makes the I2C communication speed independent from the PCLK reprogramming
- Wake-up from Stop capability
- Programmable analog and digital noise filters
- 1-byte buffer with DMA capability

Table 6. I2C implementation

Feature(1)	I2C1	I2C2	I2C3	I2C4
Standard-mode (up to 100 Kbit/s)	X	X	X	X
Fast-mode (up to 400 Kbit/s)	X	X	X	X
Fast-mode Plus with 20 mA output drive I/Os (up to 1 Mbit/s)	X	X	X	X
Programmable analog and digital noise filters	X	X	X	X
SMBus/PMBus hardware support	X	X	X	X
Independent clock	X	X	X	X
Wake-up capability	X	X	X	X

1. X: supported

3.45 Improved inter-integrated circuit (I3C)

The I3C interface handles communication between the MCU and others, like sensors and host processor(s), all connected on an I3C bus.

The peripheral implements the required features of the MIPI I3C specification v1.1. It can control I3C bus-specific sequencing, protocol, arbitration and timing, and can act as controller (formerly known as master) or as target (formerly known as slave). When acting as controller, the peripheral improves the features of the I2C interface, preserving some backward compatibility. It allows an I2C target to operate on an I3C bus in legacy I2C fast-mode (Fm) or legacy I2C fast-mode plus (Fm+), provided that the latter does not perform clock stretching.

The I3C peripheral can be used with DMA to off-load the CPU.

Table 7. I3C peripheral controller/target features versus MIPI v1.1

Feature	MIPI v1.1	When controller	When target	Comments
I3C SDR message	X	X	X	-
Legacy I^2C message (Fm/Fm+)	X	X	-	Mandatory when controller, and the I3C bus is mixed with (external) legacy I^2C target(s). Optional in MIPI v1.1 when target.
HDR DDR message	X	-	-	Optional in MIPI v1.1
HDR-TSL/TSP, HDR-BT	X	-	-	
Dynamic address assignment	X	X	X	-
Static address	X	X	-	No (intended) support of I3C peripheral as a target on an I^2C bus
Grouped addressing	X	X	-	Optional in MIPI v1.1
CCCs	X	X	X	Mandatory and some optional CCCs supported
Error detection and recovery	X	X	X	-
In-band interrupt (with MDB)	X	X	X	-
Secondary controller	X	X	X	-
Hot-join mechanism	X	X	X	-
Target reset	X	X	X	-
Synchronous timing control	X	X	-	Optional in MIPI v1.1
Asynchronous timing control 0	X	X	-	Mandatory in MIPI v1.1 when controller, optional when target
Asynchronous timing control 1, 2, 3	X	-	-	Optional in MIPI v1.1
Device to device tunneling	X	X	-	
Multi-lane data transfer	X	-	-	
Monitoring device early termination	X	-	-	

3.46 Universal synchronous/asynchronous receiver transmitter (USART/UART) and low-power universal asynchronous receiver transmitter (LPUART)

The devices embed four universal synchronous receiver transmitters (USART1/USART2/USART3/USART6), two universal asynchronous receiver transmitters (UART4/UART5), one low-power universal asynchronous receiver transmitter (LPUART1).

Table 8. USART, UART and LPUART features

Mode/feature(1)	USART 1/2/3/6/10/11	UART 4/5/7/8/9/12	LPUART 1
Hardware flow control for modem	X	X	X
Continuous communication using DMA	X	X	X

Table 8. USART, UART and LPUART features (continued)

Mode/feature[1]	USART 1/2/3/6/10/11	UART 4/5/7/8/9/12	LPUART 1
Multiprocessor communication	X	X	X
Synchronous mode (master/slave)	X	-	-
Smartcard mode	X	-	-
Single-wire half-duplex communication	X	X	X
IrDA SIR ENDEC block	X	X	-
LIN mode	X	X	-
Dual-clock domain and wake-up from Stop mode	X[2]	X[2]	X[2]
Receiver timeout interrupt	X	X	-
Modbus communication	X	X	-
Auto-baud rate detection	X	X	-
Driver enable	X	X	X
USART data length	7, 8, and 9 bits		
Tx/Rx FIFO	X	X	X
Tx/Rx FIFO size	8 bytes		

1. X = supported.
2. Wake-up supported from Stop mode.

3.46.1 Universal synchronous/asynchronous receiver transmitter (USART/UART)

The USART offers a flexible means to perform full-duplex data exchange with external equipments requiring an industry standard NRZ asynchronous serial data format. A very wide range of baud rates can be achieved through a fractional baud rate generator.

The USART supports both synchronous one-way and half-duplex single-wire communications, as well as LIN (local interconnection network), Smartcard protocol, IrDA (infrared data association) SIR ENDEC specifications, and modem operations (CTS/RTS). Multiprocessor communications are also supported.

High-speed data communication (up to 20 Mbauds) is possible by using the DMA (direct memory access) for multibuffer configuration.

The USART main features are:

- Full-duplex asynchronous communication
- NRZ standard format (mark/space)
- Configurable oversampling method by 16 or by 8, to achieve the best compromise between speed and clock tolerance
- Baud rate generator systems
- Two internal FIFOs for transmit and receive data
  Each FIFO can be enabled/disabled by software and come with a status flag.
- A common programmable transmit and receive baud rate
- Dual-clock domain with dedicated kernel clock for peripherals independent from PCLK

- Auto baud rate detection
- Programmable data word length (7, 8 or 9 bits)
- Programmable data order with MSB-first or LSB-first shifting
- Configurable stop bits (1 or 2 stop bits)
- Synchronous Master/Slave mode and clock output/input for synchronous communications
- SPI slave transmission underrun error flag
- Single-wire half-duplex communications
- Continuous communications using DMA
- Received/transmitted bytes are buffered in reserved SRAM using centralized DMA
- Separate enable bits for transmitter and receiver
- Separate signal polarity control for transmission and reception
- Swappable Tx/Rx pin configuration
- Hardware flow control for modem and RS-485 transceiver
- Communication control/error detection flags
- Parity control:
  - Transmits parity bit
  - Checks parity of received data byte
- Interrupt sources with flags
- Multiprocessor communications: wake-up from Mute mode by idle line detection or address mark detection
- Autonomous functionality in Stop mode with wake-up from stop capability
- LIN master synchronous break send capability and LIN slave break detection capability
  - 13-bit break generation and 10/11-bit break detection when USART is hardware configured for LIN
- IrDA SIR encoder decoder supporting 3/16 bit duration for Normal mode
- Smartcard mode
  - Supports the T = 0 and T = 1 asynchronous protocols for smartcards as defined in the ISO/IEC 7816-3 standard
  - 0.5 and 1.5 stop bits for Smartcard operation
- Support for Modbus communication
  - Timeout feature
  - CR/LF character recognition

3.46.2 Low-power universal asynchronous receiver transmitter (LPUART)

The LPUART supports bidirectional asynchronous serial communication with minimum power consumption. It also supports half-duplex single-wire communication and modem operations (CTS/RTS). It allows multiprocessor communication.

Only a 32.768 kHz clock (LSE) is needed to allow LPUART communication up to 9600 baud. Therefore, even in Stop mode, the LPUART can wait for an incoming frame while having an extremely low energy consumption. Higher-speed clock can be used to reach higher baud-rates.

The LPUART interface can be served by the DMA controller.

The LPUART main features are:

- Full-duplex asynchronous communications
- NRZ standard format (mark/space)
- Programmable baud rate
- From 300 to 9600 bauds using a 32.768 kHz clock source
- Higher baud rates can be achieved by using a higher frequency clock source
- Two internal FIFOs to transmit and receive data
  Each FIFO can be enabled/disabled by software and come with status flags for FIFOs states.
- Dual-clock domain with dedicated kernel clock for peripherals independent from PCLK
- Programmable data word length (7 or 8 or 9 bits)
- Programmable data order with MSB-first or LSB-first shifting
- Configurable stop bits (1 or 2 stop bits)
- Single-wire half-duplex communications
- Continuous communications using DMA
- Received/transmitted bytes are buffered in reserved SRAM using centralized DMA
- Separate enable bits for transmitter and receiver
- Separate signal polarity control for transmission and reception
- Swappable Tx/Rx pin configuration
- Hardware flow control for modem and RS-485 transceiver
- Transfer detection flags:
  - Receive buffer full
  - Transmit buffer empty
  - Busy and end of transmission flags
- Parity control:
  - Transmits parity bit
  - Checks parity of received data byte
- Four error detection flags:
  - Overrun error
  - Noise detection
  - Frame error
  - Parity error
- Interrupt sources with flags
- Multiprocessor communications: wake-up from Mute mode by idle line detection or address mark detection
- Wake-up from Stop capability

3.47 Serial peripheral interface (SPI) / inter-integrated sound interface (I2S)

The devices embed serial peripheral interfaces (SPI) that can be used to communicate with external devices while using the specific synchronous protocol. The SPI protocol supports half-duplex, full-duplex and simplex synchronous, serial communication with external devices.

The interface can be configured as master or slave, and can operate in multi-slave or multi-master configurations. The device configured as master provides communication clock (SCK) to the slave device. The slave select (SS) and ready (RDY) signals can be applied optionally just to set up communication with concrete slave and to assure it handles the data flow properly. The Motorola data format is used by default, but some other specific modes are supported as well.

The SPI main features are:

- Full-duplex synchronous transfers on three lines
- Half-duplex synchronous transfer on two lines (with bidirectional data line)
- Simplex synchronous transfers on two lines (with unidirectional data line)
- 4-bit to 32-bit data size selection or fixed to 8-bit and 16-bit only
- Multi master or multi slave mode capability
- Dual-clock domain, separated clock for the peripheral kernel that can be independent of PCLK
- Baud rate prescaler up to kernel frequency divided by 2 or bypass from RCC in Master mode
- Protection of configuration and setting
- Hardware or software management of SS for both master and slave
- Adjustable minimum delays between data and between SS and data flow
- Configurable SS signal polarity and timing, MISO x MOSI swap capability
- Programmable clock polarity and phase
- Programmable data order with MSB-first or LSB-first shifting
- Programmable number of data within a transaction to control SS and CRC
- Dedicated transmission and reception flags with interrupt capability
- SPI Motorola and TI formats support
- Hardware CRC feature can secure communication at the end of transaction by:
  - Adding CRC value in Tx mode
  - Automatic CRC error checking for Rx mode
- Error detection with interrupt capability in case of data overrun, CRC error, data underrun at slave, mode fault at master
- Two 16x or 8x 8-bit embedded Rx and TxFIFOs with DMA capability
- Programmable number of data in transaction
- Configurable FIFO thresholds (data packing)
- Configurable behavior at slave underrun condition (support of cascaded circular buffers)
- Wake-up from Stop capability
- Optional status pin RDY signalizing the slave device ready to handle the data flow.

Three standard I2S interfaces (multiplexed with SPI1, SPI2 and SPI3) are available. They can be operated in Master or Slave mode, in full-duplex communication modes, and can be configured to operate with configurable resolution as input or output channel.

I2S main features:

- Full duplex communication
- Simplex communication (only transmitter or receiver)
- Master or slave operations
- 8-bit programmable linear prescaler
- Data length may be 16, 24 or 32 bits
- Channel length can be 16 or 32 in master, any value in slave
- Programmable clock polarity
- Error flags signaling for improved reliability: Underrun, Overrun, and Frame Error
- Embedded Rx and TxFIFOs
- Supported I2S protocols:
  - I2S Philips standard
  - MSB-Justified standard (left-justified)
  - LSB-Justified standard (right-justified)
  - PCM standard (with short and long frame synchronization)
- Data ordering programmable (LSb or MSb first)
- DMA capability for transmission and reception
- Master clock can be output to drive an external audio component. The ratio is fixed at 256 x FWS (where FWS is the audio sampling frequency)

Table 9. SPI features

Feature	SPI1, SPI2, SPI3 (full feature set instances)	SPI4, SPI5, SPI6 (limited feature set instances)
Data size	Configurable from 4- to 32-bit	Configurable from 4- to 16-bit
CRC computation	CRC polynomial length configurable from 5- to 33-bit	CRC polynomial length configurable from 5- to 17-bit
Size of FIFOs	16x 8-bit	8x 8-bit
Number of transfered data	Up to 65535	
I2S feature	Yes	No

3.48 Serial audio interface (SAI)

The devices embed two SAIs. Refer to *Table 10* for the features implementation. The SAI bus interface handles communications between the MCU and the serial audio protocol.

The SAI peripheral supports:

- Two independent audio sub-blocks that can be transmitters or receivers with their respective FIFO
- 8-word integrated FIFOs for each audio sub-block
- Synchronous or Asynchronous mode between the audio sub-blocks

- Master or slave configuration independent for both audio sub-blocks
- Clock generator for each audio block to target independent audio frequency sampling when both audio sub-blocks are configured in master mode
- Data size configurable: 8-, 10-, 16-, 20-, 24-, 32-bit
- Peripheral with large configurability and flexibility, allowing to target the following audio protocols: I2S, LSB or MSB-justified, PCM/DSP, TDM, AC'97 and SPDIF out
- Up to 16 slots available with configurable size and with the possibility to select which ones are active in the audio frame
- Number of bits by frame may be configurable
- Frame synchronization active level configurable (offset, bit length, level)
- First active bit position in the slot is configurable
- LSB first or MSB first for data transfer
- Mute mode
- Stereo/mono audio frame capability
- Communication clock strobing edge configurable (SCK)
- Error flags with associated interrupts if enabled respectively
  - Overrun and underrun detection
  - Anticipated frame synchronization signal detection in Slave mode
  - Late frame synchronization signal detection in Slave mode
  - Codec not ready for the AC'97 mode in reception
- Interruption sources when enabled:
  - Errors
  - FIFO requests
- DMA interface with two dedicated channels to handle access to the dedicated integrated FIFO of each SAI audio sub-block.

Table 10. SAI implementation

Feature(1)	SAI1	SAI2
I2S, LSB or MSB-justified, PCM/DSP, TDM, AC'97	X	X
Mute mode	X	X
Stereo/mono audio frame capability.	X	X
16 slots	X	X
Data size configurable: 8-, 10-, 16-, 20-, 24-, 32-bit	X	X
FIFO size	X (8 words)	X (8 words)
SPDIF	X	X
PDM	X	-

1. X: supported

3.49 Secure digital input/output and MultiMediaCards interface (SDMMC)

The SD/SDIO, embedded MultiMediaCard (*e*MMC™) host interface (SDMMC) provides an interface between the AHB bus and SD memory cards, SDIO cards, and *e*MMC devices.

The MultiMediaCard system specifications are available through the MultiMediaCard association website at www.mmca.org, published by the MMCA technical committee.

SD memory card and SD I/O card system specifications are available through the SD card association website at www.sdcard.org.

The SDMMC features include the following:

- Compliance with Embedded MultiMediaCard System Specification Version 5.1

  Card support for three different databus modes: 1-bit (default), 4-bit and 8-bit (HS200 SDMMC_CK speed limited to maximum allowed I/O speed, HS400 is not supported).
- Full compatibility with previous versions of MultiMediaCards (backward compatibility).
- Full compliance with SD memory card specifications version 6.0

  (SDR104 SDMMC_CK speed limited to maximum allowed I/O speed, SPI mode and UHS-II mode not supported).
- Full compliance with SDIO card specification version 4.0

  Card support for two different databus modes: 1-bit (default) and 4-bit (SDR104 SDMMC_CK speed limited to maximum allowed I/O speed, SPI mode and UHS-II mode not supported).
- Data transfer up to 208 Mbyte/s for the 8-bit mode, depending maximum allowed I/O speed.
- Data and command output enable signals to control external bidirectional drivers
- IDMA linked list support

The MultiMediaCard/SD bus connects cards to the host.

The current version of the SDMMC supports only one SD/SDIO/*e*MMC card at any one time and a stack of *e*MMC.

Table 11. SDMMC features

Mode/feature(1)	SDMMC1	SDMMC2
Variable delay (SDR104, HS200)	X	X
SDMMC_CKIN	X	X
SDMMC_CDIR, SDMMC_D0DIR	X	-
SDMMC_D123DIR	X	-

1. X = supported.

3.50 Controller area network (FDCAN1, FDCAN2, FDCAN3)

The controller area network (CAN) subsystem consists of one CAN module, a shared message RAM memory and a configuration block.

The modules (FDCAN) are compliant with ISO 11898-1: 2015 (CAN protocol specification version 2.0 part A, B) and CAN FD protocol specification version 1.0.

A 3-Kbyte message RAM implements filters, receives FIFOs, transmits event FIFOs, and transmits FIFOs.

The FDCAN main features are:

- Conform with CAN protocol version 2.0 part A, B and ISO 11898-1: 2015, -4
- CAN FD with maximum 64 data bytes supported
- CAN error logging
- AUTOSAR and J1939 support
- Improved acceptance filtering
- Two receive FIFOs of three payloads each (up to 64 bytes per payload)
- Separate signaling on reception of high priority messages
- Configurable transmit FIFO / queue of three payload (up to 64 bytes per payload)
- Configurable transmit Event FIFO
- Programmable loop-back test mode
- Maskable module interrupts
- Two clock domains: APB bus interface and CAN core kernel clock
- Power-down support

3.51 USB on-the-go full-speed (OTG_FS)

The devices embed a USB OTG full-speed device/host/OTG peripheral with integrated transceivers. The USB OTG_FS peripheral is compliant with the USB 2.0 specification and with the OTG 2.0 specification. It has software-configurable endpoint setting and supports suspend/resume.

This interface requires a precise 48 MHz clock that can be generated from the internal main PLL (the clock source must use a HSE crystal oscillator) or by the internal 48 MHz oscillator (HSI48) in automatic-trimming mode. The synchronization for this oscillator can be taken from the USB data stream itself (SOF signalization) that allows crystal less operation.

The OTG_FS features are:

- Planned USB-IF certification to the Universal Serial Bus Specification Rev 2.0
- On-chip full-speed PHY
- Full support (PHY) for the optional OTG (on-the-go) protocol detailed in the OTG Supplement Rev 2.0 specification
- Software-configurable to operate as:
  - USB FS peripheral (B-device)
  - USB FS/LS host (A-device)
- Supports FS SOF and LS keep-alives with
  - SOF pulse PAD connectivity
  - SOF pulse internal connection to timer (TIMx)
  - Configurable framing period
  - Configurable end of frame interrupt
- USB 2.0 link power management (LPM) support
- Includes power saving features such as system stop during USB suspend, switch-off of clock domains internal to the digital core, PHY, and DFIFO power management.

- Dedicated RAM of 1.25 Kbytes with advanced FIFO control:
  - Configurable partitioning of RAM space into different FIFOs for flexible and efficient use of RAM
  - Each FIFO able to hold multiple packets
  - Dynamic memory allocation
  - Configurable FIFO sizes that are not powers of two to allow the use of contiguous memory locations
- Max guaranteed USB bandwidth for up to one frame (1 ms) without system intervention
- Support of charging port detection as described in *Battery Charging Specification* revision 1.2 on the FS PHY transceiver only.

Host-mode features:

- External charge pump for VBUS voltage generation.
- Up to 12 host channels (pipes): each channel is dynamically reconfigurable to allocate any type of USB transfer.
- Built-in hardware scheduler holding:
  - Up to 12 interrupt plus isochronous transfer requests in the periodic hardware queue
  - Up to 12 control plus bulk transfer requests in the nonperiodic hardware queue
- Management of a shared Rx FIFO, a periodic Tx FIFO and a nonperiodic Tx FIFO for efficient usage of the USB data RAM

Peripheral-mode features:

- 1 bidirectional control endpoint0
- 5 IN endpoints (EPs) configurable to support bulk, interrupt, or isochronous transfers
- 5 OUT endpoints configurable to support bulk, interrupt, or isochronous transfers
- Management of a shared Rx FIFO and a Tx-OUT FIFO for efficient usage of the USB data RAM
- Management of up to 6 dedicated Tx-IN FIFOs (one for each active IN EP) to put less load on the application
- Support for the soft disconnect feature

3.52 USB on-the-go high-speed (OTG_HS)

The devices embed an USB OTG high-speed device/host/OTG peripheral with integrated transceivers. The OTG_HS peripheral is compliant with the USB 2.0 specification and with the OTG 2.0 specification. It has software-configurable endpoint setting and supports suspend/resume.

Note: The OTG_HS uses a dedicated digital power supply, $V_{DD11USB}$. It should be connected to VCAP when in use, and to GND when not in use.

This interface requires a precise 60 MHz clock that is generated from the internal USB PHY PLL (the clock source must use a HSE crystal oscillator).

The OTG_HS features are:

- Planned USB-IF certification to the Universal Serial Bus Specification Rev 2.0
- On-chip high-speed PHY

- Full support (PHY) for the optional OTG (on-the-go) protocol detailed in the OTG Supplement Rev 2.0 specification
- Software-configurable to operate as USB on-the-go high-speed dual role device
- Supports HS/FS SOF and LS keep-alives with
  - SOF pulse PAD connectivity
  - SOF pulse internal connection to timer (TIMx)
  - Configurable framing period
  - Configurable end of frame interrupt
- USB 2.0 link power management (LPM) support
- Internal DMA with thresholding support and software selectable AHB burst type in DMA mode
- Power saving features such as system stop during USB suspend, switch-off of clock domains internal to the digital core, PHY and DFIFO power management
- Dedicated RAM of 4 Kbytes with advanced FIFO control:
  - Configurable partitioning of RAM space into different FIFOs for flexible and efficient use of RAM
  - Each FIFO able to hold multiple packets
  - Dynamic memory allocation
  - Configurable FIFO sizes that are not powers of two to allow the use of contiguous memory locations
- Max guaranteed USB bandwidth for up to one frame (1 ms) without system intervention
- Support of charging port detection as described in *Battery Charging Specification* revision 1.2

Host-mode features:

- External charge pump for VBUS voltage generation
- Up to 16 host channels (pipes): each channel is dynamically reconfigurable to allocate any type of USB transfer
- Built-in hardware scheduler holding:
  - Up to 16 interrupt plus isochronous transfer requests in the periodic hardware queue
  - Up to 16 control plus bulk transfer requests in the non-periodic hardware queue
- Management of a shared Rx FIFO, a periodic Tx FIFO and a non periodic Tx FIFO for efficient usage of the USB data RAM

Peripheral-mode features:

- 1 bidirectional control endpoint0
- 8 IN endpoints (EPs) configurable to support bulk, interrupt or isochronous transfers
- 8 OUT endpoints configurable to support bulk, interrupt or isochronous transfers
- Management of a shared Rx FIFO and a Tx-OUT FIFO for efficient usage of the USB data RAM
- Management of up to 9 dedicated Tx-IN FIFOs (one for each active IN EP) to put less load on the application
- Support for the soft disconnect feature

3.53 USB Type-C/USB power delivery controller (UCPD)

The devices embed one controller (UCPD) compliant with USB Type-C Cable and Connector Specification release 2.0 and USB Power Delivery Rev. 3.0 specifications.

The controller uses specific I/Os supporting the USB Type-C and USB power delivery requirements, featuring:

- USB Type-C pull-up (Rp, all values) and pull-down (Rd) resistors
- “Dead battery” support
- USB power delivery message transmission and reception
- FRS (fast role swap) support

The digital controller handles:

- USB Type-C level detection with debounce, generating interrupts
- FRS detection, generating an interrupt
- Byte-level interface for USB power delivery payload, generating interrupts (DMA compatible)
- USB power delivery timing dividers (including a clock pre-scaler)
- CRC generation/checking
- 4b5b encode/decode
- Ordered sets (with a programmable ordered set mask at receive)
- Frequency recovery in receiver during preamble

The interface offers low-power operation compatible with Stop mode, maintaining the capacity to detect incoming USB power delivery messages and FRS signaling.

3.54 Ethernet MAC interface with dedicated DMA controller (ETH)

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

The devices include the following features:

- Support of 10 and 100 Mbit/s rates
- Dedicated DMA controller allowing high-speed transfers between the dedicated SRAM and the descriptors
- Tagged MAC frame support (VLAN support)
- Half-duplex (CSMA/CD) and full-duplex operation
- MAC control sublayer (control frames) support
- 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 2-Kbyte FIFOs to buffer transmit and receive frames

- Support of hardware PTP (precision time protocol) in accordance with IEEE 1588 2008 (PTP V2) with the time stamp comparator connected to the TIM2 input
- Trigger of interrupt when system time becomes greater than target time

3.55 High-definition multimedia interface (HDMI) - consumer electronics control (CEC)

The devices embed an HDMI-CEC controller that provides hardware support for the Consumer Electronics Control (CEC) protocol (Supplement 1 to the HDMI standard).

This protocol provides high-level control functions between all audiovisual products in an environment. It is specified to operate at low speeds with minimum processing and memory overhead. It has a clock domain independent from the CPU clock, allowing the HDMI-CEC controller to wake up the MCU from Stop mode on data reception.

3.56 Development support

3.56.1 Serial-wire/JTAG debug port (SWJ-DP)

The Arm SWJ-DP interface is embedded and is a combined JTAG and serial-wire debug port that enables either a serial wire debug or a JTAG probe to be connected to the target.

Debug is performed using two pins only instead of five required by the JTAG (JTAG pins can be re-used as GPIO with alternate function): the JTAG TMS and TCK pins are shared with SWDIO and SWCLK, respectively, and a specific sequence on the TMS pin is used to switch between JTAG-DP and SW-DP.

3.56.2 Embedded Trace Macrocell

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 devices through a small number of ETM pins to an external hardware trace port analyzer (TPA) device.

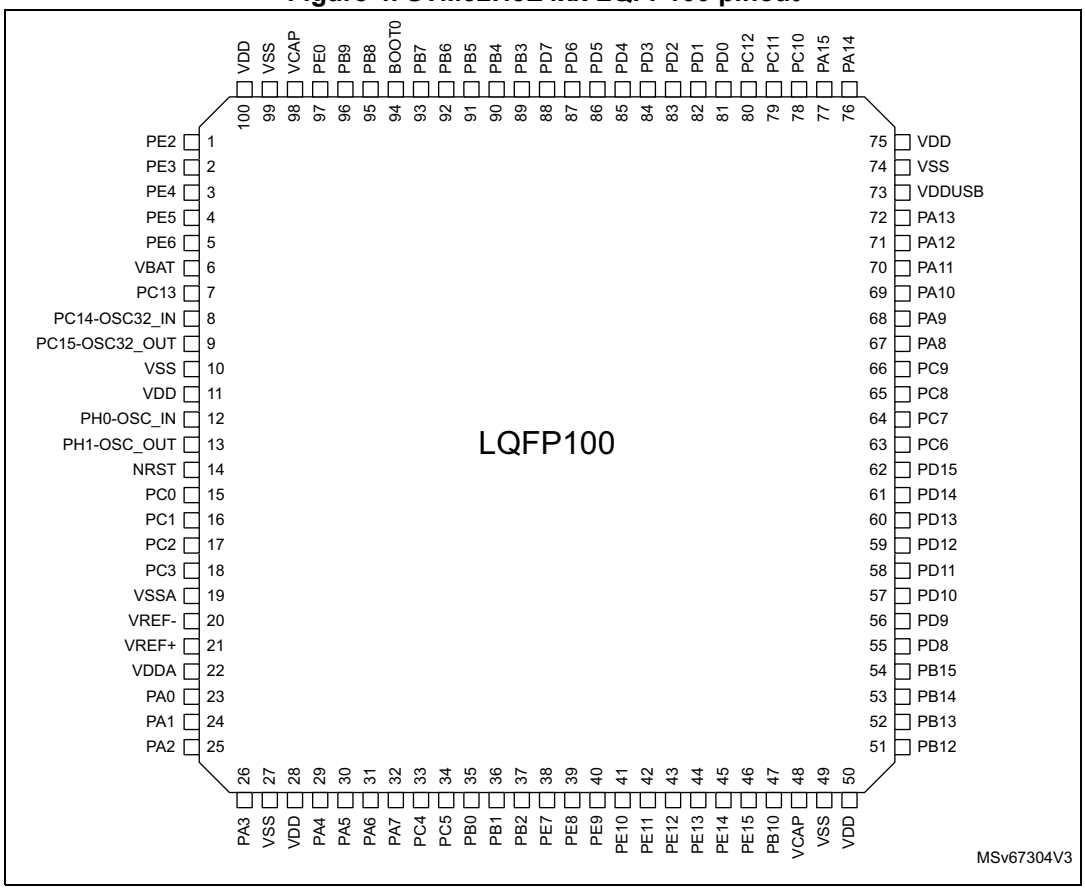
Real-time instruction and data flow activity be recorded and then formatted for display on the host computer that runs the debugger software. TPA hardware is commercially available from common development tool vendors.

The ETM operates with third party debugger software tools.

4 Pinout, pin description and alternate function

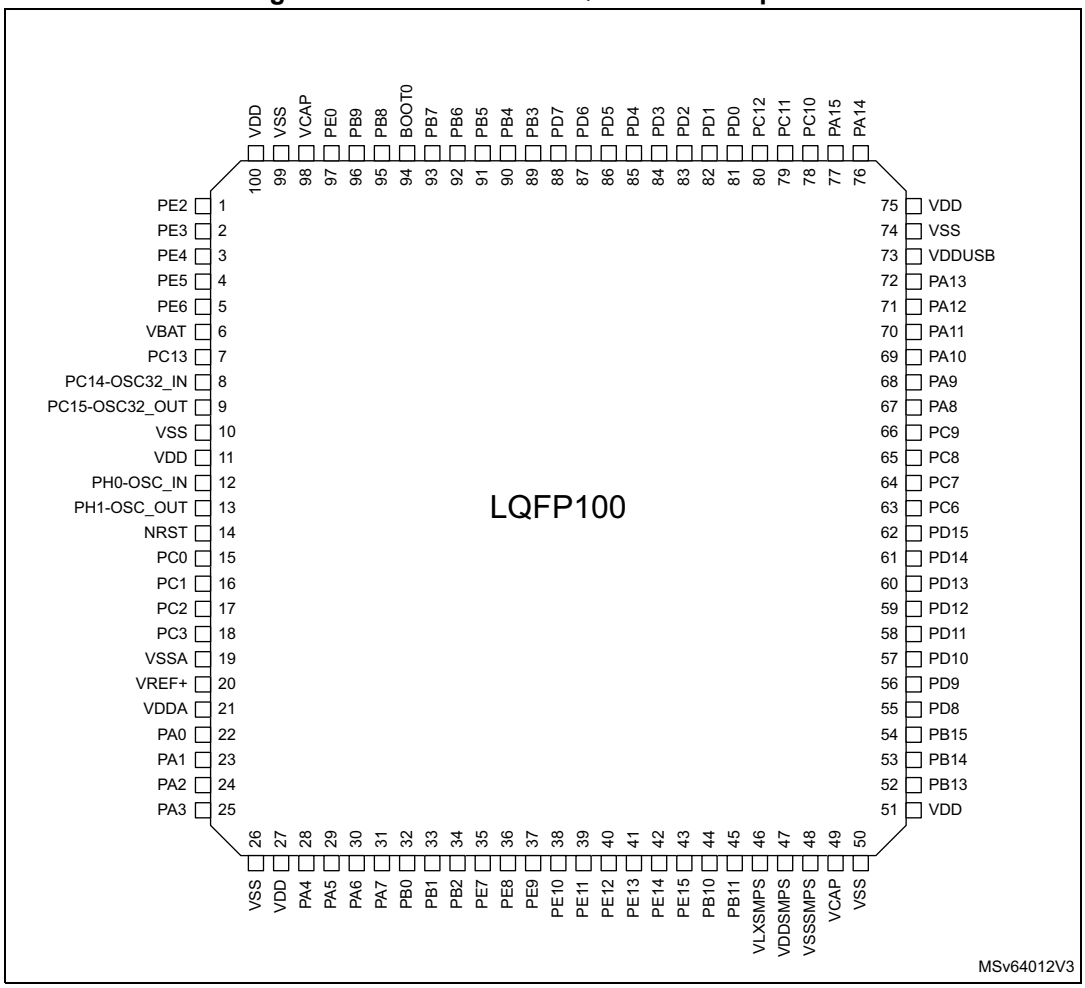
4.1 Pinout/ballout schematics

Figure 4. STM32H5E4xx LQFP100 pinout



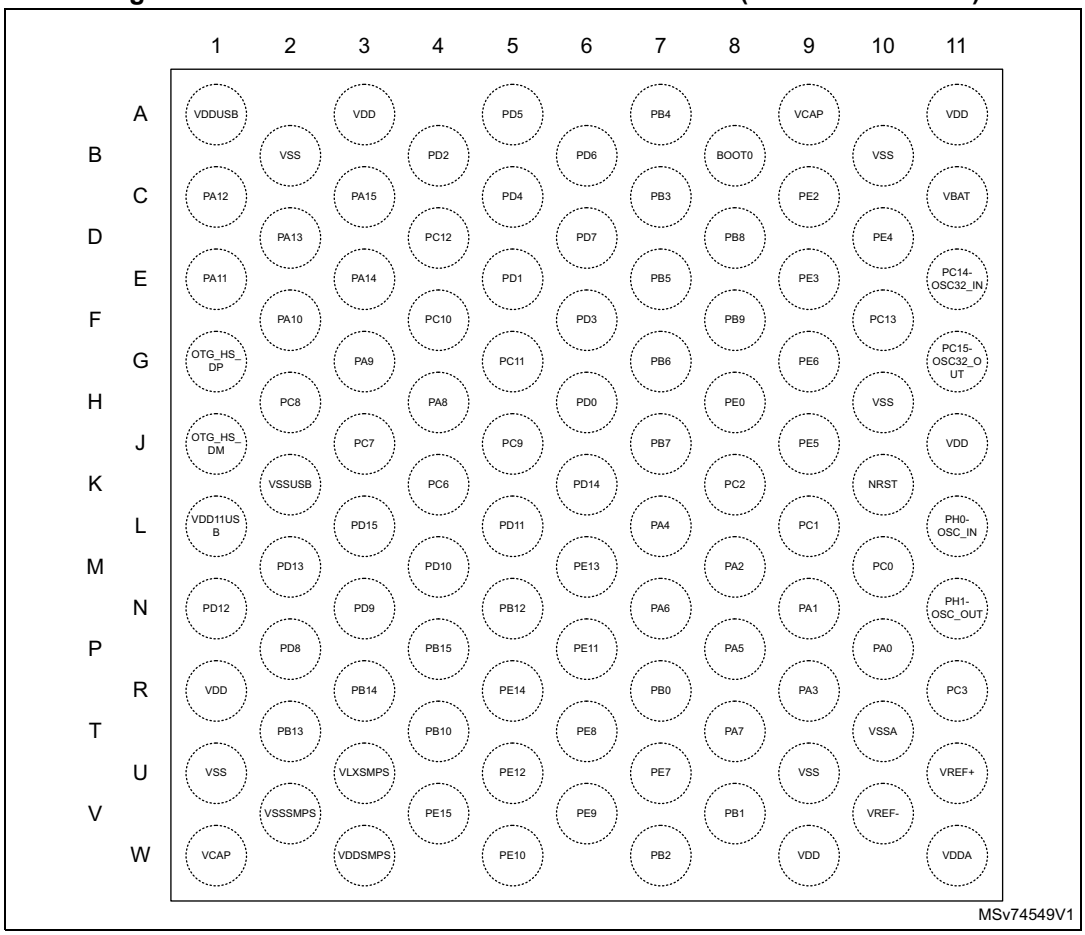
1. The above figure shows the package top view.

Figure 5. STM32H5E4xx LQFP100 SMPS pinout



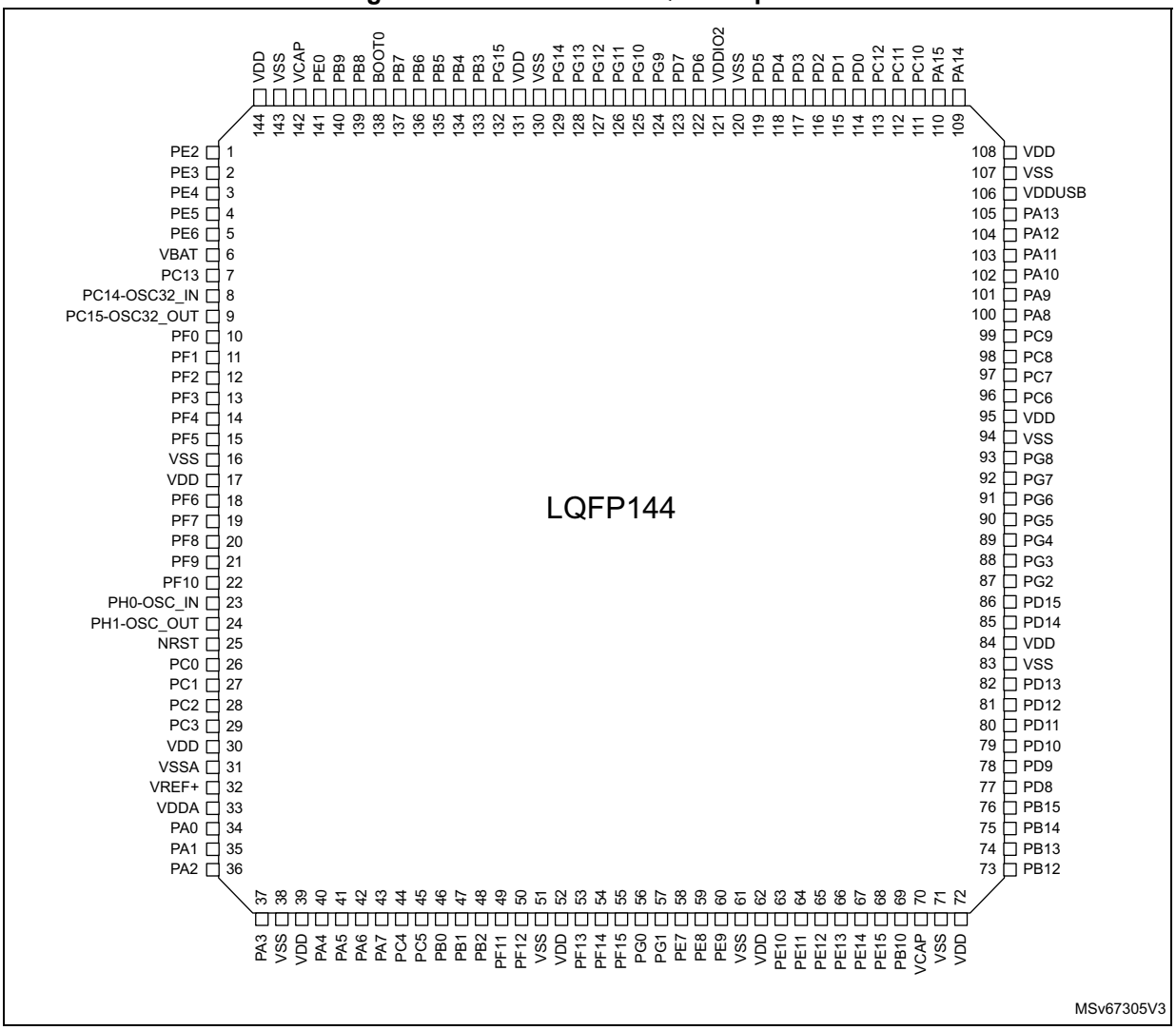
1. The above figure shows the package top view.

Figure 6. STM32H5E5xx WLCSP105 SMPS ballout (with USB HS PHY)



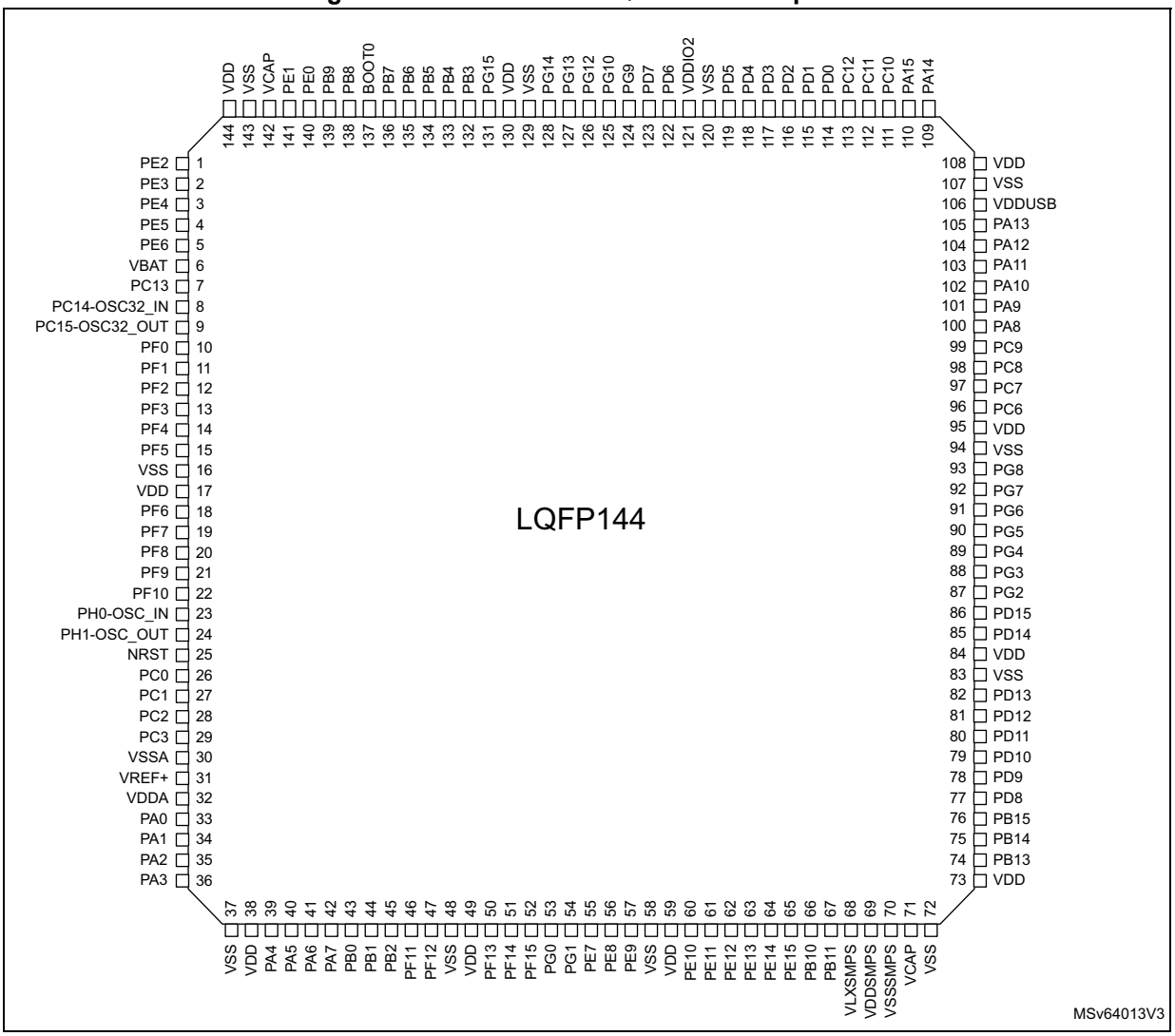
1. The above figure shows the package top view.

Figure 7. STM32H5E4xx LQFP144 pinout



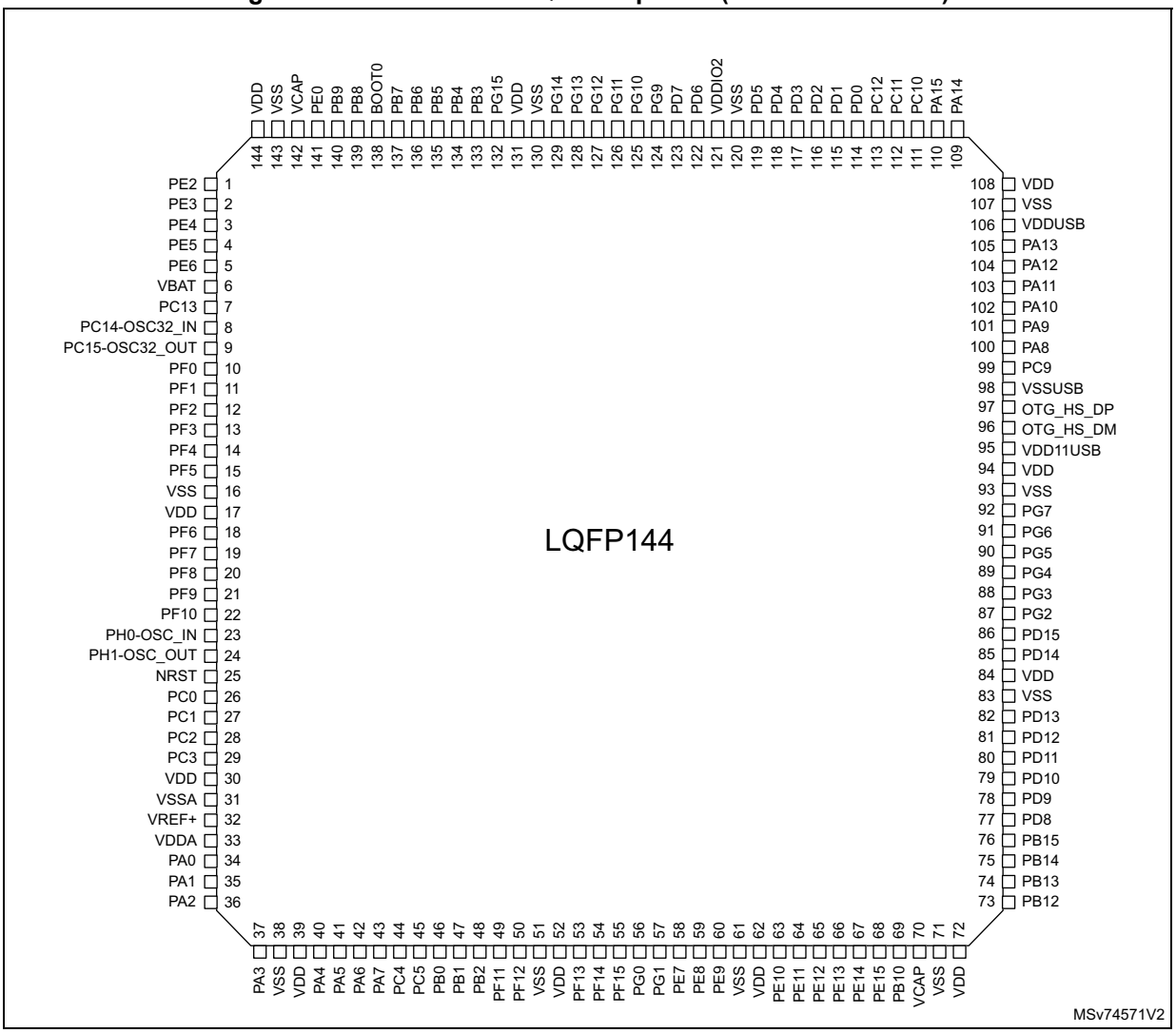
1. The above figure shows the package top view.

Figure 8. STM32H5E4xx LQFP144 SMPS pinout



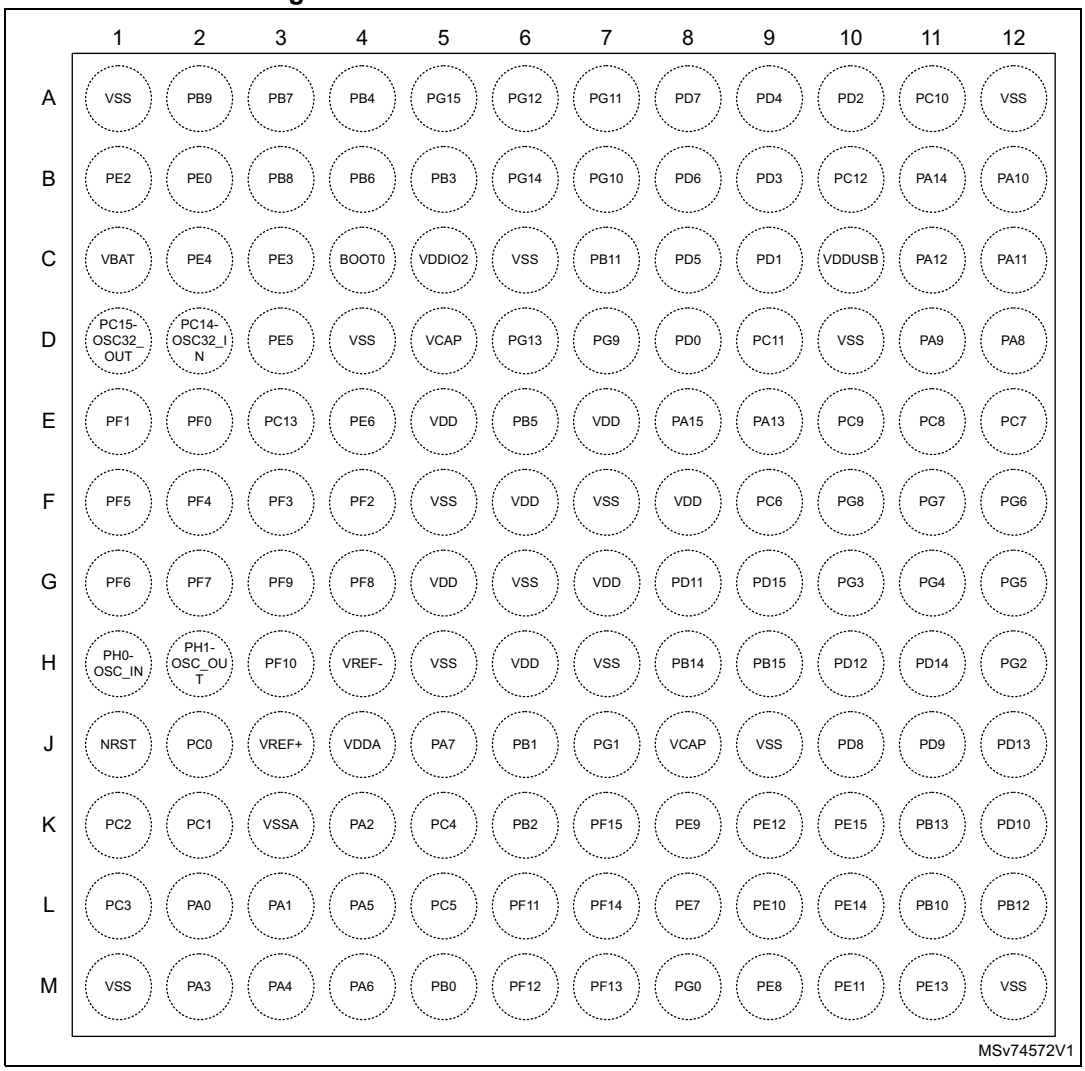
1. The above figure shows the package top view.

Figure 9. STM32H5E5xx LQFP144 pinout (with USB HS PHY)



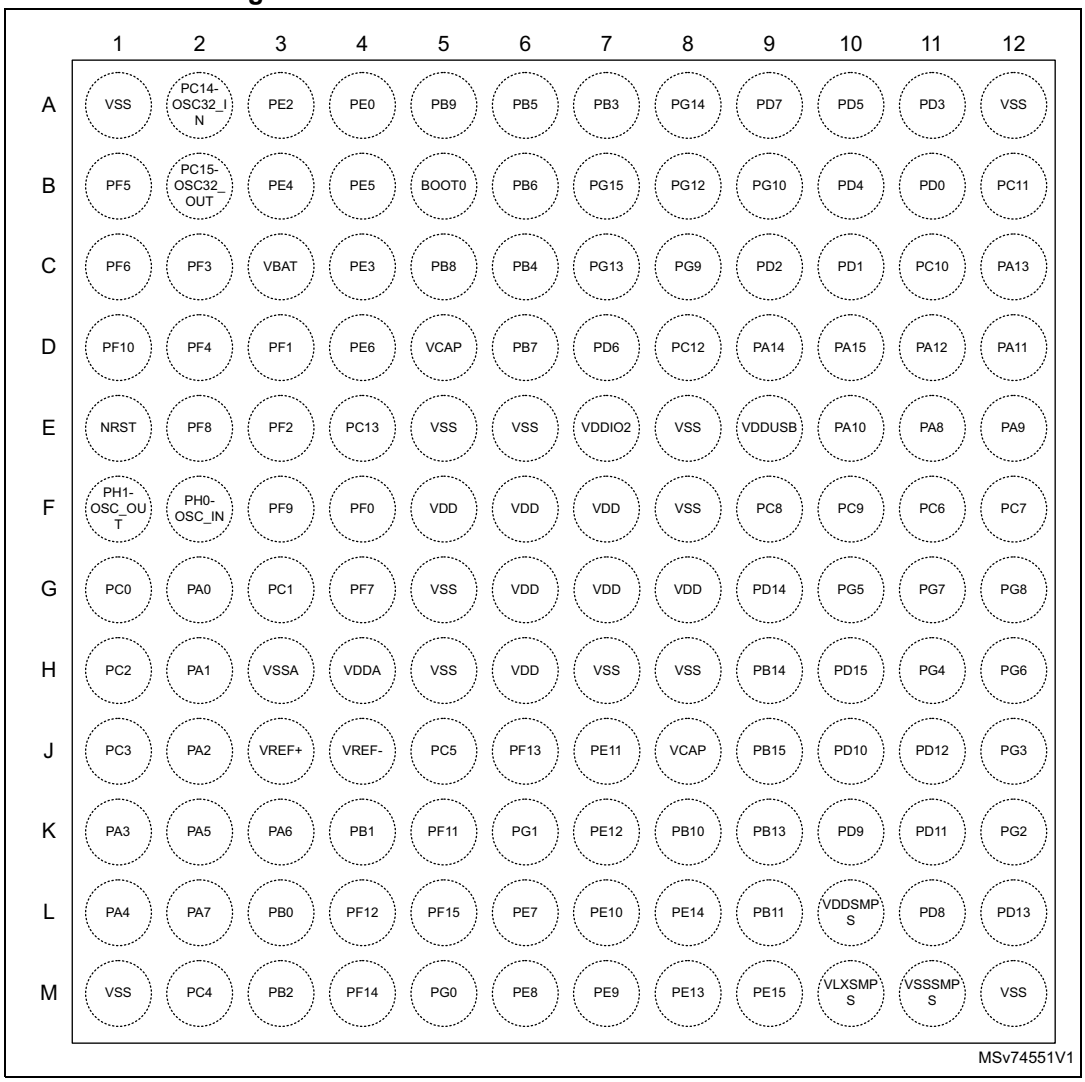
1. The above figure shows the package top view.

Figure 10. STM32H5E4xx UFBGA144 ballout



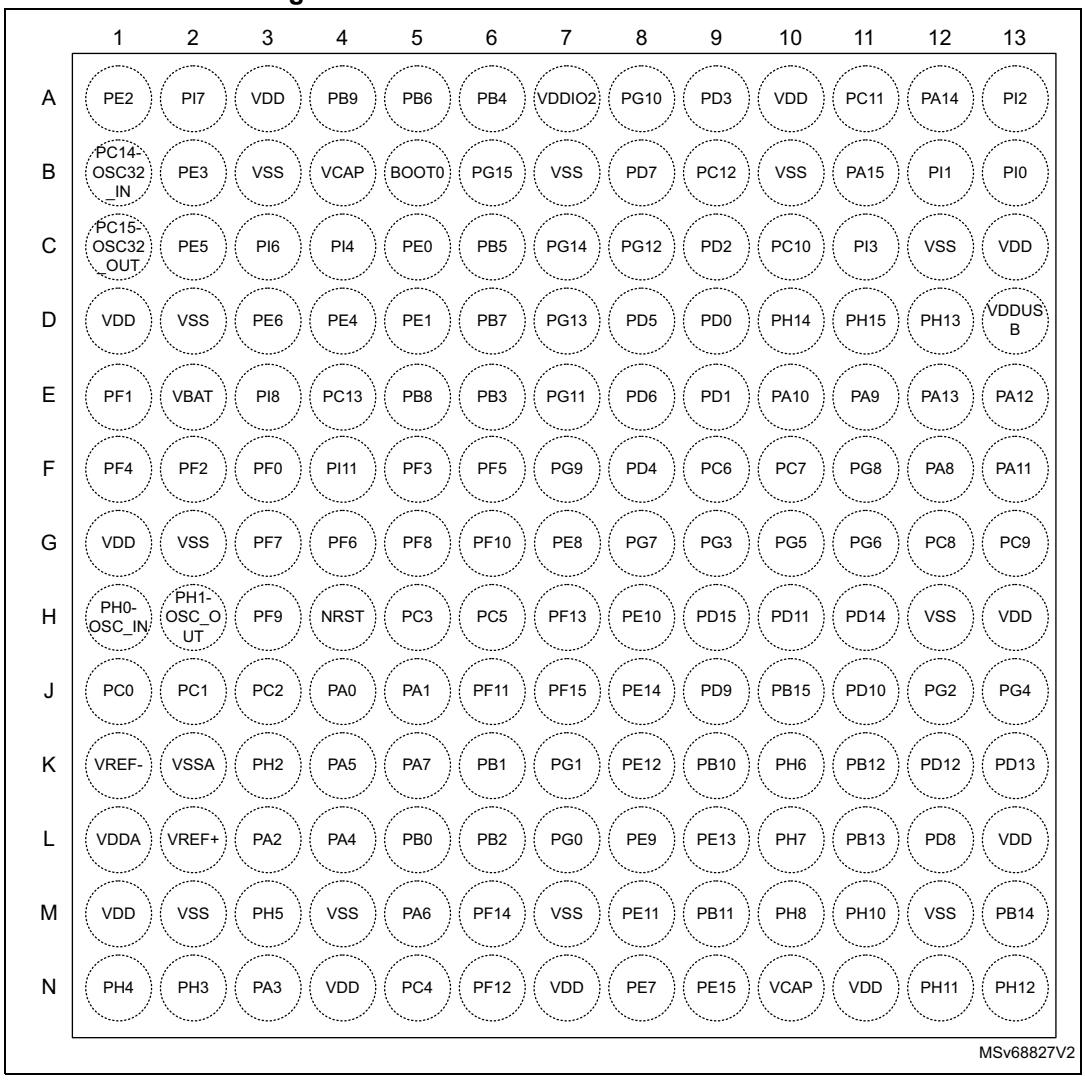
1. The above figure shows the package top view.

Figure 11. STM32H5E4xx UFBGA144 SMPS ballout



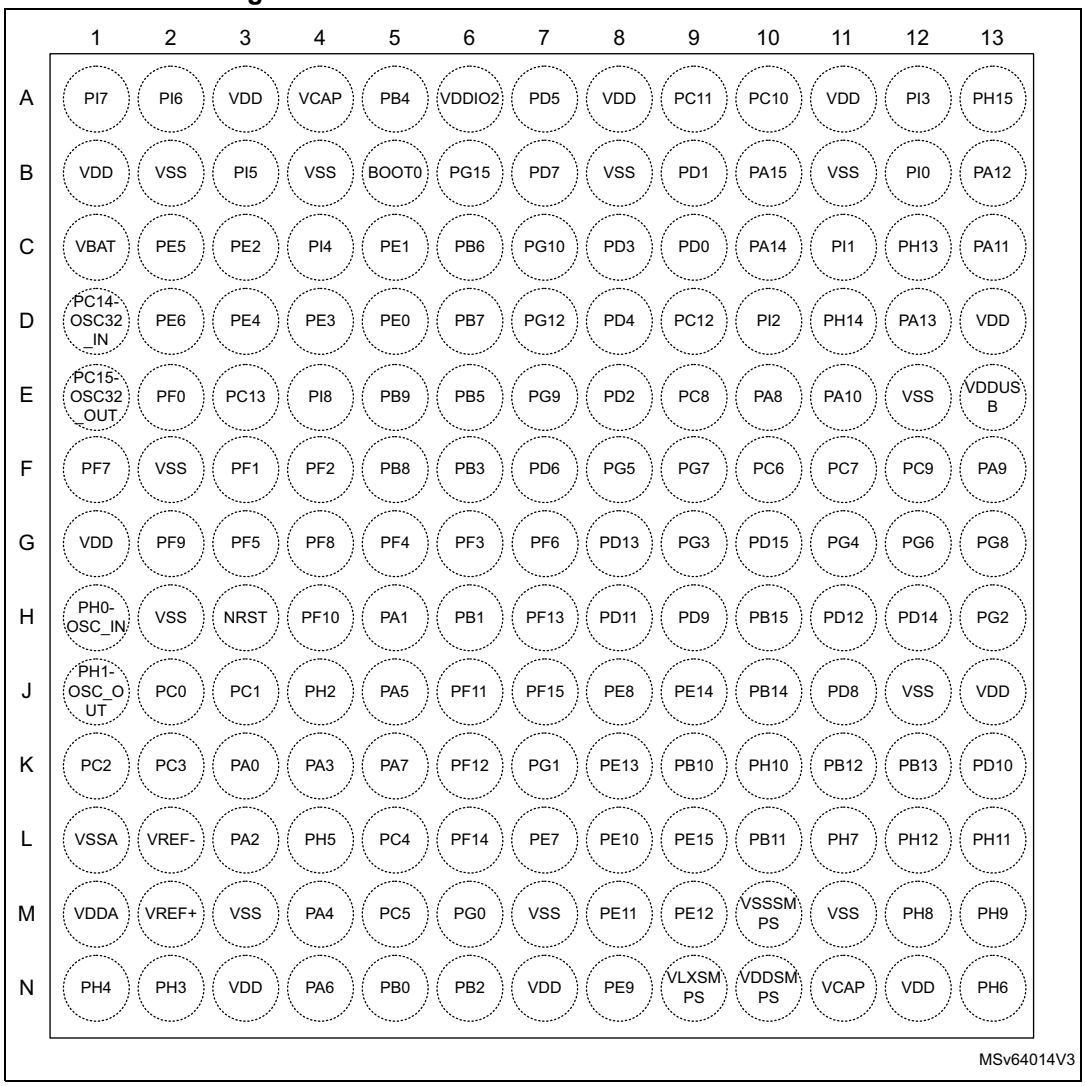
1. The above figure shows the package top view.

Figure 12. STM32H5E4xx UFBGA169 ballout



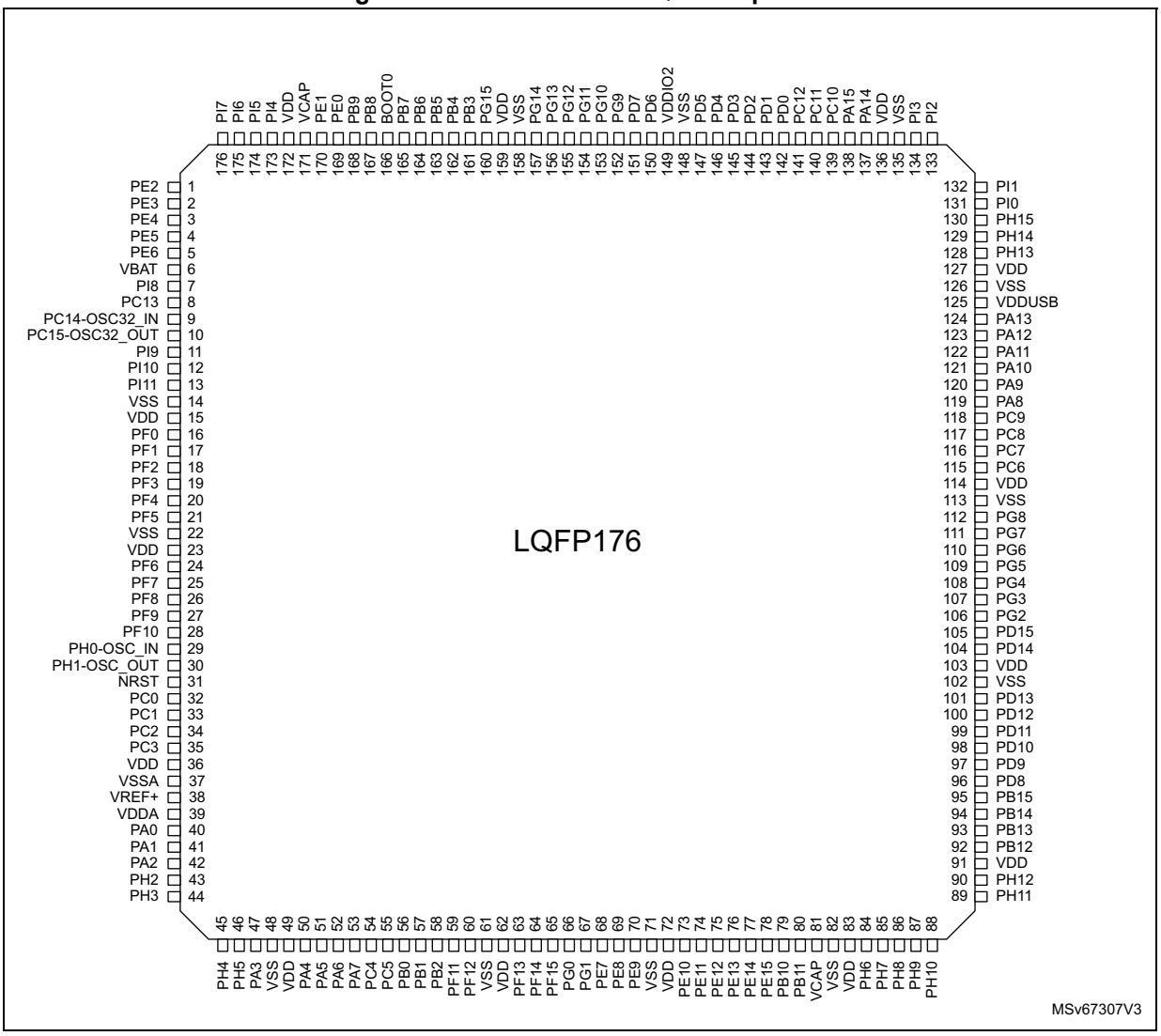
1. The above figure shows the package top view.

Figure 13. STM32H5E4xx UFBGA169 SMPS ballout



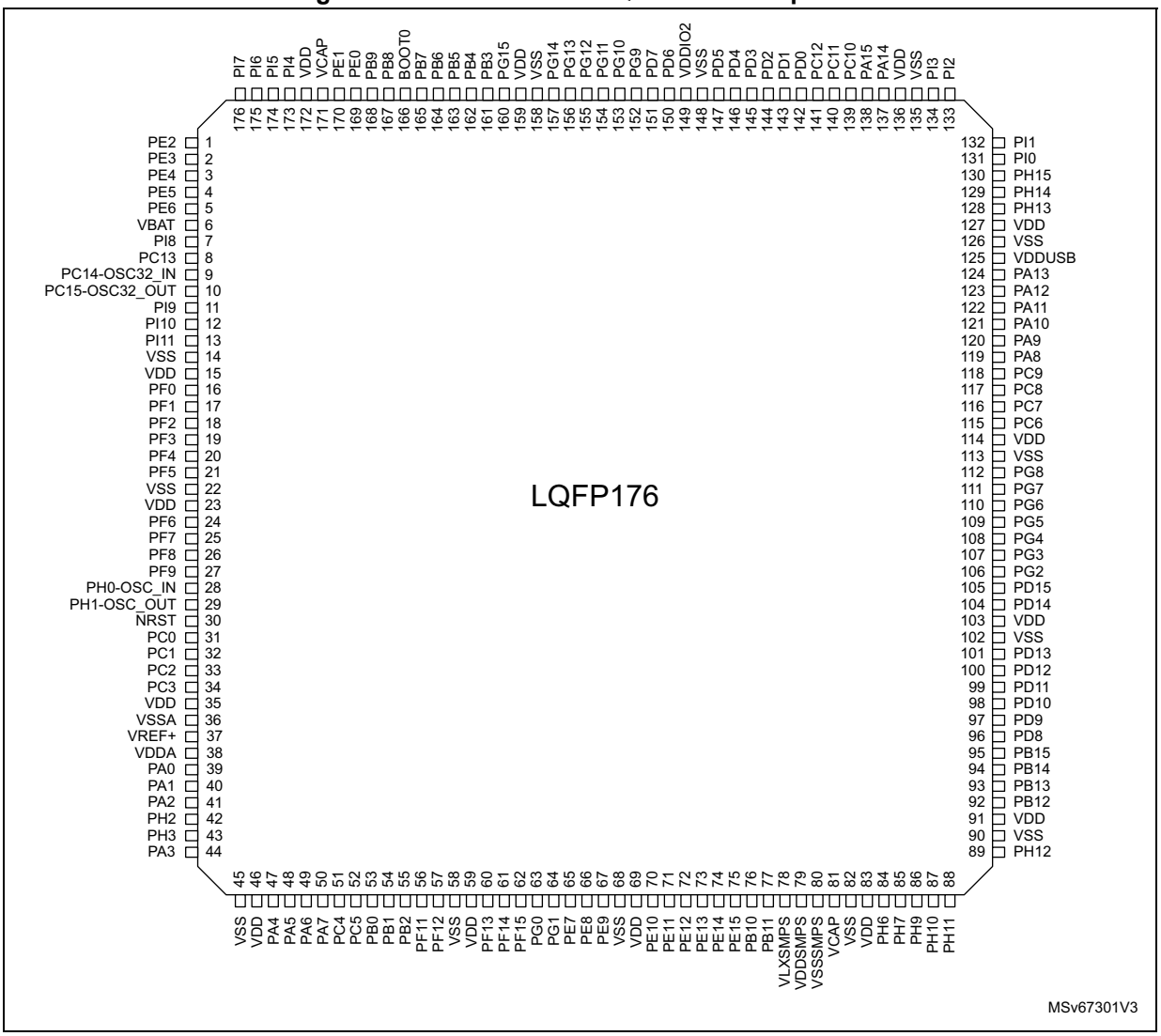
1. The above figure shows the package top view.

Figure 14. STM32H5E4xx LQFP176 pinout



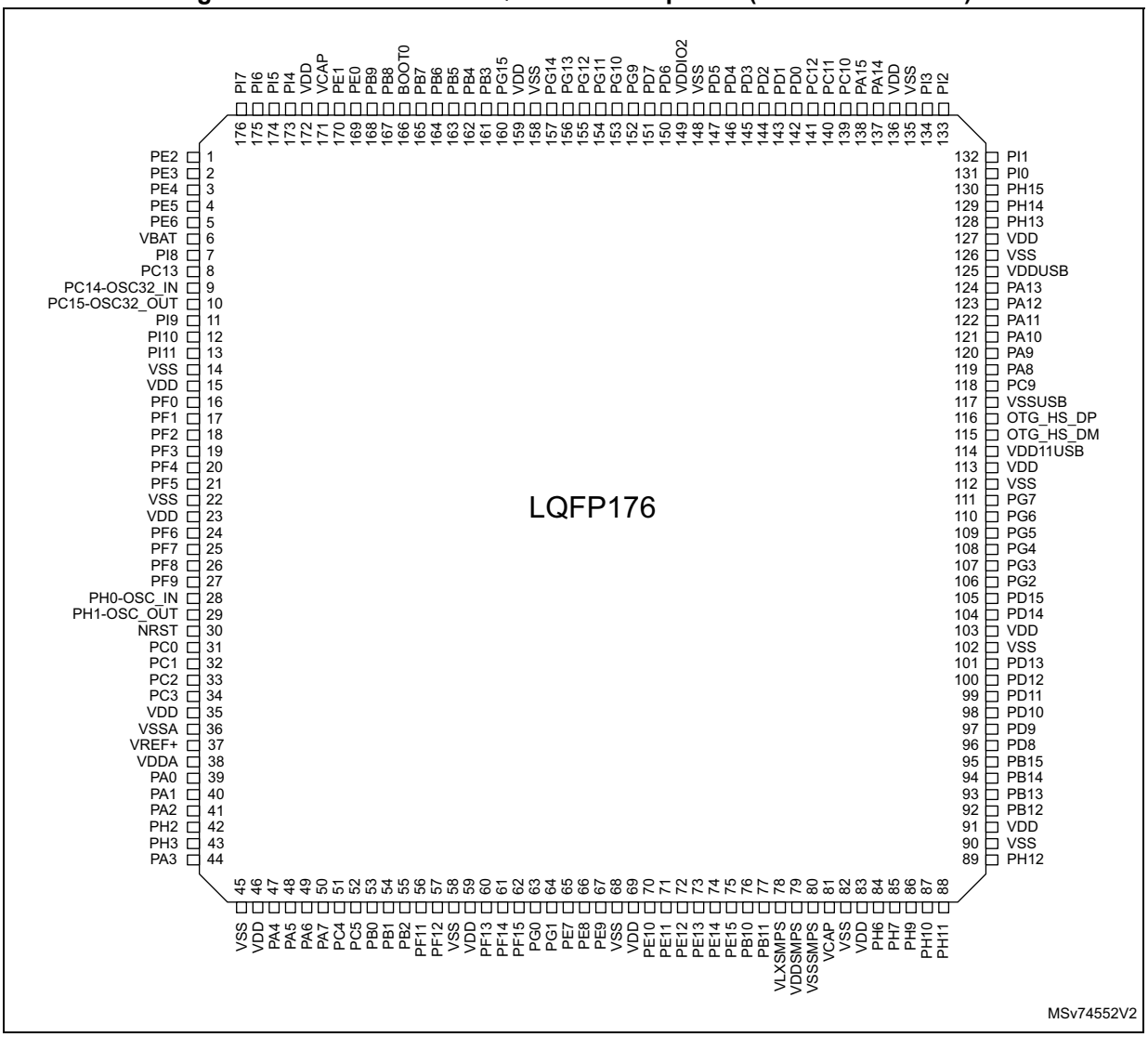
1. The above figure shows the package top view.

Figure 15. STM32H5E4xx LQFP176 SMPS pinout



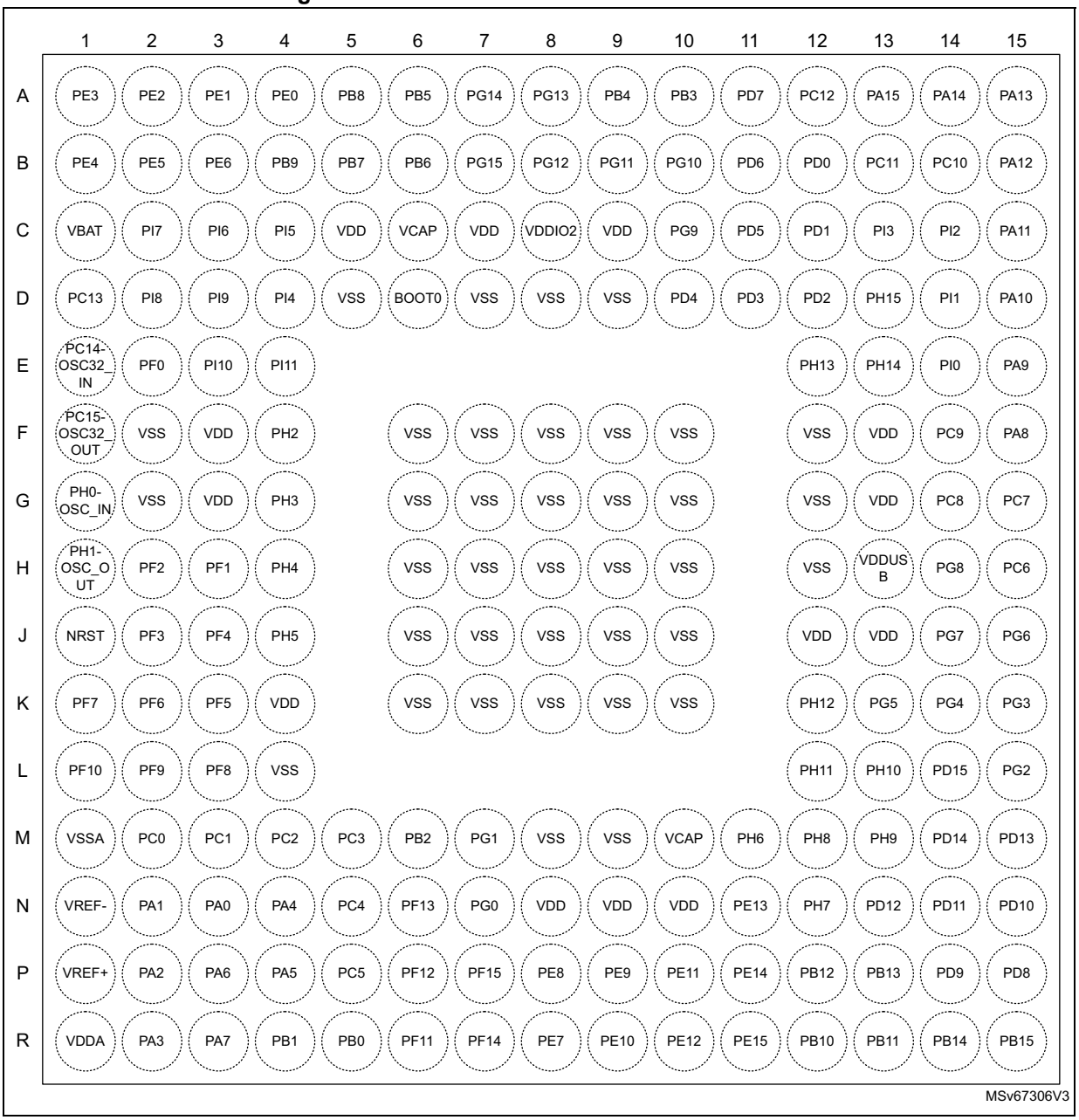
1. The above figure shows the package top view.

Figure 16. STM32H5E5xx LQFP176 SMPS pinout (with USB HS PHY)



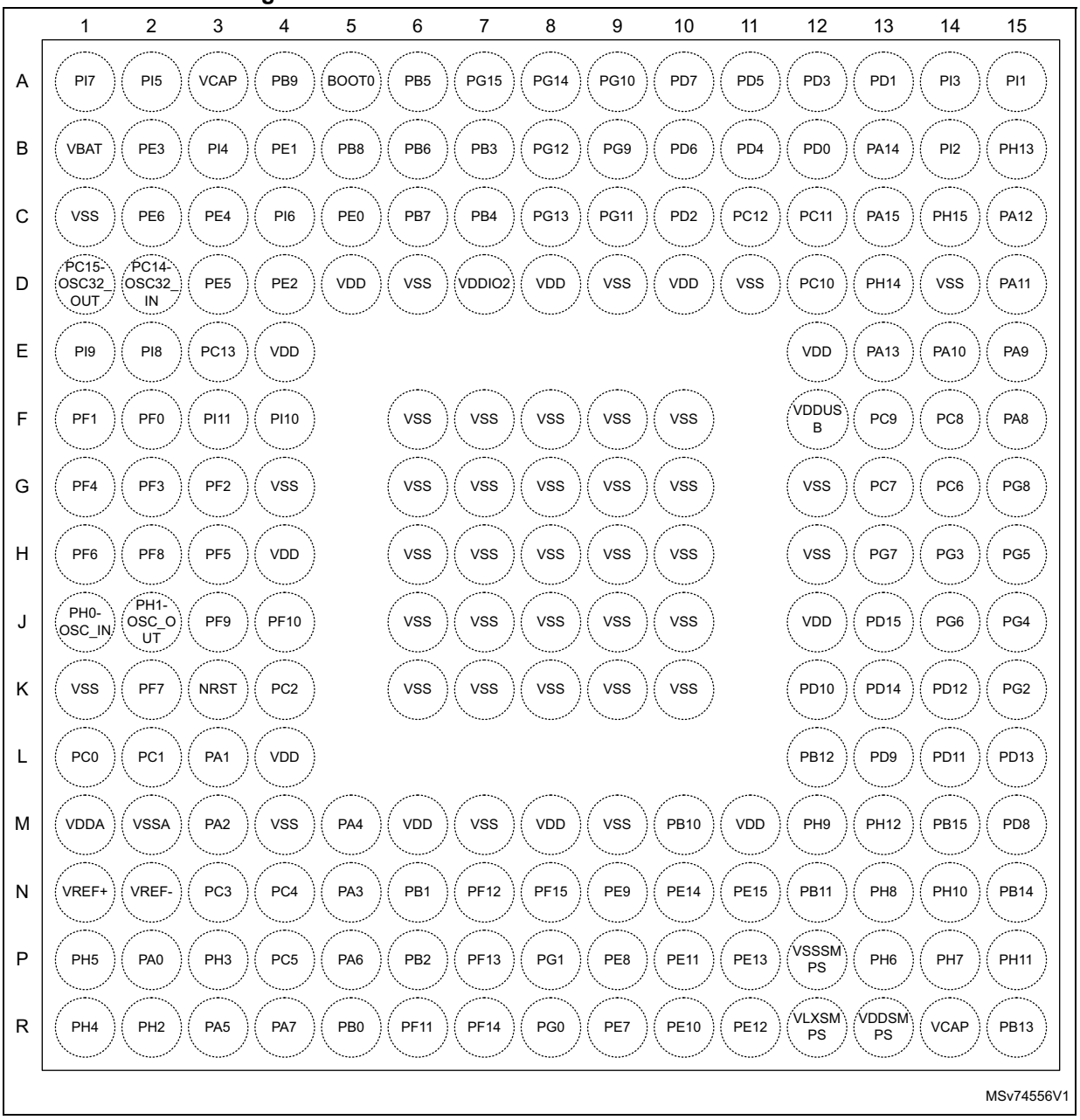
1. The above figure shows the package top view.

Figure 17. STM32H5E4xx UFBGA176+25 ballout



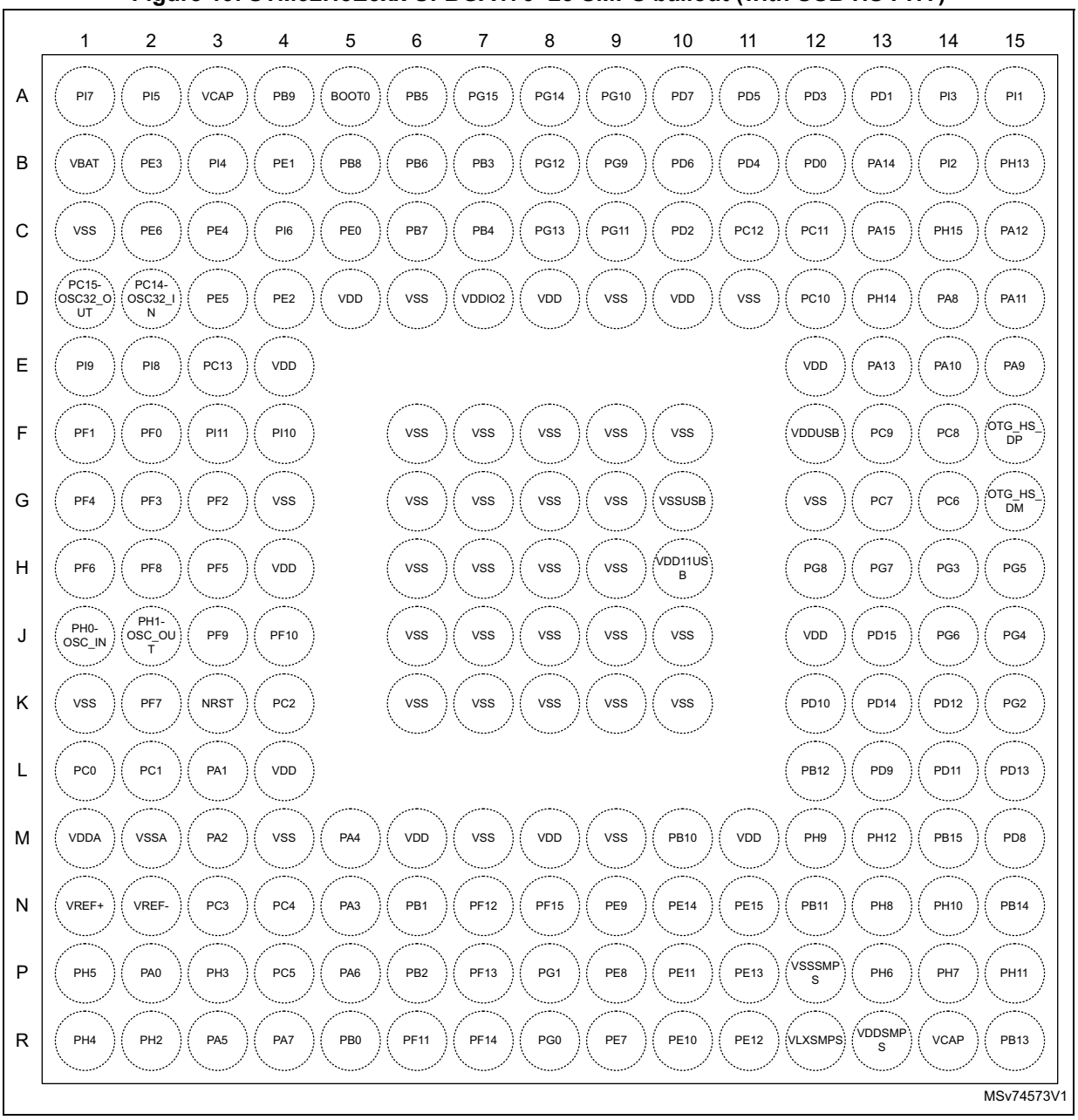
1. The above figure shows the package top view.

Figure 18. STM32H5E4xx UFBGA176+25 SMPS ballout



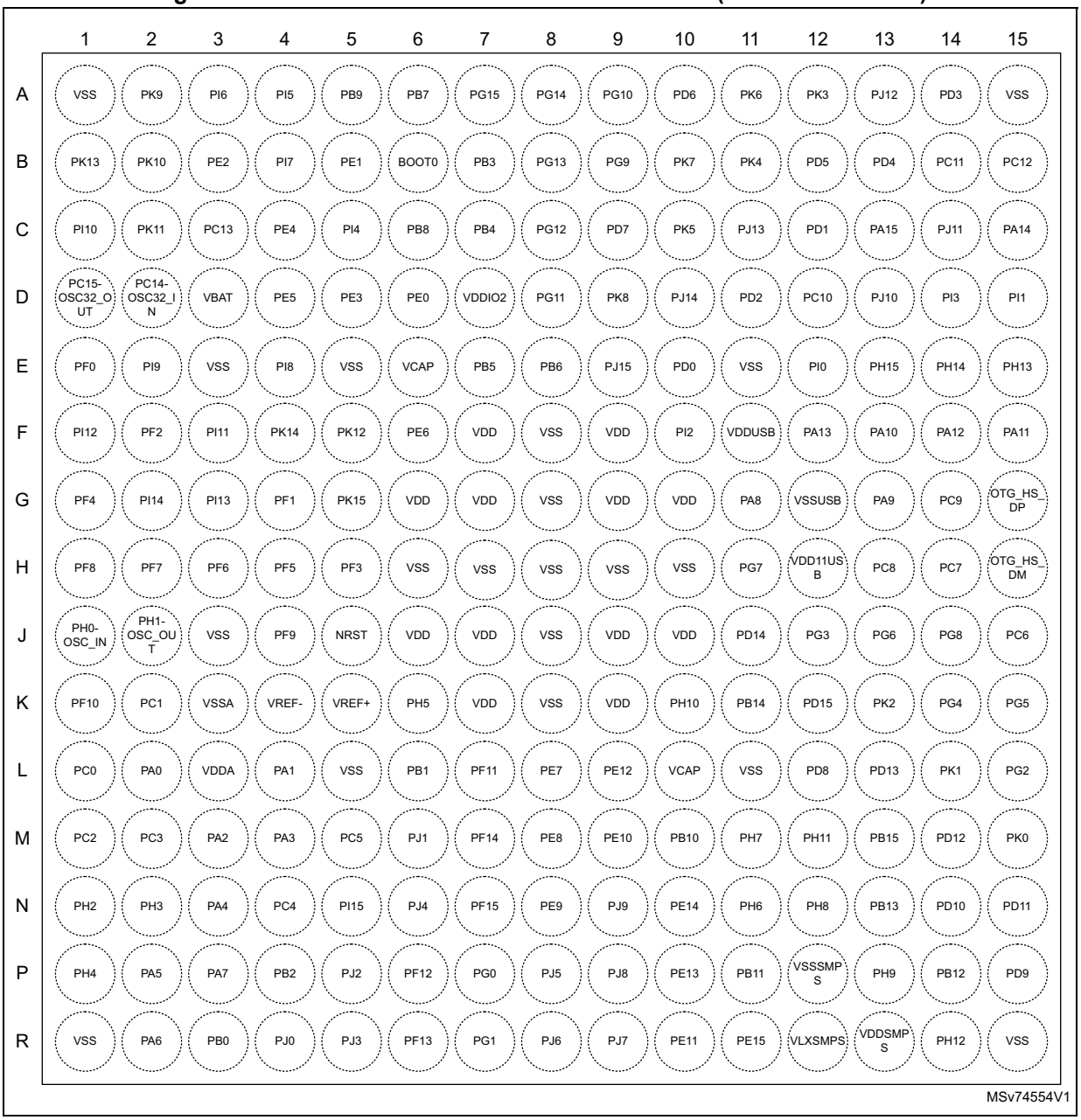
1. The above figure shows the package top view.

Figure 19. STM32H5E5xx UFBGA176+25 SMPS ballout (with USB HS PHY)



1. The above figure shows the package top view.

Figure 20. STM32H5E5xx TFBGA225 SMPS ballout (with USB HS PHY)



1. The above figure shows the package top view.

4.2 Pin description

Table 12. Legend/abbreviations used in the pinout table

Name		Abbreviation	Definition
Pin name		Unless otherwise specified in brackets below the pin name, the pin function during and after reset is the same as the actual pin name	
Pin type		S	Supply pin
		I	Input only pin
		I/O	Input/output pin
I/O structure		FT	5V-tolerant I/O
		TT	3.6V-tolerant I/O
		RST	Bidirectional reset pin with embedded weak pull-up resistor
		Option for TT or FT I/Os(1)	
		_a	I/O, with analog switch function supplied by V_{DDA}
		_c	I/O with USB Type-C power delivery function
		_d	I/O with USB Type-C power delivery dead battery function
		_f	I/O, Fm+ capable
		_h	I/O with high-speed low-voltage mode
		_s	I/O supplied only by V_{DDIO2}
		_t	I/O with tamper function functional in VBAT mode
		_u	I/O, with USB function supplied by V_{DDUSB}
Notes		Unless otherwise specified by a note, all I/Os are set as analog inputs during and after reset.	
Pin functions	Alternate functions	Functions selected through GPIOx_AFR registers	
	Additional functions	Functions directly selected/enabled through peripheral registers	

1. The related I/O structures in the table below are a concatenation of various options. Examples: FT_hat, FT_fs, FT_u, TT_a.

Table 13. STM32H5Exxx pin/ball definition

Pin number[1]																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
1	1	A3	C3	D4	1	1	1	B1	A1	A2	1	C9	1	1	D4	B3	PE2	I/O	FT_h	-	TRACECLK, LPTIM1_IN2, SAI1_CK1, ADF1_CCK0, MDF1_CCK0, SPI4_SCK, SAI1_MCLK_A, USART10_RX, UART8_TX, OCTOSPIM_P1_IO2, ETH_MII_TXD3, FMC_A23, DCMI_D3/PSSI_D3, PLAY1_OUT8, EVENTOUT	-
2	2	C4	D4	B2	2	2	2	C3	B2	A1	2	E9	2	2	B2	D5	PE3	I/O	FT_h	-	TRACED0, TIM15_BKIN, GFXTIM_TE, SAI1_SD_B, USART10_TX, MDF1_CKI2, OCTOSPIM_P2_IO0, FMC_A19, LCD_G1, PLAY1_IN9, EVENTOUT	TAMP_IN6/TAMP_OUT3
3	3	B3	D3	C3	3	3	3	C2	D4	B1	3	D10	3	3	C3	C4	PE4	I/O	FT_h	-	TRACED1, SAI1_D2, ADF1_SDI0, TIM15_CH1N, SPI4_NSS, SAI1_FS_A, MDF1_SDI2, OCTOSPIM_P2_IO1, LCD_G3, ETH_MII_RXD0/ETH_RMII_RXD0, FMC_A20, DCMI_D4/PSSI_D4, PLAY1_OUT9, EVENTOUT	TAMP_IN7/TAMP_OUT8

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number(1)																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
4	4	B4	C2	D3	4	4	4	D3	C2	B2	4	J9	4	4	D3	D4	PE5	I/O	FT_h	-	TRACED2, ADF1_CCK1, SAI1_CK2, TIM15_CH1, SPI4_MISO, SAI1_SCK_A, MDF1_CCK1, OCTOSPIM_P2_IO2, LCD_B6, ETH_MII_RXD1/ETH_RMII_RXD1, FMC_A21, DCMI_D6/PSSI_D6, PLAY1_IN10, EVENTOUT	TAMP_IN8/TAMP_OUT7
5	5	D4	D2	C2	5	5	5	E4	D3	B3	5	G9	5	5	C2	F6	PE6	I/O	FT_h	-	TRACED3, TIM1_BKIN2, SAI1_D1, ADF1_SDI0, TIM15_CH2, SPI4_MOSI, SAI1_SD_A, MDF1_SDI1, OCTOSPIM_P2_IO3, SAI2_MCLK_B, LCD_R2, FMC_A22, DCMI_D7/PSSI_D7, PLAY1_OUT10, EVENTOUT	TAMP_IN3/TAMP_OUT6
-	-	F5	A3	D5	-	-	-	E5	A3	C5	-	A11	-	-	D5	F7	VDD	S	-	-	-	-
-	-	A1	B2	C1	-	-	-	A1	B3	D5	-	B10	-	-	C1	A1	VSS	S	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A2	PK9	I/O	FT_fh	-	TIM12_CH1, I3C1_SCL, I2C1_SCL, SDMMC1_D4, SDMMC1_CKIN, PLAY1_IN14, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	B2	PK10	I/O	FT_fh	-	TIM12_CH2, I3C1_SDA, I2C1_SDA, SDMMC1_D5, SDMMC1_CDIR, PLAY1_IN15, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																					
STM32H5E4xx													STM32H5E5xx					Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C2	PK11	I/O	FT_h	-	TRACECLK, TIM3_CH1, I2S3_MCK, USART6_RTS/USART6_DE, SDMMC1_D6, SDMMC1_D0DIR, LCD_B0, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	F5	PK12	I/O	FT_h	-	TRACED0, TIM3_CH2, USART6_CTS/USART6_NSS, SDMMC1_D7, SDMMC1_D123DIR, LCD_B3, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	B1	PK13	I/O	FT_h	-	TRACED1, TIM3_CH3, USART6_TX, OCTOSPIM_P2_IO5, LCD_B2, EVENTOUT	-
-	-	F6	A8	D8	-	-	-	E7	A10	C7	-	-	-	-	D8	F9	VDD	S	-	-	-	-
-	-	A12	B4	D6	-	-	-	A12	B7	D7	-	H10	-	-	D6	A15	VSS	S	-	-	-	-
6	6	C3	C1	B1	6	6	6	C1	E2	C1	6	C11	6	6	B1	D3	VBAT	S	-	-	-	-
-	-	E5	B8	D9	-	-	-	C6	B10	D8	-	-	-	-	D9	E3	VSS	S	-	-	-	-
-	-	-	E4	E2	7	-	-	-	E3	D2	7	-	-	7	E2	E4	PI8	I/O	FT_t	(4)	EVENTOUT	TAMP_IN2/TAMP_OUT3, RTC_OUT2, WKUP3
7	7	E4	E3	E3	8	7	7	E3	E4	D1	8	F10	7	8	E3	C3	PC13	I/O	FT_t	(4)	EVENTOUT	TAMP_IN1/TAMP_OUT2/ TAMP_OUT3, RTC_OUT1/RTC_TS, WKUP4
-	-	E6	B11	D11	-	-	-	D4	C12	D9	-	-	-	-	D11	E5	VSS	S	-	-	-	-
8	8	A2	D1	D2	9	8	8	D2	B1	E1	9	E11	8	9	D2	D2	PC14-OSC32_IN(OSC32_IN)	I/O	FT	-	EVENTOUT	OSC32_IN

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number(1)																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
9	9	B2	E1	D1	10	9	9	D1	C1	F1	10	G11	9	10	D1	D1	PC15-OSC32_OUT(OSC32_OUT)	I/O	FT	-	EVENTOUT	OSC32_OUT
-	-	F7	A11	D10	-	-	-	F6	C13	C9	-	J11	-	-	D10	G6	VDD	S	-	-	-	-
-	-	E8	E12	D14	-	-	-	D10	D2	F2	-	-	-	-	F6	E11	VSS	S	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	F4	PK14	I/O	FT_h	-	TRACED2, TIM3_CH4, USART6_RX, OCTOSPIM_P2_IO6, LCD_R3, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G5	PK15	I/O	FT_h	-	TRACED3, TIM3_ETR, USART6_CK, OCTOSPIM_P2_IO7, ETH_MII_RX_DV/ETH_RMII_CRS_DV, LCD_G0, EVENTOUT	-
-	-	-	-	E1	11	-	-	-	-	D3	11	-	-	11	E1	E2	PI9	I/O	FT_h	-	TIM1_CH3, SAI1_FS_A, UART4_RX, FDCAN1_RX, EVENTOUT	-
-	-	-	-	F4	12	-	-	-	-	E3	12	-	-	12	F4	C1	PI10	I/O	FT_h	-	TIM1_CH4N, SAI1_SCK_A, USART11_RX, FDCAN1_RX, ETH_MII_RX_ER, PSSI_D14, EVENTOUT	-
-	-	-	-	F3	13	-	-	-	F4	E4	13	-	-	13	F3	F3	PI11	I/O	FT_h	-	TIM1_CH4, SAI1_MCLK_A, LPTIM1_CH2, USART11_TX, PSSI_D15, LCD_B1, EVENTOUT	TAMP_IN4/TAMP_OUT5
-	-	F8	F2	F6	14	-	-	F5	G2	F6	14	-	-	14	F7	F8	VSS	S	-	-	-	-
-	-	G6	B1	E4	15	-	-	F8	D1	F3	15	-	-	15	E4	G7	VDD	S	-	-	-	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	10	F4	E2	F2	16	-	10	E2	F3	E2	16	-	10	16	F2	E1	PF0	I/O	FT_fh	-	TIM2_CH1, TIM2_ETR, COMP1_OUT, I2C2_SDA, I3C2_SDA, SDMMC2_D2, UART9_RX, FMC_A0, LPTIM5_CH1, PLAY1_IN0, EVENTOUT	-
-	11	D3	F3	F1	17	-	11	E1	E1	H3	17	-	11	17	F1	G4	PF1	I/O	FT_fh	-	TIM2_CH2, COMP2_OUT, I2C2_SCL, I3C2_SCL, SDMMC2_D3, UART9_TX, FMC_A1, LPTIM5_CH2, PLAY1_IN1, EVENTOUT	-
-	12	E3	F4	G3	18	-	12	F4	F2	H2	18	-	12	18	G3	F2	PF2	I/O	FT_h	-	LPTIM3_CH2, LPTIM3_IN2, I2C2_SMBA, GFXTIM_TE, UART12_TX, USART11_CK, SDMMC2_D4, FMC_A2, LPTIM5_IN1, PLAY1_IN2, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	F1	PI12	I/O	FT_h	-	TIM1_BKIN, LPUART1_TX, TIM15_BKIN, SAI1_SD_B, MDF1_CKI5, LCD_R5, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G3	PI13	I/O	FT_h	-	LPUART1_RX, TIM15_CH1N, SAI1_MCLK_B, MDF1_SDI5, LCD_G5, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G2	PI14	I/O	FT_h	-	LPUART1_CTS, TIM15_CH1, SAI1_SCK_B, TIM13_CH1, LCD_B7, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	13	C2	G6	G2	19	-	13	F3	F5	J2	19	-	13	19	G2	H5	PF3	I/O	FT_h	-	TIM2_CH3, LPTIM3_IN1, USART11_TX, SDMMC2_D5, FMC_A3, LPTIM5_IN2, PLAY1_OUT0, EVENTOUT	-
-	14	D2	G5	G1	20	-	14	F2	F1	J3	20	-	14	20	G1	G1	PF4	I/O	FT_h	-	TIM2_CH4, LPTIM3_ETR, USART11_RX, OCTOSPIM_P2_NCS2, SDMMC2_D6, FMC_A4, DCMI_D6/PSSI_D6, PLAY1_OUT1, EVENTOUT	-
-	15	B1	G3	H3	21	-	15	F1	F6	K3	21	-	15	21	H3	H4	PF5	I/O	FT_fh	-	LPTIM3_CH1, I2C4_SCL, I3C1_SCL, UART12_RX, USART11_CTS/USART11_NSS, OCTOSPIM_P2_DQS, SDMMC2_D7, SDMMC2_CKIN, FMC_A5, LPTIM3_IN1, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	VDD	S	-	-	-	-
10	16	G5	H2	F7	22	10	16	F7	H12	F7	22	-	16	22	F8	G8	VSS	S	-	-	-	-
11	17	G7	D13	E12	23	11	17	G5	G1	F13	23	-	17	23	E12	G9	VDD	S	-	-	-	-
-	18	C1	G7	H1	24	-	18	G1	G4	K2	24	-	18	24	H1	H3	PF6	I/O	FT_h	-	TIM16_CH1, SPI5_NSS, SAI1_SD_B, UART7_RX, SDMMC1_D0, FDCAN3_TX, OCTOSPIM_P1_IO3, FMC_D16, LPTIM5_CH1, LCD_DE, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	19	G4	F1	K2	25	-	19	G2	G3	K1	25	-	19	25	K2	H2	PF7	I/O	FT_h	-	TIM17_CH1, MDF1_CKI1, SPI5_SCK, SAI1_MCLK_B, UART7_TX, SDMMC1_D1, FDCAN3_RX, OCTOSPIM_P1_IO2, FMC_D17, LPTIM5_CH2, LCD_G3, EVENTOUT	-
-	20	E2	G4	H2	26	-	20	G4	G5	L3	26	-	20	26	H2	H1	PF8	I/O	FT_h	-	TIM16_CH1N, SPI5_MISO, SAI1_SCK_B, UART7_RTS/UART7_DE, SDMMC1_D2, TIM13_CH1, OCTOSPIM_P1_IO0, ETH_MII_TX_ER, FMC_D18, LPTIM5_IN1, LCD_R7, EVENTOUT	-
-	21	F3	G2	J3	27	-	21	G3	H3	L2	27	-	21	27	J3	J4	PF9	I/O	FT_h	-	TIM17_CH1N, MDF1_CCK0, SPI5_MOSI, SAI1_FS_B, UART7_CTS, SDMMC1_D3, TIM14_CH1, OCTOSPIM_P1_IO1, ETH_MDC, FMC_D19, LPTIM5_IN2, LCD_B1, EVENTOUT	-
-	22	D1	H4	J4	-	-	22	H3	G6	L1	28	-	22	-	J4	K1	PF10	I/O	FT_h	-	TIM16_BKIN, SAI1_D3, PSSI_D15, MDF1_SDI3, OCTOSPIM_P1_CLK, DCMI_D11/PSSI_D11, LCD_G6, EVENTOUT	-
12	23	F2	H1	J1	28	12	23	H1	H1	G1	29	L11	23	28	J1	J1	PH0-OSC_IN(PH0)	I/O	FT	-	EVENTOUT	OSC_IN
13	24	F1	J1	J2	29	13	24	H2	H2	H1	30	N11	24	29	J2	J2	PH1-OSC_OUT(PH1)	I/O	FT	-	EVENTOUT	OSC_OUT

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
14	25	E1	H3	K3	30	14	25	J1	H4	J1	31	K10	25	30	K3	J5	NRST	I/O	RST	-	-	-
15	26	G1	J2	L1	31	15	26	J2	J1	M2	32	M10	26	31	L1	L1	PC0	I/O	FT_ah	-	TIM16_BKIN, TIM8_CH1, MDF1_CKI1, SAI1_MCLK_A, SPI2_RDY, SAI2_FS_B, FMC_A25, OCTOSPIM_P1_IO7, FMC_SDNWE, FMC_INT, LCD_G3, EVENTOUT	ADC12_INP10
16	27	G3	J3	L2	32	16	27	K2	J2	M3	33	L9	27	32	L2	K2	PC1	I/O	FT_ah	-	TRACED0, ADF1_SDI0, SAI1_D1, TIM8_CH2, MDF1_SDI1, SPI2_MOSI/I2S2_SDO, SAI1_SD_A, USART11_RTS/USART11_DE, SAI2_SD_A, SDMMC2_CK, OCTOSPIM_P1_IO4, ETH_MDC, FMC_NE2/FMC_NCE, LCD_G2, EVENTOUT	ADC12_INP11, ADC12_INN10, TAMP_IN3/TAMP_OUT5, WKUP6
17	28	H1	K1	K4	33	17	28	K1	J3	M4	34	K8	28	33	K4	M1	PC2	I/O	FT_ah	-	PWR_CSLEEP, TIM17_CH1, TIM4_CH4, TIM8_CH3, SPI2_MISO/I2S2_SDI, OCTOSPIM_P1_IO5, OCTOSPIM_P1_IO2, SDMMC2_D6, ETH_MII_TXD2, FMC_SDNE0, FMC_NE1/FMC_NCE, LCD_HSYNC, EVENTOUT	ADC12_INP12, ADC12_INN11

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
18	29	J1	K2	N3	34	18	29	L1	H5	M5	35	R11	29	34	N3	M2	PC3	I/O	FT_ah	-	PWR_CSTOP, SAI1_D3, LPTIM3_CH1, SPI2_MOSI/I2S2_SDO, OCTOSPIM_P1_IO6, MDF1_SDI3, OCTOSPIM_P1_IO0, SDMMC2_D7, ETH_MII_TX_CLK, FMC_SDCKE0, LCD_VSYNC, EVENTOUT	ADC12_INP13, ADC12_INN12
-	-	G8	G1	H4	35	-	30	G7	H13	G3	36	-	30	35	H4	G10	VDD	S	-	-	-	-
-	-	H5	J12	F8	-	-	-	G6	M2	F8	-	-	-	-	F9	H6	VSS	S	-	-	-	-
19	30	H3	L1	M2	36	19	31	K3	K2	M1	37	T10	31	36	M2	K3	VSSA	S	-	-	-	-
-	-	J4	L2	N2	-	20	-	H4	K1	N1	-	V10	-	-	N2	K4	VREF-	S	-	-	-	-
20	31	J3	M2	N1	37	21	32	J3	L2	P1	38	U11	32	37	N1	K5	VREF+	S	-	-	-	-
21	32	H4	M1	M1	38	22	33	J4	L1	R1	39	W11	33	38	M1	L3	VDDA	S	-	-	-	-
22	33	G2	K3	P2	39	23	34	L2	J4	N3	40	P10	34	39	P2	L2	PA0	I/O	FT_aht	[4]	TIM2_CH1, TIM5_CH1, TIM8_ETR, TIM15_BKIN, SPI6_NSS, SPI3_RDY, USART2_CTS/USART2_NSS, UART4_TX, SDMMC2_CMD, SAI2_SD_B, ETH_MII_CRS, LCD_G6, TIM2_ETR, EVENTOUT	ADC12_INP0, ADC12_INN1, TAMP_IN2/TAMP_OUT1, WKUP1

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
23	34	H2	H5	L3	40	24	35	L3	J5	N2	41	N9	35	40	L3	L4	PA1	I/O	FT_aht	(4)	TIM2_CH2, TIM5_CH2, TIM15_CH1N, LPTIM1_IN1, OCTOSPIM_P1_DQS, USART2_RTS/USART2_DE, UART4_RX, OCTOSPIM_P1_IO3, SAI2_MCLK_B, ETH_MII_RX_CLK/ETH_RMII_REF_CLK, LCD_B7, EVENTOUT	ADC12_INP1, TAMP_IN5/TAMP_OUT4
24	35	J2	L3	M3	41	25	36	K4	L3	P2	42	M8	36	41	M3	M3	PA2	I/O	FT_aht	(4)	TIM2_CH3, TIM5_CH3, TIM15_CH1, LPTIM1_IN2, USART2_TX(boot), SAI2_SCK_B, OCTOSPIM_P2_IO4, ETH_MDIO, LCD_R0, LCD_B6, EVENTOUT	ADC12_INP14, TAMP_IN4/TAMP_OUT3, WKUP2
-	-	-	J4	R2	42	-	-	-	K3	F4	43	-	-	42	R2	N1	PH2	I/O	FT_h	-	LPTIM1_IN2, MDF1_CKI2, OCTOSPIM_P2_CLK, OCTOSPIM_P1_IO4, SAI2_SCK_B, ETH_MII_CRS, FMC_SDCKE0, FMC_NBL0, PLAY1_OUT2, EVENTOUT	-
-	-	H6	J13	J12	-	-	-	H6	L13	G13	-	W9	-	-	J12	J6	VDD	S	-	-	-	-
-	-	H7	M3	F9	-	-	-	H5	M4	F9	-	U9	-	-	F10	H7	VSS	S	-	-	-	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	-	-	N2	P3	43	-	-	-	N2	G4	44	-	-	43	P3	N2	PH3	I/O	FT_h	-	MDF1_SDI2, OCTOSPIM_P2_NCLK, OCTOSPIM_P1_IO5, SAI2_MCLK_B, ETH_MII_COL, FMC_SDNE0, FMC_NBL2, PLAY1_OUT3, EVENTOUT	-
-	-	-	N1	R1	-	-	-	-	N1	H4	45	-	-	-	R1	P1	PH4	I/O	FT_fh	-	I3C2_SCL, I2C2_SCL, SPI5_RDY, SPI6_RDY, PSSI_D14, LCD_R7, EVENTOUT	-
-	-	-	L4	P1	-	-	-	-	M3	J4	46	-	-	-	P1	K6	PH5	I/O	FT_fh	-	I3C2_SDA, I2C2_SDA, SPI5_NSS, SPI6_RDY, FMC_SDNWE, EVENTOUT	-
25	36	K1	K4	N5	44	26	37	M2	N3	R2	47	R9	37	44	N5	M4	PA3	I/O	FT_ah	-	DMA2D_GPFLAG0, TIM2_CH4, TIM5_CH4, OCTOSPIM_P1_CLK, TIM15_CH2, SPI2_NSS/I2S2_WS, SAI1_SD_B, USART2_RX(boot), ETH_MII_COL, LCD_B5, EVENTOUT	ADC12_INP15
26	37	H8	M7	F10	45	27	38	H7	M7	F10	48	-	38	45	G4	H8	VSS	S	-	-	-	-
27	38	-	N3	L4	46	28	39	-	M1	J12	49	-	39	46	L4	J7	VDD	S	-	-	-	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number(1)																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
28	39	L1	M4	M5	47	29	40	M3	L4	N4	50	L7	40	47	M5	N3	PA4	I/O	TT_ah	-	TIM5_ETR, LPTIM2_CH1, SPI1_NSS/I2S1_WS, I2S3_WS/SPI3_NSS, USART2_CK, SPI6_NSS, OTG_HS_SOF, FMC_NBL2, DCMI_HSYNC/PSSI_DE, LCD_B4, EVENTOUT	ADC12_INP18, OPAMP1_VINM, DAC1_OUT1
29	40	K2	J5	R3	48	30	41	L4	K4	P4	51	P8	41	48	R3	P2	PA5	I/O	TT_ah	-	TIM2_CH1, TIM8_CH1N, SPI1_SCK/I2S1_CK, SPI6_SCK, OCTOSPIM_P2_IO5, LCD_G5, ETH_MII_TX_EN/ETH_RMII_TX_EN, PSSI_D14, TIM2_ETR, EVENTOUT	ADC12_INP19, ADC12_INN18, OPAMP1_VINP, DAC1_OUT2
30	41	K3	N4	P5	49	31	42	M4	M5	P3	52	N7	42	49	P5	R2	PA6	I/O	FT_ah	-	TIM1_BKIN, TIM3_CH1, TIM8_BKIN, SPI1_MISO/I2S1_SDI, OCTOSPIM_P1_IO3, USART11_TX, SPI6_MISO, TIM13_CH1, FMC_D31, DCMI_PIXCLK/PSSI_PDCK, LCD_B3, EVENTOUT	ADC12_INP3, COMP1_INM
31	42	L2	K5	R4	50	32	43	J5	K5	R3	53	T8	43	50	R4	P3	PA7	I/O	FT_ah	-	TIM1_CH1N, TIM3_CH2, TIM8_CH1N, SPI1_MOSI/I2S1_SDO, USART11_RX, SPI6_MOSI, TIM14_CH1, OCTOSPIM_P1_IO2, ETH_MII_RX_DV/ETH_RMII_CRS_DV, FMC_SDNWE, FMC_NWE, LCD_B2, EVENTOUT	ADC12_INP7, ADC12_INN3, COMP1_INP

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	-	M2	L5	N4	51	33	44	K5	N5	N5	54	-	44	51	N4	N4	PC4	I/O	FT_ah	-	TIM2_CH4, SAI1_CK1, LPTIM2_ETR, ADF1_CCK0, I2S1_MCK, USART3_RX, MDF1_CCK0, ETH_MII_RXD0/ETH_RMII_RXD0, FMC_SDNE0, LCD_DE, EVENTOUT	ADC12_INP4
-	-	J5	M5	P4	52	34	45	L5	H6	P5	55	-	45	52	P4	M5	PC5	I/O	FT_ah	-	TIM1_CH4N, SAI1_D3, PSSI_D15, SAI1_FS_A, UART12_RTS/UART12_DE, MDF1_SDI3, OCTOSPIM_P1_DQS, ETH_MII_RXD1/ETH_RMII_RXD1, FMC_SDCKE0, LCD_G1, EVENTOUT	ADC12_INP8, ADC12_INN4
-	-	-	N7	M6	-	-	-	-	N4	J13	-	-	-	-	M6	J9	VDD	S	-	-	-	-
-	-	M1	M11	G4	-	-	-	J9	M12	F12	-	-	-	-	G6	H9	VSS	S	-	-	-	-
32	43	L3	N5	R5	53	35	46	M5	L5	R5	56	R7	46	53	R5	R3	PB0	I/O	FT_ah	-	TIM1_CH2N, TIM3_CH3, TIM8_CH2N, OCTOSPIM_P1_IO1, USART11_CK, UART4_CTS, OCTOSPIM_P2_NCS1, ETH_MII_RXD2, LCD_R4, LPTIM3_CH1, EVENTOUT	ADC12_INP9, ADC12_INN5, COMP2_INP
33	44	K4	H6	N6	54	36	47	J6	K6	R4	57	V8	47	54	N6	L6	PB1	I/O	TT_ah	-	TIM1_CH3N, TIM3_CH4, TIM8_CH3N, OCTOSPIM_P1_IO0, OCTOSPIM_P1_NCLK, ETH_MII_RXD3, LCD_B3, LPTIM3_CH2, EVENTOUT	ADC12_INP5, COMP2_INM, OPAMP1_VOUT

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number(1)																					
STM32H5E4xx												STM32H5E5xx					Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
34	45	M3	N6	P6	55	37	48	K6	L6	M6	58	W7	48	55	P6	P4	PB2	I/O	FT_ah	-	RTC_OUT2, ADF1_SDI0, SAI1_D1, TIM8_CH4N, SPI1_RDY, LPTIM1_CH1, SAI1_SD_A, SPI3_MOSI/I2S3_SDO, OCTOSPIM_P1_CLK, OCTOSPIM_P1_DQS, ETH_MII_RXD0/ETH_RMII_RXD0, SDMMC1_CMD, LPTIM5_ETR, LCD_R3, EVENTOUT	ADC3_INP0, COMP1_INP, LSCO
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N5	PI15	I/O	FT_h	-	LPUART1_RTS/LPUART1_DE, TIM15_CH2, GFXTIM_TE, SAI1_FS_B, TIM14_CH1, LCD_R4, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R4	PJ0	I/O	FT_h	-	TIM17_BKIN, TIM4_ETR, MDF1_CKI1, USART3_CK, OCTOSPIM_P1_NCS2, PLAY1_IN4, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M6	PJ1	I/O	FT_h	-	TIM17_CH1, MDF1_SDI1, USART3_TX, OCTOSPIM_P1_DQS, ETH_PTP_AUX_TS, PLAY1_OUT4, EVENTOUT	-
-	-	-	N12	M8	-	-	-	-	N7	K4	-	-	-	-	M8	J10	VDD	S	-	-	-	-
-	-	M12	-	G6	-	-	-	M1	-	G2	-	-	-	-	G7	H10	VSS	S	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P5	PJ2	I/O	FT_h	-	SAI1_FS_A, MDF1_CCK0, USART3_RX, OCTOSPIM_P2_NCS2, ETH_PHY_INTN, PLAY1_IN5, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																				
STM32H5E4xx												STM32H5E5xx					Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R5	PJ3	I/O	FT_h	-	TIM4_CH1, MDF1_SDI4, USART3_RTS/USART3_DE, OCTOSPIM_P2_DQS, LCD_G1, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N6	PJ4	I/O	FT_h	-	TIM4_CH2, LPTIM2_IN2, MDF1_CCK1, USART3_CTS/USART3_NSS, LCD_G2, EVENTOUT	-
-	46	K5	J6	R6	56	-	49	L6	J6	R6	59	-	49	56	R6	L7	PF11	I/O	FT_ah	-	TIM2_CH3, SPI5_MOSI, SDMMC1_D4, OCTOSPIM_P1_NCLK, SAI2_SD_B, FMC_NRAS, DCMI_D12/PSSI_D12, LPTIM6_CH1, EVENTOUT	ADC1_INP2
-	47	L4	K6	N7	57	-	50	M6	N6	P6	60	-	50	57	N7	P6	PF12	I/O	FT_ah	-	TIM2_CH4, SDMMC1_D5, SDMMC1_CKIN, FMC_A6, LCD_CLK, LPTIM6_CH2, EVENTOUT	ADC1_INP6, ADC1_INN2
-	48	-	-	G7	58	-	51	M12	-	G6	61	-	51	58	G8	J3	VSS	S	-	-	-	-
-	49	-	-	M11	59	-	52	-	N11	N8	62	-	52	59	M11	K7	VDD	S	-	-	-	-
-	50	J6	H7	P7	60	-	53	M7	H7	N6	63	-	53	60	P7	R6	PF13	I/O	FT_ah	-	ADF1_CCK0, LPTIM2_CH2, I2C4_SMBA, SDMMC1_D6, SDMMC1_CDIR, FMC_A7, LCD_B6, LPTIM6_IN1, EVENTOUT	ADC2_INP2

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	51	M4	L6	R7	61	-	54	L7	M6	R7	64	-	54	61	R7	M7	PF14	I/O	FT_ah	-	ADF1_CCK1, TIM3_ETR, LPTIM2_IN1, SPI3_MISO/I2S3_SDI, SDMMC1_D7, SDMMC1_D123DIR, FMC_A8, LCD_G5, LPTIM6_IN2, EVENTOUT	ADC2_INP6, ADC2_INN2
-	52	L5	J7	N8	62	-	55	K7	J7	P7	65	-	55	62	N8	N7	PF15	I/O	FT_fh	-	ADF1_SDI0, TIM4_ETR, I2C4_SDA, I3C1_SDA, SDMMC1_CMD, OCTOSPIM_P2_NCS2, ETH_CLK, FMC_A9, LCD_B7, EVENTOUT	-
-	53	M5	M6	R8	63	-	56	M8	L7	N7	66	-	56	63	R8	P7	PG0	I/O	FT_h	-	TIM4_CH1, SDMMC1_CK, OCTOSPIM_P2_IO0, UART9_RX, FMC_A10, LPTIM4_IN1, EVENTOUT	-
-	-	-	-	G8	-	-	-	-	-	G7	-	-	-	-	G9	J8	VSS	S	-	-	-	-
-	-	-	-	-	-	-	-	-	-	N9	-	-	-	-	-	K9	VDD	S	-	-	-	-
-	54	K6	K7	P8	64	-	57	J7	K7	M7	67	-	57	64	P8	R7	PG1	I/O	FT_h	-	TIM4_CH2, SPI2_MOSI/I2S2_SDO, OCTOSPIM_P2_IO1, UART9_TX, FMC_A11, PLAY1_IN3, EVENTOUT	-
35	55	L6	L7	R9	65	38	58	L8	N8	R8	68	U7	58	65	R9	L8	PE7	I/O	FT_ah	-	TIM1_ETR, USART2_RX, UART12_RTS/UART12_DE, UART7_RX, MDF1_CKI0, OCTOSPIM_P1_IO4, FMC_D4/FMC_AD4, PLAY1_IN11, EVENTOUT	ADC3_INP1, COMP2_INP

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
36	56	M6	J8	P9	66	39	59	M9	G7	P8	69	T6	59	66	P9	M8	PE8	I/O	FT_ah	-	TIM1_CH1N, USART2_TX, UART12_CTS, UART7_TX, MDF1_SDI0, OCTOSPIM_P1_IO5, FMC_D5/FMC_AD5, DCMI_D8/PSSI_D8, PLAY1_OUT11, EVENTOUT	ADC3_INP2
37	57	M7	N8	N9	67	40	60	K8	L8	P9	70	V6	60	67	N9	N8	PE9	I/O	FT_ah	-	TIM1_CH1, UART12_RX, UART7_RTS/UART7_DE, MDF1_CKI4, OCTOSPIM_P1_IO6, FMC_D6/FMC_AD6, PLAY1_IN12, EVENTOUT	ADC3_INP3, COMP2_INM
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P8	PJ5	I/O	FT_h	-	TIM4_CH3, ADF1_CCK0, USART10_RX, OCTOSPIM_P2_NCS1, ETH_PPS_OUT, PLAY1_IN6, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R8	PJ6	I/O	FT_h	-	TIM4_CH4, ADF1_CCK1, USART10_TX, OCTOSPIM_P2_IO0, ETH_MDIO, PLAY1_OUT5, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R9	PJ7	I/O	FT_h	-	TIM5_CH1, ADF1_SDI0, USART10_CK, OCTOSPIM_P2_IO1, ETH_MDC, PLAY1_IN7, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number(1)																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P9	PJ8	I/O	FT_h	-	TIM5_CH2, COMP1_OUT, MDF1_CKI4, UART5_RTS/UART5_DE, LPTIM5_ETR, LCD_R1, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N9	PJ9	I/O	FT_h	-	TIM5_CH3, COMP2_OUT, UART5_CTS, SAI2_MCLK_A, LPTIM5_IN1, LCD_CLK, EVENTOUT	-
-	58	-	-	G9	68	-	61	-	-	G8	71	-	61	68	G12	K8	VSS	S	-	-	-	-
-	59	-	-	-	69	-	62	-	-	N10	72	-	62	69	-	-	VDD	S	-	-	-	-
38	60	L7	L8	R10	70	41	63	L9	H8	R9	73	W5	63	70	R10	M9	PE10	I/O	FT_ah	-	TIM1_CH2N, UART12_TX, UART7_CTS, MDF1_SDI4, OCTOSPIM_P1_IO7, FMC_D7/FMC_AD7, PLAY1_OUT12, EVENTOUT	ADC3_INP4, COMP1_INM
39	61	J7	M8	P10	71	42	64	M10	M8	P10	74	P6	64	71	P10	R10	PE11	I/O	TT_ah	-	TIM1_CH2, SPI1_RDY, SPI4_NSS, OCTOSPIM_P1_NCS1, USART6_TX, MDF1_CKI5, OCTOSPIM_P2_NCS2, SAI2_SD_B, FMC_D8/FMC_AD8, LCD_B5, PLAY1_IN13, EVENTOUT	ADC3_INP5, OPAMP1_VINP

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
40	62	K7	M9	R11	72	43	65	K9	K8	R10	75	U5	65	72	R11	L9	PE12	I/O	FT_ah	-	GFXTIM_LCKCAL, TIM1_CH3N, SPI4_SCK, USART6_RX, MDF1_SDI5, FDCAN3_TX, SAI2_SCK_B, ETH_MDIO, FMC_D9/FMC_AD9, DCMI_D0/PSSI_D0, PLAY1_OUT13, EVENTOUT	ADC3_INP6, OPAMP1_VINP
41	63	M8	K8	P11	73	44	66	M11	L9	N11	76	M6	66	73	P11	P10	PE13	I/O	TT_ah	-	GFXTIM_FCKCAL, TIM1_CH3, SPI4_MISO, USART6_CK, UART5_RTS/UART5_DE, FDCAN3_RX, SAI2_FS_B, LCD_R1, FMC_D10/FMC_AD10, DCMI_HSYNC/PSSI_DE, PLAY1_IN14, EVENTOUT	ADC3_INP7, OPAMP1_VINM
42	64	L8	J9	N10	74	45	67	L10	J8	P11	77	R5	67	74	N10	N10	PE14	I/O	FT_ah	-	TIM1_CH4, SPI4_MOSI, OCTOSPIM_P2_CLK, SAI2_MCLK_B, LCD_B0, FMC_D11/FMC_AD11, DCMI_VSYNC/PSSI_RDY, PLAY1_OUT14, EVENTOUT	ADC3_INP8, COMP2_INM
43	65	M9	L9	N11	75	46	68	K10	N9	R11	78	V4	68	75	N11	R11	PE15	I/O	FT_ah	-	TIM1_BKIN, TIM1_CH4N, USART10_CK, OCTOSPIM_P2_NCS1, LCD_R0, FMC_D12/FMC_AD12, DCMI_PIXCLK/PSSI_PDCK, PLAY1_OUT15, EVENTOUT	ADC3_INP9

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
44	66	K8	K9	M10	76	47	69	L11	K9	R12	79	T4	69	76	M10	M10	PB10	I/O	FT_fh	-	TIM2_CH3, LPTIM3_CH1, LPTIM2_IN1, I2C2_SCL, SPI2_SCK/I2S2_CK, USART3_TX, I3C2_SCL, OCTOSPIM_P1_NCS1, FMC_NRAS, ETH_MII_RX_ER, FMC_NWAIT, LCD_G4, EVENTOUT	-
45	67	L9	L10	N12	77	-	-	C7	M9	R13	80	-	-	77	N12	P11	PB11	I/O	FT_fh	-	TIM2_CH4, LPTIM2_ETR, I2C2_SDA, SPI2_RDY, SPI4_RDY, USART3_RX, I3C2_SDA, ETH_MII_TX_EN/ETH_RMII_TX_EN, FMC_NBL1, LCD_G7, PLAY1_IN15, EVENTOUT	-
46	68	M10	N9	R12	78	-	-	-	-	-	-	U3	-	78	R12	R12	VLXSMPS	S	-	-	-	-
47	69	L10	N10	R13	79	-	-	-	-	-	-	W3	-	79	R13	R13	VDDSMPS	S	-	-	-	-
48	70	M11	M10	P12	80	-	-	-	-	-	-	V2	-	80	P12	P12	VSSSMPS	S	-	-	-	-
49	71	J8	N11	R14	81	48	70	J8	N10	M10	81	W1	70	81	R14	L10	VCAP	S	-	-	-	-
50	72	-	-	G10	82	49	71	-	-	G12	82	U1	71	82	H6	L5	VSS	S	-	-	-	-
51	73	-	-	-	83	50	72	-	-	-	83	R1	72	83	-	-	VDD	S	-	-	-	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	-	-	N13	P13	84	-	-	-	K10	M11	84	-	-	84	P13	N11	PH6	I/O	FT_h	-	TIM1_CH3N, TIM12_CH1, TIM8_CH1, I2C2_SMBA, SPI5_SCK, OCTOSPIM_P2_IO0, ETH_MII_RXD2, FMC_SDNE1, DCMI_D8/PSSI_D8, PLAY1_OUT11, EVENTOUT	-
-	-	-	L11	P14	85	-	-	-	L10	N12	85	-	-	85	P14	M11	PH7	I/O	FT_fh	-	TIM1_CH3, TIM8_CH1N, I2C3_SCL, SPI5_MISO, OCTOSPIM_P2_IO1, ETH_MII_RXD3, FMC_SDCKE1, DCMI_D9/PSSI_D9, PLAY1_OUT12, EVENTOUT	-
-	-	-	M12	N13	-	-	-	-	M10	M12	86	-	-	-	N13	N12	PH8	I/O	FT_fh	-	TIM1_CH2N, TIM5_ETR, TIM8_CH2, I2C3_SDA, SPI5_MOSI, DCMI_HSYNC/PSSI_DE, EVENTOUT	-
-	-	-	M13	M12	86	-	-	-	-	M13	87	-	-	86	M12	P13	PH9	I/O	FT_h	-	TIM1_CH2, TIM12_CH2, TIM8_CH2N, I2C3_SMBA, SPI5_NSS, DCMI_D0/PSSI_D0, LCD_R7, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	-	-	K10	N14	87	-	-	-	M11	L13	88	-	-	87	N14	K10	PH10	I/O	FT_h	-	TIM1_CH1N, TIM5_CH1, TIM8_CH3, I2C4_SMBA, SPI5_RDY, OCTOSPIM_P2_IO2, FMC_D20, DCMI_D1/PSSI_D1, PLAY1_OUT13, EVENTOUT	-
-	-	-	L13	P15	88	-	-	-	N12	L12	89	-	-	88	P15	M12	PH11	I/O	FT_fh	-	TIM1_CH1, TIM5_CH2, TIM8_CH3N, I2C4_SCL, I3C1_SCL, OCTOSPIM_P2_IO3, FMC_D21, DCMI_D2/PSSI_D2, PLAY1_OUT14, EVENTOUT	-
-	-	-	L12	M13	89	-	-	-	N13	K12	90	-	-	89	M13	R14	PH12	I/O	FT_fh	-	TIM1_BKIN, TIM5_CH3, TIM8_BKIN, I2C4_SDA, I3C1_SDA, OCTOSPIM_P2_IO4, TIM8_CH4N, FMC_D3/FMC_AD3, DCMI_D3/PSSI_D3, PLAY1_OUT15, EVENTOUT	-
-	-	-	-	H7	90	-	-	-	-	H8	-	-	-	90	H9	R15	VSS	S	-	-	-	-
-	-	-	-	-	91	-	-	-	-	-	91	-	-	91	-	-	VDD	S	-	-	-	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	-	-	K11	L12	92	51	73	L12	K11	P12	92	N5	73	92	L12	P14	PB12	I/O	FT_fh	-	TIM1_BKIN, OCTOSPIM_P1_NCLK, I2C2_SDA, SPI2_NSS/I2S2_WS, UCPD1_FRSTX, USART3_CK, I3C2_SDA, FDCAN2_RX, ETH_MII_TXD0/ETH_RMII_TXD0, LCD_R1, UART5_RX, EVENTOUT	-
52	74	K9	K12	R15	93	52	74	K11	L11	P13	93	T2	74	93	R15	N13	PB13	I/O	FT_h	-	TIM1_CH1N, LPTIM3_IN1, LPTIM2_CH1, I2C2_SMBA, SPI2_SCK/I2S2_CK, USART3_CTS/USART3_NSS, FDCAN2_TX, UART5_TX, EVENTOUT	UCPD1_CC1
53	75	H9	J10	N15	94	53	75	H8	M13	R14	94	R3	75	94	N15	K11	PB14	I/O	FT_h	-	TIM1_CH2N, TIM12_CH1, TIM8_CH2N, USART1_TX, SPI2_MISO/I2S2_SDI, USART3_RTS/USART3_DE, UART4_RTS/UART4_DE, LPTIM3_ETR, EVENTOUT	UCPD1_CC2
54	76	J9	H10	M14	95	54	76	H9	J10	R15	95	P4	76	95	M14	M13	PB15	I/O	FT_ah	-	RTC_REFIN, TIM1_CH3N, TIM12_CH2, TIM8_CH3N, USART1_RX, SPI2_MOSI/I2S2_SDO, USART11_CTS/USART11_NSS, UART4_CTS, SDMMC2_D1, OCTOSPIM_P1_CLK, ETH_MII_TXD1/ETH_RMII_TXD1, LCD_G0, DCMI_D2/PSSI_D2, UART5_RX, EVENTOUT	PVD_IN

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
55	77	L11	J11	M15	96	55	77	J10	L12	P15	96	P2	77	96	M15	L12	PD8	I/O	FT_h	-	TIM12_CH2, I2S3_MCK, USART3_TX(boot), ETH_MII_RXD0/ETH_RMII_RXD0, FDCAN3_TX, SDMMC2_D0, FMC_D13/FMC_AD13, LCD_R5, PLAY1_IN4, EVENTOUT	-
56	78	K10	H9	L13	97	56	78	J11	J9	P14	97	N3	78	97	L13	P15	PD9	I/O	FT_h	-	TIM13_CH1, HDMI_CEC, USART3_RX(boot), FDCAN2_RX, FMC_D14/FMC_AD14, LCD_R4, PLAY1_OUT4, EVENTOUT	-
57	79	J10	K13	K12	98	57	79	K12	J11	N15	98	M4	79	98	K12	N14	PD10	I/O	FT_h	-	TIM14_CH1, LPTIM2_CH2, AUDIOCLK, USART3_CK, ETH_MII_CRS, FDCAN3_RX, FMC_D15/FMC_AD15, LCD_R7, PLAY1_IN5, EVENTOUT	-
58	80	K11	H8	L14	99	58	80	G8	H10	N14	99	L5	80	99	L14	N15	PD11	I/O	FT_h	-	ADF1_CCK0, SAI1_CK1, LPTIM2_IN2, I2C4_SMBA, GFXTIM_TE, USART3_CTS/USART3_NSS, UART4_RX, OCTOSPIM_P1_IO0, SAI2_SD_A, ETH_PTP_AUX_TS, FMC_A16/FMC_CLE, LCD_R6, PLAY1_OUT5, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
59	81	J11	H11	K14	100	59	81	H10	K12	N13	100	N1	81	100	K14	M14	PD12	I/O	FT_fh	-	LPTIM1_IN1, TIM4_CH1, LPTIM2_IN1, I2C4_SCL(boot), I3C1_SCL, SAI1_D1, USART3_RTS/USART3_DE, UART4_TX, OCTOSPIM_P1_IO1, SAI2_FS_A, LCD_G2, FMC_A17/FMC_ALE, DCMI_D12/PSSI_D12, PLAY1_IN6, EVENTOUT	-
60	82	L12	G8	L15	101	60	82	J12	K13	M15	101	M2	82	101	L15	L13	PD13	I/O	FT_fh	-	LPTIM1_CH1, TIM4_CH2, LPTIM2_CH1, I2C4_SDA(boot), I3C1_SDA, I2C1_SDA, OCTOSPIM_P1_IO3, SAI2_SCK_A, UART9_RTS/UART9_DE, FMC_A18, DCMI_D13/PSSI_D13, LPTIM4_IN1, EVENTOUT	-
-	83	-	-	H8	102	-	83	-	-	H9	102	-	83	102	J6	-	VSS	S	-	-	-	-
-	84	-	-	-	103	-	84	-	-	-	103	-	84	103	-	-	VDD	S	-	-	-	-
61	85	G9	H12	K13	104	61	85	H11	H11	M14	104	K6	85	104	K13	J11	PD14	I/O	FT_h	-	TIM4_CH3, PSSI_D15, SAI1_FS_A, UART8_CTS, OCTOSPIM_P2_CLK, UART9_RX, FMC_D0/FMC_AD0, LCD_B1, PLAY1_OUT6, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
62	86	H10	G10	J13	105	62	86	G9	H9	L14	105	L3	86	105	J13	K12	PD15	I/O	FT_h	-	TIM4_CH4, SAI1_FS_B, SPI6_RDY, UART8_RTS/UART8_DE, OCTOSPIM_P2_NCLK, UART9_TX, FMC_D1/FMC_AD1, LCD_CLK, PLAY1_IN7, EVENTOUT	-
-	-	-	-	H9	-	-	-	-	-	H10	-	-	-	-	J7	-	VSS	S	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M15	PK0	I/O	FT_h	-	SAI1_D2, TIM8_CH1, MDF1_SDI2, USART1_CK, OCTOSPIM_P2_IO2, LPTIM6_IN1, PLAY1_IN8, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L14	PK1	I/O	FT_h	-	SAI1_CK2, TIM8_CH1N, MDF1_CKI2, USART1_TX, OCTOSPIM_P2_IO3, LPTIM6_IN2, PLAY1_OUT6, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	K13	PK2	I/O	FT_h	-	TIM8_CH2, USART1_RX, OCTOSPIM_P2_IO4, LPTIM6_CH1, PLAY1_IN9, EVENTOUT	-
-	87	K12	H13	K15	106	-	87	H12	J12	L15	106	-	87	106	K15	L15	PG2	I/O	FT_h	-	TIM4_CH3, TIM8_BKIN, I2S1_MCK, UART12_RX, OCTOSPIM_P2_IO2, FMC_A12, LCD_R2, LPTIM6_ETR, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	88	J12	G9	H14	107	-	88	G10	G9	K15	107	-	88	107	H14	J12	PG3	I/O	FT_h	-	TIM4_CH4, TIM8_BKIN2, UART12_TX, OCTOSPIM_P2_IO3, ETH_MII_RX_ER, UART7_RX, FMC_A13, LPTIM5_ETR, LCD_G0, EVENTOUT	-
-	89	H11	G11	J15	108	-	89	G11	J13	K14	108	-	89	108	J15	K14	PG4	I/O	FT_h	-	TIM1_BKIN2, MDF1_CKI0, OCTOSPIM_P2_IO4, FMC_A14/FMC_BA0, LCD_VSYNC, LPTIM4_ETR, EVENTOUT	-
-	90	G10	F8	H15	109	-	90	G12	G10	K13	109	-	90	109	H15	K15	PG5	I/O	FT_h	-	TIM1_ETR, MDF1_SDI0, OCTOSPIM_P2_IO5, FMC_A15/FMC_BA1, LCD_HSYNC, PLAY1_OUT9, EVENTOUT	-
-	91	H12	G12	J14	110	-	91	F12	G11	J15	110	-	91	110	J14	J13	PG6	I/O	FT_fh	-	TIM17_BKIN, I3C1_SDA, I2C4_SDA, SPI1_RDY, OCTOSPIM_P2_NCS1, OCTOSPIM_P1_NCS1, UCPD1_FRSTX, FMC_NE3, DCMI_D12/PSSI_D12, PLAY1_OUT10, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number(1)																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	92	G11	F9	H13	111	-	92	F11	G8	J14	111	-	92	111	H13	H11	PG7	I/O	FT_fh	-	ADF1_CCK1, SAI1_CK2, I3C1_SCL, I2C4_SCL, SAI1_MCLK_A, USART6_CK, MDF1_CCK1, OCTOSPIM_P2_CLK, UCPD1_FRSTX, FMC_INT, DCMI_D13/PSSI_D13, LCD_R5, EVENTOUT	-
-	93	G12	G13	G15	112	-	93	F10	F11	H14	112	-	-	-	H12	J14	PG8	I/O	FT_h	-	TIM16_CH1N, TIM8_ETR, SPI6_NSS, USART6_RTS/USART6_DE, OCTOSPIM_P2_NCLK, ETH_PPS_OUT, FMC_SDCLK, LCD_B2, LPTIM4_OUT, EVENTOUT	-
-	94	-	-	H10	113	-	94	-	-	H12	113	-	93	112	J8	-	VSS	S	-	-	-	-
-	95	-	-	-	114	-	95	-	-	-	114	-	94	113	-	-	VDD	S	-	-	-	-
63	96	F11	F10	G14	115	63	96	F9	F9	H15	115	K4	-	-	G14	J15	PC6	I/O	FT_h	-	TIM3_CH1, TIM8_CH1, I2S2_MCK, SAI1_SCK_A, USART6_TX, SDMMC1_D0DIR, FMC_NWAIT, SDMMC2_D6, OCTOSPIM_P1_IO5, SDMMC1_D6, DCMI_D0/PSSI_D0, LCD_G0, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
64	97	F12	F11	G13	116	64	97	E12	F10	G15	116	J3	-	-	G13	H14	PC7	I/O	FT_h	-	TRGIO, TIM3_CH2, TIM8_CH2, I2S3_MCK, USART6_RX, SDMMC1_D123DIR, FMC_NE1, SDMMC2_D7, OCTOSPIM_P1_IO6, SDMMC1_D7, DCMI_D1/PSSI_D1, LCD_R1, EVENTOUT	-
65	98	F9	E9	F14	117	65	98	E11	G12	G14	117	H2	-	-	F14	H13	PC8	I/O	FT_h	-	TRACED1, TIM3_CH3, TIM8_CH3, USART6_CK, UART5_RTS/UART5_DE, FMC_NE2/FMC_NCE, FMC_INT, FMC_A17/FMC_ALE, SDMMC1_D0, DCMI_D2/PSSI_D2, LCD_R0, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	L1	95	114	H10	H12	VDD11USB	S	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	J1	96	115	G15	H15	OTG_HS_DM	I/O	TT_u	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	G1	97	116	F15	G15	OTG_HS_DP	I/O	TT_u	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	K2	98	117	G10	G12	VSSUSB	S	-	-	-	-
66	99	F10	F12	F13	118	66	99	E10	G13	F14	118	J5	99	118	F13	G14	PC9	I/O	FT_dfh	-	MCO2, TIM3_CH4, TIM8_CH4, I2C3_SDA(boot), AUDIOCLK, UART5_CTS, OCTOSPIM_P1_IO0, FMC_NCAS, FMC_A16/FMC_CLE, SDMMC1_D1, DCMI_D3/PSSI_D3, LCD_B1, EVENTOUT	UCPD1_DB2

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	-	-	-	J7	-	-	-	-	-	J8	-	-	-	-	J9	-	VSS	S	-	-	-	-
67	100	E11	E10	F15	119	67	100	D12	F12	F15	119	H4	100	119	D14	G11	PA8	I/O	FT_fh	-	MCO1, TIM1_CH1, TIM8_BKIN2, I2C3_SCL(boot), SPI1_RDY, USART1_CK, OCTOSPIM_P2_DQS, OTG_FS_SOF, UART7_RX, FMC_NOE, DCMI_D3/PSSI_D3, LCD_CLK, EVENTOUT	-
68	101	E12	F13	E15	120	68	101	D11	E11	E15	120	G3	101	120	E15	G13	PA9	I/O	FT_dh	-	TIM1_CH2, LPUART1_TX, I2C3_SMBA, SPI2_SCK/I2S2_CK, USART1_TX(boot), OCTOSPIM_P2_IO3, ETH_MII_TX_ER, FMC_NWE, DCMI_D0/PSSI_D0, LCD_R7, EVENTOUT	UCPD1_DB1
69	102	E10	E11	E14	121	69	102	B12	E10	D15	121	F2	102	121	E14	F13	PA10	I/O	FT_h	-	DMA2D_GPFLAG1, TIM1_CH3, LPUART1_RX, LPTIM2_IN2, UCPD1_FRSTX, USART1_RX(boot), FDCAN2_TX, ETH_CLK, SDMMC1_D0, DCMI_D1/PSSI_D1, LCD_R6, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
70	103	D12	C13	D15	122	70	103	C12	F13	C15	122	E1	103	122	D15	F15	PA11	I/O	FT_hu	-	DMA2D_GPFLAG2, TIM1_CH4, LPUART1_CTS, SPI2_NSS/I2S2_WS, UART4_RX, USART1_CTS/USART1_NSS, FDCAN1_RX, FMC_A17/FMC_ALE, LCD_R5, EVENTOUT	OTG_FS_DM(boot)
71	104	D11	B13	C15	123	71	104	C11	E13	B15	123	C1	104	123	C15	F14	PA12	I/O	FT_hu	-	DMA2D_GPFLAG3, TIM1_ETR, LPUART1_RTS/LPUART1_DE, SPI2_SCK/I2S2_CK, UART4_TX, USART1_RTS/USART1_DE, SAI2_FS_B, FDCAN1_TX, SDMMC2_D4, LCD_R4, EVENTOUT	OTG_FS_DP(boot)
72	105	C12	D12	E13	124	72	105	E9	E12	A15	124	D2	105	124	E13	F12	PA13	I/O	FT_h	(5)	JTMS/SWDIO, EVENTOUT	-
73	106	E9	E13	F12	125	73	106	C10	D13	H13	125	A1	106	125	F12	F11	VDDUSB	S	-	-	-	-
74	107	-	-	J8	126	74	107	-	-	J9	126	B2	107	126	J10	-	VSS	S	-	-	-	-
-	-	-	-	J10	-	-	-	-	-	K6	-	-	-	-	K6	-	VSS	S	-	-	-	-
75	108	-	-	-	127	75	108	-	-	-	127	A3	108	127	-	-	VDD	S	-	-	-	-
-	-	-	C12	B15	128	-	-	-	D12	E12	128	-	-	128	B15	E15	PH13	I/O	FT_h	-	LPTIM1_IN2, TIM8_CH1N, UART8_TX, UART4_TX, FDCAN1_TX, OCTOSPIM_P2_IO5, FMC_D22, DCMI_D3/PSSI_D3, LCD_R3, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	-	-	D11	D13	129	-	-	-	D10	E13	129	-	-	129	D13	E14	PH14	I/O	FT_h	-	TIM8_CH2N, MDF1_CKI3, UART4_RX, FDCAN1_RX, OCTOSPIM_P2_IO6, FMC_D23, DCMI_D4/PSSI_D4, LCD_R6, EVENTOUT	-
-	-	-	A13	C14	130	-	-	-	D11	D13	130	-	-	130	C14	E13	PH15	I/O	FT_h	-	TRACECLK, TIM8_CH3N, MDF1_SDI3, SDMMC2_CKIN, OCTOSPIM_P2_IO7, FMC_D24, DCMI_D11/PSSI_D11, LCD_G1, EVENTOUT	-
-	-	-	B12	-	131	-	-	-	B13	E14	131	-	-	131	-	E12	PI0	I/O	FT_h	-	TIM5_CH4, SPI2_NSS/I2S2_WS, USART11_CK, DCMI_D13/PSSI_D13, LCD_B1, EVENTOUT	-
-	-	-	C11	A15	132	-	-	-	B12	D14	132	-	-	132	A15	D15	PI1	I/O	FT_h	-	TRACED0, TIM1_BKIN2, TIM8_BKIN2, MDF1_CKI4, SPI2_SCK/I2S2_CK, SDMMC2_D0, FMC_A24, FMC_D25, DCMI_D8/PSSI_D8, EVENTOUT	-
-	-	-	D10	B14	133	-	-	-	A13	C14	133	-	-	133	B14	F10	PI2	I/O	FT_h	-	TRACED1, TIM1_ETR, TIM8_CH4, MDF1_SDI4, SPI2_MISO/I2S2_SDI, SDMMC2_D1, FMC_D26, DCMI_D9/PSSI_D9, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	-	-	A12	A14	134	-	-	-	C11	C13	134	-	-	134	A14	D14	PI3	I/O	FT_h	-	TRACED2, TIM1_CH1N, TIM8_ETR, SPI2_MOSI/I2S2_SDO, SDMMC2_D2, FMC_D27, DCMI_D10/PSSI_D10, LCD_DE, EVENTOUT	-
-	-	-	-	K6	135	-	-	-	-	K8	135	-	-	135	K8	-	VSS	S	-	-	-	-
-	-	-	-	-	136	-	-	-	-	-	136	-	-	136	-	-	VDD	S	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	D13	PJ10	I/O	FT_h	-	TIM5_CH4, UART5_RX, SAI2_FS_A, LCD_HSYNC, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C14	PJ11	I/O	FT_h	-	TIM5_ETR, LPTIM1_ETR, UART5_TX, SAI2_SCK_A, LCD_VSYNC, EVENTOUT	-
76	109	D9	C10	B13	137	76	109	B11	A12	A14	137	E3	109	137	B13	C15	PA14	I/O	FT_h	(5)	JTCK/SWCLK, EVENTOUT	-
77	110	D10	B10	C13	138	77	110	E8	B11	A13	138	C3	110	138	C13	C13	PA15	I/O	FT_h	(5)	JTDI, TIM2_CH1, LPTIM3_IN2, HDMI_CEC, SPI1_NSS/I2S1_WS, I2S3_WS/SPI3_NSS, SPI6_NSS, UART4_RTS/UART4_DE, OCTOSPIM_P2_IO6, ETH_PHY_INTN, UART7_TX, FMC_NBL1, DCMI_D11/PSSI_D11, TIM2_ETR, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number(1)																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
78	111	C11	A10	D12	139	78	111	A11	C10	B14	139	F4	111	139	D12	D12	PC10	I/O	FT_h	-	GFXTIM_LCKCAL, LPTIM3_ETR, SAI1_SCK_B, I2S3_CK/SPI3_SCK, USART3_TX, UART4_TX, OCTOSPIM_P1_IO1, ETH_MII_TXD0/ETH_RMII_TXD0, SDMMC1_D2, DCMI_D8/PSSI_D8, LCD_B0, EVENTOUT	-
79	112	B12	A9	C12	140	79	112	D9	A11	B13	140	G5	112	140	C12	B14	PC11	I/O	FT_h	-	GFXTIM_FCKCAL, LPTIM3_IN1, COMP1_OUT, I2S3_SDI/SPI3_MISO, USART3_RX, UART4_RX, OCTOSPIM_P1_NCS1, LCD_VSYNC, SDMMC1_D3, DCMI_D4/PSSI_D4, PLAY1_IN0, EVENTOUT	-
80	113	D8	D9	C11	141	80	113	B10	B9	A12	141	D4	113	141	C11	B15	PC12	I/O	FT_h	-	TRACED3, TIM15_CH1, COMP2_OUT, SPI6_SCK, I2S3_SDO/SPI3_MOSI, USART3_CK, UART5_TX, OCTOSPIM_P2_IO7, ETH_PPS_OUT, LCD_G4, SDMMC1_CK, DCMI_D9/PSSI_D9, PLAY1_OUT0, EVENTOUT	-
-	-	-	-	K7	-	-	-	-	-	K9	-	-	-	-	K9	-	VSS	S	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	VDD	S	-	-	-	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
81	114	B11	C9	B12	142	81	114	D8	D9	B12	142	H6	114	142	B12	E10	PD0	I/O	FT_h	-	TIM8_CH4N, I2S1_MCK, SDMMC1_D0DIR, UART4_RX, FDCAN1_RX, OCTOSPIM_P1_NCS2, UART9_CTS, FMC_D2/FMC_AD2, LCD_R2, PLAY1_IN1, EVENTOUT	-
82	115	C10	B9	A13	143	82	115	C9	E9	C12	143	E5	115	143	A13	C12	PD1	I/O	FT_h	-	I2S2_MCK, SAI1_MCLK_B, SDMMC1_D123DIR, UART4_TX, FDCAN1_TX, OCTOSPIM_P2_DQS, ETH_MII_RX_DV/ETH_RMII_CRS_DV, FMC_D3/FMC_AD3, LCD_DE, PLAY1_OUT1, EVENTOUT	-
83	116	C9	E8	C10	144	83	116	A10	C9	D12	144	B4	116	144	C10	D11	PD2	I/O	FT_fh	-	TRACED2, TIM3_ETR, TIM15_BKIN, I3C2_SCL, I2C2_SCL, UART5_RX, OCTOSPIM_P1_NCS2, OCTOSPIM_P2_IO1, LCD_G7, SDMMC1_CMD, DCMI_D11/PSSI_D11, LPTIM4_ETR, EVENTOUT	WKUP7
84	117	A11	C8	A12	145	84	117	B9	A9	D11	145	F6	117	145	A12	A14	PD3	I/O	FT_h	-	TIM8_CH4, SPI2_SCK/I2S2_CK, USART2_CTS/USART2_NSS, OCTOSPIM_P2_IO0, LCD_B4, FMC_CLK, DCMI_D5/PSSI_D5, PLAY1_IN2, EVENTOUT	WKUP8

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number(1)																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
85	118	B10	D8	B11	146	85	118	A9	F8	D10	146	C5	118	146	B11	B13	PD4	I/O	FT_h	-	TRGIO, COMP1_OUT, USART2_RTS/USART2_DE, MDF1_CKI3, OCTOSPIM_P1_IO4, ETH_CLK, FMC_NOE, LCD_B7, PLAY1_OUT2, EVENTOUT	-
86	119	A10	A7	A11	147	86	119	C8	D8	C11	147	A5	119	147	A11	B12	PD5	I/O	FT_h	-	TIM1_CH4N, COMP2_OUT, SPI2_RDY, ETH_MII_CRS, USART2_TX, UART8_RX, FDCAN1_TX, OCTOSPIM_P1_IO5, FMC_NWE, LCD_B2, PLAY1_IN3, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A13	PJ12	I/O	FT_h	-	SAI1_SD_A, I2S2_MCK, USART11_CTS/USART11_NSS, MDF1_CKI0, FDCAN3_TX, LCD_G7, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C11	PJ13	I/O	FT_h	-	TIM17_CH1N, I2C3_SMBA, USART11_RTS/USART11_DE, MDF1_SDI0, FDCAN3_RX, LCD_B5, EVENTOUT	-
-	-	-	-	K8	-	-	-	-	-	K10	-	-	-	-	K10	-	VSS	S	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	D10	PJ14	I/O	FT_fh	-	TIM16_BKIN, SAI1_SD_A, I2C3_SCL, USART10_CTS/USART10_NSS, ETH_MII_TXD0/ETH_RMII_TXD0, LCD_R6, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																		Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx													STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	E9	PJ15	I/O	FT_fh	-	TIM16_CH1, I2C3_SDA, USART10_RTS/USART10_DE, ETH_MII_TXD1/ETH_RMII_TXD1, LCD_G6, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A12	PK3	I/O	FT_h	-	TIM8_CH2N, USART1_CTS/USART1_NSS, SDMMC1_D0, FDCAN2_TX, PLAY1_IN10, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	B11	PK4	I/O	FT_h	-	TIM8_CH3, SPI4_RDY, USART1_RTS/USART1_DE, SDMMC1_D1, FDCAN2_RX, PLAY1_OUT7, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C10	PK5	I/O	FT_h	-	TIM8_CH3N, SPI4_SCK, SDMMC1_D2, LCD_G3, PLAY1_IN11, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A11	PK6	I/O	FT_h	-	TIM8_CH4, SPI4_NSS, SDMMC1_D3, LCD_G4, PLAY1_IN12, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	B10	PK7	I/O	FT_h	-	TIM8_CH4N, SPI4_MISO, SDMMC1_CMD, PLAY1_OUT8, EVENTOUT	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	D9	PK8	I/O	FT_h	-	TIM8_ETR, SPI4_MOSI, SDMMC1_CK, PLAY1_IN13, EVENTOUT	-
-	120	-	-	K9	148	-	120	-	-	L4	148	-	120	148	M4	-		VSS	S	-	-	-	-
-	121	E7	A6	D7	149	-	121	C5	A7	C8	149	-	121	149	D7	D7		VDDIO2	S	-	-	-	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
87	122	D7	F7	B10	150	87	122	B8	E8	B11	150	B6	122	150	B10	A10	PD6	I/O	FT_sfh	-	ADF1_SDI0, SAI1_D1, I2C3_SDA, SPI3_MOSI/I2S3_SDO, SAI1_SD_A, USART2_RX, MDF1_SDI1, OCTOSPIM_P2_IO4, OCTOSPIM_P1_IO6, SDMMC2_CK, FMC_NWAIT, DCMI_D10/PSSI_D10, PLAY1_OUT3, EVENTOUT	-
88	123	A9	B7	A10	151	88	123	A8	B8	A11	151	D6	123	151	A10	C9	PD7	I/O	FT_sfh	-	TIM12_CH1, I2C3_SCL, SPI1_MOSI/I2S1_SDO, USART2_CK, OCTOSPIM_P1_IO7, SDMMC2_CMD, FMC_NE1/FMC_NCE, LCD_R3, LPTIM4_OUT, EVENTOUT	-
-	124	C8	E7	B9	152	-	124	D7	F7	C10	152	-	124	152	B9	B9	PG9	I/O	FT_sh	-	TIM12_CH1, SPI1_MISO/I2S1_SDI, USART10_RX, USART6_RX, OCTOSPIM_P1_IO4, OCTOSPIM_P1_IO6, SAI2_FS_B, SDMMC2_D0, FMC_NE2/FMC_NCE, DCMI_VSYNC/PSSI_RDY, LCD_B5, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	125	B9	C7	A9	153	-	125	B7	A8	B10	153	-	125	153	A9	A9	PG10	I/O	FT_sh	-	TIM12_CH2, I2C3_SMBA, SPI1_NSS/I2S1_WS, USART10_CK, USART6_CK, OCTOSPIM_P1_IO5, OCTOSPIM_P2_IO6, SAI2_SD_B, SDMMC2_D1, FMC_NE3, DCMI_D2/PSSI_D2, LCD_B6, EVENTOUT	-
-	-	-	-	C9	154	-	126	A7	E7	B9	154	-	126	154	C9	D8	PG11	I/O	FT_sh	-	LPTIM1_IN2, SPI1_SCK/I2S1_CK, USART10_RX, USART11_RTS/USART11_DE, SDMMC2_D2, ETH_MII_TX_EN/ETH_RMII_TX_EN, DCMI_D3/PSSI_D3, LCD_B4, EVENTOUT	-
-	126	B8	D7	B8	155	-	127	A6	C8	B8	155	-	127	155	B8	C8	PG12	I/O	FT_sh	-	LPTIM1_IN1, LPTIM2_CH1, PSSI_D15, SPI6_MISO, USART10_TX, USART6_RTS/USART6_DE, FMC_SDCLK, OCTOSPIM_P2_CLK, SDMMC2_D3, ETH_MII_TXD1/ETH_RMII_TXD1, FMC_NE4, DCMI_D11/PSSI_D11, LPTIM5_CH1, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	127	C7	-	C8	156	-	128	D6	D7	A8	156	-	128	156	C8	B8	PG13	I/O	FT_sh	-	TRACED0, LPTIM1_CH1, SPI6_SCK, USART10_CTS/USART10_NSS, USART6_CTS/USART6_NSS, OCTOSPIM_P2_NCS1, SDMMC2_D6, ETH_MII_TXD0/ETH_RMII_TXD0, FMC_A24, LPTIM5_CH2, LCD_G4, EVENTOUT	-
-	128	A8	-	A8	157	-	129	B6	C7	A7	157	-	129	157	A8	A8	PG14	I/O	FT_sh	-	TRACED1, LPTIM1_ETR, LPTIM1_CH2, SPI6_MOSI, USART10_RTS/USART10_DE, USART6_TX, OCTOSPIM_P1_IO7, SDMMC2_D7, ETH_MII_TXD1/ETH_RMII_TXD1, FMC_A25, LPTIM5_IN1, LCD_B0, EVENTOUT	-
-	129	-	-	K10	158	-	130	-	-	M8	158	-	130	158	M7	-	VSS	S	-	-	-	-
-	130	-	-	-	159	-	131	-	-	-	159	-	131	159	-	-	VDD	S	-	-	-	-
-	131	B7	B6	A7	160	-	132	A5	B6	B7	160	-	132	160	A7	A7	PG15	I/O	FT_h	-	TIM16_CH1, SPI4_RDY, USART10_CK, USART6_CTS/USART6_NSS, OCTOSPIM_P2_IO7, FMC_NCAS, DCMI_D13/PSSI_D13, LCD_G2, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
89	132	A7	F6	B7	161	89	133	B5	E6	A10	161	C7	133	161	B7	B7	PB3	I/O	FT_fh	-	JTDO/TRACESWO, TIM2_CH2, I3C2_SDA, I2C2_SDA, SPI1_SCK/I2S1_CK, I2S3_CK/SPI3_SCK, UART12_CTS, SPI6_SCK, SDMMC2_D2, CRS_SYNC, UART7_RX, ETH_MDC, LCD_HSYNC, LPTIM6_ETR, EVENTOUT	-
90	133	C6	A5	C7	162	90	134	A4	A6	A9	162	A7	134	162	C7	C7	PB4	I/O	FT_h	(5)	NJTRST, TIM16_BKIN, TIM3_CH1, OCTOSPIM_P1_CLK, LPTIM1_CH2, SPI1_MISO/I2S1_SDI, I2S3_SDI/SPI3_MISO, SPI2_NSS/I2S2_WS, SPI6_MISO, SDMMC2_D3, ETH_MDIO, UART7_TX, FMC_NBL3, DCMI_D7/PSSI_D7, LCD_R2, EVENTOUT	-
91	134	A6	E6	A6	163	91	135	E6	C6	A6	163	E7	135	163	A6	E7	PB5	I/O	FT_h	-	GFXTIM_LCKCAL, TIM17_BKIN, TIM3_CH2, OCTOSPIM_P1_NCLK, I2C1_SMBA, SPI1_MOSI/I2S1_SDO, I2C4_SMBA, SPI3_MOSI/I2S3_SDO, SPI6_MOSI, FDCAN2_RX, OCTOSPIM_P2_CLK, ETH_PPS_OUT, FMC_SDCKE1, DCMI_D10/PSSI_D10, UART5_RX, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
92	135	B6	C6	B6	164	92	136	B4	A5	B6	164	G7	136	164	B6	E8	PB6	I/O	FT_fh	-	GFXTIM_FCKCAL, TIM16_CH1N, TIM4_CH1, I3C1_SCL(boot), I2C1_SCL, HDMI_CEC, I2C4_SCL, USART1_TX, LPUART1_TX, FDCAN2_TX, OCTOSPIM_P1_NCS1, ETH_MII_TX_ER, FMC_SDNE1, DCMI_D5/PSSI_D5, UART5_TX, EVENTOUT	-
93	136	D6	D6	C6	165	93	137	A3	D6	B5	165	J7	137	165	C6	A6	PB7	I/O	FT_fh	-	TIM17_CH1N, TIM4_CH2, I3C1_SDA(boot), I2C1_SDA, I2C4_SDA, USART1_RX, LPUART1_RX, FDCAN1_TX, SDMMC2_D5, SDMMC2_CKIN, FMC_NL, DCMI_VSYNC/PSSI_RDY, LCD_G7, EVENTOUT	WKUP5
94	137	B5	B5	A5	166	94	138	C4	B5	D6	166	B8	138	166	A5	B6	BOOT0	I	B	-	-	-
95	138	C5	F5	B5	167	95	139	B3	E5	A5	167	D8	139	167	B5	C6	PB8	I/O	FT_sfh	(2)	TIM16_CH1, TIM4_CH3, I3C1_SCL, I2C1_SCL, SPI4_RDY, I2C4_SCL, SDMMC1_CKIN, UART4_RX, FDCAN1_RX, SDMMC2_D4, ETH_MII_TXD3, SDMMC1_D4, DCMI_D6/PSSI_D6, LCD_G6, EVENTOUT	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) [2][3]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
96	139	A5	E5	A4	168	96	140	A2	A4	B4	168	F8	140	168	A4	A5	PB9	I/O	FT_sfh	(2)	TIM17_CH1, TIM4_CH4, I3C1_SDA, I2C1_SDA, SPI2_NSS/I2S2_WS, I2C4_SDA, SDMMC1_CDIR, UART4_TX, FDCAN1_TX, SDMMC2_D5, SDMMC2_CKIN, SDMMC1_D5, DCMI_D7/PSSI_D7, LCD_G5, EVENTOUT	-
97	140	A4	D5	C5	169	97	141	B2	C5	A4	169	H8	141	169	C5	D6	PE0	I/O	FT_h	-	LPTIM1_ETR, TIM4_ETR, LPTIM2_CH2, LPTIM2_ETR, SPI3_RDY, UART8_RX, FDCAN1_RX, SAI2_MCLK_A, OCTOSPIM_P1_NCS2, FMC_NBL0, DCMI_D2/PSSI_D2, PLAY1_OUT7, EVENTOUT	-
-	141	-	C5	B4	170	-	-	-	D5	A3	170	-	-	170	B4	B5	PE1	I/O	FT_h	-	LPTIM1_IN2, UART8_TX, FDCAN1_TX, FMC_NWAIT, FMC_NBL1, DCMI_D3/PSSI_D3, PLAY1_IN8, EVENTOUT	-
98	142	D5	A4	A3	171	98	142	D5	B4	C6	171	A9	142	171	A3	E6	VCAP	S	-	-	-	-
99	143	-	-	M7	-	99	143	-	-	-	-	-	143	-	-	-	VSS	S	-	-	-	-
100	144	-	-	-	172	100	144	-	-	-	172	-	144	172	-	-	VDD	S	-	-	-	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	-	-	C4	B3	173	-	-	-	C4	D4	173	-	-	173	B3	C5	PI4	I/O	FT_h	-	TRACED3, TIM1_CH1, TIM8_BKIN, SPI2_RDY, SDMMC2_D3, SAI2_MCLK_A, FMC_D28, DCMI_D5/PSSI_D5, EVENTOUT	-
-	-	-	B3	A2	174	-	-	-	-	C4	174	-	-	174	A2	A4	PI5	I/O	FT_h	-	TIM1_CH2N, TIM8_CH1, I2S1_MCK, SAI2_SCK_A, DCMI_VSYNC/PSSI_RDY, LCD_R0, EVENTOUT	-
-	-	-	A2	C4	175	-	-	-	C3	C3	175	-	-	175	C4	A3	PI6	I/O	FT_h	-	TIM1_CH2, TIM8_CH2, MDF1_CKI5, SDMMC2_CMD, SAI2_SD_A, FMC_D29, DCMI_D6/PSSI_D6, EVENTOUT	-
-	-	-	A1	A1	176	-	-	-	A2	C2	176	-	-	176	A1	B4	PI7	I/O	FT_h	-	TIM1_CH3N, TIM8_CH3, MDF1_SDI5, SDMMC2_CK, SAI2_FS_A, FMC_D30, DCMI_D7/PSSI_D7, EVENTOUT	-
-	-	-	-	G12	-	-	-	-	-	G9	-	-	-	-	H7	L11	VSS	S	-	-	-	-
-	-	-	-	H6	-	-	-	-	-	G10	-	-	-	-	H8	R1	VSS	S	-	-	-	-
-	-	-	-	H12	-	-	-	-	-	H6	-	-	-	-	K7	-	VSS	S	-	-	-	-
-	-	-	-	J6	-	-	-	-	-	H7	-	-	-	-	M9	-	VSS	S	-	-	-	-
-	-	-	-	J9	-	-	-	-	-	J6	-	-	-	-	K1	-	VSS	S	-	-	-	-
-	-	-	-	K1	-	-	-	-	-	J7	-	-	-	-	-	-	VSS	S	-	-	-	-
-	-	-	-	M4	-	-	-	-	-	J10	-	-	-	-	-	-	VSS	S	-	-	-	-

Table 13. STM32H5Exxx pin/ball definition (continued)

Pin number[1]																	Pin name (function after reset) (2)(3)	Pin type	I/O structure	Notes	Alternate functions	Additional functions
STM32H5E4xx												STM32H5E5xx										
LQFP100 SMPS	LQFP144 SMPS	UFBGA144 SMPS	UFBGA169 SMPS	UFBGA176+25 SMPS	LQFP176 SMPS	LQFP100	LQFP144	UFBGA144	UFBGA169	UFBGA176+25	LQFP176	WLCSP105 SMPS	LQFP144	LQFP176 SMPS	UFBGA176+25 SMPS	TFBGA225 SMPS						
-	-	-	-	M9	-	-	-	-	-	K7	-	-	-	-	-	-	VSS	S	-	-	-	-
-	-	-	-	-	-	-	-	-	-	M9	-	-	-	-	-	-	VSS	S	-	-	-	-

1. The devices with SMPS correspond to the commercial code STM32H5xxxIxxQ.
2. PC13, PC14, and PC15 are supplied through the power switch (by V_{SW}). This switch sinks a limited amount of current, hence the use of PC13 to PC15 GPIOs in output mode is limited: The speed must not exceed 2 MHz with a maximum load of 30 pF. These GPIOs must not be used as current sources (for example to drive a LED).
3. After a backup domain power-up, PC13, PC14, and PC15 operate as GPIOs. Their function depends upon the content of the RTC registers that are not reset by the system reset. For details on how to manage these GPIOs, refer to the backup domain and RTC register descriptions in the product reference manual.
4. As a tamper input, only PC13, PI8, PA0, PA1, and PA2 are functional in standby and VBAT mode. As a tamper output, only PC13, PA1, and PI8 are functional in standby and VBAT mode.
5. After reset, these pins are configured as JTAG/SW debug alternate functions. The internal pull-up on PA15, PA13, PB4 pins and the internal pull-down on PA14 pin are activated too.

4.3 Alternate functions

Table 14. Alternate function AF0 to AF7

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
		GFXTIM/SYS	ADF1/LPTIM1/ TIM1/2	LPTIM3/SAI1/ TIM1/2/3/4/5	ADF1/COMP1/2/ I2C3/I3C1/2/ LPTIM2/3/ LPUART1/ OCTOSPIM_P1_/ TIM1/8	ADF1/DCMI/PSSI/ HDMI_CEC/ I2C1/2/3/4/ LPTIM1/2/MDF1/ SAI1/SPI1/I2S1/ TIM1/USART1	GFXTIM/ HDMI_CEC/I3C1/2/ LPTIM1/SPI1/I2S1/ SPI2/I2S2/SPI3/ I2S3/SPI4/5/SPI6/ I2S6/SYS/USART2	ETH_/I2C1/2/4/ OCTOSPIM_P1_/ SAI1/SPI3/I2S3/ SPI4/UART4/12/ UCPD1_/ USART1/10	ETH_/SDMMC1/ SPI2/I2S2/SPI3/ I2S3/SPI6/I2S6/ UART7/8/12/ USART1/2/3/6/10/11
Port A	PA0	-	TIM2_CH1	TIM5_CH1	TIM8_ETR	TIM15_BKIN	SPI6_NSS	SPI3_RDY	USART2_CTS/USART2_NSS
	PA1	-	TIM2_CH2	TIM5_CH2	-	TIM15_CH1N	LPTIM1_IN1	OCTOSPIM_P1_DQS	USART2_RTS/USART2_DE
	PA2	-	TIM2_CH3	TIM5_CH3	-	TIM15_CH1	LPTIM1_IN2	-	USART2_TX
	PA3	DMA2D_GPFLAG0	TIM2_CH4	TIM5_CH4	OCTOSPIM_P1_CLK	TIM15_CH2	SPI2_NSS/I2S2_WS	SAI1_SD_B	USART2_RX
	PA4	-	-	TIM5_ETR	LPTIM2_CH1	-	SPI1_NSS/I2S1_WS	I2S3_WS/SPI3_NSS	USART2_CK
	PA5	-	TIM2_CH1	-	TIM8_CH1N	-	SPI1_SCK/I2S1_CK	-	-
	PA6	-	TIM1_BKIN	TIM3_CH1	TIM8_BKIN	-	SPI1_MISO/I2S1_SDI	OCTOSPIM_P1_IO3	USART11_TX
	PA7	-	TIM1_CH1N	TIM3_CH2	TIM8_CH1N	-	SPI1_MOSI/I2S1_SDO	-	USART11_RX
	PA8	MCO1	TIM1_CH1	-	TIM8_BKIN2	I2C3_SCL	SPI1_RDY	-	USART1_CK
	PA9	-	TIM1_CH2	-	LPUART1_TX	I2C3_SMBA	SPI2_SCK/I2S2_CK	-	USART1_TX
	PA10	DMA2D_GPFLAG1	TIM1_CH3	-	LPUART1_RX	LPTIM2_IN2	-	UCPD1_FRSTX	USART1_RX
	PA11	DMA2D_GPFLAG2	TIM1_CH4	-	LPUART1_CTS	-	SPI2_NSS/I2S2_WS	UART4_RX	USART1_CTS/USART1_NSS
	PA12	DMA2D_GPFLAG3	TIM1_ETR	-	LPUART1_RTS/LPUART1_DE	-	SPI2_SCK/I2S2_CK	UART4_TX	USART1_RTS/USART1_DE
	PA13	JTMS/SWDIO	-	-	-	-	-	-	-
	PA14	JTCK/SWCLK	-	-	-	-	-	-	-
	PA15	JTDI	TIM2_CH1	LPTIM3_IN2	-	HDMI_CEC	SPI1_NSS/I2S1_WS	I2S3_WS/SPI3_NSS	SPI6_NSS

Table 14. Alternate function AF0 to AF7 (continued)

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
		GFXTIM/SYS	ADF1/LPTIM1/ TIM1/2	LPTIM3/SAI1/ TIM1/2/3/4/5	ADF1/COMP1/2/ I2C3/I3C1/2/ LPTIM2/3/ LPUART1/ OCTOSPIM_P1_/ TIM1/8	ADF1/DCMI/PSSI/ HDMI_CEC/ I2C1/2/3/4/ LPTIM1/2/MDF1/ SAI1/SPI1/I2S1/ TIM1/USART1	GFXTIM/ HDMI_CEC/I3C1/2/ LPTIM1/SPI1/I2S1/ SPI2/I2S2/SPI3/ I2S3/SPI4/5/SPI6/ I2S6/SYS/USART2	ETH_/I2C1/2/4/ OCTOSPIM_P1_/ SAI1/SPI3/I2S3/ SPI4/UART4/12/ UCPD1_/ USART1/10	ETH_/SDMMC1/ SPI2/I2S2/SPI3/ I2S3/SPI6/I2S6/ UART7/8/12/ USART1/2/3/6/10/11
Port B	PB0	-	TIM1_CH2N	TIM3_CH3	TIM8_CH2N	-	-	OCTOSPIM_P1_IO1	USART11_CK
	PB1	-	TIM1_CH3N	TIM3_CH4	TIM8_CH3N	-	-	OCTOSPIM_P1_IO0	-
	PB2	RTC_OUT2	ADF1_SDI0	SAI1_D1	TIM8_CH4N	SPI1_RDY	LPTIM1_CH1	SAI1_SD_A	SPI3_MOSI/I2S3_SDO
	PB3	JTDO/TRACESWO	TIM2_CH2	-	I3C2_SDA	I2C2_SDA	SPI1_SCK/I2S1_CK	I2S3_CK/SPI3_SCK	UART12_CTS
	PB4	NJTRST	TIM16_BKIN	TIM3_CH1	OCTOSPIM_P1_CLK	LPTIM1_CH2	SPI1_MISO/I2S1_SDI	I2S3_SDI/SPI3_MISO	SPI2_NSS/I2S2_WS
	PB5	GFXTIM_LCKCAL	TIM17_BKIN	TIM3_CH2	OCTOSPIM_P1_NCLK	I2C1_SMBA	SPI1_MOSI/I2S1_SDO	I2C4_SMBA	SPI3_MOSI/I2S3_SDO
	PB6	GFXTIM_FCKCAL	TIM16_CH1N	TIM4_CH1	I3C1_SCL	I2C1_SCL	HDMI_CEC	I2C4_SCL	USART1_TX
	PB7	-	TIM17_CH1N	TIM4_CH2	I3C1_SDA	I2C1_SDA	-	I2C4_SDA	USART1_RX
	PB8	-	TIM16_CH1	TIM4_CH3	I3C1_SCL	I2C1_SCL	SPI4_RDY	I2C4_SCL	SDMMC1_CKIN
	PB9	-	TIM17_CH1	TIM4_CH4	I3C1_SDA	I2C1_SDA	SPI2_NSS/I2S2_WS	I2C4_SDA	SDMMC1_CDIR
	PB10	-	TIM2_CH3	LPTIM3_CH1	LPTIM2_IN1	I2C2_SCL	SPI2_SCK/I2S2_CK	-	USART3_TX
	PB11	-	TIM2_CH4	-	LPTIM2_ETR	I2C2_SDA	SPI2_RDY	SPI4_RDY	USART3_RX
	PB12	-	TIM1_BKIN	-	OCTOSPIM_P1_NCLK	I2C2_SDA	SPI2_NSS/I2S2_WS	UCPD1_FRSTX	USART3_CK
	PB13	-	TIM1_CH1N	LPTIM3_IN1	LPTIM2_CH1	I2C2_SMBA	SPI2_SCK/I2S2_CK	-	USART3_CTS/USART3_NSS
	PB14	-	TIM1_CH2N	TIM12_CH1	TIM8_CH2N	USART1_TX	SPI2_MISO/I2S2_SDI	-	USART3_RTS/USART3_DE
	PB15	RTC_REFIN	TIM1_CH3N	TIM12_CH2	TIM8_CH3N	USART1_RX	SPI2_MOSI/I2S2_SDO	-	USART11_CTS/USART11_NSS

Table 14. Alternate function AF0 to AF7 (continued)

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
		GFXTIM/SYS	ADF1/LPTIM1/ TIM1/2	LPTIM3/SAI1/ TIM1/2/3/4/5	ADF1/COMP1/2/ I2C3/I3C1/2/ LPTIM2/3/ LPUART1/ OCTOSPIM_P1_/ TIM1/8	ADF1/DCMI/PSSI/ HDMI_CEC/ I2C1/2/3/4/ LPTIM1/2/MDF1/ SAI1/SPI1/I2S1/ TIM1/USART1	GFXTIM/ HDMI_CEC/I3C1/2/ LPTIM1/SPI1/I2S1/ SPI2/I2S2/SPI3/ I2S3/SPI4/5/SPI6/ I2S6/SYS/USART2	ETH_/I2C1/2/4/ OCTOSPIM_P1_/ SAI1/SPI3/I2S3/ SPI4/UART4/12/ UCPD1_/ USART1/10	ETH_/SDMMC1/ SPI2/I2S2/SPI3/ I2S3/SPI6/I2S6/ UART7/8/12/ USART1/2/3/6/10/11
Port C	PC0	-	TIM16_BKIN	-	TIM8_CH1	MDF1_CKI1	-	SAI1_MCLK_A	SPI2_RDY
	PC1	TRACED0	ADF1_SDI0	SAI1_D1	TIM8_CH2	MDF1_SDI1	SPI2_MOSI/I2S2_SDO	SAI1_SD_A	USART11_RTS/USART11_DE
	PC2	PWR_CSLEEP	TIM17_CH1	TIM4_CH4	TIM8_CH3	-	SPI2_MISO/I2S2_SDI	OCTOSPIM_P1_IO5	-
	PC3	PWR_CSTOP	-	SAI1_D3	LPTIM3_CH1	-	SPI2_MOSI/I2S2_SDO	OCTOSPIM_P1_IO6	-
	PC4	-	TIM2_CH4	SAI1_CK1	LPTIM2_ETR	ADF1_CCK0	I2S1_MCK	-	USART3_RX
	PC5	-	TIM1_CH4N	SAI1_D3	-	PSSI_D15	-	SAI1_FS_A	UART12_RTS/UART12_DE
	PC6	-	-	TIM3_CH1	TIM8_CH1	-	I2S2_MCK	SAI1_SCK_A	USART6_TX
	PC7	TRGIO	-	TIM3_CH2	TIM8_CH2	-	-	I2S3_MCK	USART6_RX
	PC8	TRACED1	-	TIM3_CH3	TIM8_CH3	-	-	-	USART6_CK
	PC9	MCO2	-	TIM3_CH4	TIM8_CH4	I2C3_SDA	AUDIOCLK	-	-
	PC10	GFXTIM_LCKCAL	-	LPTIM3_ETR	-	SAI1_SCK_B	-	I2S3_CK/SPI3_SCK	USART3_TX
	PC11	GFXTIM_FCKCAL	-	LPTIM3_IN1	COMP1_OUT	-	-	I2S3_SDI/SPI3_MISO	USART3_RX
	PC12	TRACED3	-	TIM15_CH1	COMP2_OUT	-	SPI6_SCK	I2S3_SDO/SPI3_MOSI	USART3_CK
	PC13	-	-	-	-	-	-	-	-
	PC14	-	-	-	-	-	-	-	-
	PC15	-	-	-	-	-	-	-	-

Table 14. Alternate function AF0 to AF7 (continued)

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
		GFXTIM/SYS	ADF1/LPTIM1/ TIM1/2	LPTIM3/SAI1/ TIM1/2/3/4/5	ADF1/COMP1/2/ I2C3/I3C1/2/ LPTIM2/3/ LPUART1/ OCTOSPIM_P1_/ TIM1/8	ADF1/DCMI/PSSI/ HDMI_CEC/ I2C1/2/3/4/ LPTIM1/2/MDF1/ SAI1/SPI1/I2S1/ TIM1/USART1	GFXTIM/ HDMI_CEC/I3C1/2/ LPTIM1/SPI1/I2S1/ SPI2/I2S2/SPI3/ I2S3/SPI4/5/SPI6/ I2S6/SYS/USART2	ETH_/I2C1/2/4/ OCTOSPIM_P1_/ SAI1/SPI3/I2S3/ SPI4/UART4/12/ UCPD1_/ USART1/10	ETH_/SDMMC1/ SPI2/I2S2/SPI3/ I2S3/SPI6/I2S6/ UART7/8/12/ USART1/2/3/6/10/11
Port D	PD0	-	-	-	TIM8_CH4N	-	I2S1_MCK	-	SDMMC1_D0DIR
	PD1	-	-	-	-	-	I2S2_MCK	SAI1_MCLK_B	SDMMC1_D123DIR
	PD2	TRACED2	-	TIM3_ETR	-	TIM15_BKIN	I3C2_SCL	I2C2_SCL	-
	PD3	-	-	-	TIM8_CH4	-	SPI2_SCK/I2S2_CK	-	USART2_CTS/USART2_NSS
	PD4	TRGIO	-	-	COMP1_OUT	-	-	-	USART2_RTS/USART2_DE
	PD5	-	TIM1_CH4N	-	COMP2_OUT	-	SPI2_RDY	ETH_MII_CRS	USART2_TX
	PD6	-	ADF1_SDI0	SAI1_D1	-	I2C3_SDA	SPI3_MOSI/I2S3_SDO	SAI1_SD_A	USART2_RX
	PD7	-	-	TIM12_CH1	-	I2C3_SCL	SPI1_MOSI/I2S1_SDO	-	USART2_CK
	PD8	-	-	TIM12_CH2	-	-	-	I2S3_MCK	USART3_TX
	PD9	-	-	TIM13_CH1	-	-	HDMI_CEC	-	USART3_RX
	PD10	-	-	TIM14_CH1	LPTIM2_CH2	-	AUDIOCLK	-	USART3_CK
	PD11	-	ADF1_CCK0	SAI1_CK1	LPTIM2_IN2	I2C4_SMBA	GFXTIM_TE	-	USART3_CTS/USART3_NSS
	PD12	-	LPTIM1_IN1	TIM4_CH1	LPTIM2_IN1	I2C4_SCL	I3C1_SCL	SAI1_D1	USART3_RTS/USART3_DE
	PD13	-	LPTIM1_CH1	TIM4_CH2	LPTIM2_CH1	I2C4_SDA	I3C1_SDA	I2C1_SDA	-
	PD14	-	-	TIM4_CH3	-	PSSI_D15	-	SAI1_FS_A	-
	PD15	-	-	TIM4_CH4	-	-	-	SAI1_FS_B	SPI6_RDY

Table 14. Alternate function AF0 to AF7 (continued)

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
		GFXTIM/SYS	ADF1/LPTIM1/ TIM1/2	LPTIM3/SAI1/ TIM1/2/3/4/5	ADF1/COMP1/2/ I2C3/I3C1/2/ LPTIM2/3/ LPUART1/ OCTOSPIM_P1_/ TIM1/8	ADF1/DCMI/PSSI/ HDMI_CEC/ I2C1/2/3/4/ LPTIM1/2/MDF1/ SAI1/SPI1/I2S1/ TIM1/USART1	GFXTIM/ HDMI_CEC/I3C1/2/ LPTIM1/SPI1/I2S1/ SPI2/I2S2/SPI3/ I2S3/SPI4/5/SPI6/ I2S6/SYS/USART2	ETH_/I2C1/2/4/ OCTOSPIM_P1_/ SAI1/SPI3/I2S3/ SPI4/UART4/12/ UCPD1_/ USART1/10	ETH_/SDMMC1/ SPI2/I2S2/SPI3/ I2S3/SPI6/I2S6/ UART7/8/12/ USART1/2/3/6/10/11
Port E	PE0	-	LPTIM1_ETR	TIM4_ETR	LPTIM2_CH2	LPTIM2_ETR	-	SPI3_RDY	-
	PE1	-	LPTIM1_IN2	-	-	-	-	-	-
	PE2	TRACECLK	LPTIM1_IN2	SAI1_CK1	ADF1_CCK0	MDF1_CCK0	SPI4_SCK	SAI1_MCLK_A	USART10_RX
	PE3	TRACED0	-	-	-	TIM15_BKIN	GFXTIM_TE	SAI1_SD_B	USART10_TX
	PE4	TRACED1	-	SAI1_D2	ADF1_SDI0	TIM15_CH1N	SPI4_NSS	SAI1_FS_A	-
	PE5	TRACED2	ADF1_CCK1	SAI1_CK2	-	TIM15_CH1	SPI4_MISO	SAI1_SCK_A	-
	PE6	TRACED3	TIM1_BKIN2	SAI1_D1	ADF1_SDI0	TIM15_CH2	SPI4_MOSI	SAI1_SD_A	-
	PE7	-	TIM1_ETR	-	-	-	USART2_RX	UART12_RTS/UART 12_DE	UART7_RX
	PE8	-	TIM1_CH1N	-	-	-	USART2_TX	UART12_CTS	UART7_TX
	PE9	-	TIM1_CH1	-	-	-	-	UART12_RX	UART7_RTS/UART7 _DE
	PE10	-	TIM1_CH2N	-	-	-	-	UART12_TX	UART7_CTS
	PE11	-	TIM1_CH2	-	-	SPI1_RDY	SPI4_NSS	OCTOSPIM_P1_NC S1	USART6_TX
	PE12	GFXTIM_LCKCAL	TIM1_CH3N	-	-	-	SPI4_SCK	-	USART6_RX
	PE13	GFXTIM_FCKCAL	TIM1_CH3	-	-	-	SPI4_MISO	-	USART6_CK
	PE14	-	TIM1_CH4	-	-	-	SPI4_MOSI	-	-
	PE15	-	TIM1_BKIN	-	TIM1_CH4N	-	-	-	USART10_CK

Table 14. Alternate function AF0 to AF7 (continued)

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
		GFXTIM/SYS	ADF1/LPTIM1/ TIM1/2	LPTIM3/SAI1/ TIM1/2/3/4/5	ADF1/COMP1/2/ I2C3/I3C1/2/ LPTIM2/3/ LPUART1/ OCTOSPIM_P1_/ TIM1/8	ADF1/DCMI/PSSI/ HDMI_CEC/ I2C1/2/3/4/ LPTIM1/2/MDF1/ SAI1/SPI1/I2S1/ TIM1/USART1	GFXTIM/ HDMI_CEC/I3C1/2/ LPTIM1/SPI1/I2S1/ SPI2/I2S2/SPI3/ I2S3/SPI4/5/SPI6/ I2S6/SYS/USART2	ETH_/I2C1/2/4/ OCTOSPIM_P1_/ SAI1/SPI3/I2S3/ SPI4/UART4/12/ UCPD1_/ USART1/10	ETH_/SDMMC1/ SPI2/I2S2/SPI3/ I2S3/SPI6/I2S6/ UART7/8/12/ USART1/2/3/6/10/11
Port F	PF0	-	TIM2_CH1	TIM2_ETR	COMP1_OUT	I2C2_SDA	I3C2_SDA	-	-
	PF1	-	TIM2_CH2	-	COMP2_OUT	I2C2_SCL	I3C2_SCL	-	-
	PF2	-	-	LPTIM3_CH2	LPTIM3_IN2	I2C2_SMBA	GFXTIM_TE	UART12_TX	USART11_CK
	PF3	-	TIM2_CH3	LPTIM3_IN1	-	-	-	-	USART11_TX
	PF4	-	TIM2_CH4	LPTIM3_ETR	-	-	-	-	USART11_RX
	PF5	-	-	LPTIM3_CH1	-	I2C4_SCL	I3C1_SCL	UART12_RX	USART11_CTS/USART11_NSS
	PF6	-	TIM16_CH1	-	-	-	SPI5_NSS	SAI1_SD_B	UART7_RX
	PF7	-	TIM17_CH1	-	-	MDF1_CKI1	SPI5_SCK	SAI1_MCLK_B	UART7_TX
	PF8	-	TIM16_CH1N	-	-	-	SPI5_MISO	SAI1_SCK_B	UART7_RTS/UART7_DE
	PF9	-	TIM17_CH1N	-	-	MDF1_CCK0	SPI5_MOSI	SAI1_FS_B	UART7_CTS
	PF10	-	TIM16_BKIN	SAI1_D3	-	PSSI_D15	-	-	-
	PF11	-	TIM2_CH3	-	-	-	SPI5_MOSI	-	-
	PF12	-	TIM2_CH4	-	-	-	-	-	-
	PF13	-	ADF1_CCK0	-	LPTIM2_CH2	I2C4_SMBA	-	-	-
	PF14	-	ADF1_CCK1	TIM3_ETR	LPTIM2_IN1	-	-	SPI3_MISO/I2S3_SDI	-
	PF15	-	ADF1_SDI0	TIM4_ETR	-	I2C4_SDA	I3C1_SDA	-	-

Table 14. Alternate function AF0 to AF7 (continued)

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
		GFXTIM/SYS	ADF1/LPTIM1/ TIM1/2	LPTIM3/SAI1/ TIM1/2/3/4/5	ADF1/COMP1/2/ I2C3/I3C1/2/ LPTIM2/3/ LPUART1/ OCTOSPIM_P1_/ TIM1/8	ADF1/DCMI/PSSI/ HDMI_CEC/ I2C1/2/3/4/ LPTIM1/2/MDF1/ SAI1/SPI1/I2S1/ TIM1/USART1	GFXTIM/ HDMI_CEC/I3C1/2/ LPTIM1/SPI1/I2S1/ SPI2/I2S2/SPI3/ I2S3/SPI4/5/SPI6/ I2S6/SYS/USART2	ETH_/I2C1/2/4/ OCTOSPIM_P1_/ SAI1/SPI3/I2S3/ SPI4/UART4/12/ UCPD1_/ USART1/10	ETH_/SDMMC1/ SPI2/I2S2/SPI3/ I2S3/SPI6/I2S6/ UART7/8/12/ USART1/2/3/6/10/11
Port G	PG0	-	-	TIM4_CH1	-	-	-	-	-
	PG1	-	-	TIM4_CH2	-	-	-	-	SPI2_MOSI/I2S2_SDO
	PG2	-	-	TIM4_CH3	TIM8_BKIN	-	I2S1_MCK	-	UART12_RX
	PG3	-	-	TIM4_CH4	TIM8_BKIN2	-	-	-	UART12_TX
	PG4	-	TIM1_BKIN2	-	-	MDF1_CKI0	-	-	-
	PG5	-	TIM1_ETR	-	-	MDF1_SDI0	-	-	-
	PG6	-	TIM17_BKIN	-	I3C1_SDA	I2C4_SDA	SPI1_RDY	-	-
	PG7	-	ADF1_CCK1	SAI1_CK2	I3C1_SCL	I2C4_SCL	-	SAI1_MCLK_A	USART6_CK
	PG8	-	TIM16_CH1N	-	TIM8_ETR	-	SPI6_NSS	-	USART6_RTS/USART6_DE
	PG9	-	-	TIM12_CH1	-	-	SPI1_MISO/I2S1_SDI	USART10_RX	USART6_RX
	PG10	-	-	TIM12_CH2	I2C3_SMBA	-	SPI1_NSS/I2S1_WS	USART10_CK	USART6_CK
	PG11	-	LPTIM1_IN2	-	-	-	SPI1_SCK/I2S1_CK	USART10_RX	USART11_RTS/USART11_DE
	PG12	-	LPTIM1_IN1	-	LPTIM2_CH1	PSSI_D15	SPI6_MISO	USART10_TX	USART6_RTS/USART6_DE
	PG13	TRACED0	LPTIM1_CH1	-	-	-	SPI6_SCK	USART10_CTS/USART10_NSS	USART6_CTS/USART6_NSS
	PG14	TRACED1	LPTIM1_ETR	-	-	LPTIM1_CH2	SPI6_MOSI	USART10_RTS/USART10_DE	USART6_TX
	PG15	-	TIM16_CH1	-	-	-	SPI4_RDY	USART10_CK	USART6_CTS/USART6_NSS

Table 14. Alternate function AF0 to AF7 (continued)

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
		GFXTIM/SYS	ADF1/LPTIM1/ TIM1/2	LPTIM3/SAI1/ TIM1/2/3/4/5	ADF1/COMP1/2/ I2C3/I3C1/2/ LPTIM2/3/ LPUART1/ OCTOSPIM_P1_/ TIM1/8	ADF1/DCMI/PSSI/ HDMI_CEC/ I2C1/2/3/4/ LPTIM1/2/MDF1/ SAI1/SPI1/I2S1/ TIM1/USART1	GFXTIM/ HDMI_CEC/I3C1/2/ LPTIM1/SPI1/I2S1/ SPI2/I2S2/SPI3/ I2S3/SPI4/5/SPI6/ I2S6/SYS/USART2	ETH_/I2C1/2/4/ OCTOSPIM_P1_/ SAI1/SPI3/I2S3/ SPI4/UART4/12/ UCPD1_/ USART1/10	ETH_/SDMMC1/ SPI2/I2S2/SPI3/ I2S3/SPI6/I2S6/ UART7/8/12/ USART1/2/3/6/10/11
Port H	PH0	-	-	-	-	-	-	-	-
	PH1	-	-	-	-	-	-	-	-
	PH2	-	LPTIM1_IN2	-	-	MDF1_CKI2	-	-	-
	PH3	-	-	-	-	MDF1_SDI2	-	-	-
	PH4	-	-	-	I3C2_SCL	I2C2_SCL	SPI5_RDY	-	SPI6_RDY
	PH5	-	-	-	I3C2_SDA	I2C2_SDA	SPI5_NSS	-	SPI6_RDY
	PH6	-	TIM1_CH3N	TIM12_CH1	TIM8_CH1	I2C2_SMBA	SPI5_SCK	-	-
	PH7	-	TIM1_CH3	-	TIM8_CH1N	I2C3_SCL	SPI5_MISO	-	-
	PH8	-	TIM1_CH2N	TIM5_ETR	TIM8_CH2	I2C3_SDA	SPI5_MOSI	-	-
	PH9	-	TIM1_CH2	TIM12_CH2	TIM8_CH2N	I2C3_SMBA	SPI5_NSS	-	-
	PH10	-	TIM1_CH1N	TIM5_CH1	TIM8_CH3	I2C4_SMBA	SPI5_RDY	-	-
	PH11	-	TIM1_CH1	TIM5_CH2	TIM8_CH3N	I2C4_SCL	I3C1_SCL	-	-
	PH12	-	TIM1_BKIN	TIM5_CH3	TIM8_BKIN	I2C4_SDA	I3C1_SDA	-	-
	PH13	-	LPTIM1_IN2	-	TIM8_CH1N	-	-	-	UART8_TX
	PH14	-	-	-	TIM8_CH2N	MDF1_CKI3	-	-	-
	PH15	TRACECLK	-	-	TIM8_CH3N	MDF1_SDI3	-	-	-

Table 14. Alternate function AF0 to AF7 (continued)

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
		GFXTIM/SYS	ADF1/LPTIM1/ TIM1/2	LPTIM3/SAI1/ TIM1/2/3/4/5	ADF1/COMP1/2/ I2C3/I3C1/2/ LPTIM2/3/ LPUART1/ OCTOSPIM_P1_/ TIM1/8	ADF1/DCMI/PSSI/ HDMI_CEC/ I2C1/2/3/4/ LPTIM1/2/MDF1/ SAI1/SPI1/I2S1/ TIM1/USART1	GFXTIM/ HDMI_CEC/I3C1/2/ LPTIM1/SPI1/I2S1/ SPI2/I2S2/SPI3/ I2S3/SPI4/5/SPI6/ I2S6/SYS/USART2	ETH_/I2C1/2/4/ OCTOSPIM_P1_/ SAI1/SPI3/I2S3/ SPI4/UART4/12/ UCPD1_/ USART1/10	ETH_/SDMMC1/ SPI2/I2S2/SPI3/ I2S3/SPI6/I2S6/ UART7/8/12/ USART1/2/3/6/10/11
Port I	PI0	-	-	TIM5_CH4	-	-	SPI2_NSS/I2S2_WS	-	USART11_CK
	PI1	TRACED0	TIM1_BKIN2	-	TIM8_BKIN2	MDF1_CKI4	SPI2_SCK/I2S2_CK	-	-
	PI2	TRACED1	TIM1_ETR	-	TIM8_CH4	MDF1_SDI4	SPI2_MISO/I2S2_SDI	-	-
	PI3	TRACED2	TIM1_CH1N	-	TIM8_ETR	-	SPI2_MOSI/I2S2_SDO	-	-
	PI4	TRACED3	TIM1_CH1	-	TIM8_BKIN	-	-	-	SPI2_RDY
	PI5	-	TIM1_CH2N	-	TIM8_CH1	-	I2S1_MCK	-	-
	PI6	-	TIM1_CH2	-	TIM8_CH2	MDF1_CKI5	-	-	-
	PI7	-	TIM1_CH3N	-	TIM8_CH3	MDF1_SDI5	-	-	-
	PI8	-	-	-	-	-	-	-	-
	PI9	-	TIM1_CH3	SAI1_FS_A	-	-	-	-	-
	PI10	-	TIM1_CH4N	SAI1_SCK_A	-	-	-	-	USART11_RX
	PI11	-	TIM1_CH4	SAI1_MCLK_A	-	LPTIM1_CH2	-	-	USART11_TX
	PI12	-	TIM1_BKIN	-	LPUART1_TX	TIM15_BKIN	-	SAI1_SD_B	-
	PI13	-	-	-	LPUART1_RX	TIM15_CH1N	-	SAI1_MCLK_B	-
	PI14	-	-	-	LPUART1_CTS	TIM15_CH1	-	SAI1_SCK_B	-
	PI15	-	-	-	LPUART1_RTS/LPUART1_DE	TIM15_CH2	GFXTIM_TE	SAI1_FS_B	-

Table 14. Alternate function AF0 to AF7 (continued)

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
		GFXTIM/SYS	ADF1/LPTIM1/ TIM1/2	LPTIM3/SAI1/ TIM1/2/3/4/5	ADF1/COMP1/2/ I2C3/I3C1/2/ LPTIM2/3/ LPUART1/ OCTOSPIM_P1_/ TIM1/8	ADF1/DCMI/PSSI/ HDMI_CEC/ I2C1/2/3/4/ LPTIM1/2/MDF1/ SAI1/SPI1/I2S1/ TIM1/USART1	GFXTIM/ HDMI_CEC/I3C1/2/ LPTIM1/SPI1/I2S1/ SPI2/I2S2/SPI3/ I2S3/SPI4/5/SPI6/ I2S6/SYS/USART2	ETH_/I2C1/2/4/ OCTOSPIM_P1_/ SAI1/SPI3/I2S3/ SPI4/UART4/12/ UCPD1_/ USART1/10	ETH_/SDMMC1/ SPI2/I2S2/SPI3/ I2S3/SPI6/I2S6/ UART7/8/12/ USART1/2/3/6/10/11
Port J	PJ0	-	TIM17_BKIN	TIM4_ETR	-	MDF1_CKI1	-	-	USART3_CK
	PJ1	-	TIM17_CH1	-	-	MDF1_SDI1	-	-	USART3_TX
	PJ2	-	-	SAI1_FS_A	-	MDF1_CCK0	-	-	USART3_RX
	PJ3	-	-	TIM4_CH1	-	MDF1_SDI4	-	-	USART3_RTS/USART3_DE
	PJ4	-	-	TIM4_CH2	LPTIM2_IN2	MDF1_CCK1	-	-	USART3_CTS/USART3_NSS
	PJ5	-	-	TIM4_CH3	ADF1_CCK0	-	-	USART10_RX	-
	PJ6	-	-	TIM4_CH4	ADF1_CCK1	-	-	USART10_TX	-
	PJ7	-	-	TIM5_CH1	ADF1_SDI0	-	-	USART10_CK	-
	PJ8	-	-	TIM5_CH2	COMP1_OUT	MDF1_CKI4	-	-	-
	PJ9	-	-	TIM5_CH3	COMP2_OUT	-	-	-	-
	PJ10	-	-	TIM5_CH4	-	-	-	-	-
	PJ11	-	-	TIM5_ETR	-	LPTIM1_ETR	-	-	-
	PJ12	-	-	SAI1_SD_A	-	-	I2S2_MCK	-	USART11_CTS/USART11_NSS
	PJ13	-	TIM17_CH1N	-	-	I2C3_SMBA	-	-	USART11_RTS/USART11_DE
	PJ14	-	TIM16_BKIN	SAI1_SD_A	-	I2C3_SCL	-	USART10_CTS/USART10_NSS	-
	PJ15	-	TIM16_CH1	-	-	I2C3_SDA	-	USART10_RTS/USART10_DE	-

Table 14. Alternate function AF0 to AF7 (continued)

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
		GFXTIM/SYS	ADF1/LPTIM1/ TIM1/2	LPTIM3/SAI1/ TIM1/2/3/4/5	ADF1/COMP1/2/ I2C3/I3C1/2/ LPTIM2/3/ LPUART1/ OCTOSPIM_P1_/ TIM1/8	ADF1/DCMI/PSSI/ HDMI_CEC/ I2C1/2/3/4/ LPTIM1/2/MDF1/ SAI1/SPI1/I2S1/ TIM1/USART1	GFXTIM/ HDMI_CEC/I3C1/2/ LPTIM1/SPI1/I2S1/ SPI2/I2S2/SPI3/ I2S3/SPI4/5/SPI6/ I2S6/SYS/USART2	ETH_/I2C1/2/4/ OCTOSPIM_P1_/ SAI1/SPI3/I2S3/ SPI4/UART4/12/ UCPD1_/ USART1/10	ETH_/SDMMC1/ SPI2/I2S2/SPI3/ I2S3/SPI6/I2S6/ UART7/8/12/ USART1/2/3/6/10/11
Port K	PK0	-	-	SAI1_D2	TIM8_CH1	MDF1_SDI2	-	-	USART1_CK
	PK1	-	-	SAI1_CK2	TIM8_CH1N	MDF1_CKI2	-	-	USART1_TX
	PK2	-	-	-	TIM8_CH2	-	-	-	USART1_RX
	PK3	-	-	-	TIM8_CH2N	-	-	-	USART1_CTS/USART1_NSS
	PK4	-	-	-	TIM8_CH3	-	SPI4_RDY	-	USART1_RTS/USART1_DE
	PK5	-	-	-	TIM8_CH3N	-	SPI4_SCK	-	-
	PK6	-	-	-	TIM8_CH4	-	SPI4_NSS	-	-
	PK7	-	-	-	TIM8_CH4N	-	SPI4_MISO	-	-
	PK8	-	-	-	TIM8_ETR	-	SPI4_MOSI	-	-
	PK9	-	-	TIM12_CH1	I3C1_SCL	I2C1_SCL	-	-	-
	PK10	-	-	TIM12_CH2	I3C1_SDA	I2C1_SDA	-	-	-
	PK11	TRACECLK	-	TIM3_CH1	-	-	I2S3_MCK	-	USART6_RTS/USART6_DE
	PK12	TRACED0	-	TIM3_CH2	-	-	-	-	USART6_CTS/USART6_NSS
	PK13	TRACED1	-	TIM3_CH3	-	-	-	-	USART6_TX
	PK14	TRACED2	-	TIM3_CH4	-	-	-	-	USART6_RX
	PK15	TRACED3	-	TIM3_ETR	-	-	-	-	USART6_CK

Table 15. Alternate function AF8 to AF15

Port		AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		ETH_/FMC/I3C2/ LPUART1/MDF1/ OCTOSPIM_P1_/ OCTOSPIM_P2_/SAI2/ SDMMC1/SPI6/I2S6/	FDCAN1/2/3/FMC/O CTOSPIM_P1_/ OCTOSPIM_P2_/ SDMMC1/2/TIM1	CRS/ETH_/FMC/ LCD/OCTOSPIM_P1 _/OCTOSPIM_P2_/ OTG_FS/OTG_HS/ SAI2/SDMMC2/	ETH_/FMC/LCD/ OCTOSPIM_P1_/ SDMMC2/UART7/9/U CPD1	ETH_/FMC/ LCD/ SDMMC1	DCMI/ PSSI /FMC/ LCD/ LPTIM5/6	LCD/ LPTIM3/4/5/6/ PLAY1_IN/ PLAY1_OUT/ TIM2/UART5	SYS
Port A	PA0	UART4_TX	SDMMC2_CMD	SAI2_SD_B	ETH_MII_CRS	-	LCD_G6	TIM2_ETR	EVENTOUT
	PA1	UART4_RX	OCTOSPIM_P1_IO3	SAI2_MCLK_B	ETH_MII_RX_CLK/ ETH_RMII_REF_CLK	-	-	LCD_B7	EVENTOUT
	PA2	SAI2_SCK_B	OCTOSPIM_P2_IO4	-	ETH_MDIO	-	LCD_R0	LCD_B6	EVENTOUT
	PA3	-	-	-	ETH_MII_COL	-	-	LCD_B5	EVENTOUT
	PA4	SPI6_NSS	-	OTG_HS_SOF	-	FMC_NBL2	DCMI_HSYNC/ PSSI_DE	LCD_B4	EVENTOUT
	PA5	SPI6_SCK	OCTOSPIM_P2_IO5	LCD_G5	ETH_MII_TX_EN/ETH_ RMII_TX_EN	-	PSSI_D14	TIM2_ETR	EVENTOUT
	PA6	SPI6_MISO	TIM13_CH1	-	-	FMC_D31	DCMI_PIXCLK/ PSSI_PDCK	LCD_B3	EVENTOUT
	PA7	SPI6_MOSI	TIM14_CH1	OCTOSPIM_P1_IO2	ETH_MII_RX_DV/ ETH_RMII_CRS_DV	FMC_SDNWE	FMC_NWE	LCD_B2	EVENTOUT
	PA8	-	OCTOSPIM_P2_DQS	OTG_FS_SOF	UART7_RX	FMC_NOE	DCMI_D3/PSSI _D3	LCD_CLK	EVENTOUT
	PA9	-	-	OCTOSPIM_P2_IO3	ETH_MII_TX_ER	FMC_NWE	DCMI_D0/PSSI _D0	LCD_R7	EVENTOUT
	PA10	-	FDCAN2_TX	-	ETH_CLK	SDMMC1_D0	DCMI_D1/PSSI _D1	LCD_R6	EVENTOUT
	PA11	-	FDCAN1_RX	-	-	FMC_A17/ FMC_ALE	-	LCD_R5	EVENTOUT
	PA12	SAI2_FS_B	FDCAN1_TX	SDMMC2_D4	-	-	-	LCD_R4	EVENTOUT
	PA13	-	-	-	-	-	-	-	EVENTOUT
	PA14	-	-	-	-	-	-	-	EVENTOUT
	PA15	UART4_RTS/ UART4_DE	OCTOSPIM_P2_IO6	ETH_PHY_INTN	UART7_TX	FMC_NBL1	DCMI_D11/ PSSI_D11	TIM2_ETR	EVENTOUT

Table 15. Alternate function AF8 to AF15 (continued)

Port		AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		ETH_/FMC/I3C2/ LPUART1/MDF1/ OCTOSPIM_P1_/ OCTOSPIM_P2_/SAI2/ SDMMC1/SPI6/I2S6/	FDCAN1/2/3/FMC/O CTOSPIM_P1_/ OCTOSPIM_P2_/ SDMMC1/2/TIM1	CRS/ETH_/FMC/ LCD/OCTOSPIM_P1 _/OCTOSPIM_P2_/ OTG_FS/OTG_HS/ SAI2/SDMMC2/	ETH_/FMC/LCD/ OCTOSPIM_P1_/ SDMMC2/UART7/9/U CPD1	ETH_/FMC/ LCD/ SDMMC1	DCMI/ PSSI /FMC/ LCD/ LPTIM5/6	LCD/ LPTIM3/4/5/6/ PLAY1_IN/ PLAY1_OUT/ TIM2/UART5	SYS
Port B	PB0	UART4_CTS	OCTOSPIM_P2_NCS1	-	ETH_MII_RXD2	-	LCD_R4	LPTIM3_CH1	EVENTOUT
	PB1	-	OCTOSPIM_P1_NCLK	-	ETH_MII_RXD3	-	LCD_B3	LPTIM3_CH2	EVENTOUT
	PB2	-	OCTOSPIM_P1_CLK	OCTOSPIM_P1_DQS	ETH_MII_RXD0/ ETH_RMII_RXD0	SDMMC1_CMD	LPTIM5_ETR	LCD_R3	EVENTOUT
	PB3	SPI6_SCK	SDMMC2_D2	CRS_SYNC	UART7_RX	ETH_MDC	LCD_HSYNC	LPTIM6_ETR	EVENTOUT
	PB4	SPI6_MISO	SDMMC2_D3	ETH_MDIO	UART7_TX	FMC_NBL3	DCMI_D7/ PSSI_D7	LCD_R2	EVENTOUT
	PB5	SPI6_MOSI	FDCAN2_RX	OCTOSPIM_P2_CLK	ETH_PPS_OUT	FMC_SDCKE1	DCMI_D10/ PSSI_D10	UART5_RX	EVENTOUT
	PB6	LPUART1_TX	FDCAN2_TX	OCTOSPIM_P1_NCS1	ETH_MII_TX_ER	FMC_SDNE1	DCMI_D5/PSSI _D5	UART5_TX	EVENTOUT
	PB7	LPUART1_RX	FDCAN1_TX	SDMMC2_D5	SDMMC2_CKIN	FMC_NL	DCMI_VSYNC/ PSSI_RDY	LCD_G7	EVENTOUT
	PB8	UART4_RX	FDCAN1_RX	SDMMC2_D4	ETH_MII_TXD3	SDMMC1_D4	DCMI_D6/PSSI _D6	LCD_G6	EVENTOUT
	PB9	UART4_TX	FDCAN1_TX	SDMMC2_D5	SDMMC2_CKIN	SDMMC1_D5	DCMI_D7/PSSI _D7	LCD_G5	EVENTOUT
	PB10	I3C2_SCL	OCTOSPIM_P1_NCS1	FMC_NRAS	ETH_MII_RX_ER	-	FMC_NWAIT	LCD_G4	EVENTOUT
	PB11	I3C2_SDA	-	-	ETH_MII_TX_EN/ ETH_RMII_TX_EN	FMC_NBL1	LCD_G7	PLAY1_IN15	EVENTOUT
	PB12	I3C2_SDA	FDCAN2_RX	-	ETH_MII_TXD0/ ETH_RMII_TXD0	-	LCD_R1	UART5_RX	EVENTOUT
	PB13	-	FDCAN2_TX	-	-	-	-	UART5_TX	EVENTOUT
	PB14	UART4_RTS/UART4_DE	-	-	-	-	-	LPTIM3_ETR	EVENTOUT
	PB15	UART4_CTS	SDMMC2_D1	OCTOSPIM_P1_CLK	ETH_MII_TXD1/ ETH_RMII_TXD1	LCD_G0	DCMI_D2/PSSI _D2	UART5_RX	EVENTOUT

Table 15. Alternate function AF8 to AF15 (continued)

Port		AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		ETH_/FMC/I3C2/ LPUART1/MDF1/ OCTOSPIM_P1_/ OCTOSPIM_P2_/SAI2/ SDMMC1/SPI6/I2S6/	FDCAN1/2/3/FMC/O CTOSPIM_P1_/ OCTOSPIM_P2_/ SDMMC1/2/TIM1	CRS/ETH_/FMC/ LCD/OCTOSPIM_P1 _/OCTOSPIM_P2_/ OTG_FS/OTG_HS/ SAI2/SDMMC2/	ETH_/FMC/LCD/ OCTOSPIM_P1_/ SDMMC2/UART7/9/U CPD1	ETH_/FMC/ LCD/ SDMMC1	DCMI/ PSSI /FMC/ LCD/ LPTIM5/6	LCD/ LPTIM3/4/5/6/ PLAY1_IN/ PLAY1_OUT/ TIM2/UART5	SYS
Port C	PC0	SAI2_FS_B	FMC_A25	OCTOSPIM_P1_IO7	-	FMC_SDNWE	FMC_INT	LCD_G3	EVENTOUT
	PC1	SAI2_SD_A	SDMMC2_CK	OCTOSPIM_P1_IO4	ETH_MDC	-	FMC_NE2/ FMC_NCE	LCD_G2	EVENTOUT
	PC2	-	OCTOSPIM_P1_IO2	SDMMC2_D6	ETH_MII_TXD2	FMC_SDNE0	FMC_NE1 /FMC_NCE	LCD_HSYNC	EVENTOUT
	PC3	MDF1_SDI3	OCTOSPIM_P1_IO0	SDMMC2_D7	ETH_MII_TX_CLK	FMC_SDCKE0	-	LCD_VSYNC	EVENTOUT
	PC4	MDF1_CCK0	-	-	ETH_MII_RXD0/ ETH_RMII_RXD0	FMC_SDNE0	-	LCD_DE	EVENTOUT
	PC5	MDF1_SDI3	-	OCTOSPIM_P1_DQS	ETH_MII_RXD1/ ETH_RMII_RXD1	FMC_SDCKE0	-	LCD_G1	EVENTOUT
	PC6	SDMMC1_D0DIR	FMC_NWAIT	SDMMC2_D6	OCTOSPIM_P1_IO5	SDMMC1_D6	DCMI_D0/PSSI _D0	LCD_G0	EVENTOUT
	PC7	SDMMC1_D123DIR	FMC_NE1	SDMMC2_D7	OCTOSPIM_P1_IO6	SDMMC1_D7	DCMI_D1/PSSI _D1	LCD_R1	EVENTOUT
	PC8	UART5_RTS/UART5_DE	FMC_NE2/FMC_NCE	FMC_INT	FMC_A17/FMC_ALE	SDMMC1_D0	DCMI_D2/PSSI _D2	LCD_R0	EVENTOUT
	PC9	UART5_CTS	OCTOSPIM_P1_IO0	FMC_NCAS	FMC_A16/FMC_CLE	SDMMC1_D1	DCMI_D3/PSSI _D3	LCD_B1	EVENTOUT
	PC10	UART4_TX	OCTOSPIM_P1_IO1	-	ETH_MII_TXD0/ ETH_RMII_TXD0	SDMMC1_D2	DCMI_D8/PSSI _D8	LCD_B0	EVENTOUT
	PC11	UART4_RX	OCTOSPIM_P1_NCS1	-	LCD_VSYNC	SDMMC1_D3	DCMI_D4/PSSI _D4	PLAY1_IN0	EVENTOUT
	PC12	UART5_TX	OCTOSPIM_P2_IO7	ETH_PPS_OUT	LCD_G4	SDMMC1_CK	DCMI_D9/PSSI _D9	PLAY1_OUT0	EVENTOUT
	PC13	-	-	-	-	-	-	-	EVENTOUT
	PC14	-	-	-	-	-	-	-	EVENTOUT
	PC15	-	-	-	-	-	-	-	EVENTOUT

Table 15. Alternate function AF8 to AF15 (continued)

Port		AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		ETH_/FMC/I3C2/ LPUART1/MDF1/ OCTOSPIM_P1_/ OCTOSPIM_P2_/SAI2/ SDMMC1/SPI6/I2S6/	FDCAN1/2/3/FMC/O CTOSPIM_P1_/ OCTOSPIM_P2_/ SDMMC1/2/TIM1	CRS/ETH_/FMC/ LCD/OCTOSPIM_P1 _/OCTOSPIM_P2_/ OTG_FS/OTG_HS/ SAI2/SDMMC2/	ETH_/FMC/LCD/ OCTOSPIM_P1_/ SDMMC2/UART7/9/U CPD1	ETH_/FMC/ LCD/ SDMMC1	DCMI/ PSSI /FMC/ LCD/ LPTIM5/6	LCD/ LPTIM3/4/5/6/ PLAY1_IN/ PLAY1_OUT/ TIM2/UART5	SYS
Port D	PD0	UART4_RX	FDCAN1_RX	OCTOSPIM_P1_NCS2	UART9_CTS	FMC_D2/FMC_AD2	LCD_R2	PLAY1_IN1	EVENTOUT
	PD1	UART4_TX	FDCAN1_TX	OCTOSPIM_P2_DQS	ETH_MII_RX_DV/ ETH_RMII_CRS_DV	FMC_D3/ FMC_AD3	LCD_DE	PLAY1_OUT1	EVENTOUT
	PD2	UART5_RX	OCTOSPIM_P1_NCS2	OCTOSPIM_P2_IO1	LCD_G7	SDMMC1_CMD	DCMI_D11/ PSSI_D11	LPTIM4_ETR	EVENTOUT
	PD3	-	OCTOSPIM_P2_IO0	LCD_B4	-	FMC_CLK	DCMI_D5/ PSSI_D5	PLAY1_IN2	EVENTOUT
	PD4	MDF1_CKI3	-	OCTOSPIM_P1_IO4	ETH_CLK	FMC_NOE	LCD_B7	PLAY1_OUT2	EVENTOUT
	PD5	UART8_RX	FDCAN1_TX	OCTOSPIM_P1_IO5	-	FMC_NWE	LCD_B2	PLAY1_IN3	EVENTOUT
	PD6	MDF1_SDI1	OCTOSPIM_P2_IO4	OCTOSPIM_P1_IO6	SDMMC2_CK	FMC_NWAIT	DCMI_D10/ PSSI_D10	PLAY1_OUT3	EVENTOUT
	PD7	-	-	OCTOSPIM_P1_IO7	SDMMC2_CMD	FMC_NE1/ FMC_NCE	LCD_R3	LPTIM4_OUT	EVENTOUT
	PD8	ETH_MII_RXD0/ ETH_RMII_RXD0	FDCAN3_TX	-	SDMMC2_D0	FMC_D13/ FMC_AD13	LCD_R5	PLAY1_IN4	EVENTOUT
	PD9	-	FDCAN2_RX	-	-	FMC_D14/ FMC_AD14	LCD_R4	PLAY1_OUT4	EVENTOUT
	PD10	ETH_MII_CRS	FDCAN3_RX	-	-	FMC_D15/ FMC_AD15	LCD_R7	PLAY1_IN5	EVENTOUT
	PD11	UART4_RX	OCTOSPIM_P1_IO0	SAI2_SD_A	ETH_PTP_AUX_TS	FMC_A16/ FMC_CLE	LCD_R6	PLAY1_OUT5	EVENTOUT
	PD12	UART4_TX	OCTOSPIM_P1_IO1	SAI2_FS_A	LCD_G2	FMC_A17/ FMC_ALE	DCMI_D12/ PSSI_D12	PLAY1_IN6	EVENTOUT
	PD13	-	OCTOSPIM_P1_IO3	SAI2_SCK_A	UART9_RTS/ UART9_DE	FMC_A18	DCMI_D13 /PSSI_D13	LPTIM4_IN1	EVENTOUT
	PD14	UART8_CTS	OCTOSPIM_P2_CLK	-	UART9_RX	FMC_D0/FMC_AD0	LCD_B1	PLAY1_OUT6	EVENTOUT
	PD15	UART8_RTS/UART8_DE	OCTOSPIM_P2_NCLK	-	UART9_TX	FMC_D1/FMC_AD1	LCD_CLK	PLAY1_IN7	EVENTOUT

Table 15. Alternate function AF8 to AF15 (continued)

Port		AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		ETH_/FMC/I3C2/ LPUART1/MDF1/ OCTOSPIM_P1_/ OCTOSPIM_P2_/SAI2/ SDMMC1/SPI6/I2S6/	FDCAN1/2/3/FMC/O CTOSPIM_P1_/ OCTOSPIM_P2_/ SDMMC1/2/TIM1	CRS/ETH_/FMC/ LCD/OCTOSPIM_P1 _/OCTOSPIM_P2_/ OTG_FS/OTG_HS/ SAI2/SDMMC2/	ETH_/FMC/LCD/ OCTOSPIM_P1_/ SDMMC2/UART7/9/U CPD1	ETH_/FMC/ LCD/ SDMMC1	DCMI/ PSSI /FMC/ LCD/ LPTIM5/6	LCD/ LPTIM3/4/5/6/ PLAY1_IN/ PLAY1_OUT/ TIM2/UART5	SYS
Port E	PE0	UART8_RX	FDCAN1_RX	SAI2_MCLK_A	OCTOSPIM_P1_NCS2	FMC_NBL0	DCMI_D2/ PSSI_D2	PLAY1_OUT7	EVENTOUT
	PE1	UART8_TX	FDCAN1_TX	-	FMC_NWAIT	FMC_NBL1	DCMI_D3/ PSSI_D3	PLAY1_IN8	EVENTOUT
	PE2	UART8_TX	OCTOSPIM_P1_IO2	-	ETH_MII_TXD3	FMC_A23	DCMI_D3/ PSSI_D3	PLAY1_OUT8	EVENTOUT
	PE3	MDF1_CKI2	OCTOSPIM_P2_IO0	-	-	FMC_A19	LCD_G1	PLAY1_IN9	EVENTOUT
	PE4	MDF1_SDI2	OCTOSPIM_P2_IO1	LCD_G3	ETH_MII_RXD0/ETH_R MII_RXD0	FMC_A20	DCMI_D4/ PSSI_D4	PLAY1_OUT9	EVENTOUT
	PE5	MDF1_CCK1	OCTOSPIM_P2_IO2	LCD_B6	ETH_MII_RXD1 /ETH_RMII_RXD1	FMC_A21	DCMI_D6/ PSSI_D6	PLAY1_IN10	EVENTOUT
	PE6	MDF1_SDI1	OCTOSPIM_P2_IO3	SAI2_MCLK_B	LCD_R2	FMC_A22	DCMI_D7/ PSSI_D7	PLAY1_OUT10	EVENTOUT
	PE7	MDF1_CKI0	-	OCTOSPIM_P1_IO4	-	FMC_D4/FMC_AD4	-	PLAY1_IN11	EVENTOUT
	PE8	MDF1_SDI0	-	OCTOSPIM_P1_IO5	-	FMC_D5/FMC_AD5	DCMI_D8/PSSI _D8	PLAY1_OUT11	EVENTOUT
	PE9	MDF1_CKI4	-	OCTOSPIM_P1_IO6	-	FMC_D6/FMC_AD6	-	PLAY1_IN12	EVENTOUT
	PE10	MDF1_SDI4	-	OCTOSPIM_P1_IO7	-	FMC_D7/FMC_AD7	-	PLAY1_OUT12	EVENTOUT
	PE11	MDF1_CKI5	OCTOSPIM_P2_NCS2	SAI2_SD_B	-	FMC_D8/FMC_AD8	LCD_B5	PLAY1_IN13	EVENTOUT
	PE12	MDF1_SDI5	FDCAN3_TX	SAI2_SCK_B	ETH_MDIO	FMC_D9/FMC_AD9	DCMI_D0/ PSSI_D0	PLAY1_OUT13	EVENTOUT
	PE13	UART5_RTS/UART5_DE	FDCAN3_RX	SAI2_FS_B	LCD_R1	FMC_D10/FMC_AD 10	DCMI_HSYNC/ PSSI_DE	PLAY1_IN14	EVENTOUT
	PE14	-	OCTOSPIM_P2_CLK	SAI2_MCLK_B	LCD_B0	FMC_D11/FMC_AD 11	DCMI_VSYNC/ PSSI_RDY	PLAY1_OUT14	EVENTOUT
	PE15	-	OCTOSPIM_P2_NCS1	-	LCD_R0	FMC_D12/FMC_AD 12	DCMI_PIXCLK/ PSSI_PDCK	PLAY1_OUT15	EVENTOUT

Table 15. Alternate function AF8 to AF15 (continued)

Port		AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		ETH_/FMC/I3C2/ LPUART1/MDF1/ OCTOSPIM_P1_/ OCTOSPIM_P2_/SAI2/ SDMMC1/SPI6/I2S6/	FDCAN1/2/3/FMC/O CTOSPIM_P1_/ OCTOSPIM_P2_/ SDMMC1/2/TIM1	CRS/ETH_/FMC/ LCD/OCTOSPIM_P1 _/OCTOSPIM_P2_/ OTG_FS/OTG_HS/ SAI2/SDMMC2/	ETH_/FMC/LCD/ OCTOSPIM_P1_/ SDMMC2/UART7/9/U CPD1	ETH_/FMC/ LCD/ SDMMC1	DCMI/ PSSI /FMC/ LCD/ LPTIM5/6	LCD/ LPTIM3/4/5/6/ PLAY1_IN/ PLAY1_OUT/ TIM2/UART5	SYS
Port F	PF0	-	-	SDMMC2_D2	UART9_RX	FMC_A0	LPTIM5_CH1	PLAY1_IN0	EVENTOUT
	PF1	-	-	SDMMC2_D3	UART9_TX	FMC_A1	LPTIM5_CH2	PLAY1_IN1	EVENTOUT
	PF2	-	-	SDMMC2_D4	-	FMC_A2	LPTIM5_IN1	PLAY1_IN2	EVENTOUT
	PF3	-	-	SDMMC2_D5	-	FMC_A3	LPTIM5_IN2	PLAY1_OUT0	EVENTOUT
	PF4	-	OCTOSPIM_P2_NCS2	SDMMC2_D6	-	FMC_A4	DCMI_D6/ PSSI_D6	PLAY1_OUT1	EVENTOUT
	PF5	-	OCTOSPIM_P2_DQS	SDMMC2_D7	SDMMC2_CKIN	FMC_A5	-	LPTIM3_IN1	EVENTOUT
	PF6	SDMMC1_D0	FDCAN3_TX	OCTOSPIM_P1_IO3	-	FMC_D16	LPTIM5_CH1	LCD_DE	EVENTOUT
	PF7	SDMMC1_D1	FDCAN3_RX	OCTOSPIM_P1_IO2	-	FMC_D17	LPTIM5_CH2	LCD_G3	EVENTOUT
	PF8	SDMMC1_D2	TIM13_CH1	OCTOSPIM_P1_IO0	ETH_MII_TX_ER	FMC_D18	LPTIM5_IN1	LCD_R7	EVENTOUT
	PF9	SDMMC1_D3	TIM14_CH1	OCTOSPIM_P1_IO1	ETH_MDC	FMC_D19	LPTIM5_IN2	LCD_B1	EVENTOUT
	PF10	MDF1_SDI3	OCTOSPIM_P1_CLK	-	-	-	DCMI_D11/ PSSI_D11	LCD_G6	EVENTOUT
	PF11	SDMMC1_D4	OCTOSPIM_P1_NCLK	SAI2_SD_B	-	FMC_NRAS	DCMI_D12/ PSSI_D12	LPTIM6_CH1	EVENTOUT
	PF12	SDMMC1_D5	SDMMC1_CKIN	-	-	FMC_A6	LCD_CLK	LPTIM6_CH2	EVENTOUT
	PF13	SDMMC1_D6	SDMMC1_CDIR	-	-	FMC_A7	LCD_B6	LPTIM6_IN1	EVENTOUT
	PF14	SDMMC1_D7	SDMMC1_D123DIR	-	-	FMC_A8	LCD_G5	LPTIM6_IN2	EVENTOUT
	PF15	SDMMC1_CMD	OCTOSPIM_P2_NCS2	-	ETH_CLK	FMC_A9	LCD_B7	-	EVENTOUT

Table 15. Alternate function AF8 to AF15 (continued)

Port		AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		ETH_/FMC/I3C2/ LPUART1/MDF1/ OCTOSPIM_P1_/ OCTOSPIM_P2_/SAI2/ SDMMC1/SPI6/I2S6/	FDCAN1/2/3/FMC/O CTOSPIM_P1_/ OCTOSPIM_P2_/ SDMMC1/2/TIM1	CRS/ETH_/FMC/ LCD/OCTOSPIM_P1 _/OCTOSPIM_P2_/ OTG_FS/OTG_HS/ SAI2/SDMMC2/	ETH_/FMC/LCD/ OCTOSPIM_P1_/ SDMMC2/UART7/9/U CPD1	ETH_/FMC/ LCD/ SDMMC1	DCMI/ PSSI /FMC/ LCD/ LPTIM5/6	LCD/ LPTIM3/4/5/6/ PLAY1_IN/ PLAY1_OUT/ TIM2/UART5	SYS
Port G	PG0	SDMMC1_CK	OCTOSPIM_P2_IO0	-	UART9_RX	FMC_A10	-	LPTIM4_IN1	EVENTOUT
	PG1	-	OCTOSPIM_P2_IO1	-	UART9_TX	FMC_A11	-	PLAY1_IN3	EVENTOUT
	PG2	-	OCTOSPIM_P2_IO2	-	-	FMC_A12	LCD_R2	LPTIM6_ETR	EVENTOUT
	PG3	-	OCTOSPIM_P2_IO3	ETH_MII_RX_ER	UART7_RX	FMC_A13	LPTIM5_ETR	LCD_G0	EVENTOUT
	PG4	-	OCTOSPIM_P2_IO4	-	-	FMC_A14/ FMC_BA0	LCD_VSYNC	LPTIM4_ETR	EVENTOUT
	PG5	-	OCTOSPIM_P2_IO5	-	-	FMC_A15/ FMC_BA1	LCD_HSYNC	PLAY1_OUT9	EVENTOUT
	PG6	-	OCTOSPIM_P2_NCS1	OCTOSPIM_P1_NCS1	UCPD1_FRSTX	FMC_NE3	DCMI_D12/ PSSI_D12	PLAY1_OUT10	EVENTOUT
	PG7	MDF1_CCK1	OCTOSPIM_P2_CLK	-	UCPD1_FRSTX	FMC_INT	DCMI_D13/ PSSI_D13	LCD_R5	EVENTOUT
	PG8	-	OCTOSPIM_P2_NCLK	-	ETH_PPS_OUT	FMC_SDCLK	LCD_B2	LPTIM4_OUT	EVENTOUT
	PG9	OCTOSPIM_P1_IO4	OCTOSPIM_P1_IO6	SAI2_FS_B	SDMMC2_D0	FMC_NE2/FMC_NC E	DCMI_VSYNC/ PSSI_RDY	LCD_B5	EVENTOUT
	PG10	OCTOSPIM_P1_IO5	OCTOSPIM_P2_IO6	SAI2_SD_B	SDMMC2_D1	FMC_NE3	DCMI_D2/ PSSI_D2	LCD_B6	EVENTOUT
	PG11	-	-	SDMMC2_D2	ETH_MII_TX_EN/ ETH_RMII_TX_EN	-	DCMI_D3/ PSSI_D3	LCD_B4	EVENTOUT
	PG12	FMC_SDCLK	OCTOSPIM_P2_CLK	SDMMC2_D3	ETH_MII_TXD1/ ETH_RMII_TXD1	FMC_NE4	DCMI_D11/ PSSI_D11	LPTIM5_CH1	EVENTOUT
	PG13	-	OCTOSPIM_P2_NCS1	SDMMC2_D6	ETH_MII_TXD0/ ETH_RMII_TXD0	FMC_A24	LPTIM5_CH2	LCD_G4	EVENTOUT
	PG14	-	OCTOSPIM_P1_IO7	SDMMC2_D7	ETH_MII_TXD1/ ETH_RMII_TXD1	FMC_A25	LPTIM5_IN1	LCD_B0	EVENTOUT
	PG15	-	OCTOSPIM_P2_IO7	-	-	FMC_NCAS	DCMI_D13/ PSSI_D13	LCD_G2	EVENTOUT

Table 15. Alternate function AF8 to AF15 (continued)

Port		AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		ETH_/FMC/I3C2/ LPUART1/MDF1/ OCTOSPIM_P1_/ OCTOSPIM_P2_/SAI2/ SDMMC1/SPI6/I2S6/	FDCAN1/2/3/FMC/O CTOSPIM_P1_/ OCTOSPIM_P2_/ SDMMC1/2/TIM1	CRS/ETH_/FMC/ LCD/OCTOSPIM_P1 _/OCTOSPIM_P2_/ OTG_FS/OTG_HS/ SAI2/SDMMC2/	ETH_/FMC/LCD/ OCTOSPIM_P1_/ SDMMC2/UART7/9/U CPD1	ETH_/FMC/ LCD/ SDMMC1	DCMI/ PSSI /FMC/ LCD/ LPTIM5/6	LCD/ LPTIM3/4/5/6/ PLAY1_IN/ PLAY1_OUT/ TIM2/UART5	SYS
Port H	PH0	-	-	-	-	-	-	-	EVENTOUT
	PH1	-	-	-	-	-	-	-	EVENTOUT
	PH2	OCTOSPIM_P2_CLK	OCTOSPIM_P1_IO4	SAI2_SCK_B	ETH_MII_CRS	FMC_SDCKE0	FMC_NBL0	PLAY1_OUT2	EVENTOUT
	PH3	OCTOSPIM_P2_NCLK	OCTOSPIM_P1_IO5	SAI2_MCLK_B	ETH_MII_COL	FMC_SDNE0	FMC_NBL2	PLAY1_OUT3	EVENTOUT
	PH4	-	-	-	-	-	PSSI_D14	LCD_R7	EVENTOUT
	PH5	-	-	-	-	FMC_SDNWE	-	-	EVENTOUT
	PH6	-	OCTOSPIM_P2_IO0	-	ETH_MII_RXD2	FMC_SDNE1	DCMI_D8/PSSI _D8	PLAY1_OUT11	EVENTOUT
	PH7	-	OCTOSPIM_P2_IO1	-	ETH_MII_RXD3	FMC_SDCKE1	DCMI_D9/PSSI _D9	PLAY1_OUT12	EVENTOUT
	PH8	-	-	-	-	-	DCMI_HSYNC/ PSSI_DE	-	EVENTOUT
	PH9	-	-	-	-	-	DCMI_D0/PSSI _D0	LCD_R7	EVENTOUT
	PH10	-	OCTOSPIM_P2_IO2	-	-	FMC_D20	DCMI_D1/PSSI _D1	PLAY1_OUT13	EVENTOUT
	PH11	-	OCTOSPIM_P2_IO3	-	-	FMC_D21	DCMI_D2/PSSI _D2	PLAY1_OUT14	EVENTOUT
	PH12	-	OCTOSPIM_P2_IO4	TIM8_CH4N	-	FMC_D3/FMC_AD3	DCMI_D3/PSSI _D3	PLAY1_OUT15	EVENTOUT
	PH13	UART4_TX	FDCAN1_TX	OCTOSPIM_P2_IO5	-	FMC_D22	DCMI_D3/PSSI _D3	LCD_R3	EVENTOUT
	PH14	UART4_RX	FDCAN1_RX	OCTOSPIM_P2_IO6	-	FMC_D23	DCMI_D4/PSSI _D4	LCD_R6	EVENTOUT
	PH15	-	SDMMC2_CKIN	OCTOSPIM_P2_IO7	-	FMC_D24	DCMI_D11/ PSSI_D11	LCD_G1	EVENTOUT

Table 15. Alternate function AF8 to AF15 (continued)

Port		AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		ETH_/FMC/I3C2/ LPUART1/MDF1/ OCTOSPIM_P1_/ OCTOSPIM_P2_/SAI2/ SDMMC1/SPI6/I2S6/	FDCAN1/2/3/FMC/O CTOSPIM_P1_/ OCTOSPIM_P2_/ SDMMC1/2/TIM1	CRS/ETH_/FMC/ LCD/OCTOSPIM_P1 _/OCTOSPIM_P2_/ OTG_FS/OTG_HS/ SAI2/SDMMC2/	ETH_/FMC/LCD/ OCTOSPIM_P1_/ SDMMC2/UART7/9/U CPD1	ETH_/FMC/ LCD/ SDMMC1	DCMI/ PSSI /FMC/ LCD/ LPTIM5/6	LCD/ LPTIM3/4/5/6/ PLAY1_IN/ PLAY1_OUT/ TIM2/UART5	SYS
Port I	PI0	-	-	-	-	-	DCMI_D13/ PSSI_D13	LCD_B1	EVENTOUT
	PI1	-	SDMMC2_D0	-	FMC_A24	FMC_D25	DCMI_D8/ PSSI_D8	-	EVENTOUT
	PI2	-	SDMMC2_D1	-	-	FMC_D26	DCMI_D9/ PSSI_D9	-	EVENTOUT
	PI3	-	SDMMC2_D2	-	-	FMC_D27	DCMI_D10/ PSSI_D10	LCD_DE	EVENTOUT
	PI4	-	SDMMC2_D3	SAI2_MCLK_A	-	FMC_D28	DCMI_D5/ PSSI_D5	-	EVENTOUT
	PI5	-	-	SAI2_SCK_A	-	-	DCMI_VSYNC/ PSSI_RDY	LCD_R0	EVENTOUT
	PI6	-	SDMMC2_CMD	SAI2_SD_A	-	FMC_D29	DCMI_D6/ PSSI_D6	-	EVENTOUT
	PI7	-	SDMMC2_CK	SAI2_FS_A	-	FMC_D30	DCMI_D7/ PSSI_D7	-	EVENTOUT
	PI8	-	-	-	-	-	-	-	EVENTOUT
	PI9	UART4_RX	FDCAN1_RX	-	-	-	-	-	EVENTOUT
	PI10	-	FDCAN1_RX	-	ETH_MII_RX_ER	-	PSSI_D14	-	EVENTOUT
	PI11	-	-	-	-	-	PSSI_D15	LCD_B1	EVENTOUT
	PI12	MDF1_CKI5	-	-	-	-	-	LCD_R5	EVENTOUT
	PI13	MDF1_SDI5	-	-	-	-	-	LCD_G5	EVENTOUT
	PI14	-	TIM13_CH1	-	-	-	-	LCD_B7	EVENTOUT
	PI15	-	TIM14_CH1	-	-	-	-	LCD_R4	EVENTOUT

Table 15. Alternate function AF8 to AF15 (continued)

Port		AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		ETH_/FMC/I3C2/ LPUART1/MDF1/ OCTOSPIM_P1_/ OCTOSPIM_P2_/SAI2/ SDMMC1/SPI6/I2S6/	FDCAN1/2/3/FMC/O CTOSPIM_P1_/ OCTOSPIM_P2_/ SDMMC1/2/TIM1	CRS/ETH_/FMC/ LCD/OCTOSPIM_P1 _/OCTOSPIM_P2_/ OTG_FS/OTG_HS/ SAI2/SDMMC2/	ETH_/FMC/LCD/ OCTOSPIM_P1_/ SDMMC2/UART7/9/U CPD1	ETH_/FMC/ LCD/ SDMMC1	DCMI/ PSSI /FMC/ LCD/ LPTIM5/6	LCD/ LPTIM3/4/5/6/ PLAY1_IN/ PLAY1_OUT/ TIM2/UART5	SYS
Port J	PJ0	-	-	-	OCTOSPIM_P1_NCS2	-	-	PLAY1_IN4	EVENTOUT
	PJ1	-	-	OCTOSPIM_P1_DQS	-	ETH_PTP_AUX_TS	-	PLAY1_OUT4	EVENTOUT
	PJ2	-	OCTOSPIM_P2_NCS2	-	-	ETH_PHY_INTN	-	PLAY1_IN5	EVENTOUT
	PJ3	-	OCTOSPIM_P2_DQS	-	-	-	-	LCD_G1	EVENTOUT
	PJ4	-	-	-	-	-	-	LCD_G2	EVENTOUT
	PJ5	-	-	OCTOSPIM_P2_NCS1	-	ETH_PPS_OUT	-	PLAY1_IN6	EVENTOUT
	PJ6	-	-	OCTOSPIM_P2_IO0	-	ETH_MDIO	-	PLAY1_OUT5	EVENTOUT
	PJ7	-	-	OCTOSPIM_P2_IO1	-	ETH_MDC	-	PLAY1_IN7	EVENTOUT
	PJ8	UART5_RTS/ UART5_DE	-	-	-	-	LPTIM5_ETR	LCD_R1	EVENTOUT
	PJ9	UART5_CTS	-	SAI2_MCLK_A	-	-	LPTIM5_IN1	LCD_CLK	EVENTOUT
	PJ10	UART5_RX	-	SAI2_FS_A	-	-	-	LCD_HSYNC	EVENTOUT
	PJ11	UART5_TX	-	SAI2_SCK_A	-	-	-	LCD_VSYNC	EVENTOUT
	PJ12	MDF1_CKI0	FDCAN3_TX	-	-	-	LCD_G7	-	EVENTOUT
	PJ13	MDF1_SDI0	FDCAN3_RX	-	-	-	LCD_B5	-	EVENTOUT
	PJ14	-	-	-	-	ETH_MII_TXD0/ ETH_RMII_TXD0	-	LCD_R6	EVENTOUT
	PJ15	-	-	-	-	ETH_MII_TXD1/ ETH_RMII_TXD1	-	LCD_G6	EVENTOUT

Table 15. Alternate function AF8 to AF15 (continued)

Port		AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		ETH_/FMC/I3C2/ LPUART1/MDF1/ OCTOSPIM_P1_/ OCTOSPIM_P2_/SAI2/ SDMMC1/SPI6/I2S6/	FDCAN1/2/3/FMC/O CTOSPIM_P1_/ OCTOSPIM_P2_/ SDMMC1/2/TIM1	CRS/ETH_/FMC/ LCD/OCTOSPIM_P1 _/OCTOSPIM_P2_/ OTG_FS/OTG_HS/ SAI2/SDMMC2/	ETH_/FMC/LCD/ OCTOSPIM_P1_/ SDMMC2/UART7/9/U CPD1	ETH_/FMC/ LCD/ SDMMC1	DCMI/ PSSI /FMC/ LCD/ LPTIM5/6	LCD/ LPTIM3/4/5/6/ PLAY1_IN/ PLAY1_OUT/ TIM2/UART5	SYS
Port K	PK0	-	-	OCTOSPIM_P2_IO2	-	-	LPTIM6_IN1	PLAY1_IN8	EVENTOUT
	PK1	-	-	OCTOSPIM_P2_IO3	-	-	LPTIM6_IN2	PLAY1_OUT6	EVENTOUT
	PK2	-	-	OCTOSPIM_P2_IO4	-	-	LPTIM6_CH1	PLAY1_IN9	EVENTOUT
	PK3	SDMMC1_D0	FDCAN2_TX	-	-	-	-	PLAY1_IN10	EVENTOUT
	PK4	SDMMC1_D1	FDCAN2_RX	-	-	-	-	PLAY1_OUT7	EVENTOUT
	PK5	SDMMC1_D2	-	-	-	-	LCD_G3	PLAY1_IN11	EVENTOUT
	PK6	SDMMC1_D3	-	-	-	-	LCD_G4	PLAY1_IN12	EVENTOUT
	PK7	SDMMC1_CMD	-	-	-	-	-	PLAY1_OUT8	EVENTOUT
	PK8	SDMMC1_CK	-	-	-	-	-	PLAY1_IN13	EVENTOUT
	PK9	SDMMC1_D4	-	-	-	SDMMC1_CKIN	-	PLAY1_IN14	EVENTOUT
	PK10	SDMMC1_D5	-	-	-	SDMMC1_CDIR	-	PLAY1_IN15	EVENTOUT
	PK11	SDMMC1_D6	-	-	-	SDMMC1_D0DIR	-	LCD_B0	EVENTOUT
	PK12	SDMMC1_D7	-	-	-	SDMMC1_D123DIR	-	LCD_B3	EVENTOUT
	PK13	-	-	OCTOSPIM_P2_IO5	-	-	-	LCD_B2	EVENTOUT
	PK14	-	-	OCTOSPIM_P2_IO6	-	-	-	LCD_R3	EVENTOUT
	PK15	-	-	OCTOSPIM_P2_IO7	-	ETH_MII_RX_DV/ ETH_RMII_CRS_DV	-	LCD_G0	EVENTOUT

5 Electrical characteristics

5.1 Parameter conditions

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

5.1.1 Minimum and maximum values

Unless otherwise specified, the minimum and maximum values are guaranteed in the worst conditions of ambient temperature, supply voltage, and frequencies by tests in production on 100% of the devices with an ambient temperature at T_J = 25°C and T_J = T_{Jmax} (given by the selected temperature range).

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

5.1.2 Typical values

Unless otherwise specified, typical data are based on T_J = 25°C, V_{DD} = V_{DDA} = 3.3 V (for the 1.71 ≤ V_{DD} ≤ 3.6 V voltage range). They are given only as design guidelines and are not tested.

Typical ADC accuracy values are determined by characterization of a batch of samples from a standard diffusion lot over the full temperature range, where 95% of the devices have an error less than or equal to the value indicated (mean ±2σ).

5.1.3 Typical curves

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

5.1.4 Loading capacitor

The loading conditions used for pin parameter measurement are shown in *Figure 21*.

5.1.5 Pin input voltage

The input voltage measurement on a pin of the device is described in *Figure 22*.

Figure 21. Pin loading conditions

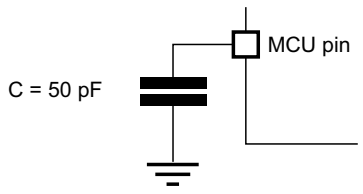
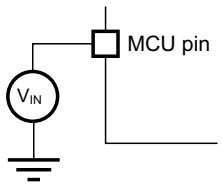
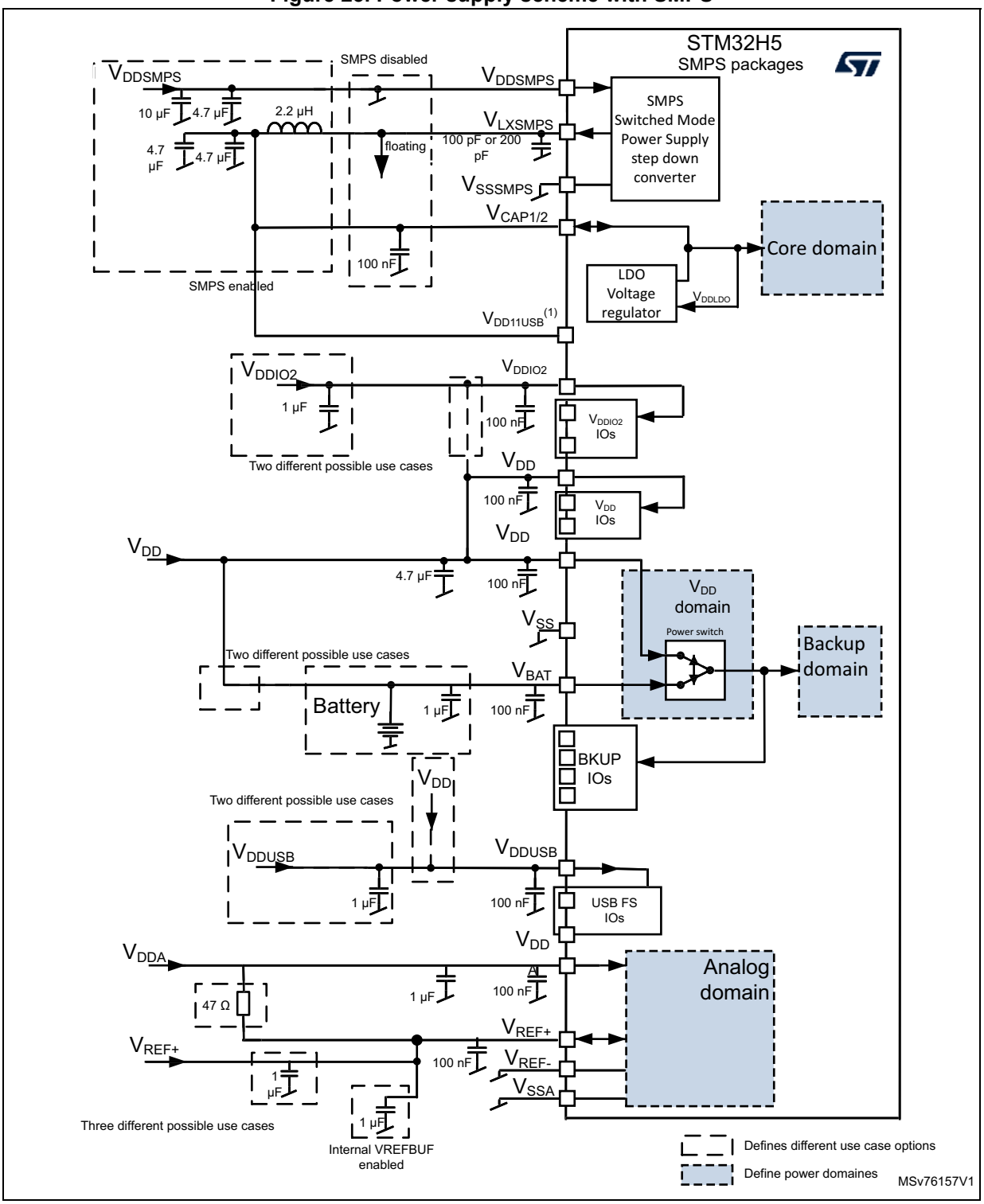


Figure 22. Pin input voltage



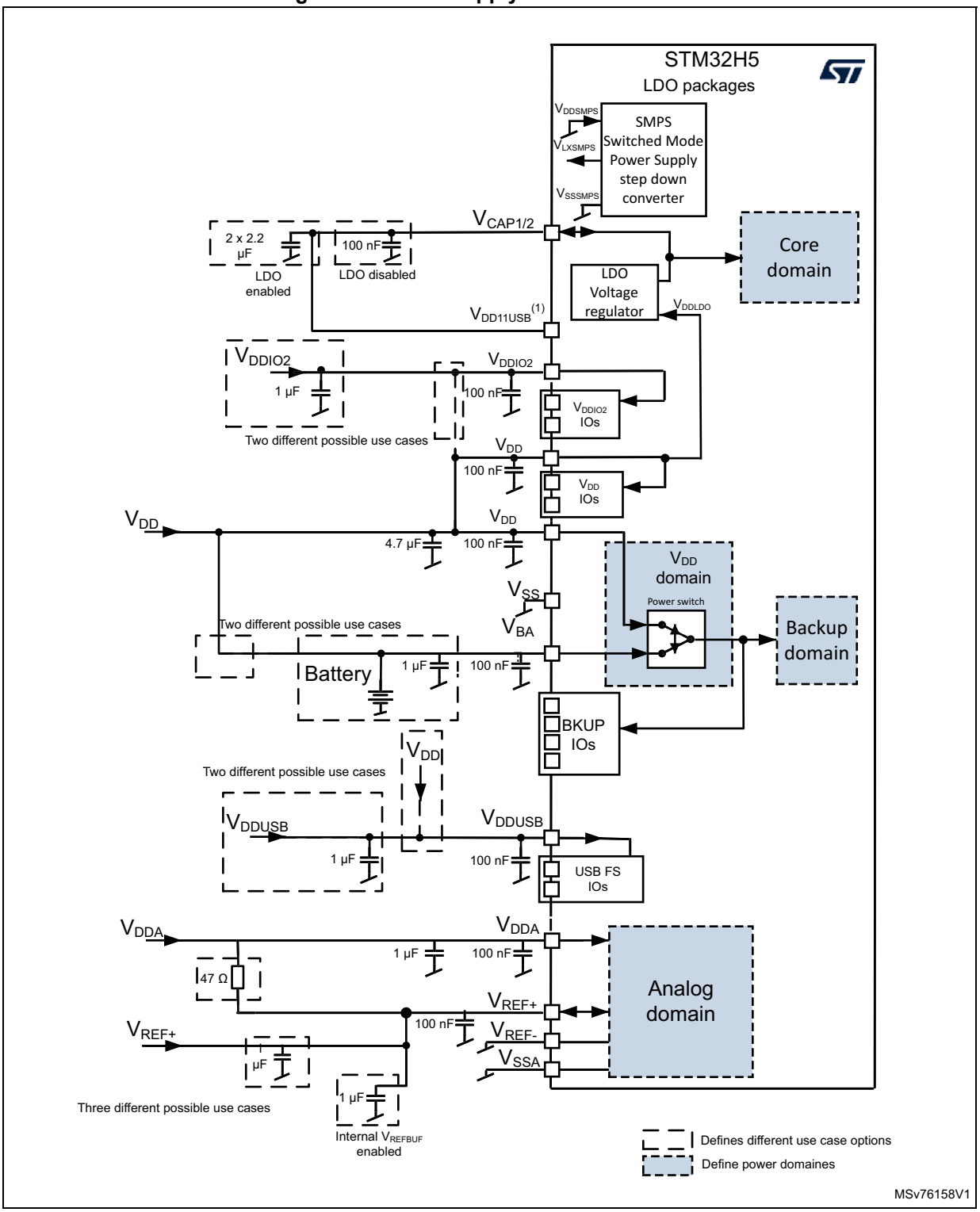
5.1.6 Power supply scheme

Figure 23. Power supply scheme with SMPS



Note: $V_{DD11USB}$ power supply is only available on STM32H5F5 devices.

Figure 24. Power supply scheme with LDO



Note: $V_{DD11USB}$ power supply is only available on STM32H5F5 devices.

Note: Refer to "Getting started with STM32H5 Series hardware development" (AN5711) for more details.

Caution: Each power supply pair must be decoupled with filtering ceramic capacitors as shown above. These capacitors must be placed as close as possible to or below the appropriate pins on the underside of the PCB to ensure the good functionality of the device. It is not recommended to remove filtering capacitors to reduce PCB size or cost. This might cause incorrect operation of the device.

5.2 Absolute maximum ratings

Stresses above the absolute maximum ratings listed in *Table 16*, *Table 17*, and *Table 18* may cause permanent damage to the device. These are stress ratings only and the functional operation of the device at these conditions is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability. Device mission profile (application conditions) is compliant with JEDEC JESD47 Qualification Standard, extended mission profiles are available on demand.

Table 16. Voltage characteristics(1)

Symbol	Ratings	Min	Max	Unit
V_{DDx} - V_{SS}	External main supply voltage (including V_{DDSMPS}, V_{DDA}, V_{DDUSB}, V_{DDIO2}, V_{BAT}, and V_{REF+})	-0.3	4.0	V
V_{DDIOx}(2) - V_{SS}	I/O supply when HSLV(2) = 0	-0.3	4.0	V
	I/O supply when HSLV(2) = 1	-0.3	2.75	
V_{IN}(3)	Input voltage on FT_xxx pins except FT_c pins	V_{SS} - 0.3	min (min(V_{DD}, V_{DDA}, V_{DDUSB}, V_{DDIO2}) + 4.0, 6.0 V)(2)(4)	V
	Input voltage on FT_t in V_{BAT} mode	V_{SS} - 0.3	min (min(V_{BAT}, V_{DDA}, V_{DDUSB}, V_{DDIO2}) + 4.0V, 6.0 V)	V
	Input voltage on TT_xx pins	V_{SS} - 0.3	4.0	
	Input voltage on BOOT0 pin	V_{SS}	min (min(V_{DD}, V_{DDA}, V_{DDUSB}, V_{DDIO2}) + 4.0, 6.0 V)(4)	
	Input voltage on FT_c pins	V_{SS} - 0.3	5.5	
	Input voltage on any other pins	V_{SS} - 0.3	4.0	
V_{REF+} - V_{DDA}	Allowed voltage difference for V_{REF+} > V_{DDA}	-	0.4	
$\lvert\Delta V_{DDx}\rvert$	Variations between different V_{DDX} power pins of the same domain	-	50.0	mV
$\lvert V_{SSx}-V_{SS}\rvert$	Variations between all the different ground pins	-	50.0	

1. All main power (VDD, VDDA, VDDUSB, VDDIO2, VREF+, VDDSMPS, VBAT) and ground (VSS, VSSA) pins must always be connected to the external power supply, in the permitted range.
2. This formula must be applied on power supplies related to the I/O structure described by the pin definition table.
3. V_{IN} maximum must always be respected. Refer to the maximum allowed injected current values.
4. To sustain a voltage higher than 4 V the internal pull-up/pull-down resistors must be disabled.

Table 17. Current characteristics

Symbol	Ratings	Max	Unit
$\sum IV_{DD}$	Total current into sum of all V_{DD} power lines (source)(1)	400	mA
$\sum IV_{SS}$	Total current out of sum of all V_{SS} ground lines (sink)(1)	400	
IV_{DD}	Maximum current into each V_{DD} power pin (source)(1)	100	
IV_{SS}	Maximum current out of each V_{SS} ground pin (sink)(1)	100	
$I_{IO(PIN)}$	Output current sunk/sourced by any I/O and control pin	20	
$\sum I_{IO(PIN)}$	Total output current sunk by sum of all I/Os and control pins(2)	140	
	Total output current sourced by sum of all I/Os and control pins(2)	140	
$I_{INJ(PIN)}$(3)(4)	Injected current on FT_xxx, TT_xx, NRST pins	-5 / 0	
$\sum\|I_{INJ(PIN)}\|$	Total injected current (sum of all I/Os and control pins)(5)	±25	

1. All main power (VDD, VDDA, VDDIO2, and VBAT) and ground (VSS, VSSA) pins must always be connected to the external power supplies, in the allowed range.
2. This current consumption must be correctly distributed over all I/Os and control pins. The total output current must not be sunk/sourced between two consecutive power supply pins referring to high pin count LQFP packages.
3. Positive injection (when $V_{IN} > V_{DDIOx}$) is not possible on these I/Os, and does not occur for input voltages lower than the specified maximum value.
4. A negative injection is induced by $V_{IN} < V_{SS}$. $I_{INJ(PIN)}$ must never be exceeded. Refer to *Table 16* for the minimum allowed input voltage values.
5. When several inputs are submitted to a current injection, the maximum $\sum|I_{INJ(PIN)}|$ is the absolute sum of the negative injected currents (instantaneous values).

Table 18. Thermal characteristics

Symbol	Ratings	Value	Unit
T_{STG}	Storage temperature range	-65 to +150	°C
T_J	Maximum junction temperature	130(1)	°C

1. The junction temperature is limited to 105°C in the VOS0 voltage range.

5.3 Operating conditions

5.3.1 General operating conditions

Table 19. General operating conditions

Symbol	Parameter	Operating conditions	Min	Typ	Max	Unit
V_{DD}	Standard operating voltage	HSLV(1) = 0	1.71(2)	-	3.6	V
		HSLV(1) = 1	1.71(2)	-	2.7	
V_{DDSMPS}	Supply voltage for the internal SMPS step-down converter	V_{DD}	V_{DD}	-	V_{DD}	V

Table 19. General operating conditions (continued)

Symbol	Parameter	Operating conditions	Min	Typ	Max	Unit
V_{DDIO2}	PB8, PB9, PD6, PD7, PG[9:14] I/Os supply voltage	At least one I/O in PB8, PB9, PD6, PD7, PG[9:14] is used, HSLV(1) = 0	1.08	-	3.6	V
		At least one I/O in PB8, PB9, PD6, PD7, PG[9:14] is used, HSLV(1) = 1	1.08	-	2.7	
		PB8, PB9, PD6, PD7, PG[9:14] are not used	0		3.6	
V_{DDUSB}	USB supply voltage	USB is used	3.0	-	3.6	V
		USB is not used	0	-	3.6	
$V_{DD11USB}$	USB OTG HS PHY digital supply voltage	USB is used	0.95	-	1.40	V
		USB is not used	0	-	1.40	
V_{DDA}	Analog supply voltage	ADC or COMP is used	1.62	-	3.6	V
		DAC is used	1.8	-		
		OPAMP is used	2.0	-		
		VREFBUF is used	2.1	-		
		ADC, DAC, COMP, OPAMP and VREFBUF are not used	0	-		
V_{BAT}	Backup domain supply voltage	-	1.2	-	3.6	V
V_{IN}	I/O input voltage	All I/Os except FT_c and TT_xx	-0.3	-	min (min (V_{DD}, V_{DDA}, V_{DDUSB}, V_{DDIO2}) + 3.6V, 5.5 V) (3)(4)	V
		Input voltage on FT_t in VBAT mode	-0.3	-	min (min (V_{BAT}, V_{DDA}, V_{DDUSB}, V_{DDIO2}) + 3.6 V, 5.5 V) (3)(4)	
		FT_c I/O	-0.3	-	5.0	
		TT_xx I/O	-0.3	-	V_{DDIOx} + 0.3	

Table 19. General operating conditions (continued)

Symbol	Parameter	Operating conditions	Min	Typ	Max	Unit
V_{CORE}	Internal regulator ON	VOS0(5) (max frequency for AHB and APB: 250 MHz)	1.30	1.35	1.40	V
		VOS1 (max frequency for AHB and APB: 200 MHz)	1.15	1.20	1.26	
		VOS2 (max frequency for AHB and APB: 150 MHz)	1.05	1.10	1.15	
		VOS3 (max frequency for AHB and APB: 100 MHz)	0.95	1.00	1.05	
	Regulator OFF: external V_{CORE} voltage must be supplied from external regulator on VCAP pins	VOS0(5)	1.32	1.35	1.40	V
		VOS1	1.17	1.20	1.26	
		VOS2	1.07	1.10	1.15	
		VOS3	0.97	1.00	1.05	
	Stop mode	SVOS3	-	1.0	-	V
		SVOS4	-	0.9	-	
		SVOS5	-	0.74	-	
f_{HCLK}	AHB clock frequency	VOS0(5)	-	-	250	MHz
		VOS1	-	-	200	
		VOS2	-	-	150	
		VOS3	-	-	100	
f_{PCLKx} (x=1,2,3)	APB1, APB2, APB3 clock frequency	VOS0(5)	-	-	250	MHz
		VOS1	-	-	200	
		VOS2	-	-	150	
		VOS3	-	-	100	
P_D	Power dissipation at T_A = 85°C for suffix 6 versions(6)	LQFP100	See *Table 151* for appropriate thermal resistance and package. Power dissipation is calculated according to ambient temperature (T_A), maximum junction temperature (T_J), and selected thermal resistance.			mW
		LQFP144				
		LQFP176				
		UFBGA144				
		UFBGA169				
		UFBGA176				
		TFBGA225				
		WLCSP105				

Table 19. General operating conditions (continued)

Symbol	Parameter	Operating conditions	Min	Typ	Max	Unit
P_D	Power dissipation at T_A = 105°C for suffix 7 version	LQFP100	See *Table 151* for appropriate thermal resistance and package. Power dissipation is calculated according to ambient temperature (T_A), maximum junction temperature (T_J), and selected thermal resistance.			mW
		LQFP144				
		LQFP176				
		UFBGA144				
		UFBGA169				
		UFBGA176				
		TFBGA225				
		WLCSP105				
T_A	Ambient temperature for the suffix 6 version	Maximum power dissipation	-40	-	85	°C
		In LDO bypass mode	-40	-	105	
	Ambient temperature for the suffix 7 version	Maximum power dissipation	-40	-	105	
		In Low power dissipation bypass mode	-40	-	125	
T_J	Junction temperature range	VOS0	-40	-	105	°C
		VOS1, VOS2, and VOS3	-40	-	130	

1. HSLV = High-speed low-voltage mode. Refer to General-purpose I/Os (GPIO) section of RM0517.
2. When RESET is released functionality is guaranteed down to BOR level 0 minimum voltage.
3. This formula must be applied on power supplies related to the I/O structure described by the pin definition table. Maximum I/O input voltage is the smallest value between min (V_{DD}, V_{DDA}, V_{DDIO2}) + 3.6 V and 5.5 V.
4. For operation with voltages higher than min (V_{DD}, V_{DDA}, V_{DDIO2}) + 0.3V, the internal pull-up and pull-down resistors must be disabled.
5. In VOS0 mode the max T_J is 105°C.
6. If T_A is lower, higher P_D values are allowed as long as T_J does not exceed T_{Jmax} (see *Table 18*).

Table 20. Maximum allowed clock frequencies

Symbol(1)(2)	Parameter	VOS0	VOS1	VOS2	VOS3	Unit
f_{CPU}	CPU	250	200	150	100	MHz
f_{HCLK}	AHB	250	200	150	100	
f_{PCLK}	APB	250	200	150	100	
-	FMC	250	200	150	100	
$f_{octospi\_ker\_ck}$	OCTOSPI[1:2]	250	200	150	100	
$f_{sdmmc\_ker\_ck}$	SDMMC[1:2]	250	200	150	100	
-	HDMI_CEC	4	4	4	4	
$f_{fdcan\_ker\_ck}$	FDCAN	250	200	150	100	
$f_{I2C\_ker\_ck}$	I2C[1:4]	250	200	150	100	
$f_{I3C\_ker\_ck}$	I3C[1:2]	250	200	150	100	
$f_{lptim\_ker\_ck}$	LPTIM[1:6]	250	200	150	100	
$f_{tim\_ker\_ck}$	TIM[1:8], TIM[12:17]	250	200	150	100	MHz
f_{rng_clk}	RNG	50	50	50	50	
$f_{play\_ker\_ck}$	PLAY1	200	150	100	64	
$f_{sai\_a\_ker\_ck}$ / $f_{sai\_b\_ker\_ck}$	SAI1/2	250	200	150	100	
$f_{spi\_ker\_ck}$	SPI(I2S)1,2,3	250	200	150	100	
	SPI4,5,6	250	200	150	100	
$f_{lpuart\_ker\_ck}$	LPUART1	250	200	150	100	
$f_{usart\_ker\_ck}$	USART/UART	250	200	150	100	
$f_{otg\_fs\_ker\_ck}$	USB (OTG_FS)	48	48	48	48	
$f_{otg\_hs\_ker\_ck}$	USB (OTG_HS)	60	60	60	60	
$f_{otghsphy\_ker\_ck}$	USB (OTG_HS PHY)	32	32	32	32	
$f_{adc\_ker\_ck\_input}$	ADC	250	200	150	100	
$f_{adc\_ker\_ck}$(3)	ADC	125	100	75	50	
$f_{dac\_ker\_ck}$	DAC	250	200	150	100	
f_{MDF1}, f_{ADF1}	MDF1, ADF1	64	64	64	64	
$f_{ucpd\_ker\_ck}$	UCPD	64	64	64	64	
$f_{rtc\_ker\_ck}$	RTC	1	1	1	1	
$f_{ltdc\_ker\_ck}$	LTDC	125	100	75	50	
-	DCMI	250	200	150	100	

1. Specified by design - Not tested in production.
2. The maximum kernel clock frequencies can be limited by the maximum peripheral clock frequency (refer to each peripheral electrical characteristics).
3. This maximum kernel clock frequency does not consider the maximum ADC clock frequency (refer to *Table 96*).

5.3.2 VCAP external capacitor

The stabilization for the embedded LDO regulator is achieved by connecting an external capacitor C_{EXT} (whose value is specified in *Table 21*) to the VCAPx (one or two pins, depending upon the package). Two external capacitors must be connected to VCAP pins (refer to AN5711 - Getting started with STM32H5 MCU hardware development).

Figure 25. External capacitor C_{EXT}

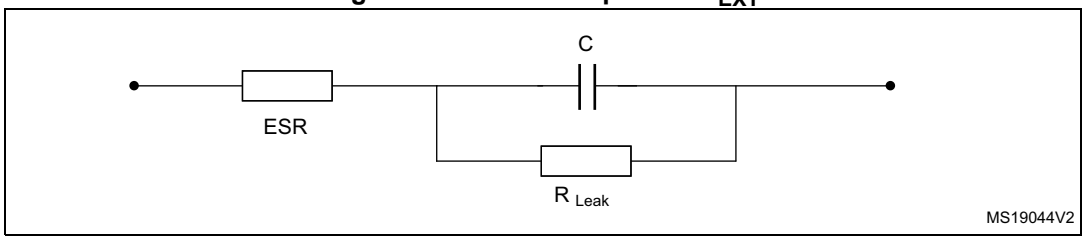


Table 21. Supply voltage and maximum frequency configuration

Symbol	Parameter	Conditions
C_{EXT}	External capacitor for LDO enabled	2.2 µF(1)
ESR	Equivalent series resistance of the external capacitor	< 100 mΩ

1. This value corresponds to C_{EXT} typical value. A variation of ±20% is tolerated

5.3.3 SMPS step-down converter

The devices embed a high power efficiency SMPS step-down converter, that needs external components.

Table 22. Characteristics of SMPS step-down converter external components

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
C_{in}	Capacitance of external capacitor on VDDSMPS pins	-	-	4.7(1)	-	µF
	ESR of external capacitor	2.4 MHz	-	-	10	mΩ
C_{filt}	Capacitance of external capacitor on VLXSMPS pin	-	-	220	-	pF
C_{OUT}	Capacitance of external capacitor on VCAP pin	-	-	10(1)	-	µF
	ESR of external capacitor	2.4 MHz	-		20	mΩ
L	Inductance of external inductor on VLXSMPS pin	-	-	2.2(1)	-	µH
	Series DC resistance	All packages	-	-	150	mΩ
I_{SAT}	DC current at which the inductance drops 30% from the value without current	-	1	-	-	A
I_{RMS}	Average current for which the temperature of the inductor is raised 40°C by the DC current	-	1	-	-	

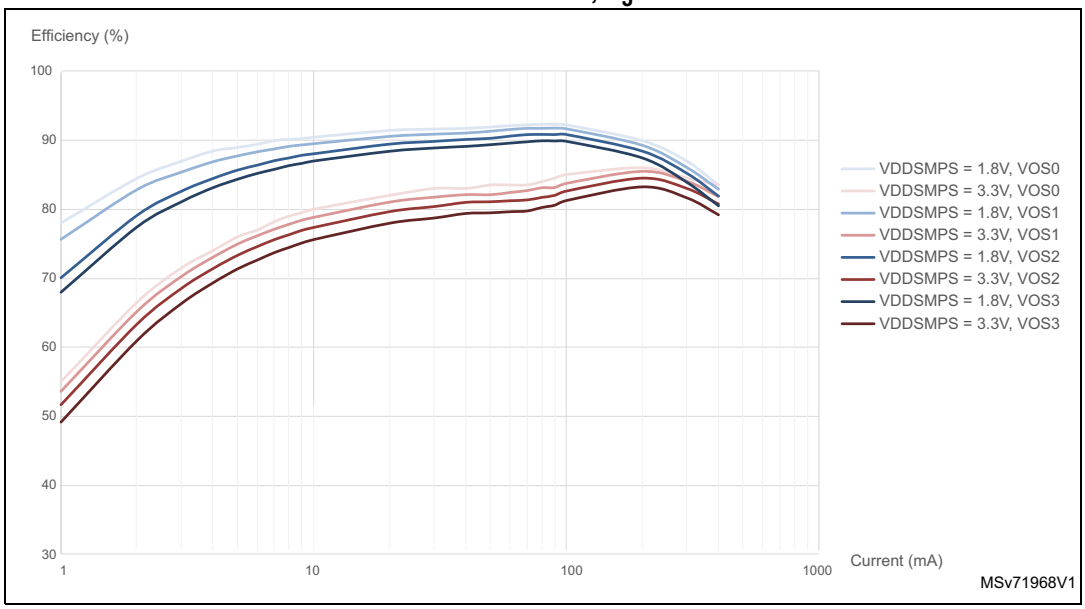
1. Tolerance: -50% and + 30% for all conditions.

The SMPS current consumption can be determined using the following formula based on the maximum LDO current consumption provided in *Section 5.3.7*:

$$I_{DDSMPS} = I_{DDLDO} \times V_{CORE} / (V_{DD} \times \text{efficiency})$$

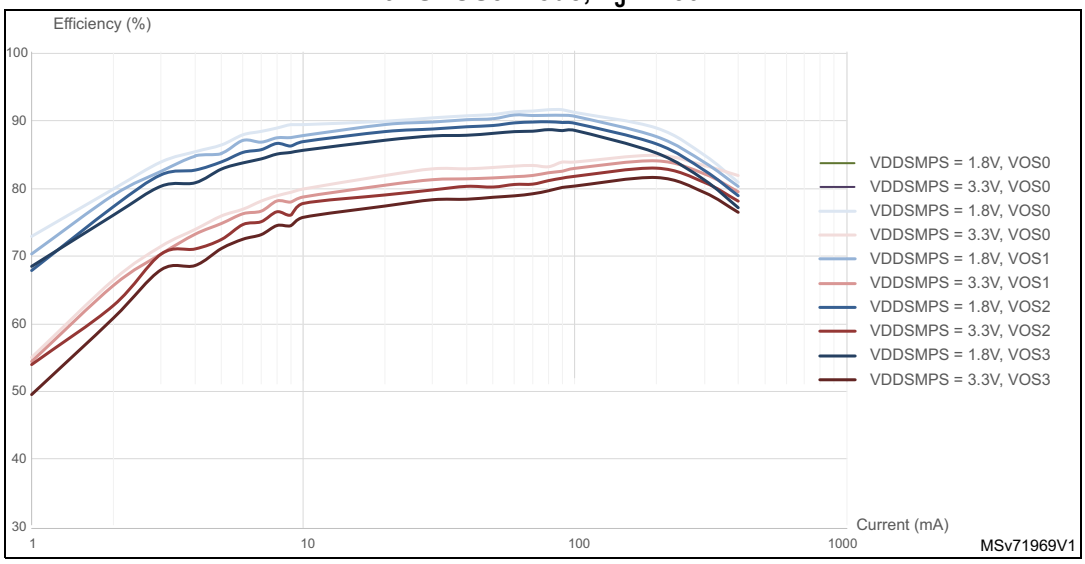
I_{DDLDO} is the current in LDO configuration given in the following tables, V_{CORE} is the digital core supply (VCAP), and efficiency is defined in the following curves.

Figure 26. SMPS efficiency versus load current in Run, Sleep, and Stop modes with SVOS3 mode, T_J = 30°C



Note: SVOS3 is equivalent to VOS3 in Run and Sleep modes.

Figure 27. SMPS efficiency versus load current in Run, Sleep, and Stop modes with SVOS3 mode, T_J = 130°C



Note: SVOS3 is equivalent to VOS3 in Run and Sleep modes.

Figure 28. SMPS efficiency versus load current in stop SVOV4, SVOS5, T_J = 30°C

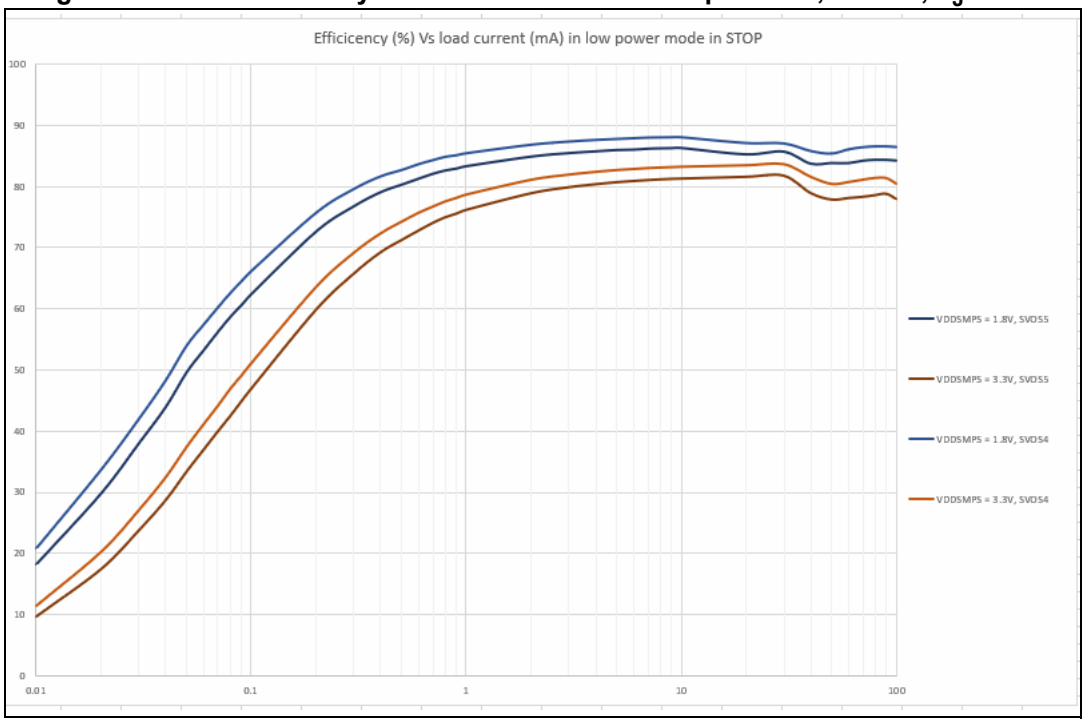
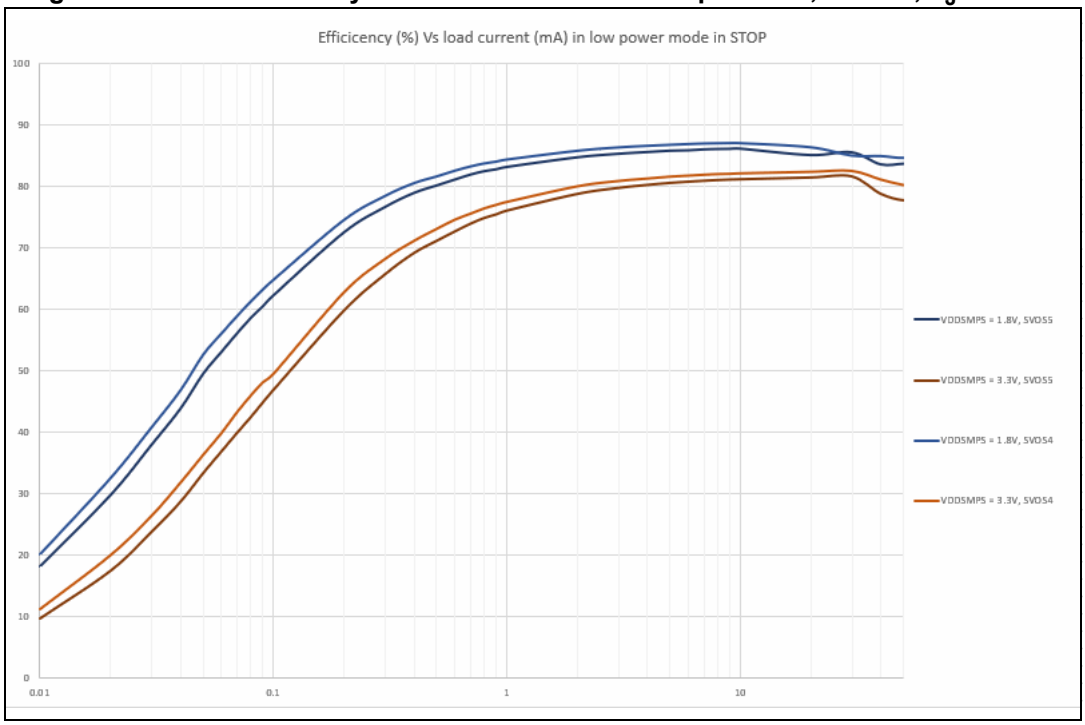


Figure 29. SMPS efficiency versus load current in stop SVOV4, SVOS5, T_J = 130°C



5.3.4 Operating conditions at power-up/down

Subject to general operating conditions for T_A.

Table 23. Operating conditions at power-up/down (regulator ON)

Symbol	Parameter	Min	Max	Unit
T_{VDD}	V_{DD} rise time rate	0	∞	µs/V
	V_{DD} fall time rate	10	∞	
T_{VDDA}	V_{DDA} rise time rate	0	∞	
	V_{DDA} fall time rate	10	∞	
T_{VDDUSB}	T_{VDDUSB} rise time rate	0	∞	
	T_{VDDUSB} fall time rate	10	∞	
T_{VDDIO2}	T_{VDDIO2} rise time rate	0	∞	
	T_{VDDIO2} fall time rate	10	∞	
T_{VBAT}	T_{VBAT} rise time rate	0	∞	
	T_{VBAT} fall time rate	10	∞	

5.3.5 Embedded reset and power control block characteristics

The parameters given in *Table 24* are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in *Table 19*.

Table 24. Embedded reset and power control block characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$t_{RSTTEMPO}$(2)	Reset temporization after BOR0 detection	V_{DD} rising	-	377	550	µs
$V_{POR/PDR}$	Power-on/down reset threshold (BORH_EN =0)	Rising edge	1.62	1.67	1.71	V
		Falling edge	1.58	1.62	1.68	
V_{BOR1}	Brownout reset threshold 1 (BORH_EN =1)	Rising edge	2.04	2.10	2.15	V
		Falling edge	1.95	2.00	2.06	
V_{BOR2}	Brownout reset threshold 2 (BORH_EN =1)	Rising edge	2.34	2.41	2.47	
		Falling edge	2.25	2.31	2.37	
V_{BOR3}	Brownout reset threshold 3 (BORH_EN =1)	Rising edge	2.63	2.70	2.78	
		Falling edge	2.54	2.61	2.68	

Table 24. Embedded reset and power control block characteristics(1) (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{PVD0}	PVD threshold 0	Rising edge	1.90	1.96	2.01	V
		Falling edge	1.81	1.86	1.91	
V_{PVD1}	PVD threshold 1	Rising edge	2.05	2.10	2.16	
		Falling edge	1.96	2.01	2.06	
V_{PVD2}	PVD threshold 2	Rising edge	2.19	2.26	2.32	
		Falling edge	2.10	2.15	2.21	
V_{PVD3}	PVD threshold 3	Rising edge	2.35	2.41	2.47	
		Falling edge	2.25	2.31	2.37	
V_{PVD4}	PVD threshold 4	Rising edge	2.49	2.56	2.62	
		Falling edge	2.39	2.45	2.51	
V_{PVD5}	PVD threshold 5	Rising edge	2.64	2.71	2.78	
		Falling edge	2.55	2.61	2.68	
V_{PVD6}	PVD threshold 6	Rising edge	2.78	2.86	2.94	
		Falling edge	2.69	2.76	2.83	
$V_{POR/PDR}$	Hysteresis for power-on/down reset	Hysteresis in Run mode	-	43	-	mV
$V_{hyst\_BOR\_PVD}$	Hysteresis voltage of BOR (unless BORH_EN = 0) and PVD	-	-	100	-	
$I_{DD\_BOR\_PVD}$(2)	BOR and PVD consumption from V_{DD}	-	-	-	0.630	µA
$I_{DD\_POR\_PDR}$	POR and PDR consumption from V_{DD}	-	0.8	-	1.2	
V_{AVD0}	V_{DDA} voltage monitor 0 threshold	Rising edge	1.66	1.71	1.76	V
		Falling edge	1.56	1.61	1.66	
V_{AVD1}	V_{DDA} voltage monitor 1threshold	Rising edge	2.06	2.12	2.19	
		Falling edge	1.96	2.02	2.08	
V_{AVD2}	V_{DDA} voltage monitor 2 threshold	Rising edge	2.42	2.50	2.58	
		Falling edge	2.35	2.42	2.49	
V_{AVD3}	V_{DDA} voltage monitor 3 threshold	Rising edge	2.74	2.83	2.91	
		Falling edge	2.64	2.72	2.80	
V_{IO2VM}	V_{DDIO2} voltage monitor threshold	-	-	0.9	-	V
V_{hyst_AVD}	Hysteresis of V_{DDA} voltage monitor	-	-	100	-	mV
$I_{DD\_AVD\_IO2VM}$(2)	Power voltage detector consumption from V_{DD} (AVD, IO2VM)	-	-	-	0.25	µA
$I_{DD\_AVD\_A}$(2)	Analog voltage detector consumption from V_{DDA} (resistor bridge)	-	-	-	0.25	

1. Evaluated by characterization and not tested in production, unless otherwise specified.
2. Specified by design - Not tested in production

5.3.6 Embedded reference voltage

The parameters given in *Table 25* are derived from tests performed under the ambient temperature and supply voltage conditions summarized in *Table 19*.

Table 25. Embedded reference voltage

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{REFINT}(1)	Internal reference voltage	-40°C < T_J < +130°C	1.180	1.216	1.255	V
$t_{S\_vrefint}$(2)(3)	ADC sampling time when reading the internal reference voltage	-	4.3	-	-	µs
$t_{start\_vrefint}$(3)	Start time of reference voltage buffer when the ADC is enabled	-	-	-	4.4	
I_{refbuf}(3)	Reference buffer consumption for ADC	V_{DD} = 3.3 V	9	13.5	23	µA
ΔV_{REFINT}(3)	Internal reference voltage spread over the temperature range	-40°C < T_J < +130°C	-	5	15	mV
T_{Coeff}	Average temperature coefficient	Average temperature coefficient	-	20	70	ppm/°C
$V_{DDcoeff}$	Average voltage coefficient	3.0 V < V_{DD} < 3.6 V	-	10	1370	ppm/V
V_{REFINT_DIV1}(3)	1/4 reference voltage	-	-	25	-	%V_{REFINT}
V_{REFINT_DIV2}(3)	1/2 reference voltage		-	50	-	
V_{REFINT_DIV3}(3)	3/4 reference voltage		-	75	-	

1. V_{REFINT} does not take into account package and soldering effects.
2. The shortest sampling time for the application can be determined by multiple iterations.
3. Specified by design - Not tested in production.

Table 26. Internal reference voltage calibration value

Symbol	Parameter	Memory address
V_{REFINT_CAL}	Raw data acquired at 30°C, V_{DDA} = 3.3 V	0x08FF F810 - 0x08FF F811

5.3.7 Supply current characteristics

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

All the run-mode current consumption measurements given in this section are performed with a CoreMark code.

Typical and maximum current consumption

The MCU is placed under the following conditions:

- All I/O pins are in analog input mode.
- All peripherals are disabled except when explicitly mentioned.

- The flash memory access time is adjusted with the minimum wait-state number, depending on the f_{HCLK} frequency (refer to the tables detailing recommended number of wait states and programming delay available in the reference manual).
- When the peripherals are enabled, the AHB clock frequency is the CPU frequency, and the APB clock frequency is AHB frequency.

The parameters given in the following tables are derived from tests performed under supply voltage conditions summarized in *Table 19*, and, unless otherwise specified, at ambient temperature.

The maximum current consumption is given for LDO regulator ON.

Table 27. Typical and maximum current consumption in Run mode, code with data processing running from flash memory, 2-way instruction cache ON, PREFETCH ON

Symbol	Parameter	Conditions		f_{HCLK} (MHz)	Typ LDO	Typ SMPS	Max(1)(2)				Unit
							T_J = 25°C	T_J = 85°C	T_J = 105°C	T_J = 130°C	
$I_{DD(Run)}$	Supply current in Run mode	All peripherals disabled	VOS0	250	37.20	19.00	43.5	83.8	129.8	-	mA
				215	32.40	16.70	38.2	78.5	124.5	-	
				200	30.00	15.40	36.0	76.2	122.2	-	
			VOS1	200	25.60	12.00	30.6	63.0	92.6	155.0	
				180	23.60	11.20	27.9	55.9	87.9	151.9	
				168	21.90	10.40	26.3	54.3	86.3	150.3	
				150	19.80	9.40	24.0	52.0	84.0	148.0	
			VOS2	150	17.90	8.02	21.6	45.2	72.1	125.8	
				100	12.70	5.86	15.6	39.1	66.0	119.7	
			VOS3	100	11.50	5.00	13.9	33.7	56.3	101.5	
				60	7.63	3.47	9.5	29.2	51.8	97.0	
				25	4.16	2.14	5.6	25.4	48.0	93.1	
		All peripherals enabled	VOS0	250	97.50	50.60	104.0	150.0	190.0	-	
				215	84.50	44.30	92.6	132.9	178.9	-	
				200	78.40	41.40	86.6	126.8	172.8	-	
			VOS1	200	67.80	32.60	75.1	106.0	136.0	198.0	
				180	61.70	29.60	66.4	99.3	129.0	192.0	
				150	51.60	24.60	56.5	84.5	116.5	180.5	
			VOS2	150	46.80	20.90	51.5	75.0	101.9	155.7	
				100	32.00	14.30	35.4	59.0	85.9	139.6	
			VOS3	100	28.90	12.10	32.0	51.8	74.4	119.5	
				60	18.10	7.74	20.3	40.1	62.7	107.9	
				25	8.54	3.92	10.1	29.9	52.5	97.7	

1. Evaluated by characterization - Not tested in production.

2. The maximum values are given for LDO regulator ON. Refer to *Section 5.3.3* for the SMPS maximum current consumption.

Table 28. Typical and maximum current consumption in Run mode, code with data processing running from flash memory, 1-way instruction cache ON, PREFETCH ON

Symbol	Parameter	Conditions		f_{HCLK} (MHz)	Typ LDO	Typ SMPS	Max(1)(2)				Unit
							T_J = 25°C	T_J = 85°C	T_J = 105°C	T_J = 130°C	
$I_{DD(Run)}$	Supply current in Run mode	All peripherals disabled	VOS0	250	33.70	17.20	39.7	79.9	125.9	-	mA
				200	27.10	13.90	32.9	73.1	119.1	-	
			VOS1	200	23.20	10.90	27.9	55.9	87.9	151.9	
				180	21.40	10.10	25.5	53.5	85.5	149.5	
				150	17.90	8.53	21.9	49.9	81.9	145.9	
			VOS2	150	16.20	7.29	19.7	43.3	70.1	123.9	
				100	11.60	5.36	14.3	37.8	64.7	118.5	
			VOS3	100	10.40	4.58	12.7	32.5	55.1	100.3	
				25	3.89	2.06	5.3	25.1	47.7	92.8	

1. Evaluated by characterization - Not tested in production.
2. The maximum values are given for LDO regulator ON. Refer to *Section 5.3.3* for the SMPS maximum current consumption.

Table 29. Typical and maximum current consumption in Run mode, code with data processing running from SRAM with cache 1-way

Symbol	Parameter	Conditions		f_{HCLK} (MHz)	Typ LDO	Typ SMPS	Max(1)(2)				Unit
							T_J = 25°C	T_J = 85°C	T_J = 105°C	T_J = 130°C	
I_{DD} (Run)	Supply current in Run mode	All peripherals disabled	VOS0	250	32.00	16.30	37.8	78.1	124.1	-	mA
				215	28.00	14.30	33.3	73.6	119.6	-	
				200	25.80	13.20	31.4	71.6	117.6	-	
			VOS1	200	22.00	10.30	26.5	54.5	86.5	150.5	
				180	20.30	9.58	24.3	52.3	84.3	148.3	
				150	17.10	8.11	20.9	48.9	80.9	144.9	
			VOS2	150	15.40	6.92	18.8	42.4	69.2	123.0	
				100	11.00	5.10	14.6	38.2	65.0	118.8	
			VOS3	100	9.90	4.35	12.1	31.9	54.5	99.7	
				60	6.69	3.13	8.4	28.2	50.8	96.0	
				25	3.76	2.01	5.2	24.9	47.5	92.7	

1. Evaluated by characterization - Not tested in production.
2. The maximum values are given for LDO regulator ON. Refer to *Section 5.3.3* for the SMPS maximum current consumption.

Table 30. Typical and maximum current consumption in Run mode, code with data processing running from SRAM with cache 2-way

Symbol	Parameter	Conditions		f_{HCLK} (MHz)	Typ LDO	Typ SMPS	Max(1)(2)				Unit
							T_J = 25°C	T_J = 85°C	T_J = 105°C	T_J = 130°C	
$I_{DD(Run)}$	Supply current in Run mode	All peripherals disabled	VOS0	250	35.20	17.80	41.3	81.6	127.6	-	mA
				215	30.70	15.60	36.4	76.6	122.6	-	
				200	28.40	14.50	34.2	74.5	120.5	-	
			VOS1	200	24.20	11.30	29.0	57.0	89.0	153.0	
				180	22.30	10.50	26.5	54.5	86.5	150.5	
				168	20.70	9.70	25.0	53.0	85.0	149.0	
				150	18.70	8.82	22.8	50.8	82.8	146.8	
			VOS2	150	16.90	7.52	20.5	44.0	70.9	124.7	
				100	12.00	5.51	14.8	38.3	65.2	119.0	
			VOS3	100	10.90	4.72	13.2	33.0	55.6	100.8	
				60	7.27	3.35	9.1	28.8	51.4	96.6	
				25	4.00	2.10	5.4	25.2	47.8	93.0	

1. Evaluated by characterization - Not tested in production.
2. The maximum values are given for LDO regulator ON. Refer to *Section 5.3.3* for the SMPS maximum current consumption.

Table 31. Typical consumption in Run mode with CoreMark running from flash memory and SRAM(1)

Symbol	Parameter	Conditions		f_{HCLK} (MHz)	Typ LDO	Typ SMPS	Unit	Typ LDO	Typ SMPS	Unit
		Peripheral	Code							
$I_{DD(Run)}$	Supply current in Run mode	All peripherals disabled, instruction cache 2-way, prefetch ON	FLASH	250	37.20	19.00	mA	76.0	148.8	µA/MHz
				200	25.60	11.20		56.0	128.0	
				168	21.90	10.40		61.9	130.4	
				150	17.90	8.02		53.5	119.3	
				100	11.50	5.00		50.0	115.0	
		All peripherals disabled, instruction cache 1-way, prefetch ON	FLASH	250	33.70	17.20		68.8	134.8	
				200	23.20	10.90		54.5	116.0	
				150	16.20	7.29		48.6	108.0	
				100	10.40	4.58		45.8	104.0	
		All peripherals disabled, instruction cache 2-way	SRAM	250	35.20	17.80		71.2	140.8	
				200	24.20	11.30		56.5	121.0	
				168	20.70	9.70		57.7	123.2	
				150	16.90	7.52		50.1	112.7	
				100	10.90	4.72		47.2	109.0	
		All peripherals disabled, instruction cache 1-way	SRAM	250	32.00	16.30		65.2	128.0	
				200	22.00	10.30		51.5	110.0	
				150	15.40	6.92		46.1	102.7	
				100	9.90	4.35		43.5	99.0	

1. Evaluated by characterization - Not tested in production.

Table 32. Typical consumption in Run mode with SecureMark running from flash memory and SRAM(1)

Symbol	Parameter	Conditions		f_{HCLK} (MHz)	Typ LDO	Typ SMPS	Unit	Typ LDO	Typ SMPS	Unit
		Peripheral	Code							
$I_{DD(Run)}$	Supply current in Run mode	All peripherals disabled, instruction cache 2-way, prefetch ON	FLASH	250	39.40	19.90	mA	79.6	157.6	µA/MHz
				180	25.00	11.70		65.0	138.9	
				168	23.20	10.90		64.9	138.1	
				150	19.00	8.44		56.3	126.7	
				100	12.20	5.24		52.4	122.0	
		All peripherals disabled, instruction cache 1-way, prefetch ON	FLASH	250	36.60	18.60		74.4	146.4	
				180	23.30	11.00		61.1	129.4	
				168	21.70	10.20		60.7	129.2	
				150	17.80	7.97		53.1	118.7	
				100	11.40	4.96		49.6	114.0	

1. Evaluated by characterization - Not tested in production.

Table 33. Typical and maximum current consumption in Sleep mode

Symbol	Parameter	Conditions		f_{HCLK} (MHz)	Typ LDO	Typ SMPS	Max(1) (2)				Unit
							T_J = 25°C	T_J = 85°C	T_J = 105°C	T_J = 130°C	
$I_{DD(sleep)}$	Supply current in sleep mode	All peripherals disabled	VOS0	250	10.10	5.63	16.6	56.8	102.8	-	mA
				200	8.32	4.69	14.4	54.7	100.7	-	
			VOS1	200	6.79	3.60	11.7	39.7	71.7	135.7	
				180	6.63	3.55	10.9	38.9	70.9	134.9	
				168	6.05	3.26	10.5	38.5	70.5	134.5	
				150	5.63	3.07	9.8	37.8	69.8	133.8	
			VOS2	150	4.93	2.60	8.7	32.2	59.1	112.9	
				100	4.02	2.24	6.9	30.4	57.3	111.1	
			VOS3	100	3.50	1.91	6.0	25.8	48.4	93.6	
				60	2.84	1.66	4.8	24.5	47.1	92.3	

1. Evaluated by characterization - Not tested in production.
2. The maximum values are given for LDO regulator ON. Refer to *Section 5.3.3* for the SMPS maximum current consumption.

Table 34. Typical and maximum current consumption in Stop mode

Symbol	Parameter	Conditions		Typ LDO	Typ SMPS	Max(1) (2)				Unit
						T_J = 25°C	T_J = 85°C	T_J = 105°C	T_J = 130°C	
$I_{DD(stop)}$	Supply current in Stop	Flash memory in low power mode, SRAMs ON	SVOS3	0.754	0.411	2.50	19.96	35.70	69.10	mA
			SVOS4	0.581	0.255	1.88	15.60	28.40	55.80	
			SVOS5	0.468	0.270	1.48	13.30	24.80	50.30	
		Flash memory in normal mode, SRAMs ON	SVOS3	0.795	0.424	2.52	20.03	35.90	69.40	
			SVOS4	0.622	0.268	1.90	15.70	28.50	56.00	
		Flash memory in low power mode, SRAMs OFF except SRAM2 16 Kbytes ON	SVOS3	0.526	0.230	1.85	13.70	24.50	47.60	
			SVOS4	0.393	0.206	1.39	10.70	19.40	38.40	
			SVOS5	0.261	0.170	0.93	7.45	13.80	28.10	
		Flash memory in low power mode, SRAMs OFF except SRAM2 ON	SVOS3	0.564	0.244	1.92	14.30	25.60	49.50	
			SVOS4	0.422	0.213	1.44	11.20	20.20	40.00	
			SVOS5	0.293	0.179	0.99	7.98	14.80	30.10	

1. Evaluated by characterization - Not tested in production.
2. The maximum values are given for LDO regulator ON. Refer to *Section 5.3.3* for the SMPS maximum current consumption.

Table 35. Typical and maximum current consumption in Standby mode

Symbol	Parameter	Conditions		Typ(1)				Max(1)				Unit
		Backup RAM	RTC and LSE(2)	1.8 V	2.4 V	3 V	3.3 V	T_J = 25°C	T_J = 85°C	T_J = 105°C	T_J = 130°C	
$I_{DD(standby)}$	Supply current in standby mode, IWDG OFF	OFF	OFF	2.66	2.88	3.15	3.33	6.5	18.4	32	59.2	µA
		ON	OFF	4.07	4.40	4.86	5.00	8.8	29.7	50.2	117	
		OFF	ON	2.97	3.24	3.60	3.81	7.5	19.6	33.3	61.2	
		ON	ON	4.70	5.04	5.46	5.72	9.8	30.9	51.5	119	

1. Evaluated by characterization - Not tested in production.
2. LSE is in medium-low drive mode.

Table 36. Typical and maximum current consumption in V_{BAT} mode

Symbol	Parameter	Conditions		Typ(1)				Max(1)				Unit
		Backup RAM	RTC and LSE(2)	1.8 V	2.4 V	3 V	3.3 V	T_J = 25°C	T_J = 85°C	T_J = 105°C	T_J = 130°C	
$I_{DD(VBAT)}$	Supply current in V_{BAT} mode	OFF	OFF	0.01	0.02	0.03	0.06	0.5	2.7	6.7	19.5	µA
		ON	OFF	1.39	1.43	1.65	1.68	4.8	22.8	46	91.5	
		OFF	ON	0.45	0.46	0.48	0.59	1.5	3.8	8	21.5	
		ON	ON	2.09	2.15	2.41	2.51	5.8	23.9	47.3	93.5	

1. Evaluated by characterization - Not tested in production.
2. LSE is in medium-low drive mode.

I/O system current consumption

All the I/Os used as inputs with pull-up generate a current consumption when the pin is externally held low. The value of this current consumption can be simply computed by using the pull-up/pull-down resistors values given in *Table 57*.

To estimate the current consumption for the output pins, consider also external pull-downs or loads.

An additional I/O current consumption is due to I/Os configured as inputs if an intermediate voltage level is externally applied. This current consumption is caused by the Schmitt trigger circuits used to discriminate the input value. Unless this specific configuration is required by the application, this current consumption can be avoided by configuring the I/Os in analog mode. This is notably the case of ADC input pins, to be configured as analog inputs.

Caution: Any floating input pin can also settle to an intermediate voltage level or switch inadvertently, as a result of external electromagnetic noise. To avoid a current consumption related to floating pins, they must either be configured in analog mode, or forced internally to a definite digital value. This can be done by using pull-up/down resistors, or by configuring the pins in output mode.

In addition to the internal peripheral current consumption, the I/Os used by an application also contribute to the current consumption. When an I/O pin switches, it uses the current from the MCU supply voltage to supply the I/O pin circuitry and to charge/discharge the capacitive load (internal or external) connected to the pin:

$$I_{SW} = V_{DDx} \times f_{SW} \times C_L$$

where

I_{SW} is the current sunk by a switching I/O to charge/discharge the capacitive load

V_{DDx} is the MCU supply voltage

f_{SW} is the I/O switching frequency

C_L is the total capacitance seen by the I/O pin: $C = C_{INT} + C_{EXT} + C_S$

The test pin is configured in push-pull output mode and is toggled by software at a fixed frequency.

On-chip peripheral current consumption

The MCU is placed under the following conditions:

- At startup, all I/O pins are in analog input configuration
- All peripherals are disabled unless otherwise mentioned
- The I/O compensation cell is enabled
- f_{HCLK} is the CPU clock, $f_{PCLK} = f_{rcc\_cpu\_ck}$, and $f_{HCLK} = f_{rcc\_cpu\_ck}$.

The given value is calculated by measuring the difference of current consumption:

- with all peripherals clocked off
- with only one peripheral clocked on
- $f_{rcc\_cpu\_ck}$ = 250 MHz (Scale 0), $f_{rcc\_cpu\_ck}$ = 200 MHz (Scale 1), $f_{rcc\_cpu\_ck}$ = 150 MHz (Scale 2), $f_{rcc\_cpu\_ck}$= 100 MHz (Scale 3)
- the ambient operating temperature is 25°C and V_{DD} = 3.0 V

Table 37. Peripheral current consumption in Sleep mode

Bus	Peripheral	IDD(Typ)				Unit
		VOS0	VOS1	VOS2	VOS3	
AHB1	BKPRAM	1.35	0.48	0.44	0.41	µA/MHz
	GTZC1	1.36	1.25	1.12	1.03	
	DCACHE	0.66	0.59	0.55	0.51	
	ICACHE	0.86	0.81	0.75	0.67	
	JPEG	1.57	1.41	1.28	1.17	
	DMA2D	3.04	2.72	2.46	2.25	
	ETHERNET	15.55	13.62	12.4	11.28	
	RAMCFG	0.72	0.69	0.6	0.58	
	MDF1	5.98	5.23	4.73	4.31	
	FMAC	1.62	1.46	1.3	1.2	
	CORDIC	0.5	0.45	0.42	0.4	
	CRC	0.22	0.21	0.18	0.18	
	FLASH	16.91	14.72	13.38	12.14	
	GPDMA2	0.51	0.4	0.35	0.34	
	GPDMA1	0.58	0.45	0.41	0.38	
	AHB1	1.35	1.15	1.05	0.94	

Table 37. Peripheral current consumption in Sleep mode (continued)

Bus	Peripheral	IDD(Typ)				Unit
		VOS0	VOS1	VOS2	VOS3	
APB2	GFXTIM	1.11	0.98	0.88	0.81	µA/MHz
	LTDC	4.9	4.24	3.86	3.51	
	SAI2	0.79	0.73	0.63	0.59	
	SAI1	0.85	0.75	0.68	0.63	
	SPI6	1.02	0.91	0.81	0.74	
	SPI4	1.02	0.91	0.8	0.74	
	TIM17	1.39	1.22	1.11	1.01	
	TIM16	1.31	1.17	1.05	0.97	
	TIM15	1.78	1.6	1.45	1.32	
	USART1	1.24	1.1	0.99	0.91	
	TIM8	3.9	3.42	3.12	2.82	
	SPI2S1	1.19	1.06	0.97	0.87	
	TIM1	3.9	3.42	3.14	2.85	
	APB2	0.56	0.46	0.43	0.39	

Table 37. Peripheral current consumption in Sleep mode (continued)

Bus	Peripheral	IDD(Typ)				Unit
		VOS0	VOS1	VOS2	VOS3	
APB1	UCPD1	1.09	0.91	0.85	0.79	µA/MHz
	FDCAN2	8.71	7.58	6.92	6.32	
	FDCAN1					
	FDCAN3					
	LPTIM2	0.86	0.74	0.68	0.64	
	DTS	1.24	1.08	1	0.93	
	UART12	1.18	1.01	0.94	0.85	
	UART9	1.16	0.98	0.9	0.82	
	UART8	1.16	0.98	0.9	0.83	
	UART7	1.15	0.98	0.9	0.84	
	CEC	0.18	0.14	0.15	0.13	
	USART11	1.18	1.03	0.95	0.88	
	USART10	1.19	1.02	0.96	0.87	
	USART6	1.18	1.02	0.94	0.86	
	CRS	0.22	0.17	0.16	0.16	
	I3C1	0.33	0.27	0.26	0.25	
	I2C2	0.52	0.45	0.43	0.39	
	I2C1	0.53	0.46	0.44	0.4	
	UART5	1.17	1.02	0.92	0.86	
	UART4	1.16	1	0.9	0.85	
	USART3	1.21	1.04	0.97	0.88	
	USART2	1.34	1.16	1.07	0.99	
	COMP1/COMP2	0.21	0.18	0.17	0.14	
	SPI2S3	1.09	0.94	0.87	0.83	
	SPI2S2	1.33	0.98	0.91	0.79	
	OPAMP	0.14	0.11	0.1	0.09	

Table 37. Peripheral current consumption in Sleep mode (continued)

Bus	Peripheral	IDD(Typ)				Unit
		VOS0	VOS1	VOS2	VOS3	
APB1	WWDG	0.39	0.35	0.35	0.3	µA/MHz
	TIM14	0.86	0.75	0.68	0.63	
	TIM13	0.88	0.76	0.7	0.64	
	TIM12	1.23	1.07	0.96	0.9	
	TIM7	0.44	0.39	0.36	0.34	
	TIM6	0.45	0.4	0.36	0.35	
	TIM5	2.56	2.23	2.02	1.87	
	TIM4	2.18	1.89	1.72	1.58	
	TIM3	2.17	1.9	1.74	1.58	
	TIM2	2.53	2.21	2.03	1.85	
AHB2	PKA+RAM	6.48	5.63	5.12	4.65	µA/MHz
	RNG	1.84	1.62	1.46	1.34	
	HASH	1.4	1.23	1.1	1.01	
	OTG_FS	5.69	5	4.54	4.13	
	OTG_HS	1.69	1.47	1.33	1.22	
	ADC3	1.07	0.96	0.86	0.79	
	ADF1	0.91	0.79	0.75	0.65	
	DCMI	3.1	2.73	2.49	2.26	
	DAC1/DAC2	1.21	1.05	1	0.89	
	ADC1/ADC2	2.18	1.91	1.75	1.59	
	GPIOK	0.04	0.02	0.02	0.01	
	GPIOJ	0.04	0.02	0.02	0.01	
	GPIOI	0.04	0.02	0.02	0.01	
	GPIOH	0.04	0.02	0.02	0.02	
	GPIOG	0.04	0.02	0.02	0.01	
	GPIOF	0.04	0.02	0.02	0.01	
	GPIOE	0.04	0.02	0.02	0.01	
	GPIOD	0.04	0.02	0.02	0.01	
	GPIOC	0.04	0.02	0.02	0.01	
	GPIOB	0.04	0.02	0.02	0.02	
	GPIOA	0.04	0.02	0.02	0.01	
	AHB2	2.03	1.79	1.65	1.47	

Table 37. Peripheral current consumption in Sleep mode (continued)

Bus	Peripheral	IDD(Typ)				Unit
		VOS0	VOS1	VOS2	VOS3	
APB3	PLAY	1.75	1.51	1.39	1.23	µA/MHz
	RTC	5.19	4.55	4.16	3.77	
	VREFBUF	0.03	0.05	0.07	0.05	
	LPTIM6	0.84	0.76	0.7	0.64	
	LPTIM5	0.81	0.72	0.67	0.62	
	LPTIM4	0.44	0.4	0.4	0.34	
	LPTIM3	0.82	0.72	0.69	0.61	
	LPTIM1	0.82	0.74	0.7	0.62	
	I3C2	0.34	0.32	0.32	0.26	
	I2C4	2.09	1.84	1.7	1.54	
	I2C3	2.06	1.82	1.67	1.52	
	LPUART1	0.94	0.84	0.8	0.69	
	SPI5	1.11	0.99	0.91	0.82	
	SBS	0.92	0.8	0.75	0.67	
	APB3	0.72	0.62	0.55	0.51	
AHB4	OCTOSPIM	2.7	2.38	2.21	1.99	µA/MHz
	OCTOSPI1	2.62	2.34	2.1	1.86	
	OCTOSPI2	9.18	7.89	7.12	6.47	
	FMC	7	6.11	5.58	5.09	
	SDMMC2	6.76	5.93	5.41	4.94	
	SDMMC1	0.45	0.38	0.33	0.33	
	OTFDEC2	0.62	0.55	0.49	0.47	
	OTFDEC1	0.42	0.38	0.36	0.32	
	AHB4	0.42	0.38	0.36	0.32	

Wake-up time from low-power modes

The times given in *Table 38* are measured starting from the wake-up event trigger up to the first instruction executed by the CPU:

- for Stop or Sleep modes: the wake-up event is WFE.
- WKUP (PA0) pin is used to wake-up from Standby, Stop, and Sleep modes.

All timings are derived from tests performed under ambient temperature and V_{DD} = 3.0 V.

Table 38. Low-power mode wake-up timings(1)

Symbol	Parameter	Conditions	Typ	Max	Unit
$t_{WUSLEEP}$	Wake-up time from Sleep mode	Instruction cache enabled	15	-	CPU clock cycles
		Instruction cache disabled	15	-	
t_{WUSTOP}	Wake-up time from Stop mode	SVOS3, HSI 64 MHz, flash memory in normal mode	4.4	-	µs
		SVOS3, HSI 64 MHz, flash memory in low-power mode	8.9	-	
		SVOS4, HSI 64 MHz, flash memory in normal mode	14	-	
		SVOS4, HSI 64 MHz, flash memory in low-power mode	18.6	-	
		SVOS5, HSI 64 MHz, flash memory in low-power mode	32.4	-	
		SVOS3, CSI 4 MHz, flash memory in normal mode	26.7	-	
		SVOS3, CSI 4 MHz, flash memory in low power mode	29	-	
		SVOS4, CSI 4 MHz, flash memory in normal mode	36.8	-	
		SVOS4, CSI 4 MHz, flash memory in low-power mode	39	-	
		SVOS5, CSI 4 MHz, flash memory in low-power mode	52.7	-	
t_{WUSTBY}	Wake-up time from Standby mode	VCAP capacitors discharged	537.6	-	

1. Evaluated by characterization - Not tested in production.

5.3.8 External clock source characteristics

High-speed external user clock generated from an external source

In bypass mode the HSE oscillator is switched off and the input pin is a standard GPIO.

The external clock signal must respect the *Table 39* in addition to *Table 57*. The external clock can be low-swing (analog) or digital. In case of a low-swing analog input clock, the clock squarer must be activated (refer to RM0517).

Table 39. High-speed external user clock characteristics(1)

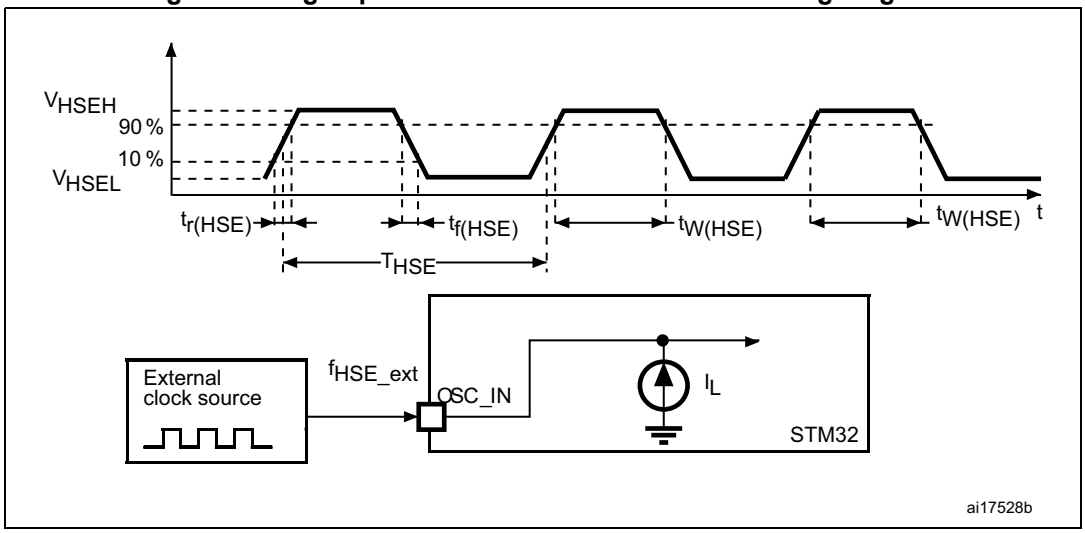
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{HSE_ext}	User external clock source frequency	External digital/analog clock	4	25	50	MHz
V_{HSEH}	Digital OSC_IN input high-level voltage	External digital clock	0.7 V_{DD}	-	V_{DD}	V
V_{HSEL}	Digital OSC_IN input low-level voltage		V_{SS}	-	0.3 V_{DD}	
$t_{w(HSEH)}$ / $t_{w(HSEL)}$(2)	Digital OSC_IN input high or low time	External digital clock	7	-	-	ns

Table 39. High-speed external user clock characteristics(1) (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{isw(HSEH)}$ (V_{HSEH} -V_{HSEL})(3)	Analog low-swing OSC_IN peak-to-peak amplitude	External analog low swing clock	0.2	-	2/3 V_{DD}	V
$DuCy_{HSE}$	Analog low-swing OSC_IN duty cycle		45	50	55	%
$t_{r(HSE)}$ / $t_{f(HSE)}$	Analog low-swing OSC_IN rise and fall times	External analog low swing clock, 10% to 90%	0.05 / f_{HSE_ext}	-	0.3 / f_{HSE_ext}	ns

1. Specified by design - Not tested in production..
2. The rise and fall times for a digital input signal are not specified, but the V_{HSEH} and V_{HSEL} conditions must be fulfilled anyway.
3. The DC component of the signal must ensure that the signal peaks are located between V_{DD} and V_{SS}.

Figure 30. High-speed external clock source AC timing diagram



Low-speed external user clock generated from an external source

In bypass mode the LSE oscillator is switched off and the input pin is a standard GPIO.

The external clock signal must respect the *Table 40* in addition to *Table 57*. The external clock must be digital.

Table 40. Low-speed external user clock characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{LSE_ext}	User external clock source frequency	External digital	-	32.768	1000	kHz

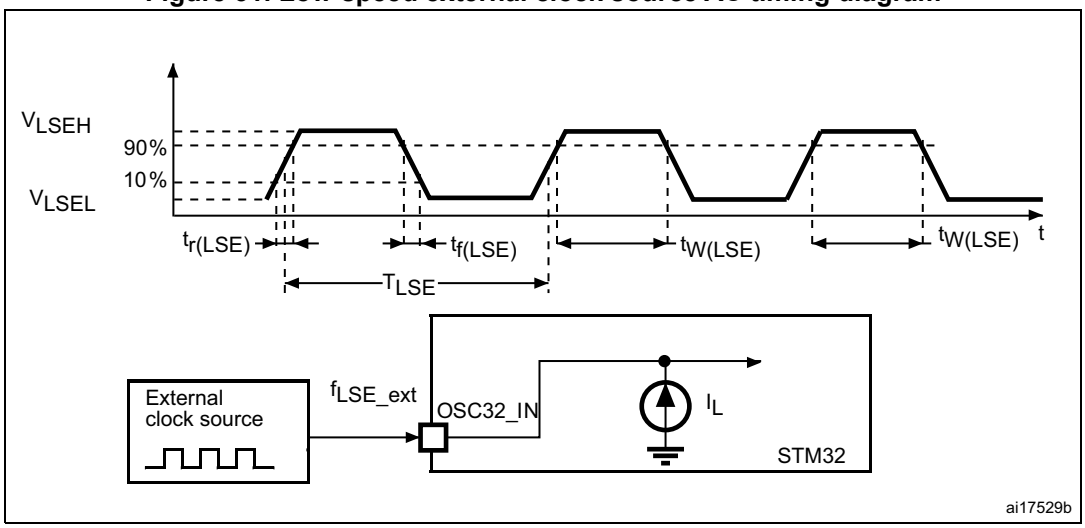
Table 40. Low-speed external user clock characteristics(1) (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{LSEH}	Digital OSC32_IN input high-level voltage	External digital clock	0.7 V_{DD}	-	V_{DD}	V
V_{LSEL}	Digital OSC32_IN input low-level voltage		V_{SS}	-	0.3 V_{DD}	
$t_{w(LSEH)}/t_{w(LSEL)}$	Digital OSC_IN input high or low time	External digital clock	250	-	-	ns

1. Specified by design - Not tested in production.

Note: For information on selecting the crystal, refer to AN2867 "Guidelines for oscillator design on STM8AF/AL/S and STM32 MCUs/MPUs" available from www.st.com.

Figure 31. Low-speed external clock source AC timing diagram



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

The high-speed external (HSE) clock can be supplied with a 4 to 50 MHz crystal/ceramic resonator oscillator.

All the information given in this paragraph are based on characterization results obtained with typical external components specified in *Table 41*. In the application, the resonator and the load capacitors must be placed as close as possible to the oscillator pins 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 41. HSE oscillator characteristics(1)

Symbol	Parameter	Operating conditions(2)	Min	Typ	Max	Unit
F	Oscillator frequency	-	4	-	50	MHz
R_F	Feedback resistor	-	-	200	-	kΩ

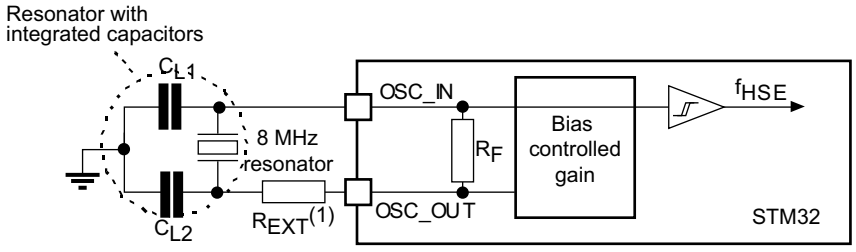
Table 41. HSE oscillator characteristics(1) (continued)

Symbol	Parameter	Operating conditions(2)	Min	Typ	Max	Unit
$I_{DD(HSE)}$	HSE current consumption	During startup(3)	-	-	10	mA
		V_{DD} = 3 V, Rm = 20 Ω, C_L = 10 pF at 4 MHz	-	0.44	-	
		V_{DD} = 3 V, Rm = 20 Ω, C_L = 10 pF at 8 MHz	-	0.44	-	
		V_{DD} = 3 V, Rm = 20 Ω, CL = 10 pF at 16 MHz	-	0.55	-	
		V_{DD} = 3 V, Rm = 20 Ω, C_L = 10 pF at 32 MHz	-	0.67	-	
		V_{DD} = 3 V, Rm = 20 Ω, C_L = 10 pF at 48 MHz	-	1.17	-	
$Gm_{critmax}$	Maximum critical crystal gm	Startup	-	-	1.5	mA/V
$t_{SU(HSE)}$(4)	Startup time	V_{DD} is stabilized	-	2	-	ms

1. Evaluated by design - Not tested in production.
2. Resonator characteristics given by the crystal/ceramic resonator manufacturer.
3. This consumption level occurs during the first 2/3 of the $t_{SU(HSE)}$ startup time
4. $t_{SU(HSE)}$ is the startup time measured from the moment it is enabled (by software) to a stabilized 8 MHz oscillation is reached. This value is measured for a standard crystal resonator, it can vary significantly with the crystal manufacturer

Note: For information on selecting the crystal, refer to AN2867 "Guidelines for oscillator design on STM8AF/AL/S and STM32 MCUs/MPUs", available from www.st.com.

Figure 32. Typical application with an 8 MHz crystal



1. R_{EXT} value depends on the crystal characteristics.

Low-speed external clock generated from a crystal resonator

The low-speed external (LSE) clock can be supplied with a 32.768 kHz crystal resonator oscillator. All the information given in this paragraph is based on design simulation results obtained with typical external components specified in *Table 42*. In the application, the resonator and the load capacitors must be placed as close as possible to the oscillator pins to minimize output distortion and startup stabilization time. Refer to the crystal resonator manufacturer for more details on the resonator characteristics (frequency, package, accuracy).

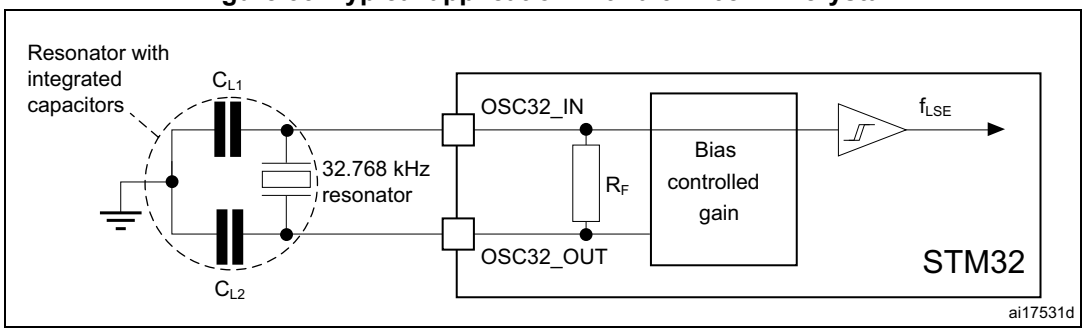
Table 42. LSE oscillator characteristics(1)

Symbol	Parameter	Conditions(2)	Min	Typ	Max	Unit
F	Oscillator frequency	-	-	32.768	-	kHz
I_{DD}	LSE current consumption	LSEDRV[1:0] = 00 Low drive capability	-	246	-	nA
		LSEDRV[1:0] = 01 Medium low drive capability	-	333	-	
		LSEDRV[1:0] = 10 Medium high drive capability	-	462	-	
		LSEDRV[1:0] = 11 High drive capability	-	747	-	
$Gm_{critmax}$	Maximum critical crystal gm	LSEDRV[1:0] = 00 Low drive capability	-	-	0.5	µA/V
		LSEDRV[1:0] = 01 Medium low drive capability	-	-	0.75	
		LSEDRV[1:0] = 10 Medium high drive capability	-	-	1.7	
		LSEDRV[1:0] = 11 High drive capability	-	-	2.7	
$t_{SU(LSE)}$(3)	Startup time	V_{DD} is stabilized	-	2	-	s

1. Specified by design - Not tested in production.
2. Refer to the note and caution paragraphs below the table, and to AN2867 "*Guidelines for oscillator design on STM8AF/AL/S and STM32 MCUs/MPUs*".
3. $t_{SU(LSE)}$ is the startup time measured from the moment it is enabled (by software) to when a stabilized 32.768 kHz oscillation is reached. This value is measured for a standard crystal, it can vary significantly with the crystal manufacturer

Note: For information on selecting the crystal, refer to AN2867 "Guidelines for oscillator design on STM8AF/AL/S and STM32 MCUs/MPUs", available from www.st.com.

Figure 33. Typical application with a 32.768 kHz crystal



Note: An external resistor is not required between OSC32_IN and OSC32_OUT, and it is forbidden to add one.

5.3.9 Internal clock source characteristics

The parameters given in *Table 43* to *Table 46* are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in *Table 19*.

48 MHz high-speed internal RC oscillator (HSI48)

Table 43. HSI48 oscillator characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{HSI48}	HSI48 frequency	V_{DD} = 3.3 V, T_J= 30°C	47.5(1)	48	48.5(1)	MHz
TRIM(3)	User trimming step	-	-	0.175	0.250	%
USER TRIM COVERAGE(2)	User trimming coverage	±32 steps	±4.70	±5.6	-	
DuCy(HSI48)(3)	Duty cycle	-	45	-	55	%
ACCHSI48_REL(3)	Accuracy of the HSI48 oscillator over temperature (reference is 30°C)	T_J = -40 to 130°C	-4.5	-	4	%
Δ_{VDD}(HSI48)	HSI48 oscillator frequency drift with V_{DD} (reference is 3.3 V)	V_{DD} = 3.0 to 3.6 V	-	0.025	0.05	%
		V_{DD} = 1.71 to 3.6 V	-	0.05	0.1	
t_{su}(HSI48)(3)	HSI48 oscillator start-up time	-	-	2.1	4.0	µs
I_{DD}(HSI48)(3)	HSI48 oscillator power consumption	-	-	350	400	µA
N_T jitter(3)	Next transition jitter accumulated jitter on 28 cycles	-	-	±0.15	-	ns
P_T jitter(3)	Paired transition jitter accumulated jitter on 56 cycles(4)	-	-	±0.25	-	

1. Calibrated during manufacturing tests.
2. Evaluated by characterization - Not tested in production.
3. Specified by design - Not tested in production.
4. Jitter measurements are performed without clock sources activated in parallel.

64 MHz high-speed internal RC oscillator (HSI)

Table 44. HSI oscillator characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{HSI}	Frequency	V_{DD} = 3.3 V, T_J = 30°C	63.7(2)	64.0(2)	64.3(2)	MHz
TRIM	User trimming step	Trimming is not a multiple of 32(3)	-	0.24	0.32	%
		Trimming is 128, 256, and 384(3)	-5.2	-1.8	-	
		Trimming is 64, 192, 320, and 488(3)	-1.4	-0.8	-	
		Other trimmings are multiples of 32 (not including multiples of 64 and 128)(3)	-0.6	-0.25	-	
DuCy(HSI)	Duty cycle	-	45	-	55	%

Table 44. HSI oscillator characteristics(1) (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Δ_{VDD}(HSI)	Frequency drift with V_{DD} (reference is 3.3 V)	V_{DD}= 1.71 to 3.6 V	-0.12	-	0.03	%
Δ_{TEMP}(HSI)	Frequency drift with V_{DD} (reference is 64 MHz)	T_J= -20 to 105°C	-1(4)	-	1(4)	%
		T_J= -40 to 130°C	-2(4)	-	1(4)	%
t_{su}(HSI)	Start-up time	-	-	1.4	2.0	µs
t_{stab}(HSI)	Stabilization time	At 1% of target frequency	-	4	8	µs
		At 1% of target frequency	-	-	4	µs
I_{DD}(HSI)	Power consumption	-	-	300	450	µA

1. Specified by design - Not tested in production, unless otherwise specified.
2. Calibrated during manufacturing tests.
3. Trimming value of HSICAL[8:0].
4. Guaranteed by characterization - Not tested in production.

4 MHz low-power internal RC oscillator (CSI)

Table 45. CSI oscillator characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{CSI}	Frequency	V_{DD} = 3.3 V, T_J = 30°C	3.96(2)	4	4.04(2)	MHz
TRIM	User trimming step	Trimming is not a multiple of 16	-	0.40	0.75	%
		Trimming is not a multiple of 32	-4.75	-2.75	0.75	%
		Other trimmings are a multiple of 32 (not including multiples of 64 and 128)	-0.43	0.00	0.75	%
DuCy(CSI)	Duty cycle	-	45	-	55	%
Δ_{TEMP}(CSI)	Frequency drift over temperature	T_J= 0 to 85°C	-3.7(3)	-	4.5(3)	%
		T_J= -40 to T_J = 130°C	-11(3)	-	7.5(3)	%
Δ_{VDD}(CSI)	Frequency drift over V_{DD}	V_{DD}= 1.71 to 3.6 V	-0.06	-	0.06	%
t_{su}(CSI)	Start-up time	-	-	1	2	µs
t_{stab}(CSI)	Stabilization time (to reach ± 3% of f_{CSI})	-	-	-	4	cycle
I_{DD}(CSI)	Power consumption	-	-	23	30	µA

1. Specified by design - Not tested in production, unless otherwise specified.
2. Calibrated during manufacturing tests.
3. Evaluated by characterization - Not tested in production.

Low-speed internal (LSI) RC oscillator

Table 46. LSI oscillator characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{LSI}	Frequency	V_{DD} = 3.3 V, T_J = 25°C	31.4(1)	32	32.6(1)	kHz
		T_J = -40 to 110°C, V_{DD} =1.71 to 3.6 V	29.76(2)	-	33.6(2)	
		T_J = -40 to 130°C, V_{DD} =1.71 to 3.6 V	29.4(2)	-	33.6(2)	
$t_{su}(LSI)$(3)	Start-up time	-	-	80	130	µs
$t_{stab}(LSI)$(3)	Stabilization time (5% of final value)	-	-	120	170	
$I_{DD}(LSI)$(3)	Power consumption	-	-	130	280	nA

1. Calibrated during manufacturing tests.
2. Evaluated by characterization - Not tested in production.
3. Specified by design - Not tested in production.

5.3.10 PLL characteristics

The parameters given in *Table 47* are derived from tests performed under temperature and V_{DD} supply voltage conditions summarized in *Table 19*.

Table 47. PLL characteristics (wide VCO frequency range)(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{PLL_IN}	PLL input clock	-	2	-	16	MHz
	PLL input clock duty cycle	-	10	-	90	%
$f_{PLL\_P\_OUT}$	PLL multiplier output clock P, Q, R	VOS0	1	-	250(2)	MHz
		VOS1	1	-	200(2)	
		VOS2	1	-	150(2)	
		VOS3	1	-	100(2)	
f_{VCO_OUT}	PLL VCO output	-	128	-	560(2)	
t_{LOCK}	PLL lock time	Normal mode	-	45	100(3)	µs
		Sigma-delta mode (f_{PLL_IN} ≥ 8 MHz)	-	60	120(3)	

Table 47. PLL characteristics (wide VCO frequency range)(1) (continued)

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
Jitter	Cycle-to-cycle jitter	f_{VCO_OUT} = 128 MHz		-	60	-	±ps
		f_{VCO_OUT} = 200 MHz		-	50	-	
		f_{VCO_OUT} = 400 MHz		-	20	-	
		f_{VCO_OUT} = 560 MHz		-	15	-	
	Long term jitter(4)	Normal mode (f_{PLL_IN} = 2 MHz), f_{VCO_OUT} = 560 MHz		-	±0.2	-	%
		Normal mode (f_{PLL_IN} = 16 MHz), f_{VCO_OUT} = 560 MHz		-	±0.8	-	
		Sigma-delta mode (f_{PLL_IN} = 2 MHz), f_{VCO_OUT} = 560 MHz		-	±0.2	-	
		Sigma-delta mode (f_{PLL_IN} = 16 MHz), f_{VCO_OUT} = 560 MHz		-	±0.8	-	
I_{DD}(PLL)	PLL power consumption on V_{DD}	f_{VCO_OUT} = 560 MHz	V_{DD}	-	330	420	µA
			V_{CORE}	-	630	-	
		f_{VCO_OUT} = 128 MHz	V_{DD}	-	155	230	
			V_{CORE}	-	170	-	

1. Specified by design - Not tested in production, unless otherwise specified.
2. This value must be limited to the maximum frequency due to the product limitation.
3. Evaluated by characterization - Not tested in production.
4. Given as percentage of the input clock period.

Table 48. PLL characteristics (medium VCO frequency range)

Symbol	Parameter	Conditions	Min(1)	Typ(1)	Max(1)	Unit
f_{PLL_IN}	PLL input clock	-	1	-	2	MHz
	PLL input clock duty cycle	-	10	-	90	%
f_{PLL_OUT}	PLL multiplier output clock P, Q, R	VOS0	1.17	-	210	MHz
		VOS1	1.17	-	210	
		VOS2	1.17	-	160(2)	
		VOS3	1.17	-	88(2)	
f_{VCO_OUT}	PLL VCO output	-	150	-	420	
t_{LOCK}	PLL lock time	Normal mode	-	45	80(3)	µs
		Sigma-delta mode	Forbidden			

Table 48. PLL characteristics (medium VCO frequency range) (continued)

Symbol	Parameter	Conditions		Min(1)	Typ(1)	Max(1)	Unit
Jitter	Cycle-to-cycle jitter	f_{VCO_OUT} = 150 MHz	-	-	60	-	±ps
		f_{VCO_OUT} = 200 MHz	-	-	40	-	
		f_{VCO_OUT} = 400 MHz	-	-	18	-	
		f_{VCO_OUT} = 420 MHz	-	-	15	-	
	Period jitter	f_{VCO_OUT} = 150 MHz	f_{PLL_OUT} = 50 MHz	-	75	-	
		f_{VCO_OUT} = 400 MHz		-	25	-	
	Long term jitter(4)	Normal mode f_{VCO_OUT} = 400 MHz		-	±0.2	-	%
I_{DD}(PLL)	PLL power consumption on V_{DD}	f_{VCO_OUT} = 420 MHz	V_{DD}	-	275	360	µA
			V_{CORE}	-	450	-	
		f_{VCO_OUT} = 150 MHz	V_{DD}	-	160	240	
			V_{CORE}	-	165	-	

1. Specified by design - Not tested in production, unless otherwise specified.
2. This value must be limited to the maximum frequency due to the product limitation.
3. Evaluated by characterization - Not tested in production.
4. Given as percentage of the input clock period.

5.3.11 Memory characteristics

Flash memory

The characteristics are given at T_J = -40 to 130°C unless otherwise specified.

The devices are shipped to customers with the flash memory erased.

Table 49. Flash memory characteristics

Symbol	Parameter	Conditions	Min	Typ	Max(1)	Unit
I_{DD}	Supply current	Word program(2)	-	2.5	3.6	mA
		Sector erase	-	1.8	4	
		Mass erase	-	2.0	4	

1. Specified by design - Not tested in production
2. Data are evaluated with a write of 50% of the programmed bits equal to 0.

Table 50. Flash memory programming(1)

Symbol	Parameter	Conditions	Min(2)	Typ	Max(1)	Unit
t_{prog}	Word program time	128 bits (user area)	-	31	100	µs
		16 bits (OTP area)	-	31	100	
t_{ERASE}	Sector erase time (8 Kbytes)		-	2	10	ms
t_{ME}	Mass erase time	-	-	1.024	5.2	s
t_{BE}	Bank erase time	-	-	0.512	2.6	

Table 50. Flash memory programming(1) (continued)

Symbol	Parameter	Conditions	Min(2)	Typ	Max(1)	Unit
V_{prog}	Programming voltage		1.71	-	3.6	V

1. Data are valid for program memory and high-cycling data memory.
2. Specified by design - Not tested in production.

Table 51. Flash memory endurance and data retention

Symbol	Parameter	Conditions	Min(1)	Unit
N_{PEND}	Endurance program memory	T_J = -40 to +130°C	10	kcycles
N_{DEND}	Endurance data memory	T_J = -40 to +130°C	100	
t_{PRET}	Program memory, data retention	1 kcycle at T_A = 125°C	10	Years
		1 kcycles at T_A = 85°C	30	
		10 kcycles at T_A = 55°C	30	
t_{DRET}	Data retention for data memory	100 kcycle at T_A = 125°C	1	
		100 kcycles at T_A = 85°C	10	
		100 kcycles at T_A = 55°C	10	

1. Evaluated by characterization - Not tested in production, unless otherwise specified.

5.3.12 EMC characteristics

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

Functional EMS (electromagnetic susceptibility)

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

- **Electrostatic discharge (ESD),** positive and negative, is applied to all device pins until a functional disturbance occurs. This test is compliant with the IEC 61000-4-2 standard.
- **FTB**: A burst of fast transient voltage (positive and negative) is applied to V_{DD} and V_{SS} through a 100 pF capacitor, until a functional disturbance occurs. This test is compliant with the IEC 61000-4-4 standard.

A device reset allows to resume normal operation.

The test results are given in *Table 52*. They are based on the EMS levels and classes defined in AN1709 "*EMC design guide for STM8, STM32 and legacy MCUs*".

Table 52. EMS characteristics

Symbol	Parameter	Conditions	Level/Class
V_{FESD}	Voltage limits to apply on any I/O pin to induce a functional disturbance	V_{DD} = 3.3 V, T_A = 25°C, TFBGA225-SMPS, $f_{rcc\_cpu\_ck}$ = 250 MHz, conform to IEC 61000-4-2	2A
V_{FTB}	Fast transient voltage burst limits to apply through 100 pF on VDD and VSS pins to induce a functional disturbance		5A

As a consequence, it is recommended to add a serial resistor (1 kΩ), located as close as possible to the MCU, to the pins exposed to noise (connected to tracks longer than 50 mm on PCB).

Designing hardened software to avoid noise problems

EMC characterization and optimization are performed at component level with a typical application environment and simplified MCU software. Good EMC performance is highly dependent upon 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 its application.

Software recommendations

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

- Corrupted program counter
- Unexpected reset
- Critical data corruption (such as control registers)

Prequalification trials

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

To complete these trials, ESD stress can be applied directly on the device, over the range of specification values. When unexpected behavior is detected, the software can be hardened to prevent unrecoverable errors occurring (see application note AN1015 *"Software techniques for improving microcontrollers EMC performance").*

Electromagnetic interference (EMI)

The electromagnetic field emitted by the device is monitored while a simple application, executing EEMBC code, is running. This emission test is compliant with SAE IEC61967-2 standard, which specifies the test board and the pin loading.

Table 53. EMI characteristics

Symbol	Parameter	Conditions	Monitored frequency band	Max vs. [f_{HSE}/f_{CPU}]	Unit
				25/250 MHz	
S_{EMI}	Peak level(1)	V_{DD} = 3.6 V, T_A = 25°C, TFBGA225-SMPS package, conforming to IEC61967-2	0.1 to 30 MHz	8	dBµV
			30 to 130 MHz	20	
			130 MHz to 1 GHz	21	
			1 GHz to 2 GHz	10	
			EMI level	3	-

1. Refer to the EMI radiated test chapter of application note AN1709 "*EMC design guide for STM8, STM32 and legacy MCUs*" available from the ST website *www.st.com*.

5.3.13 Absolute maximum ratings (electrical sensitivity)

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

Electrostatic discharge (ESD)

Electrostatic discharges (a positive pulse followed by a negative one) are applied to the pins of each sample according to each pin combination. This test conforms to the ANSI/ESDA/JEDEC JS-001 and ANSI/ESDA/JEDEC JS-002 standards.

Table 54. ESD absolute maximum ratings

Symbol	Ratings	Conditions	Packages	Class	Maximum value(1)	Unit
$V_{ESD(HBM)}$	Electrostatic discharge voltage (human body model)	T_A = 25°C, conforming to ANSI/ESDA/JEDEC JS-001	All packages	3A	4000(2)	V
$V_{ESD(CDM)}$	Electrostatic discharge voltage (charge device model)	T_A = 25°C, conforming to ANSI/ESDA/JEDEC JS-002	TFBGA225 UFBGA169 UFBGA144 LQFP144 LQFP100	C2a	500	V

1. Evaluated by characterization - Not tested in production.
2. On all pins except BOOT0, PB13, and PB14, with a maximum voltage of 3300 V.

Static latch-up

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

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

These tests are compliant with the JESD78 IC latch-up standard.

Table 55. Electrical sensitivities

Symbol	Parameter	Conditions	Class
LU	Static latch-up class	T_J = 130°C, conforming to JESD78	II level A

5.3.14 I/O current injection characteristics

As a general rule, avoid current injection to the I/O pins, due to external voltage below V_{SS} or above V_{DD} (for standard, 3.3 V-capable I/O pins) during the normal product operation. To give an indication of the device robustness when an abnormal injection accidentally happens, susceptibility tests are performed on a sample basis during the characterization.

Functional susceptibility to I/O current injection

While a simple application is executed, the device is stressed by injecting current into the I/O pins (one at the time) programmed in floating input mode, and checked for functional failures. The failure is indicated by an out of range parameter: ADC error above a certain limit (higher than 5 LSB TUE), out of conventional limits (-5 / +0 µA range) of induced

leakage current on adjacent pins, or other functional failures (such as reset, oscillator frequency deviation).

The following table shows I/Os current injection susceptibility data. Negative/positive induced leakage currents are caused, respectively, by negative/positive injection.

Table 56. I/O current injection susceptibility(1)

Symbol	Description	Functional susceptibility		Unit
		Negative injection	Positive injection	
I_{INJ}	Injected current on pins PA4, PA5, PA0, PA1 and PA2	0	0	mA
	Injected current on pins PC14, PC15, BOOT0, NRST and PA8	0	N/A	
	Injected current on all other pins	5	N/A	

1. Evaluated by characterization - Not tested in production.

5.3.15 I/O port characteristics

General input/output characteristics

Unless otherwise specified, the parameters given in *Table 57* are derived from tests performed under the conditions summarized in *Table 19*. All I/Os are CMOS and TTL compliant (except for BOOT0).

Note: For information on GPIO configuration, refer to AN4899 "STM32 GPIO configuration for hardware settings and low-power consumption", available on www.st.com.

Table 57. I/O static characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{IL}	I/O input low level voltage except BOOT0	1.08 V < V_{DDIOx} < 3.6 V	-	-	0.3 V_{DDIOx}(2)	V
	I/O input low level voltage except BOOT0		-	-	0.4 V_{DDIOx} - 0.1(3)	
	BOOT0 I/O input low level voltage		-	-	0.19 V_{DDIOx} + 0.1(3)	
V_{IH}	I/O input high level voltage except BOOT0	1.08 V < V_{DDIOx} < 3.6 V	0.7 V_{DDIOx}(2)	-	-	V
	I/O input high level voltage except BOOT0		0.52 V_{DDIOx} + 0.18(3)	-	-	
	BOOT0 I/O input high level voltage		0.17 V_{DDIOx} + 0.6(3)	-	-	
V_{HYS}(3)	TT_xx, FT_xxx and NRST I/O input hysteresis	1.08 V < V_{DDIOx} < 3.6 V	-	250	-	mV
	BOOT0 I/O input hysteresis	1.71 V < V_{DDIOx} < 3.6 V	-	200	-	

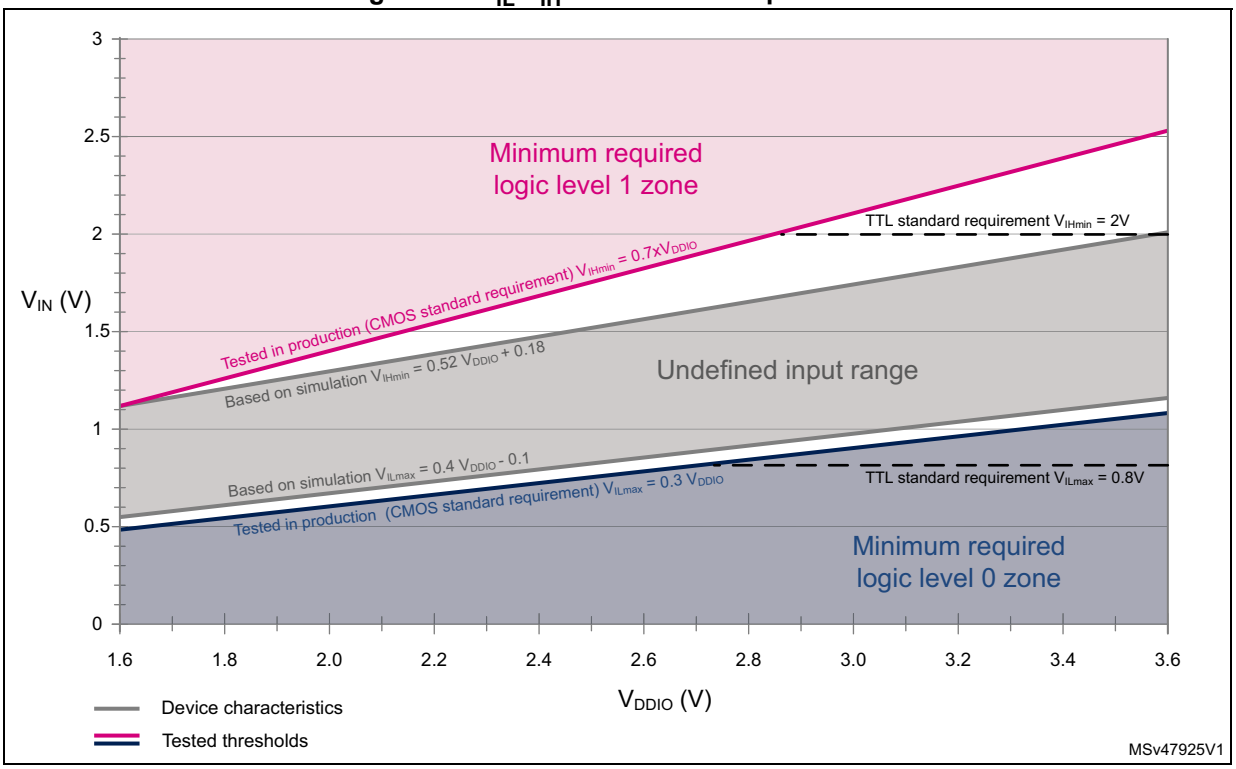
Table 57. I/O static characteristics(1) (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I_{leak}(4)	FT_xx input leakage current(3)	$0 < V_{IN} \leq Max(V_{DDXXX})$(7)	-	-	±200	nA
		$Max(V_{DDXXX}) < V_{IN} \leq Max(V_{DDXXX}) + 1\ V)$ (5)(7)	-	-	2500	
		$Max(V_{DDXXX}) < V_{IN} \leq 5.5\ V$ (5)(7)	-	-	750	
	FT_u IO input leakage current	$0 < V_{IN} \leq Max(V_{DDXXX})$ (7)	-	-	±350	
		$Max(V_{DDXXX}) < V_{IN} \leq 5.5\ V$(5)	-	-	5000(6)	
	TT_xx input leakage current	$0 < V_{IN} \leq Max(V_{DDXXX})$ (7)	-	-	±200	
	BOOT0	$0 < V_{IN} \leq V_{DDIOx}$	-	-	15	
R_{PU}	Weak pull-up equivalent resistor(6)	$V_{IN} = V_{SS}$	30	40	50	kΩ
R_{PD}	Weak pull-down equivalent resistor(6)	$V_{IN} = V_{DD}$(7)	30	40	50	
C_{IO}	I/O pin capacitance	-	-	5	-	pF

1. V_{DDIOx} represents V_{DD} or V_{DDIO2}.
2. Compliant with CMOS requirements.
3. Specified by design - Not tested in production.
4. This parameter represents the pad leakage of the I/O itself. The total product pad leakage is provided by the following formula: $I_{Total\_leak\_max}$ = 10 µA + [number of I/Os where V_{IN} is applied on the pad] x $I_{lkg(Max)}$.
5. V_{IN} must be lower than $Max(V_{DDXXX})$ + 3.6 V.
6. The pull-up and pull-down resistors are designed with a true resistance in series with a switchable PMOS/NMOS. This PMOS/NMOS contribution to the series resistance is minimal (~10%).
7. $Max(V_{DDXXX})$ is the maximum value of all the I/O supplies.

All I/Os are CMOS and TTL compliant (no software configuration required). Their characteristics cover more than the strict CMOS technology or TTL parameters. The coverage of these requirements for FT I/Os is shown in the following figure.

Figure 34. V_{IL}/V_{IH} for all I/Os except BOOT0



Output driving current

The GPIOs (general purpose input/outputs) can sink or source up to ±8 mA, and sink or source up to ±20 mA (with a relaxed V_{OL}/V_{OH}).

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

- The sum of the currents sourced by all the I/Os on $V_{DD,}$ plus the maximum Run consumption of the MCU sourced on $V_{DD,}$ cannot exceed the absolute maximum rating ΣI_{VDD} (see *Table 17*).
- The sum of the currents sunk by all the I/Os on V_{SS} plus the maximum Run consumption of the MCU sunk on V_{SS} cannot exceed the absolute maximum rating ΣI_{VSS} (see *Table 17*).

Output voltage levels

Unless otherwise specified, the parameters given in *Table 58* and *Table 60* are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in *Table 19*. All I/Os are CMOS and TTL compliant.

Table 58. Output voltage characteristics for all I/Os except PC13, PC14, PC15, and PI8

Symbol	Parameter	Conditions[1]	Min	Max	Unit
V_{OL}	Output low level voltage	CMOS port[2], I_{IO} = 8 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	-	0.4	V
V_{OH}	Output high level voltage	CMOS port[2], I_{IO} = -8 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	V_{DD}– 0.4	-	
V_{OL}[3]	Output low level voltage	TTL port[2], I_{IO} = 8 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	-	0.4	
V_{OH}[3]	Output high level voltage	TTL port[2], I_{IO} = -8 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	2.4	-	
V_{OL}[3]	Output low level voltage	I_{IO} = 20 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	-	1.3	
V_{OH}[3]	Output high level voltage	I_{IO} = -20 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	V_{DD} - 1.3	-	
V_{OL}[3]	Output low level voltage	I_{IO} = 4 mA 1.71 V ≤ V_{DD} ≤ 3.6 V	-	0.4	
V_{OH} [3]	Output high level voltage	I_{IO} = -4 mA 1.71 V ≤ V_{DD} <3.6 V	V_{DD} - 0.4	-	
V_{OL}[3]	Output low level voltage	I_{IO} = 2 mA 1.08 V ≤ V_{DD} ≤ 1.32 V	-	0.3 V_{DDIO2}	
V_{OH} [3]	Output high level voltage	I_{IO} = -2 mA 1.71 V ≤ V_{DD} < 1.32 V	0.7 V_{DDIO2}	-	
V_{OLFM+}[3]	Output low level voltage for an FTf I/O pin in (FT I/O with “f” option)	I_{IO} = 20 mA 2.3 V≤ V_{DD} ≤3.6 V	-	0.4	
		I_{IO} = 10 mA 1.71 V ≤ V_{DD} ≤ 3.6 V	-	0.4	
		I_{IO} = 4.5 mA 1.08 V ≤ V_{DD} ≤ 3.6 V	-	0.4	

1. The I_{IO} current sourced or sunk by the device must always respect the absolute maximum rating specified in *Table 16*, and the sum of the currents sourced or sunk by all the I/Os (I/O ports and control pins) must always respect the absolute maximum ratings ΣI_{IO}.
2. TTL and CMOS outputs are compatible with JEDEC standards JESD36 and JESD52.
3. Specified by design - Not tested in production.

Table 59. Output voltage characteristics for FT_c I/Os

Symbol	Parameter	Conditions[1]	Min	Max	Unit
V_{OL}	Output low level voltage	CMOS port[2], I_{IO} = 2 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	-	0.4	V
V_{OH}	Output high level voltage	CMOS port[2], I_{IO} = -2 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	V_{DD}− 0.4	-	
V_{OL}[3]	Output low level voltage	TTL port[2], I_{IO} = 2 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	-	0.4	
V_{OH}[3]	Output high level voltage	TTL port[2], I_{IO} = -2 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	2.4	-	
V_{OL}[3]	Output low level voltage	I_{IO} = 1 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	-	0.4	
V_{OH}[3]	Output high level voltage	I_{IO} = -1 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	V_{DD} - 0.4	-	
V_{OL}[3]	Output low level voltage	I_{IO} = 0.1 mA 1.71 V ≤ V_{DD} ≤ 3.6 V	-	0.4	
V_{OH} [3]	Output high level voltage	I_{IO} = -0.1 mA 1.71 V ≤ V_{DD} < 3.6 V	V_{DD} - 0.4	-	

1. The I_{IO} current sourced or sunk by the device must always respect the absolute maximum rating specified in *Table 16*, and the sum of the currents sourced or sunk by all the I/Os (I/O ports and control pins) must always respect the absolute maximum ratings ΣI_{IO}.
2. TTL and CMOS outputs are compatible with JEDEC standards JESD36 and JESD52.
3. Specified by design - Not tested in production.

Table 60. Output voltage characteristics for PC13 and PI8[1]

Symbol	Parameter	Conditions[3]	Min	Max	Unit
V_{OL}	Output low level voltage	CMOS port[2], I_{IO} = 3 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	-	0.4	V
V_{OH}	Output high level voltage	CMOS port[2], I_{IO} = -3 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	V_{DD} - 0.4	-	
V_{OL}[3]	Output low level voltage	TTL port[2], I_{IO} = 3 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	-	0.4	
V_{OH}[3]	Output high level voltage	TTL port[2], I_{IO} = -3 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	2.4	-	
V_{OL}[3]	Output low level voltage	I_{IO} = 1.5 mA 1.71 V ≤ V_{DD} ≤ 3.6 V	-	0.4	
V_{OH}[3]	Output high level voltage	I_{IO} = −1.5 mA 1.71 V ≤ V_{DD} ≤ 3.6 V	V_{DD} - 0.4	-	

1. The I_{IO} current sourced or sunk by the device must always respect the absolute maximum rating specified in *Table 16*, and the sum of the currents sourced or sunk by all the I/Os (I/O ports and control pins) must always respect the absolute maximum ratings ΣI_{IO}.
2. TTL and CMOS outputs are compatible with JEDEC standards JESD36 and JESD52.
3. Specified by design - Not tested in production.

Table 61. Output voltage characteristics for PC14 and PC15(1)

Symbol	Parameter	Conditions(3)	Min	Max	Unit
V_{OL}	Output low level voltage	CMOS port(2), I_{IO} = 0.5 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	-	0.4	V
V_{OH}	Output high level voltage	CMOS port(2), I_{IO} = -0.5 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	V_{DD} - 0.4	-	
V_{OL}(3)	Output low level voltage	TTL port(2), I_{IO} = 0.5 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	-	0.4	
V_{OH}(3)	Output high level voltage	TTL port(2), I_{IO} = -0.5 mA 2.7 V ≤ V_{DD} ≤ 3.6 V	2.4	-	
V_{OL}(3)	Output low level voltage	I_{IO} = 0.25 mA 1.71 V ≤ V_{DD} ≤ 3.6 V	-	0.4	
V_{OH}(3)	Output high level voltage	I_{IO} = -0.25 mA 1.71 V ≤ V_{DD} ≤ 3.6 V	V_{DD} - 0.4	-	

1. The I_{IO} current sourced or sunk by the device must always respect the absolute maximum rating specified in *Table 16*, and the sum of the currents sourced or sunk by all the I/Os (I/O ports and control pins) must always respect the absolute maximum ratings ΣI_{IO}.
2. TTL and CMOS outputs are compatible with JEDEC standards JESD36 and JESD52.
3. Specified by design - Not tested in production.

Output buffer timing characteristics (HSLV option disabled)

The HSLV bit of GPIOx_HSLVR register can be used to optimize the I/O speed when the voltage is below 2.7 V.

Table 62. Output timing characteristics (HSLV OFF)(1)

Speed	Symbol	Parameter	Conditions	Min	Max	Unit
00	F_{max}(2)(3)	Maximum frequency	C = 50 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	8	MHz
			C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	5	
			C = 40 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	10	
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	5	
			C = 30 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	12	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	5	
			C = 20 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	14	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	5	
			C = 10 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	16	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	5	
	t_r/t_f(4)(5)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	18.0	ns
			C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	36.0	
			C = 40 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	17.0	
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	34.0	
			C = 30 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	15.5	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	32.0	
			C = 20 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	14.2	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	30.0	
			C = 10 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	12.2	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	27	

Table 62. Output timing characteristics (HSLV OFF)(1) (continued)

Speed	Symbol	Parameter	Conditions	Min	Max	Unit
01	F_{max}(2)(3)	Maximum frequency	C = 50 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V		40	MHz
			C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	12	
			C = 40 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	45	
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	14	
			C = 30 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	50	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	16	
			C = 20 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	55	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	18	
			C = 10 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	60	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	20	
	t_r/t_f(4)(5)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	6.2	ns
			C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	11.4	
			C = 40 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	5.7	
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	10.5	
			C = 30 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	5.1	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	9.5	
			C = 20 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	4.5	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V		8.4	
			C = 10 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V		3.7	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V		7.0	

Table 62. Output timing characteristics (HSLV OFF)(1) (continued)

Speed	Symbol	Parameter	Conditions	Min	Max	Unit
10	F_{max}(2)(3)(6)	Maximum frequency	C = 50 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	80	MHz
			C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	30	
			C = 40 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	90	
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	35	
			C = 30 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	100	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	40	
			C = 20 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	110	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	45	
			C = 10 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	133	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	50	
	t_r/t_f(4)(5)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	3.8	ns
			C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	7.5	
			C = 40 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	3.4	
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	6.6	
			C = 30 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	2.9	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	5.7	
			C = 20 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	2.5	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	4.7	
			C = 10 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	1.9	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	3.7	

Table 62. Output timing characteristics (HSLV OFF)(1) (continued)

Speed	Symbol	Parameter	Conditions	Min	Max	Unit
11	F_{max}(2)(3)(7)	Maximum frequency	C = 50 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	100	MHz
			C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	40	
			C = 40 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	120	
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	50	
			C = 30 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	140	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	60	
			C = 20 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	166	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	70	
			C = 10 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	200	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	80	
	t_r/t_f(4)(5)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 2.7 V≤ V_{DD} ≤ 3.6 V	-	3.3	ns
			C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	6.3	
			C = 40 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	2.8	
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	5.5	
			C = 30 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	2.3	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	4.6	
			C = 20 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	1.9	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	3.7	
			C = 10 pF, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	1.4	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	3	

1. Specified by design - Not tested in production.
2. The maximum frequency is defined with the conditions (t_r + t_f) ≤ 2/3 T, Skew ≤ 1/20 T, and 45% < Duty cycle < 55%.
3. When 2 V < V_{DD} < 2.7 V the maximum frequency is between values given for V_{DD} = 1.98 V and V_{DD} = 2.7 V.
4. The fall and rise times are defined between 90% and 10% and between 10% and 90% of the output waveform, respectively.
5. When 2 V < V_{DD} < 2.7 V the maximum t_{rise}/t_{fall} is between values given for V_{DD} = 1.98 V and V_{DD} = 2.7 V.
6. For LQFP100 and LQFP100-SMPS packages, the maximum frequency is 100 MHz.
7. For LQFP100 and LQFP100-SMPS packages, the maximum frequency is reduced by up to 20%.

Output buffer timing characteristics (HSLV option enabled)

Table 63. Output timing characteristics (HSLV ON)(1)

Speed	Symbol	Parameter	Conditions	Min	Max	Unit
00	F_{max}(2)	Maximum frequency	C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	8	MHz
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	10	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	12	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	14	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	16	
	t_r/t_f(3)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	17.8	ns
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	15.8	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	14.4	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	13.1	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	11.4	
01	F_{max}(2)	Maximum frequency	C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	40	MHz
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	45	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	50	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	55	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	60	
	t_r/t_f(3)(4)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	7.2	ns
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	6.5	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	5.6	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	4.8	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	3.8	
10	F_{max}(2)(4)(5)	Maximum frequency	C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	60	MHz
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	70	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	90	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	110	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	140	
	t_r/t_f(3)(4)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	5.3	ns
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	4.6	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	3.8	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	3.0	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	2.2	

Table 63. Output timing characteristics (HSLV ON)(1) (continued)

Speed	Symbol	Parameter	Conditions	Min	Max	Unit
11	F_{max}(2)(4)(6)	Maximum frequency	C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	67	MHz
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	100	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	120	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	155	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	200	
	t_r/t_f(3)(4)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	5.0	ns
			C = 40 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	4.1	
			C = 30 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	3.3	
			C = 20 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	2.5	
			C = 10 pF, 1.71 V ≤ V_{DD} ≤ 2 V	-	1.8	

1. Specified by design - Not tested in production.
2. The maximum frequency is defined with the conditions: (t_r+t_f) ≤ 2/3 T, Skew ≤ 1/20 T, 45% < Duty cycle < 55%.
3. The fall and rise times are defined, respectively, between 90 and 10% and between 10 and 90% of the output waveform.
4. Compensation system enabled.
5. For LQFP100 and LQFP100-SMPS packages, the maximum frequency is 100 MHz.
6. For LQFP100 and LQFP100-SMPS packages, the maximum frequency is reduced by up to 20%.

Table 64. Output timing characteristics V_{DDIO2} 1.2 V range (HSLV OFF)(1)

Speed	Symbol	Parameter	Conditions	Min	Max	Unit
00	F_{max}(2)	Maximum frequency	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	1	MHz
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	1	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	1	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	1	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	1	
	t_r/t_f(3)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	83.0	ns
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	79.0	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	46.0	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	72.0	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	68.0	

Table 64. Output timing characteristics V_{DDIO2} 1.2 V range (HSLV OFF)(1) (continued)

Speed	Symbol	Parameter	Conditions	Min	Max	Unit
01	F_{max}(2)	Maximum frequency	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	5	MHz
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	5	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	5	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	5	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	5	
	t_r/t_f(3)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	24.5	ns
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	22.2	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	20.0	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	17.8	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	15.0	
10	F_{max}(2)	Maximum frequency	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	10	MHz
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	10	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	10	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	10	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	10	
	t_r/t_f(3)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	16.2	ns
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	14.3	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	12.2	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	10.0	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	7.9	
11	F_{max}(2)(4)	Maximum frequency	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	20	MHz
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	23	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	25	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	28	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	30	
	t_r/t_f(3)(4)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	14.0	ns
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	12.0	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	10.0	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	8.0	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	6.0	

1. Specified by design - Not tested in production.
2. The maximum frequency is defined with the conditions (t_r + t_f) ≤ 2/3 T, Skew ≤ 1/20 T, 45% < Duty cycle < 55%.
3. The fall and rise times are defined between 90% and 10% and between 10% and 90% of the output waveform, respectively.
4. Compensation system enabled.

Table 65. Output timing characteristics V_{DDIO2} 1.2 V (HSLV ON)(1)

Speed	Symbol	Parameter	Conditions	Min	Max	Unit
00	F_{max}(2)	Maximum frequency	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	5	MHz
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	5	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	5	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	5	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	5	
	t_r/t_f(3)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	32.5	ns
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	30.0	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	27.5	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	25.0	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	22.5	
01	F_{max}(2)	Maximum frequency	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	15.0	MHz
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	17.5	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	20.0	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	22.5	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	25.0	
	t_r/t_f(3)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	14.6	ns
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	12.9	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	11.2	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	9.3	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	7.3	
10	F_{max}(2)(4)	Maximum frequency	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	25	MHz
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	30	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	33	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	44	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	55	
	t_r/t_f(3)(4)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	11.6	ns
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	9.7	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	7.8	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	6.1	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	4.3	

Table 65. Output timing characteristics V_{DDIO2} 1.2 V (HSLV ON)(1) (continued)

Speed	Symbol	Parameter	Conditions	Min	Max	Unit
11	F_{max}(2)(4)	Maximum frequency	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	30	MHz
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	35	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	44	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	55	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	77	
	t_r/t_f(3)(4)	Output high to low level fall time and output low to high level rise time	C = 50 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	11.1	ns
			C = 40 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	9.2	
			C = 30 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	7.2	
			C = 20 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	5.4	
			C = 10 pF, 1.08 V ≤ V_{DDIO2} ≤ 1.32 V	-	3.6	

1. Specified by design - Not tested in production.
2. The maximum frequency is defined with the conditions (t_r + t_f) ≤ 2/3 T, Skew ≤ 1/20 T, 45%< Duty cycle < 55%.
3. The fall and rise times are defined between 90% and 10% and between 10% and 90% of the output waveform, respectively.
4. Compensation system enabled.

Table 66. Output timing characteristics for FT_c I/Os (PB13/PB14)(1)(2)

Speed	Symbol	Parameter	Conditions	Min	Max	Unit
00	F_{max}	Maximum frequency	C = 50 pF, 2.7 V ≤ V_{DDIO} ≤ 3.6 V	-	2	MHz
			C = 50 pF, 1.71 V ≤ V_{DDIO} < 2.7 V	-	1	
	t_r/t_f	Output rise and fall time	C = 50 pF, 2.7 V ≤ V_{DDIO} < 3.6 V	-	166	ns
			C = 50 pF, 1.71 V ≤ V_{DDIO} < 2.7 V	-	330	
01	F_{rmax}	Maximum frequency	C = 30 pF, 2.7 V ≤ V_{DDIO} < 3.6 V	-	10	MHz
			C = 30 pF, 1.71 V ≤ V_{DDIO} < 2.7 V	-	4	
	t_r/t_f	Output rise and fall time	C = 30 pF, 2.7 V ≤ V_{DDIO} < 3.6 V	-	33	ns
			C = 30 pF, 1.71 V ≤ V_{DDIO} < 2.7 V	-	65	

1. Specified by design - Not tested in production.
2. The I/O speed is configured using the OSPEEDRy[1:0] bits. Refer to the product reference manual for a description of GPIO port configuration register.

5.3.16 NRST pin characteristics

The NRST pin input driver uses CMOS technology. It is connected to a permanent pull-up resistor, R_{PU} (see *Table 57*).

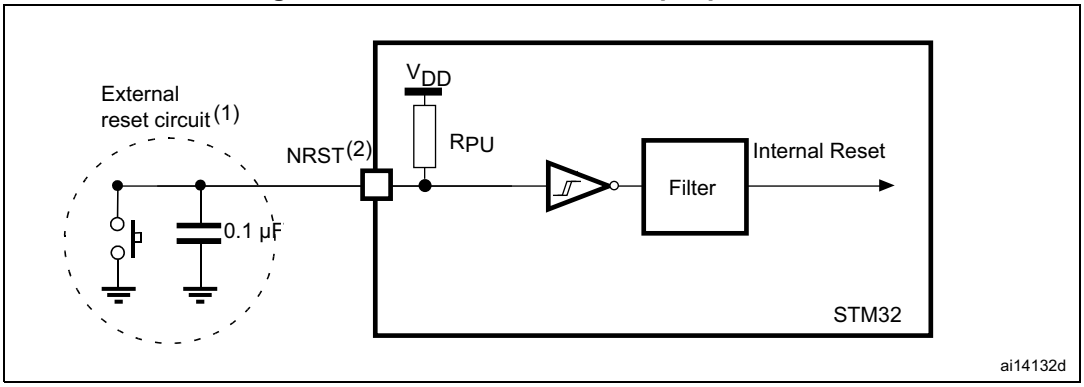
Unless otherwise specified, the parameters in *Table 67* are derived from tests performed under the ambient temperature and V_{DD} supply voltage conditions summarized in *Table 19*.

Table 67. NRST pin characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
R_{PU}(2)	Weak pull-up equivalent resistor(1)	$V_{IN} = V_{SS}$	30	40	50	kΩ
$V_{F(NRST)}$(2)	NRST input filtered pulse	1.71 V < V_{DD} < 3.6 V	-	-	50	ns
$V_{NF(NRST)}$(2)	NRST input not filtered pulse	1.71 V < V_{DD} < 3.6 V	350	-	-	

1. The pull-up is designed with a true resistance in series with a switchable PMOS. The PMOS contribution to the series resistance is minimum (~10 % order).
2. Specified by design - Not tested in production.

Figure 35. 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 57*, otherwise the reset is not taken into account by the device.

5.3.17 Extended interrupt and event controller input (EXTI) characteristics

The pulse on the interrupt input must have a minimal length to ensure its detection by the event controller.

Table 68. EXTI input characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
PLEC	Pulse length to event controller	-	20	-	-	ns

1. Specified by design - Not tested in production.

5.3.18 PLAY characteristics

Unless otherwise specified, the parameters in the following tables are derived from tests performed under the ambient temperature and supply voltage conditions summarized in table 70.

- Output speed is set to OSPEEDRy[1:0] = 11
- Capacitive load C = 30 pF
- Measurement points are done at CMOS levels: 0.5 V_{DD}
- IO Compensation cell activated.
- VOS level set to VOS0
- HSLV activated when $V_{DD} \leq 2.7$ V

Table 69. PLAY timing(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
t_{pd}	Propagation delay from input I/Os to output I/Os	Maximum PLAY propagation delay for each LUT from input I/Os to output I/Os	-	12	-	ns
$t_{pd(comp)}$		Propagation delay from comparator COMPx_INP input pin to PLAY output pin	-	39	-	

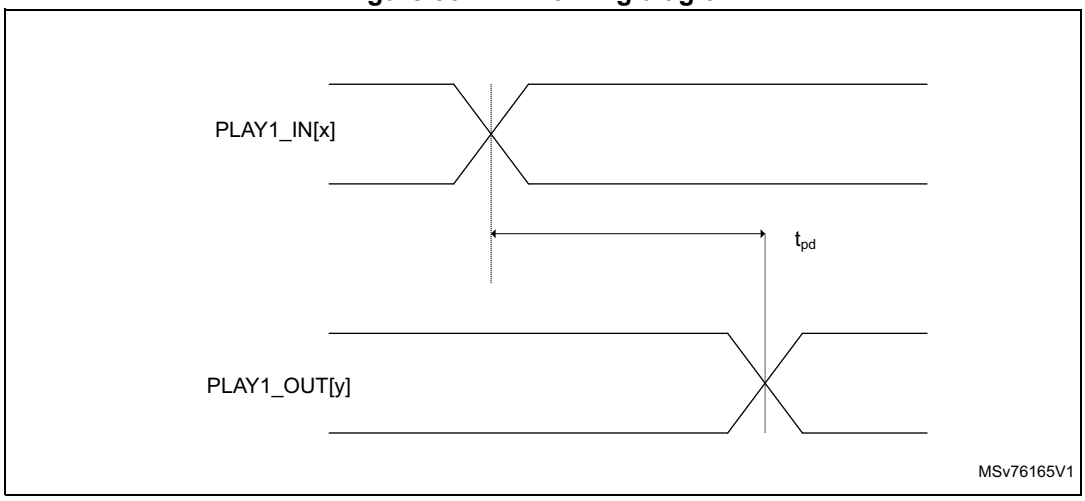
1. Evaluated by characterization - Not tested in production.

Table 70. PLAY filter characteristics(1)

Symbol	Parameter	Min	Max	Unit
t_{PF}	Maximum pulse length that is guaranteed to be filtered	-	$(N^{(2)} - 1) * T_{CK} + 2.5$	ns
t_{PP}	Minimum pulse length that is guaranteed to pass	$N * T_{CK} + 2.5$	-	

1. Evaluated by characterization - Not tested in production.
2. N is the minimum pulse length, in periods of play_clk, programmed in the filter.

Figure 36. PLAY timing diagram



5.3.19 FMC characteristics

Unless otherwise specified, the parameters given in tables *71* to *84* are derived from tests performed under the ambient temperature, f_{HCLK} frequency, and V_{DD} supply voltage conditions summarized in *Table 19*, with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 10
- Measurement points are done at CMOS levels: 0.5 V_{DD}
- I/O compensation cell activated
- HSLV activated when $V_{DD} \leq 2.7$ V
- VOS level set to VOS0

Refer to *Section 5.3.15* for more details on the input/output alternate function characteristics.

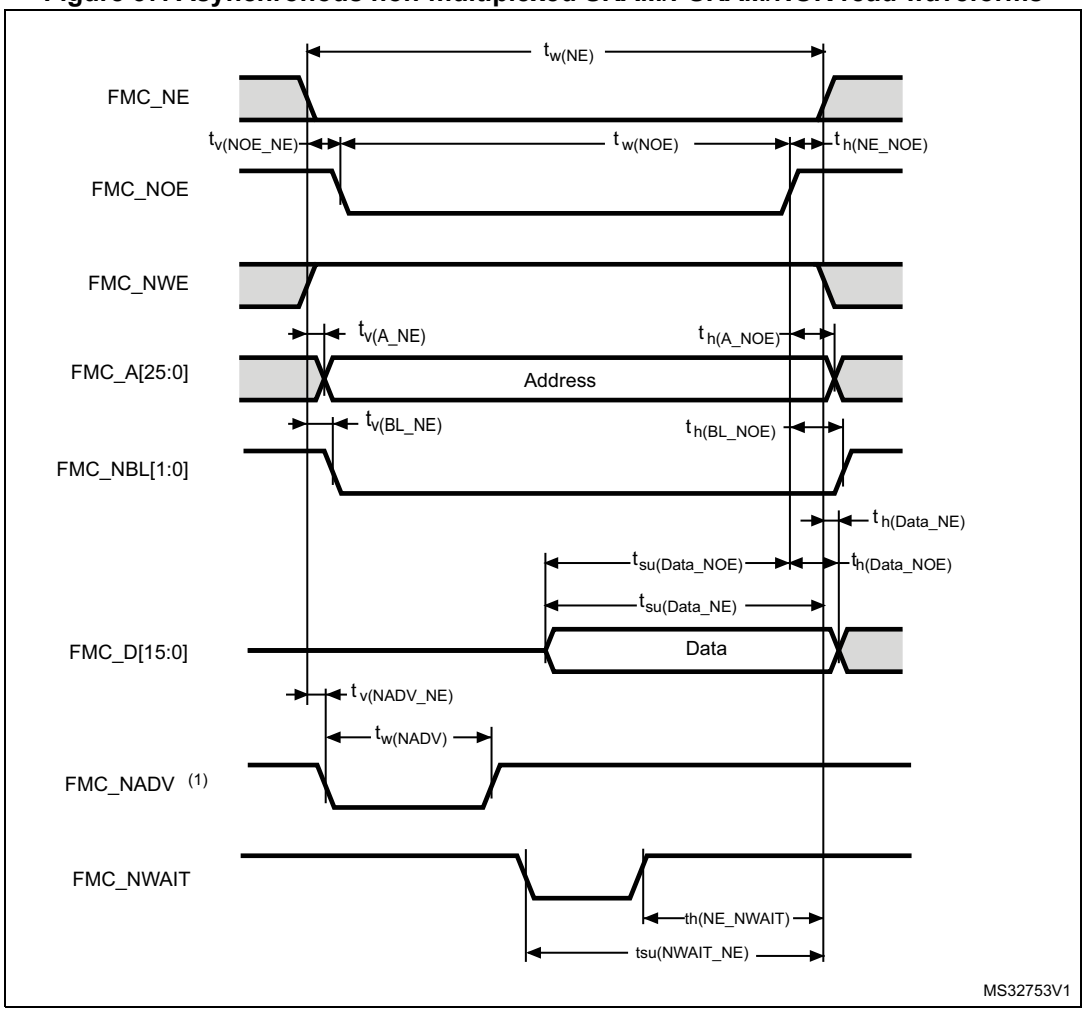
Asynchronous waveforms and timings

Figures *37* through *39* represent asynchronous waveforms, tables *71* through *78* provide the corresponding timings. The results shown in these tables are obtained with the following FMC configuration:

- AddressSetupTime = 0x1
- AddressHoldTime = 0x1
- DataSetupTime = 0x1 (except for asynchronous NWAIT mode, DataSetupTime = 0x5)
- BusTurnAroundDuration = 0x0
- Capacitive load C_L = 30 pF

In all timing tables, the $T_{fmc\_ker\_ck}$ is the f_{HCLK} clock period.

Figure 37. Asynchronous non-multiplexed SRAM/PSRAM/NOR read waveforms



1. Mode 2/B, C and D only. In Mode 1, FMC_NADV is not used.

Table 71. Asynchronous non-multiplexed SRAM/PSRAM/NOR read timings(1)

Symbol	Parameter	Min	Max	Unit
$t_{w(NE)}$	FMC_NE low time	$3\ T_{fmc\_ker\_ck} - 1$	$3\ T_{fmc\_ker\_ck} + 1$	ns
$t_{v(NOE\_NE)}$	FMC_NEx low to FMC_NOE low	0	0.5	
$t_{w(NOE)}$	FMC_NOE low time	$2\ T_{fmc\_ker\_ck} - 1$	$2\ T_{fmc\_ker\_ck} + 1$	
$t_{h(NE\_NOE)}$	FMC_NOE high to FMC_NE high hold time	$T_{fmc\_ker\_ck} - 0.5$	-	
$t_{v(A\_NE)}$	FMC_NEx low to FMC_A valid	-	1	
$t_{h(A\_NOE)}$	Address hold time after FMC_NOE high	$2\ T_{fmc\_ker\_ck} - 1.5$	-	
$t_{su(Data\_NE)}$	Data to FMC_NEx high setup time	$T_{fmc\_ker\_ck} + 10$	-	
$t_{su(Data\_NOE)}$	Data to FMC_NOEx high setup time	9	-	
$t_{h(Data\_NOE)}$	Data hold time after FMC_NOE high	0	-	
$t_{h(Data\_NE)}$	Data hold time after FMC_NEx high	0	-	
$t_{v(NADV\_NE)}$	FMC_NEx low to FMC_NADV low	-	0.5	
$t_{w(NADV)}$	FMC_NADV low time	-	$T_{fmc\_ker\_ck} + 1$	

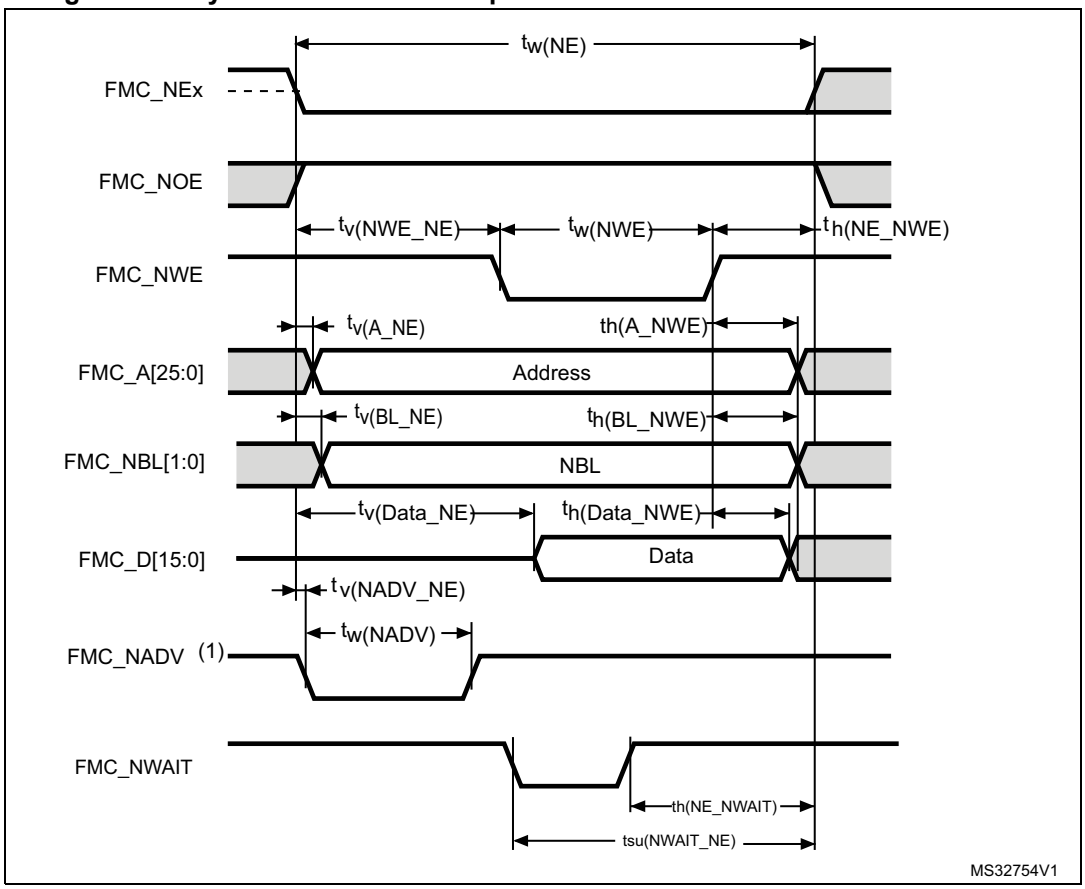
1. Evaluated by characterization - Not tested in production.

Table 72. Asynchronous non-multiplexed SRAM/PSRAM/NOR read-NWAIT timings(1)(2)

Symbol	Parameter	Min	Max	Unit
$t_{w(NE)}$	FMC_NE low time	$8\ T_{fmc\_ker\_ck} - 1$	$8\ T_{fmc\_ker\_ck} + 1$	ns
$t_{w(NOE)}$	FMC_NOE low time	$7\ T_{fmc\_ker\_ck} - 1$	$7\ T_{fmc\_ker\_ck} + 1$	
$t_{w(NWAIT)}$	FMC_NWAIT low time	$T_{fmc\_ker\_ck} - 0.5$	-	
$t_{su(NWAIT\_NE)}$	FMC_NWAIT valid before FMC_NEx high	$5\ T_{fmc\_ker\_ck} + 10$	-	
$t_{h(NE\_NWAIT)}$	FMC_NEx hold time after FMC_NWAIT invalid	$4\ T_{fmc\_ker\_ck} + 10$	-	

1. Evaluated by characterization - Not tested in production.
2. N_{WAIT} pulse width is equal to one fmc_ker_ck cycle.

Figure 38. Asynchronous non-multiplexed SRAM/PSRAM/NOR write waveforms



1. Mode 2/B, C and D only. In Mode 1, FMC_NADV is not used.

Table 73. Asynchronous non-multiplexed SRAM/PSRAM/NOR write timings(1)

Symbol	Parameter	Min	Max	Unit
$t_{w(NE)}$	FMC_NE low time	3 $T_{fmc\_ker\_ck}$ - 1	3 $T_{fmc\_ker\_ck}$ + 1	ns
$t_{v(NWE\_NE)}$	FMC_NEx low to FMC_NWE low	$T_{fmc\_ker\_ck}$ - 1	$T_{fmc\_ker\_ck}$+ 0.5	
$t_{w(NWE)}$	FMC_NWE low time	$T_{fmc\_ker\_ck}$ - 1	$T_{fmc\_ker\_ck}$ +1	
$t_{h(NE\_NWE)}$	FMC_NWE high to FMC_NE high hold time	$T_{fmc\_ker\_ck}$ - 1	-	
$t_{v(A\_NE)}$	FMC_NEx low to FMC_A valid	-	0.5	
$t_{h(A\_NWE)}$	Address hold time after FMC_NWE high	$T_{fmc\_ker\_ck}$ -1	-	
$t_{v(BL\_NE)}$	FMC_NEx low to FMC_BL valid	-	0.5	
$t_{h(BL\_NWE)}$	FMC_BL hold time after FMC_NWE high	$T_{fmc\_ker\_ck}$ -1	-	
$t_{v(Data\_NE)}$	Data to FMC_NEx low to Data valid	-	$T_{fmc\_ker\_ck}$ + 1	
$t_{h(Data\_NWE)}$	Data hold time after FMC_NWE high	$T_{fmc\_ker\_ck}$	-	
$t_{v(NADV\_NE)}$	FMC_NEx low to FMC_NADV low	-	0.5	
$t_{w(NADV)}$	FMC_NADV low time	-	$T_{fmc\_ker\_ck}$ + 1	

1. Evaluated by characterization - Not tested in production.

Table 74. Asynchronous non-multiplexed SRAM/PSRAM/NOR write-NWAIT timings(1)(2)

Symbol	Parameter	Min	Max	Unit
$t_{w(NE)}$	FMC_NE low time	8 $T_{fmc\_ker\_ck}$ - 1	8 $T_{fmc\_ker\_ck}$+ 1	ns
$t_{w(NWE)}$	FMC_NWE low time	6 $T_{fmc\_ker\_ck}$ - 1	6 $T_{fmc\_ker\_ck}$+ 1	
$t_{su(NWAIT\_NE)}$	FMC_NWAIT valid before FMC_NEx high	5 $T_{fmc\_ker\_ck}$ + 10	-	
$t_{h(NE\_NWAIT)}$	FMC_NEx hold time after FMC_NWAIT invalid	4 $T_{fmc\_ker\_ck}$ + 10	-	

1. Evaluated by characterization - Not tested in production.
2. N_{WAIT} pulse width is equal to one fmc_ker_ck cycle.

Figure 39. Asynchronous multiplexed PSRAM/NOR read waveforms

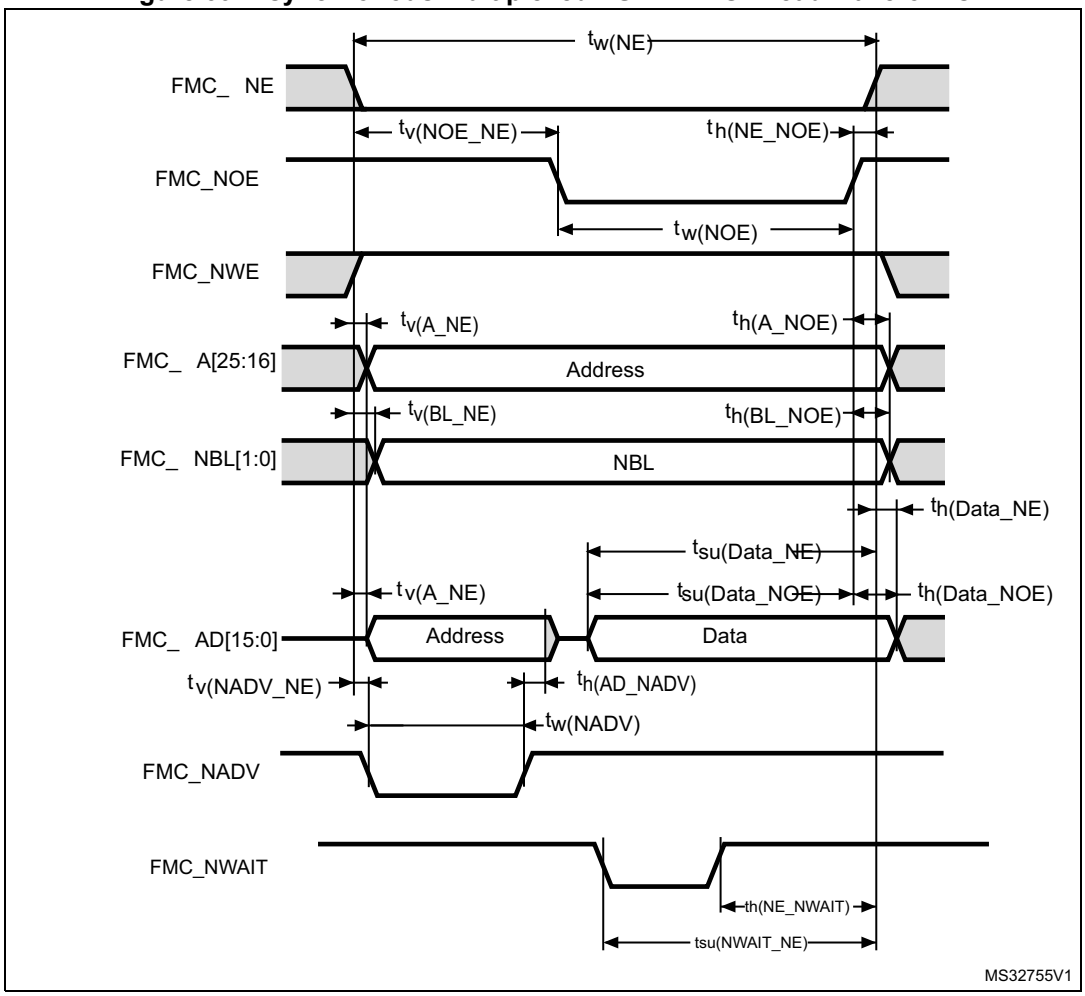


Table 75. Asynchronous multiplexed PSRAM/NOR read timings(1)

Symbol	Parameter	Min	Max	Unit
$t_{w(NE)}$	FMC_NE low time	$4\ T_{fmc\_ker\_ck} - 1$	$4\ T_{fmc\_ker\_ck} + 1$	ns
$t_{v(NOE\_NE)}$	FMC_NEx low to FMC_NOE low	$2\ T_{fmc\_ker\_ck} - 1$	$2\ T_{fmc\_ker\_ck} + 0.5$	
$t_{tw(NOE)}$	FMC_NOE low time	$T_{fmc\_ker\_ck} - 1$	$T_{fmc\_ker\_ck} + 1$	
$t_{h(NE\_NOE)}$	FMC_NOE high to FMC_NE high hold time	$T_{fmc\_ker\_ck} - 0.5$	-	
$t_{v(A\_NE)}$	FMC_NEx low to FMC_A valid	-	1	
$t_{v(NADV\_NE)}$	FMC_NEx low to FMC_NADV low	0	1	
$t_{w(NADV)}$	FMC_NADV low time	$T_{fmc\_ker\_ck} - 0.5$	$T_{fmc\_ker\_ck} + 1$	
$t_{h(AD\_NADV)}$	FMC_AD(address) valid hold time after FMC_NADV high	$T_{fmc\_ker\_ck} + 0.5$	-	
$t_{h(A\_NOE)}$	Address hold time after FMC_NOE high	$2\ T_{fmc\_ker\_ck} - 0.5$	-	
$t_{su(Data\_NE)}$	Data to FMC_NEx high setup time	$T_{fmc\_ker\_ck} + 10$	-	
$t_{su(Data\_NOE)}$	Data to FMC_NOE high setup time	9	-	
$t_{h(Data\_NE)}$	Data hold time after FMC_NEx high	0	-	
$t_{h(Data\_NOE)}$	Data hold time after FMC_NOE high	0	-	

1. Evaluated by characterization - Not tested in production.

Table 76. Asynchronous multiplexed PSRAM/NOR read-NWAIT timings(1) (2)

Symbol	Parameter	Min	Max	Unit
$t_{w(NE)}$	FMC_NE low time	$9\ T_{fmc\_ker\_ck} - 1$	$9\ T_{fmc\_ker\_ck} + 1$	ns
$t_{w(NOE)}$	FMC_NOE low time	$7\ T_{fmc\_ker\_ck} - 1$	$7\ T_{fmc\_ker\_ck} + 1$	
$t_{su(NWAIT\_NE)}$	FMC_NWAIT valid before FMC_NEx high	$4\ T_{fmc\_ker\_ck} + 10$	-	
$t_{h(NE\_NWAIT)}$	FMC_NEx hold time after FMC_NWAIT invalid	$3\ T_{fmc\_ker\_ck} + 10$	-	

1. Evaluated by characterization - Not tested in production.
2. NWAIT pulse width is equal to one fmc_ker_ck cycle.

Figure 40. Asynchronous multiplexed PSRAM/NOR write waveforms

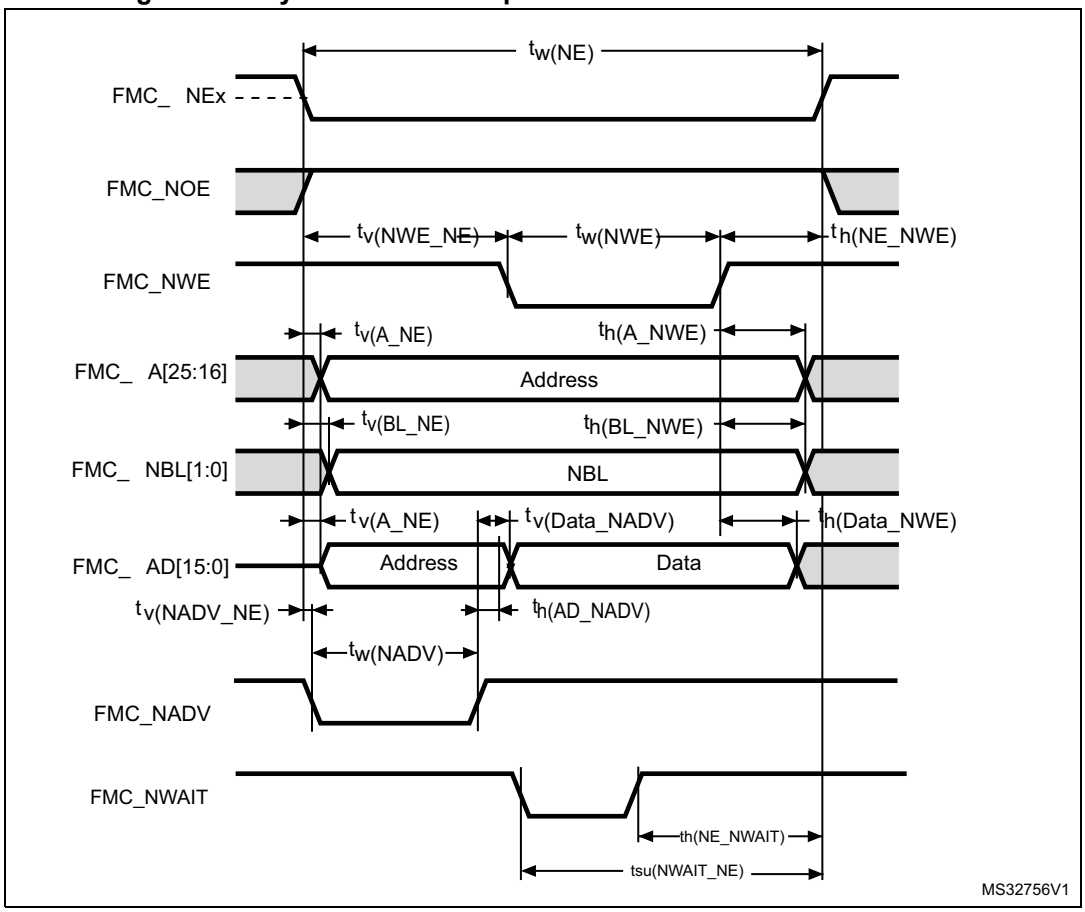


Table 77. Asynchronous multiplexed PSRAM/NOR write timings(1)

Symbol	Parameter	Min	Max	Unit
$t_{w(NE)}$	FMC_NE low time	$4\ T_{fmc\_ker\_ck}$ -1	$4\ T_{fmc\_ker\_ck}$ +1	ns
$t_{v(NWE\_NE)}$	FMC_NEx low to FMC_NWE low	$T_{fmc\_ker\_ck}$ - 1	$T_{fmc\_ker\_ck}$ +0.5	
$t_{w(NWE)}$	FMC_NWE low time	$2\ T_{fmc\_ker\_ck}$ - 1	$2\ T_{fmc\_ker\_ck}$ + 1	
$t_{h(NE\_NWE)}$	FMC_NWE high to FMC_NE high hold time	$T_{fmc\_ker\_ck}$ - 0.5	-	
$t_{v(A\_NE)}$	FMC_NEx low to FMC_A valid	-	0.5	
$t_{v(NADV\_NE)}$	FMC_NEx low to FMC_NADV low	0	1	
$t_{w(NADV)}$	FMC_NADV low time	$T_{fmc\_ker\_ck}$ - 1	$T_{fmc\_ker\_ck}$ + 1	
$t_{h(AD\_NADV)}$	FMC_AD(adress) valid hold time after FMC_NADV high	$T_{fmc\_ker\_ck}$ - 1	-	
$t_{h(A\_NWE)}$	Address hold time after FMC_NWE high	$T_{fmc\_ker\_ck}$ - 1	-	
$t_{h(BL\_NWE)}$	FMC_BL hold time after FMC_NWE high	$T_{fmc\_ker\_ck}$ - 1	-	
$t_{v(BL\_NE)}$	FMC_NEx low to FMC_BL valid	-	0.5	
$t_{v(Data\_NADV)}$	FMC_NADV high to Data valid	-	$T_{fmc\_ker\_ck}$ + 0.5	
$t_{h(Data\_NWE)}$	Data hold time after FMC_NWE high	$T_{fmc\_ker\_ck}$ - 0.5	-	

1. Evaluated by characterization - Not tested in production.

Table 78. Asynchronous multiplexed PSRAM/NOR write-NWAIT timings(1)(2)

Symbol	Parameter	Min	Max	Unit
$t_{w(NE)}$	FMC_NE low time	$9\ T_{fmc\_ker\_ck}$ - 1	$9\ T_{fmc\_ker\_ck}$ + 1	ns
$t_{w(NWE)}$	FMC_NWE low time	$7\ T_{fmc\_ker\_ck}$ -1	$7\ T_{fmc\_ker\_ck}$ + 1	
$t_{su(NWAIT\_NE)}$	FMC_NWAIT valid before FMC_NEx high	$5\ T_{fmc\_ker\_ck}$ + 10	-	
$t_{h(NE\_NWAIT)}$	FMC_NEx hold time after FMC_NWAIT invalid	$4\ T_{fmc\_ker\_ck}$ + 10	-	

1. Evaluated by characterization - Not tested in production.
2. N_{WAIT} pulse width is equal to one fmc_ker_ck cycle.

Synchronous waveforms and timings

Figures *41* through *44* represent synchronous waveforms, tables *79* through *82* provide the corresponding timings. The results shown in these tables are obtained with the following FMC configuration:

- BurstAccessMode = FMC_BurstAccessMode_Enable
- MemoryType = FMC_MemoryType_CRAM
- WriteBurst = FMC_WriteBurst_Enable
- CLKDivision = 1
- DataLatency = 1 for NOR flash, DataLatency = 0 for PSRAM.
- With capacity load C_L = 30 pF

In all the timing tables, $T_{fmc\_ker\_ck}$ is the $f_{mc\_ker\_ck}$ clock period, with the following FMC_CLK maximum values:

- For 2.7 V < V_{DD} < 3.6 V: maximum FMC_CLK = 100 MHz at C_L = 20 pF
- For 1.71 V < V_{DD} < 1.8 V: maximum FMC_CLK = 95 MHz at C_L = 20 pF
- For 1.71 V < V_{DD} < 1.8 V: maximum FMC_CLK = 100 MHz at C_L = 15 pF

Figure 41. Synchronous multiplexed NOR/PSRAM read timings

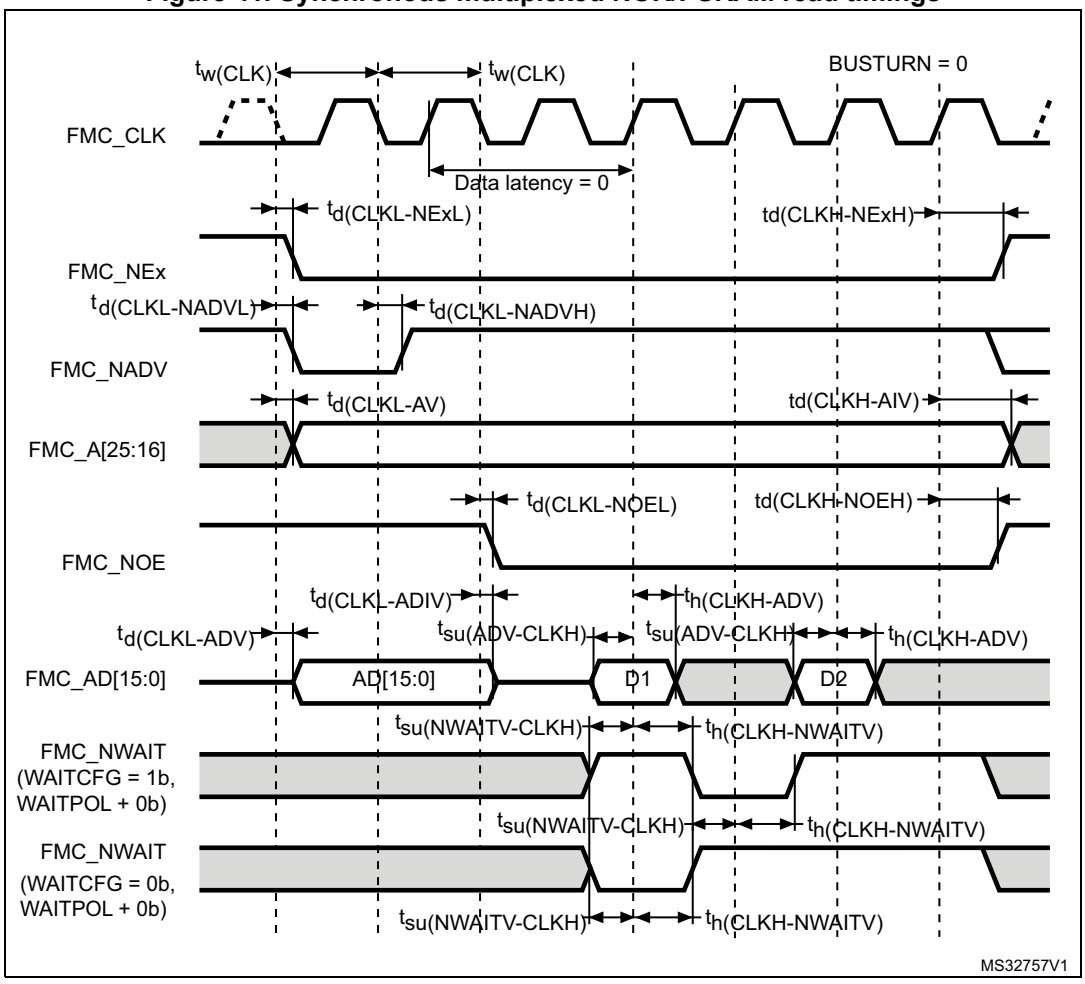


Table 79. Synchronous multiplexed NOR/PSRAM read timings(1)

Symbol	Parameter	Min	Max	Unit
$t_{w(CLK)}$	FMC_CLK period	$2T_{fmc\_ker\_ck}$ - 0.5	-	ns
$t_{d(CLKL-NExL)}$	FMC_CLK low to FMC_NEx low (x = 0..2)	-	1	
$t_{d(CLKH\_NExH)}$	FMC_CLK high to FMC_NEx high (x = 0…2)	$T_{fmc\_ker\_ck}$ -	-	
$t_{d(CLKL-NADVL)}$	FMC_CLK low to FMC_NADV low	-	1.5	
$t_{d(CLKL-NADVH)}$	FMC_CLK low to FMC_NADV high	0.5	-	
$t_{d(CLKL-AV)}$	FMC_CLK low to FMC_Ax valid (x = 16…25)	-	1	
$t_{d(CLKH-AIV)}$	FMC_CLK high to FMC_Ax invalid (x = 16…25)	$T_{fmc\_ker\_ck}$-	-	
$t_{d(CLKL-NOEL)}$	FMC_CLK low to FMC_NOE low	-	1	
$t_{d(CLKH-NOEH)}$	FMC_CLK high to FMC_NOE high	$T_{fmc\_ker\_ck}$ + 0.5	-	
$t_{d(CLKL-ADV)}$	FMC_CLK low to FMC_AD[15:0] valid	-	3.5	
$t_{d(CLKL-ADIV)}$	FMC_CLK low to FMC_AD[15:0] invalid	0.5	-	
$t_{su(ADV-CLKH)}$	FMC_A/D[15:0] valid data before FMC_CLK high	3.5	-	
$t_{h(CLKH-ADV)}$	FMC_A/D[15:0] valid data after FMC_CLK high	1.5	-	
$t_{su(NWAIT-CLKH)}$	FMC_NWAIT valid before FMC_CLK high	2.5	-	
$t_{h(CLKH-NWAIT)}$	FMC_NWAIT valid after FMC_CLK high	1.5	-	

1. Evaluated by characterization - Not tested in production.

Figure 42. Synchronous multiplexed PSRAM write timings

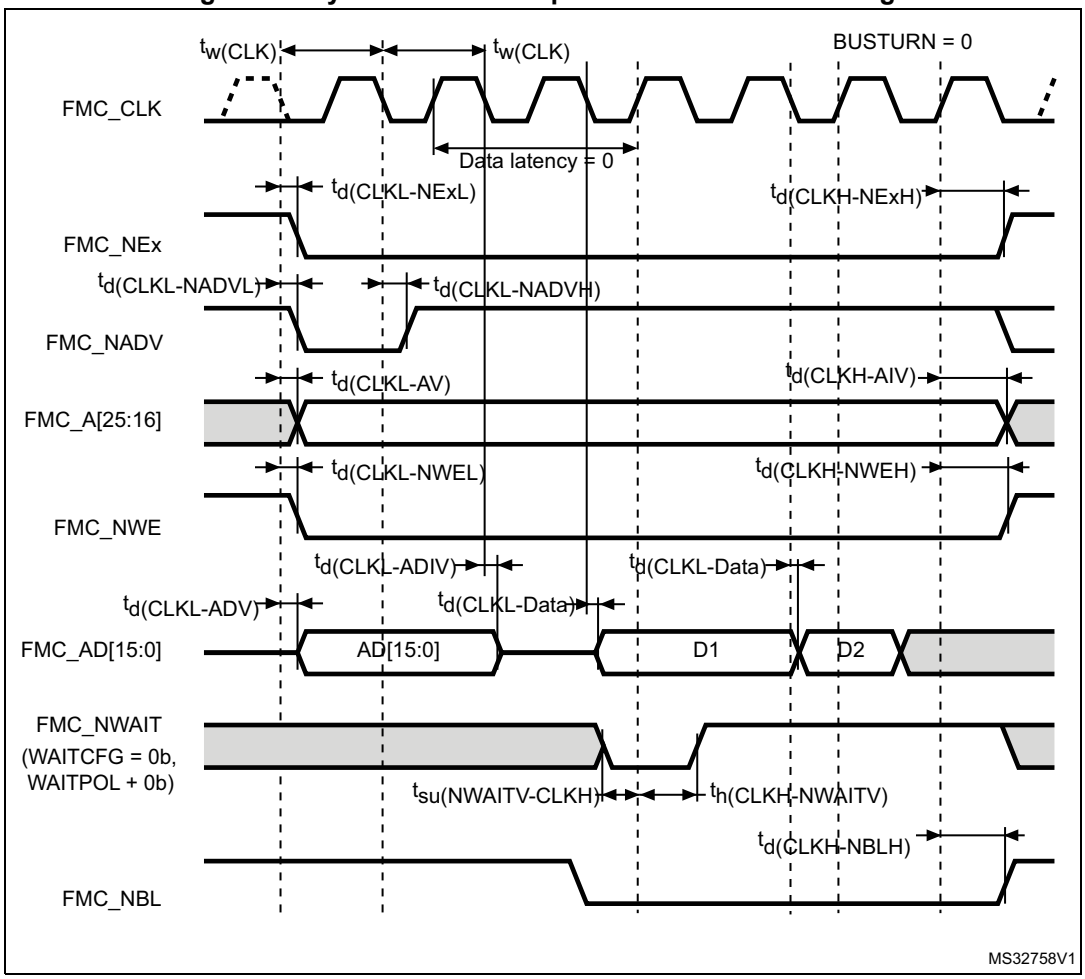


Table 80. Synchronous multiplexed PSRAM write timings(1)

Symbol	Parameter	Min	Max	Unit
$t_{w(CLK)}$	FMC_CLK period, V_{DD} = 2.7 to 3.6 V	$2T_{fmc\_ker\_ck}$ - 0.5	-	ns
$t_{d(CLKL-NExL)}$	FMC_CLK low to FMC_NEx low (x = 0..2)	-	1	
$t_{d(CLKH-NExH)}$	FMC_CLK high to FMC_NEx high (x = 0…2)	$T_{fmc\_ker\_ck}$ - 1	-	
$t_{d(CLKL-NADVL)}$	FMC_CLK low to FMC_NADV low	-	1.5	
$t_{d(CLKL-NADVH)}$	FMC_CLK low to FMC_NADV high	0.5	-	
$t_{d(CLKL-AV)}$	FMC_CLK low to FMC_Ax valid (x = 16…25)	-	1	
$t_{d(CLKH-AIV)}$	FMC_CLK high to FMC_Ax invalid (x = 16…25)	$T_{fmc\_ker\_ck}$ - 1	-	
$t_{d(CLKL-NWEL)}$	FMC_CLK low to FMC_NWE low	-	1	
$t_{(CLKH-NWEH)}$	FMC_CLK high to FMC_NWE high	$T_{fmc\_ker\_ck}$ + 0.5	-	
$t_{d(CLKL-ADV)}$	FMC_CLK low to FMC_AD[15:0] valid	-	3.5	
$t_{d(CLKL-ADIV)}$	FMC_CLK low to FMC_AD[15:0] invalid	1	-	
$t_{d(CLKL-DATA)}$	FMC_A/D[15:0] valid data after FMC_CLK low	-	1	
$t_{d(CLKL-NBLL)}$	FMC_CLK low to FMC_NBL low	-	1	
$t_{d(CLKH-NBLH)}$	FMC_CLK high to FMC_NBL high	$T_{fmc\_ker\_ck}$	-	
$t_{su(NWAIT-CLKH)}$	FMC_NWAIT valid before FMC_CLK high	2.5	-	
$t_{h(CLKH-NWAIT)}$	FMC_NWAIT valid after FMC_CLK high	1.5	-	

1. Evaluated by characterization - Not tested in production.

Figure 43. Synchronous non-multiplexed NOR/PSRAM read timings

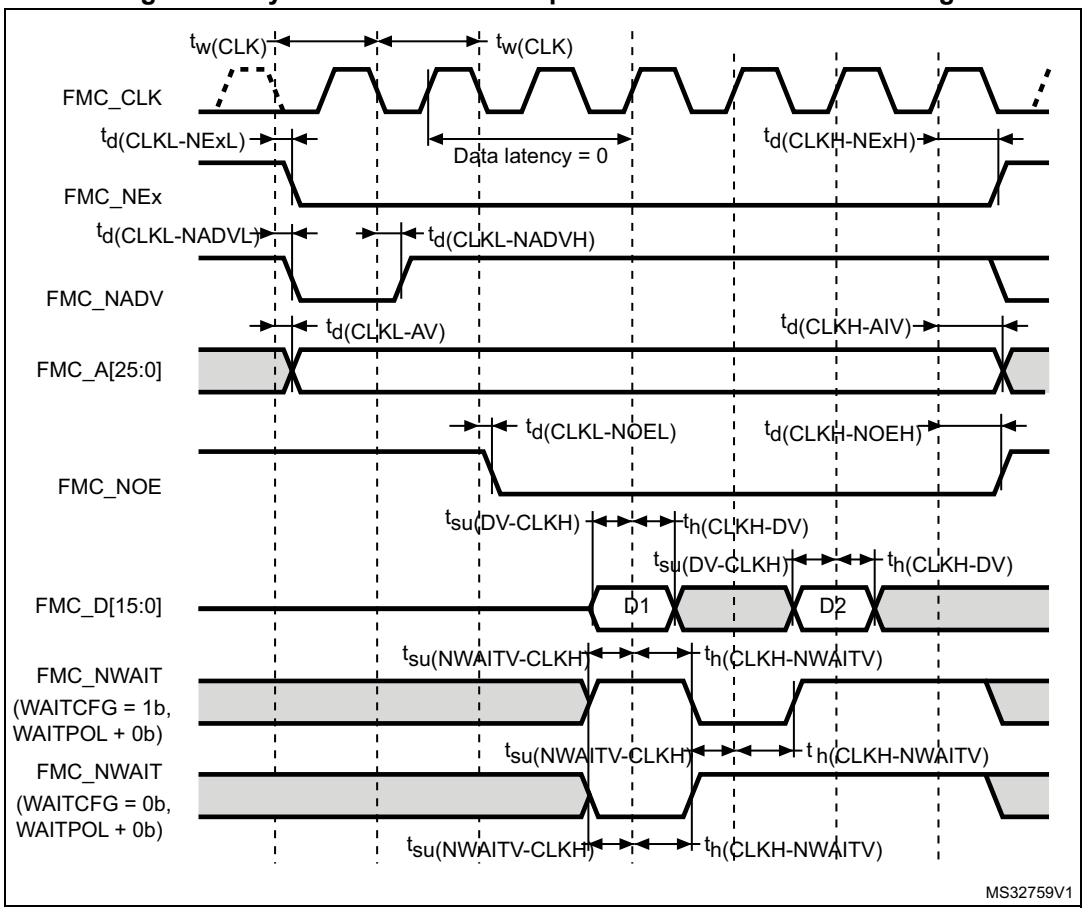


Table 81. Synchronous non-multiplexed NOR/PSRAM read timings(1)

Symbol	Parameter	Min	Max	Unit
$t_{w(CLK)}$	FMC_CLK period	$2T_{fmc\_ker\_ck}$ - 0.5	-	ns
$t_{(CLKL-NExL)}$	FMC_CLK low to FMC_NEx low (x = 0…2)	-	1	
$t_{d(CLKH-NExH)}$	FMC_CLK high to FMC_NEx high (x = 0…2)	$T_{fmc\_ker\_ck}$- 1	-	
$t_{d(CLKL-NADVL)}$	FMC_CLK low to FMC_NADV low	-	1.5	
$t_{d(CLKL-NADVH)}$	FMC_CLK low to FMC_NADV high	0.5	-	
$t_{d(CLKL-AV)}$	FMC_CLK low to FMC_Ax valid (x = 16…25)	-	1	
$t_{d(CLKH-AIV)}$	FMC_CLK high to FMC_Ax invalid (x = 16…25)	$T_{fmc\_ker\_ck}$- 1	-	
$t_{d(CLKL-NOEL)}$	FMC_CLK ow to FMC_NOE low	-	1	
$t_{d(CLKH-NOEH)}$	FMC_CLK high to FMC_NOE high	$T_{fmc\_ker\_ck}$ + 0.5	-	
$t_{su(DV-CLKH)}$	FMC_D[15:0] valid data before FMC_CLK high	3.5	-	
$t_{h(CLKH-DV)}$	FMC_D[15:0] valid data after FMC_CLK high	1.5	-	
$t_{(NWAIT-CLKH)}$	FMC_NWAIT valid before FMC_CLK high	2.5	-	
$t_{h(CLKH-NWAIT)}$	FMC_NWAIT valid after FMC_CLK high	1.5	-	

1. Evaluated by characterization - Not tested in production.

Figure 44. Synchronous non-multiplexed PSRAM write timings

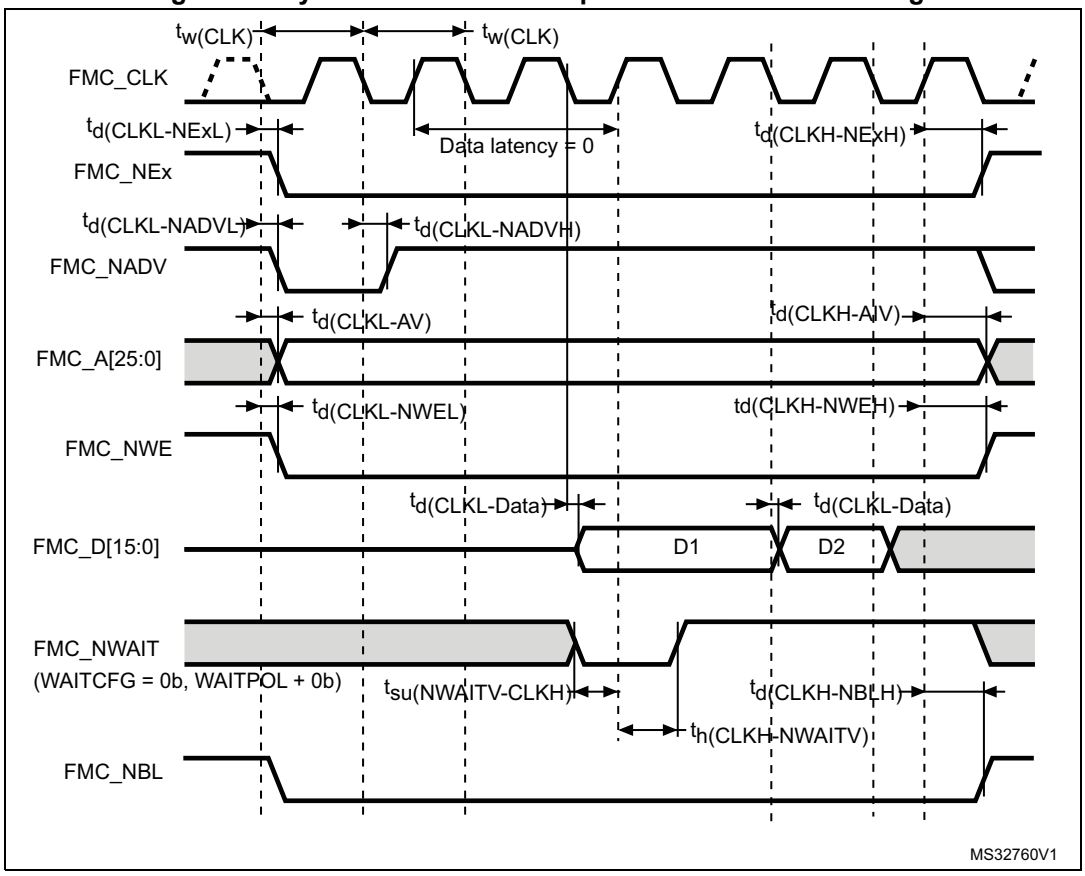


Table 82. Synchronous non-multiplexed PSRAM write timings(1)

Symbol	Parameter	Min	Max	Unit
$t_{(CLK)}$	FMC_CLK period	$2T_{fmc\_ker\_ck}$ - 0.5	-	ns
$t_{d(CLKL-NExL)}$	FMC_CLK low to FMC_NEx low (x = 0…2)	-	1	
$t_{(CLKH-NExH)}$	FMC_CLK high to FMC_NEx high (x = 0…2)	$T_{fmc\_ker\_ck}$ - 0.5	-	
$t_{d(CLKL-NADVL)}$	FMC_CLK low to FMC_NADV low	-	1.5	
$t_{d(CLKL-NADVH)}$	FMC_CLK low to FMC_NADV high	0.5	-	
$t_{d(CLKL-AV)}$	FMC_CLK low to FMC_Ax valid (x = 16…25)	-	1	
$t_{d(CLKH-AIV)}$	FMC_CLK high to FMC_Ax invalid (x = 16…25)	$T_{fmc\_ker\_ck}$ + 0.5	-	
$t_{d(CLKL-NWEL)}$	FMC_CLK low to FMC_NWE low	-	1	
$t_{d(CLKH-NWEH)}$	FMC_CLK high to FMC_NWE high	$T_{fmc\_ker\_ck}$+ 0.5	-	
$t_{d(CLKL-Data)}$	FMC_D[15:0] valid data after FMC_CLK low	-	3.5	
$t_{d(CLKL-NBLL)}$	FMC_CLK low to FMC_NBL low	-	1.5	
$t_{d(CLKH-NBLH)}$	FMC_CLK high to FMC_NBL high	$T_{fmc\_ker\_ck}$ - 0.5	-	
$t_{su(NWAIT-CLKH)}$	FMC_NWAIT valid before FMC_CLK high	2.5	-	
$t_{h(CLKH-NWAIT)}$	FMC_NWAIT valid after FMC_CLK high	1.5	-	

1. Evaluated by characterization - Not tested in production.

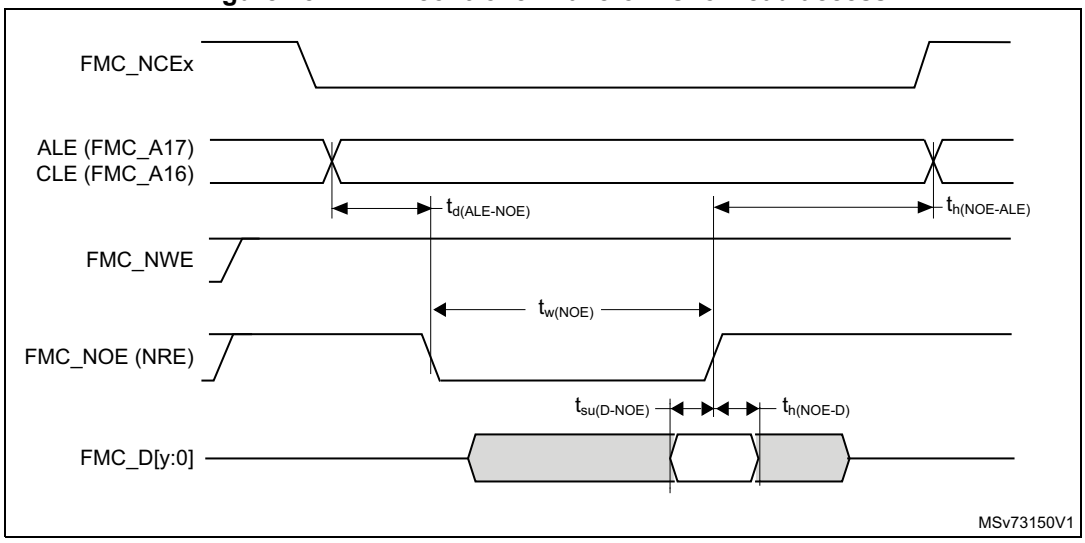
NAND controller waveforms and timings

Figures *45* through *48* represent synchronous waveforms, tables *83* and *84* provide the corresponding timings. The results are obtained with the following FMC configuration and a capacitive load (C_L) of 30 pF:

- COM.FMC_SetupTime = 0x01
- COM.FMC_WaitSetupTime = 0x03
- COM.FMC_HoldSetupTime = 0x02
- COM.FMC_HiZSetupTime = 0x01
- ATT.FMC_SetupTime = 0x01
- ATT.FMC_WaitSetupTime = 0x03
- ATT.FMC_HoldSetupTime = 0x02
- ATT.FMC_HiZSetupTime = 0x01
- Bank = FMC_Bank_NAND
- MemoryDataWidth = FMC_MemoryDataWidth_16b
- ECC = FMC_ECC_Enable
- ECCPageSize = FMC_ECCPageSize_512Bytes
- TCLRSetupTime = 0
- TARSetupTime = 0
- Capacitive load C_L = 30 pF

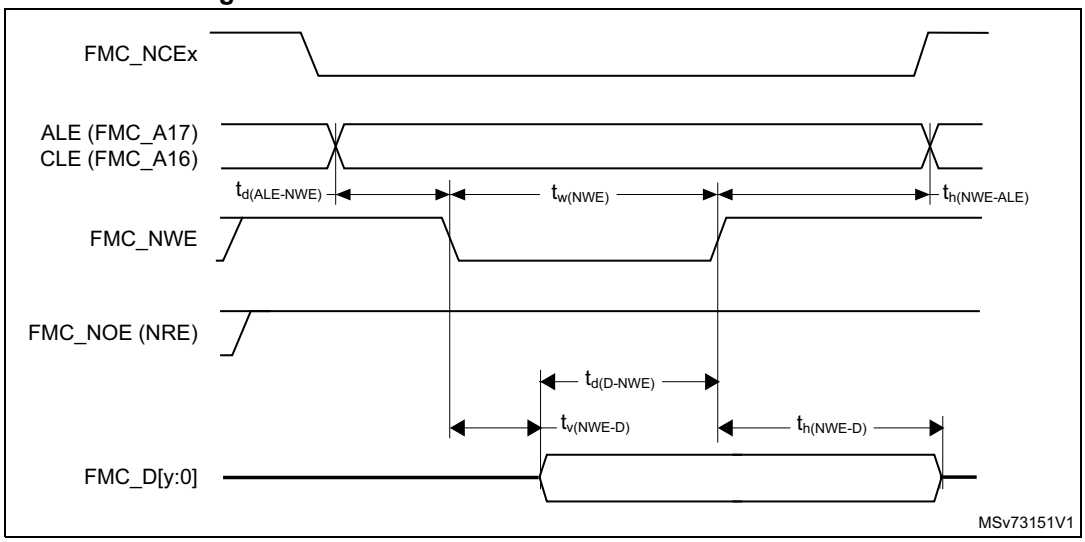
In all timing tables, $T_{fmc\_ker\_ck}$ is the HCLK clock period.

Figure 45. NAND controller waveforms for read access



1. y = 7 or 15, depending upon the NAND flash memory interface.

Figure 46. NAND controller waveforms for write access



1. y = 7 or 15, depending upon the NAND flash memory interface.

Figure 47. NAND controller waveforms for common memory read access

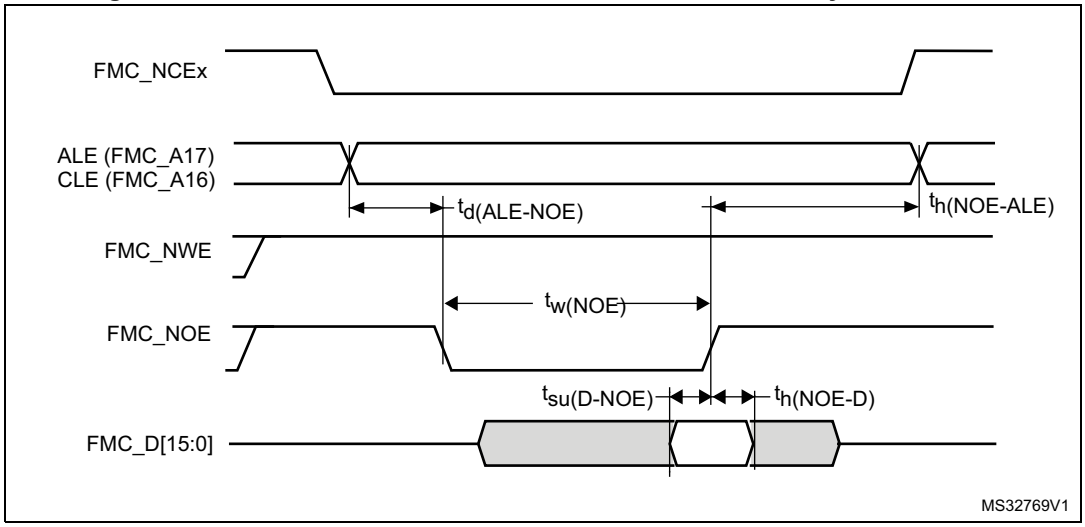


Figure 48. NAND controller waveforms for common memory write access

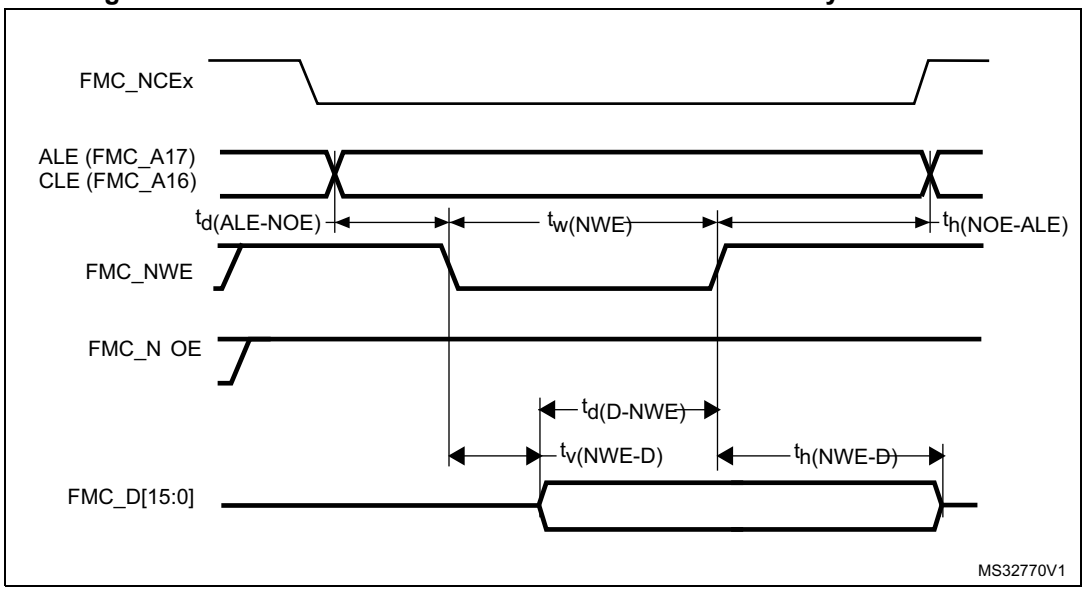


Table 83. Switching characteristics for NAND flash read cycles(1)

Symbol	Parameter	Min	Max	Unit
$t_{w(N0E)}$	FMC_NOE low width	$4T_{fmc\_ker\_ck}$ - 0.5	$4T_{fmc\_ker\_ck}$+ 0.5	ns
$t_{su(D-NOE)}$	FMC_D[15-0] valid data before FMC_NOE high	11	-	
$t_{h(NOE-D)}$	FMC_D[15-0] valid data after FMC_NOE high	0	-	
$t_{d(ALE-NOE)}$	FMC_ALE valid before FMC_NOE low	-	$3T_{fmc\_ker\_ck}$ + 0.5	
$t_{h(NOE-ALE)}$	FMC_NWE high to FMC_ALE invalid	$4T_{fmc\_ker\_ck}$ - 1.5	-	

1. Evaluated by characterization - Not tested in production.

Table 84. Switching characteristics for NAND flash write cycles(1)

Symbol	Parameter	Min	Max	Unit
$t_{w(NWE)}$	FMC_NWE low width	$4T_{fmc\_ker\_ck}$ – 0.5	$4T_{fmc\_ker\_ck}$ + 0.5	ns
$t_{v(NWE-D)}$	FMC_NWE low to FMC_D[15-0] valid	0	-	
$t_{h(NWE-D)}$	FMC_NWE high to FMC_D[15-0] invalid	$2T_{fmc\_ker\_ck}$ + 0.5	-	
$t_{d(D-NWE)}$	FMC_D[15-0] valid before FMC_NWE high	$5T_{fmc\_ker\_ck}$ - 2.5	-	
$t_{d(ALE-NWE)}$	FMC_ALE valid before FMC_NWE low	-	$3T_{fmc\_ker\_ck}$ + 0.5	
$t_{h(NWE-ALE)}$	FMC_NWE high to FMC_ALE invalid	$2T_{fmc\_ker\_ck}$ - 1	-	

1. Evaluated by characterization - Not tested in production.

SDRAM waveforms and timings

In all timing tables, the $t_{fmc\_ker\_ck}$ is the f_{HCLK} clock period, with the following FMC_SDCLK maximum values:

- For 2.7 V < V_{DD} < 3.6 V: maximum FMC_SDCLK = 95 MHz at 20 pF (100 MHz for V_{DD} > 3.0V)
- For 1.71 V < V_{DD} < 1.8 V: maximum FMC_SDCLK = 95 MHz at 15 pF
- For 1.71 V < V_{DD} < 1.8 V: maximum FMC_SDCLK = 90 MHz at 20 pF

Figure 49. SDRAM read access waveforms (CL = 1)

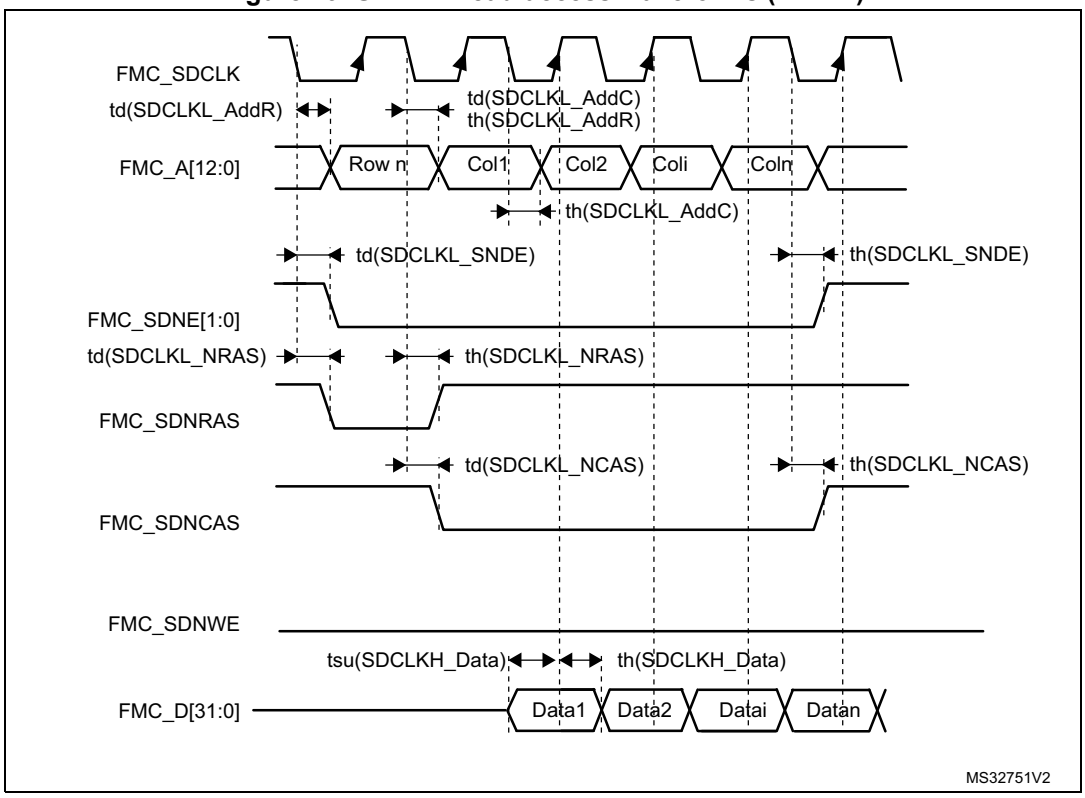


Table 85. SDRAM read timings(1)

Symbol	Parameter	Min	Max	Unit
$t_{w(SDCLK)}$	FMC_SDCLK period	$2T_{fmc\_ker\_ck}$ - 0.5	$2T_{fmc\_ker\_ck}$ + 0.5	ns
$t_{su(SDCLKH\_Data)}$	Data input setup time	3	-	
$t_{h(SDCLKH\_Data)}$	Data input hold time	0.5	-	
$t_{d(SDCLKL\_Add)}$	Address valid time	-	1.5	
$t_{d(SDCLKL-SDNE)}$	Chip select valid time	-	1.5	
$t_{h(SDCLKL\_SDNE)}$	Chip select hold time	0	-	
$t_{d(SDCLKL\_SDNRAS)}$	SDNRAS valid time	-	1.5	
$t_{h(SDCLKL\_SDNRAS)}$	SDNRAS hold time	0	-	
$t_{d(SDCLKL\_SDNCAS)}$	SDNCAS valid time	-	1	
$t_{h(SDCLKL\_SDNCAS)}$	SDNCAS hold time	0	-	

1. Evaluated by characterization - Not tested in production.

Table 86. LPSDR SDRAM read timings(1)

Symbol	Parameter	Min	Max	Unit
$t_{W(SDCLK)}$	FMC_SDCLK period	$2T_{fmc\_ker\_ck}$ - 0.5	$2T_{fmc\_ker\_ck}$ + 0.5	ns
$t_{su(SDCLKH\_Data)}$	Data input setup time	3	-	
$t_{h(SDCLKH\_Data)}$	Data input hold time	0.5	-	
$t_{d(SDCLKL\_Add)}$	Address valid time	-	1.5	
$t_{d(SDCLKL\_SDNE)}$	Chip select valid time	-	1.5	
$t_{h(SDCLKL\_SDNE)}$	Chip select hold time	0	-	
$t_{d(SDCLKL\_SDNRAS}$	SDNRAS valid time	-	1.5	
$t_{h(SDCLKL\_SDNRAS)}$	SDNRAS hold time	0	-	
$t_{d(SDCLKL\_SDNCAS)}$	SDNCAS valid time	-	1	
$t_{h(SDCLKL\_SDNCAS)}$	SDNCAS hold time	0	-	

1. Evaluated by characterization - Not tested in production.

Figure 50. SDRAM write access waveforms

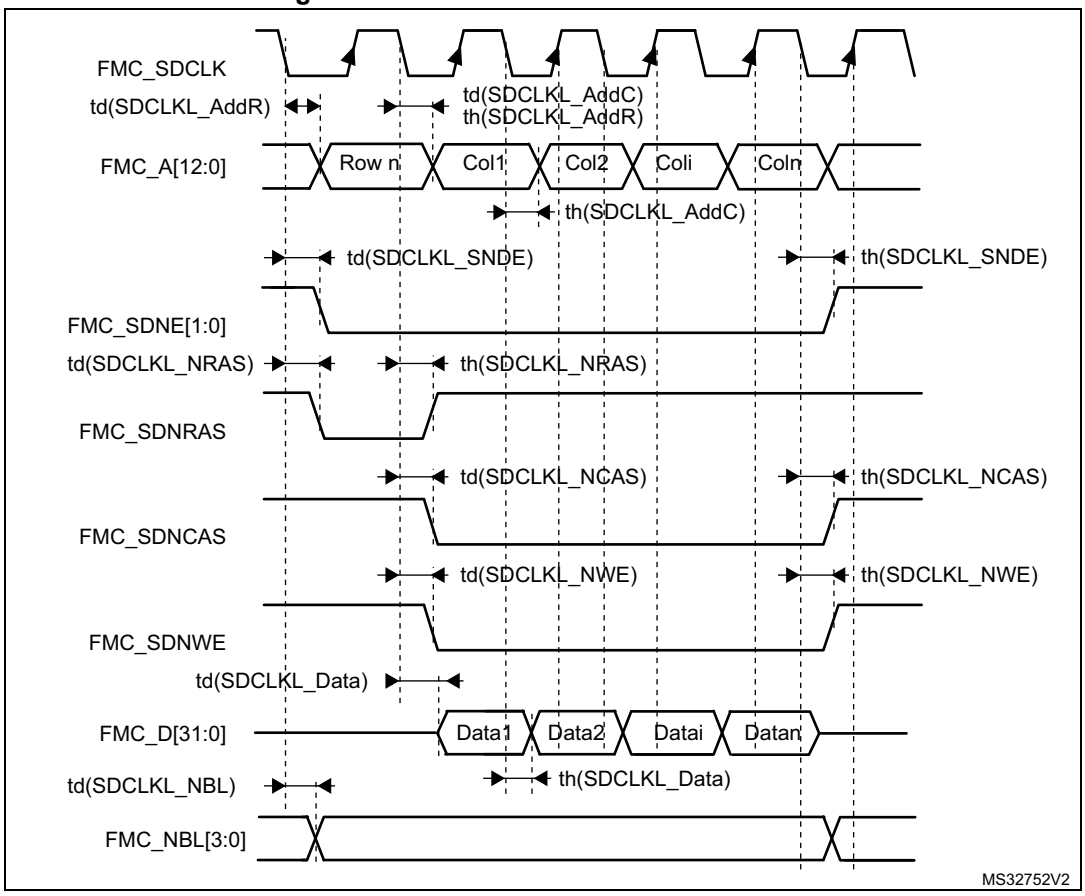


Table 87. SDRAM write timings(1)

Symbol	Parameter	Min	Max	Unit
$t_{w(SDCLK)}$	FMC_SDCLK period	$2T_{fmc\_ker\_ck} - 0.5$	$2T_{fmc\_ker\_ck}+0.5$	ns
$t_{d(SDCLKL\_Data)}$	Data output valid time	-	1	
$t_{h(SDCLKL\_Data)}$	Data output hold time	0	-	
$t_{d(SDCLKL\_Add)}$	Address valid time	-	2	
$t_{d(SDCLKL\_SDNWE)}$	SDNWE valid time	-	1	
$t_{h(SDCLKL\_SDNWE)}$	SDNWE hold time	0	-	
$t_{d(SDCLKL\_SDNE)}$	Chip select valid time	-	1	
$t_{h(SDCLKL-\_SDNE)}$	Chip select hold time	0	-	
$t_{d(SDCLKL\_SDNRAS)}$	SDNRAS valid time	-	1.5	
$t_{h(SDCLKL\_SDNRAS)}$	SDNRAS hold time	0	-	
$t_{d(SDCLKL\_SDNCAS)}$	SDNCAS valid time	-	1	
$t_{d(SDCLKL\_SDNCAS)}$	SDNCAS hold time	0	-	

1. Evaluated by characterization - Not tested in production.

Table 88. LPSDR SDRAM write timings(1)

Symbol	Parameter	Min	Max	Unit
$t_{w(SDCLK)}$	FMC_SDCLK period	$2T_{fmc\_ker\_ck} - 0.5$	$2T_{fmc\_ker\_ck}+0.5$	ns
$t_{d(SDCLKL\_Data)}$	Data output valid time	-	1	
$t_{h(SDCLKL\_Data)}$	Data output hold time	0.	-	
$t_{d(SDCLKL\_Add)}$	Address valid time	-	2	
$t_{d(SDCLKL-SDNWE)}$	SDNWE valid time	-	1	
$t_{h(SDCLKL-SDNWE)}$	SDNWE hold time	0	-	
$t_{d(SDCLKL- SDNE)}$	Chip select valid time	-	1.5	
$t_{h(SDCLKL- SDNE)}$	Chip select hold time	0	-	
$t_{d(SDCLKL-SDNRAS)}$	SDNRAS valid time	-	1.5	
$t_{h(SDCLKL-SDNRAS)}$	SDNRAS hold time	0	-	
$t_{d(SDCLKL-SDNCAS)}$	SDNCAS valid time	-	1	
$t_{d(SDCLKL-SDNCAS)}$	SDNCAS hold time	0	-	

1. Evaluated by characterization - Not tested in production.

5.3.20 Octo-SPI interface characteristics

Unless otherwise specified, the parameters given in *Table 89* and *Table 90* are derived from tests performed under the ambient temperature, f_{HCLK} frequency, and V_{DD} supply voltage conditions summarized in *Table 19*, with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 11
- Measurement points are done at CMOS levels: 0.5 V_{DD}
- I/O compensation cell activated
- HSLV activated when $V_{DD} \leq 2.7$ V
- VOS level set to VOS0

Refer to *Section 5.3.15* for more details on the input/output alternate function characteristics.

Table 89. OCTOSPI characteristics in SDR mode(1)(2)(3)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$F_{(CLK)}$	Clock frequency	1.71 V < V_{DD} < 3.6 V, C_L = 15 pF	-	-	110	MHz
		1.71 V < V_{DD} < 3.6 V, C_L =15 pF	-	-	150/120(4)	
$t_{w(CLKH)}$	Clock high and low time, even division	PRESCALER[7:0] = n (= 0, 1, 3, 5,..., 255)	$t_{(CLK)}$ / 2 - 0.5	-	$t_{(CLK)}$ / 2 + 0.5	ns
$t_{w(CLKL)}$			$t_{(CLK)}$ / 2 - 0.5	-	$t_{(CK)}$ / 2 + 0.5	
$t_{w(CLKH)}$	Clock high and low time, odd division	PRESCALER[7:0] = n (= 2, 4, 6, ..., 254)	(n / 2) * $t_{(CLK)}$ / (n + 1) - 0.5	-	(n / 2) * $t_{(CLK)}$ / (n + 1) + 0.5	
$t_{w(CLKL)}$			(n / 2 + 1) * $t_{(CLK)}$ / (n + 1) - 0.5	-	(n / 2 + 1) * $t_{(CLK)}$ / (n + 1) + 0.5	
$t_{s(IN)}$	Data input setup time	-	4	-	-	
$t_{h(IN)}$	Data input hold time	-	1	-	-	
$t_{v(OUT)}$	Data output valid time	-	-	1	1.5	
$t_{h(OUT)}$	Data output hold time	-	0	-	-	

1. All values apply to Octal- and Quad-SPI mode.
2. Evaluated by characterization - Not tested in production.
3. Delay block bypassed.
4. Maximum speed for LQFP100 and LQFP100-SMPS packages.

Figure 51. OCTOSPI SDR read/write timing diagram

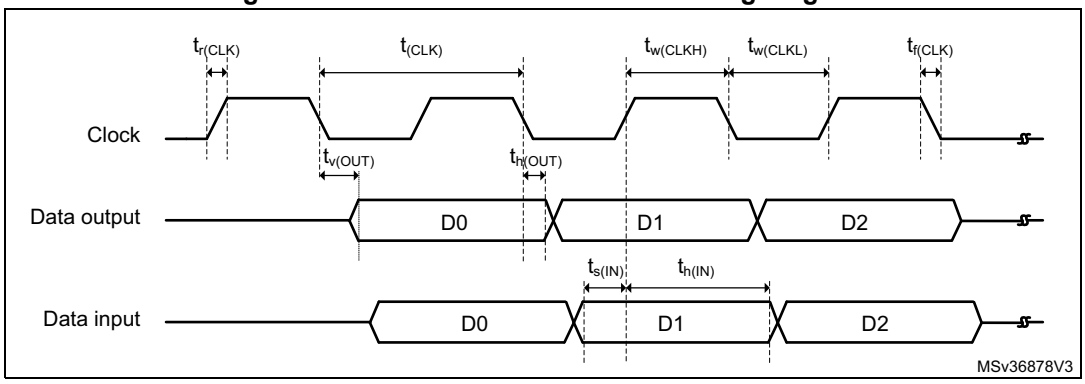


Table 90. OCTOSPI characteristics in DTR mode (no DQS)(1)(2)(3)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
F_{CLK}	OCTOSPI clock frequency	1.71 V < V_{DD} < 3.6 V, C_L = 15 pF	-	-	100(4)	MHz
		2.7 V < V_{DD} < 3.6 V, C_L = 15 pF	-	-	125(4)/120(5)	
$t_{w(CLKH)}$	OCTOSPI clock high and low time	PRESCALER[7:0] = n (= 0, 1, 3, 5, .., 255)	$t_{(CLK)}$ / 2 - 0.5	-	$t_{(CLK)}$ / 2 + 0.5	ns
$t_{w(CLKL)}$			$t_{(CLK)}$ / 2 - 0.5	-	$t_{(CLK)}$ / 2 + 0.5	
$t_{w(CLKH)}$	OCTOSPI clock high and low time	PRESCALER[7:0] = n (= 2, 4, 6, 8, ..., 254)	(n / 2) * $t_{(CLK)}$/ (n + 1) - 0.5	-	(n / 2) * $t_{(CLK)}$/ (n + 1) + 0.5	
$t_{w(CLKL)}$			(n / 2 + 1) * $t_{(CLK)}$/ (n + 1) - 0.5	-	(n / 2 + 1) * $t_{(CLK)}$/ (n + 1) + 0.5	
$t_{sr(IN)}$, $t_{sf(IN)}$	Data input setup time	-	1.5	-	-	ns
$t_{hr(IN)}$, $t_{hf(IN)}$	Data input hold time	-	4	-	-	
$t_{vr(OUT)}$ $t_{vf(OUT)}$	Data output valid time	DHQC = 0	-	3.5	4	
		DHQC = 1, Prescaler [7:0] = 1, 2...	-	$t_{(CLK)}$ / 4 + 1	$t_{(CLK)}$ / 4 + 1.5	
$t_{hr(OUT)}$ $t_{hf(OUT)}$	Data output hold time	DHQC = 0	1.5	-	-	
		DHQC = 1, Prescaler [7:0] = 1, 2...	$t_{(CLK)}$ / 4 - 1	-	-	

1. All values apply to Octal and Quad-SPI mode.
2. Evaluated by characterization - Not tested in production.
3. Delay block bypassed.
4. DHQC must be set to reach the mentioned frequency.
5. Maximum speed for LQFP100 and LQFP100-SMPS packages.

Table 91. OCTOSPI characteristics in DTR mode (with DQS) / HyperBus(1)(2)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
F_{CLK}	OCTOSPI clock frequency	1.71 V < V_{DD} < 3.6 V, C_L = 15 pF	-	-	125(3)(4)/110(5)	MHz
		2.7 V < V_{DD} < 3.6 V, C_L = 15 pF	-	-	125(3)(4)/120(5)	
$t_{w(CLKH)}$	OCTOSPI clock high and low time	PRESCALER[7:0] = n = (0, 1, 3, 5, …, 255)	$t_{(CLK)}/2$ - 0.5	-	$t_{(CLK)}/2$ + 0.5	ns
$t_{w(CLKL)}$			$t_{(CLK)}/2$ - 0.5	-	$t_{(CLK)}/2$ + 0.5	
$t_{w(CLKH)}$	OCTOSPI clock high and low time	PRESCALER[7:0] = n = (2, 4, 6, 8, …, 254)	(n/2)*$t_{(CLK)}$/(n+1) - 0.5	-	(n/2)*$t_{(CLK)}$/(n+1) + 0.5	
$t_{w(CLKL)}$			(n/2+1)*$t_{(CLK)}$/(n+1) - 0.5	-	(n/2+1)*$t_{(CLK)}$/(n+1) + 0.5	
$t_{v(CLK)}$	Clock valid time	-	-	-	$t_{(CLK)}$ + 2	
$t_{h(CLK)}$	Clock hold time	-	$t_{(CLK)}/2$ - 1	-	-	
$V_{ODr(CLK)}$(6)	CLK, NCLK crossing level on CLK rising edge	V_{DD} = 1.8 V	1000	-	1080	mV
$V_{ODf(CLK)}$(6)	CLK, NCLK crossing level on CLK falling edge	V_{DD} = 1.8 V	930	-	1040	
$t_{w(CS)}$	Chip select high time	-	3 * $t_{(CLK)}$	-	-	ns
$t_{v(DQ)}$	Data input valid time	-	3	-	-	
$t_{v(DS)}$	Data strobe input valid time	-	1	-	-	
$t_{h(DS)}$	Data strobe input hold time	-	0	-	-	
$t_{v(RWDS)}$	Data strobe output valid time	-	-	-	3 * $t_{(CLK)}$	
$t_{sr(DQ)}$, $t_{sf(DQ)}$	Data input setup time	-	-0.25	-	-	ns
$t_{hr(DQ)}$, $t_{hf(DQ)}$	Data input hold time	-	3.5	-	-	
$t_{vr(OUT)}$ $t_{vf(OUT)}$	Data output valid time	DHQC = 0	-	3	4	
		DHQC = 1, all prescaler values except 0	-	$t_{(CLK)}/4$ + 0.5	$t_{(CLK)}/4$ + 1	
$t_{hr(OUT)}$ $t_{hf(OUT)}$	Data output hold time	DHQC = 0	1.5	-	-	
		DHQC = 1, all prescaler values except 0	$t_{(CLK)}/4$ - 1	-	-	

1. Evaluated by characterization - Not tested in production.
2. Delay block activated.
3. Maximum frequency value are given for a maximum RWDS to DQ skew of ± 1.0 ns.
4. DHQC must be set to reach the mentioned frequency.
5. Maximum speed for LQFP100 and LQFP100-SMPS packages.
6. PA3/PB12, PF10/PF11, PB5/PG8 and PB5/PD15 are recommended to be in line with crossing specification.

Figure 52. OCTOSPI timing diagram - DTR mode

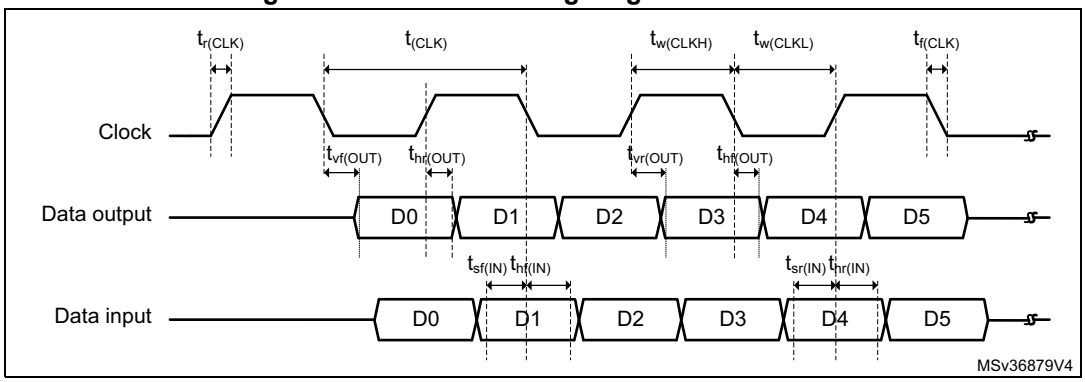


Figure 53. OCTOSPI HyperBus clock

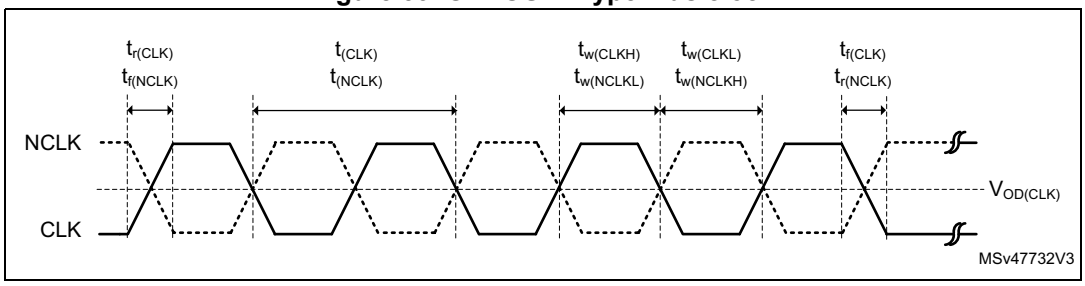


Figure 54. OCTOSPI HyperBus read

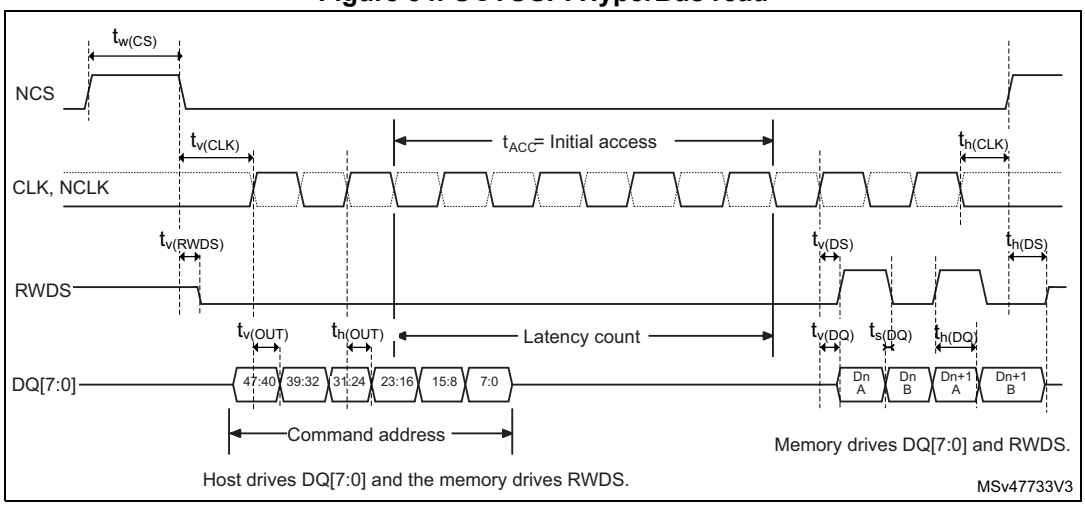
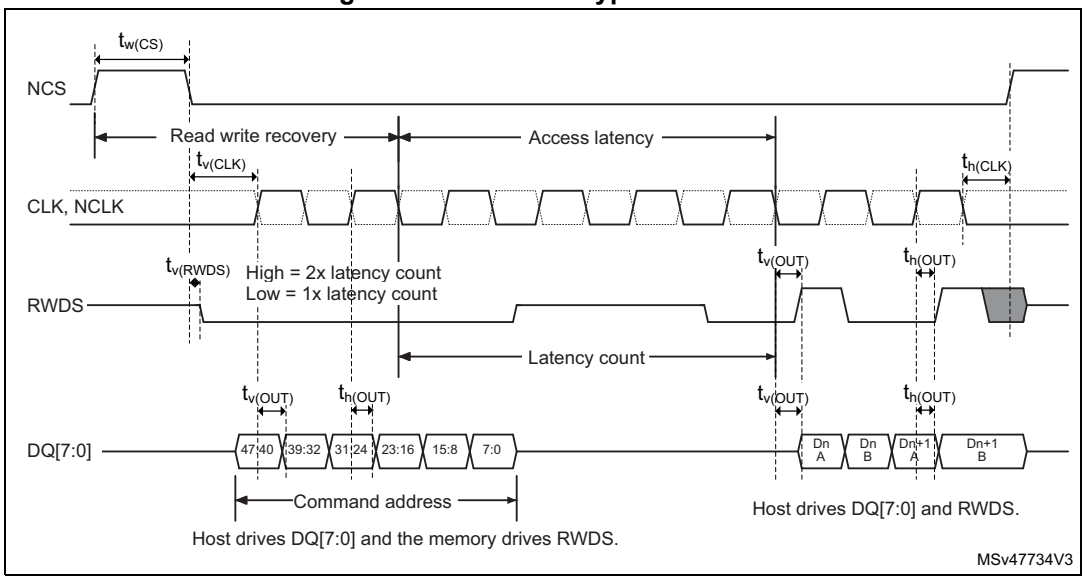


Figure 55. OCTOSPI HyperBus write



5.3.21 Delay block (DLYB) characteristics

Unless otherwise specified, the parameters given in *Table 92* are derived from tests performed under the ambient temperature, f_{HCLK} frequency, and V_{DD} supply voltage summarized in *Table 19*.

Table 92. Delay block characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
t_{init}	Initial delay	-	750	1100	1700	ps
t_{Δ}	Unit delay	-	38	44	54	ps

1. Evaluated by characterization - Not tested in production.

5.3.22 DCMI interface characteristics

Unless otherwise specified, the parameters given in *Table 93* are derived from tests performed under the ambient temperature, f_{HCLK} frequency, and V_{DD} supply voltage summarized in *Table 19*, with the following configuration:

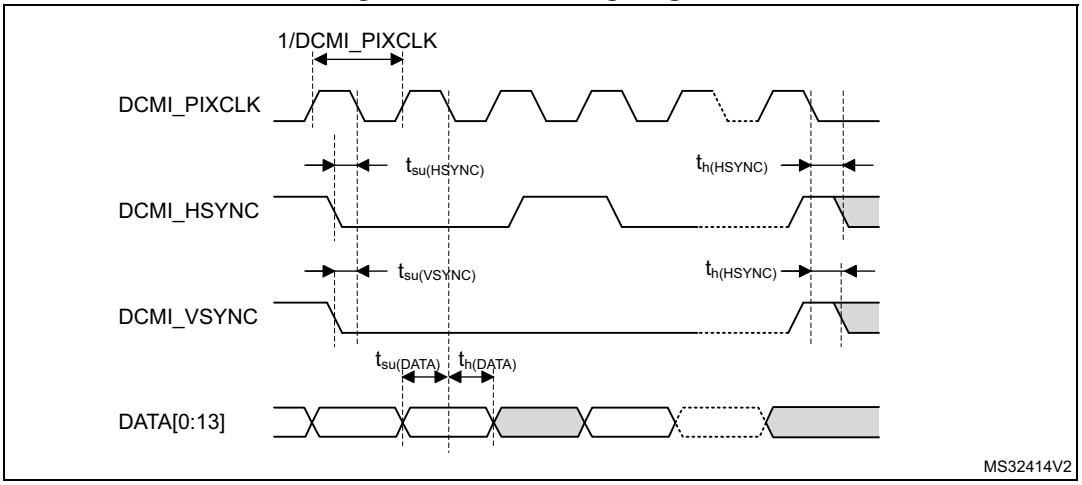
- DCMI_PIXCLK polarity: falling
- DCMI_VSYNC and DCMI_HSYNC polarity: high
- Data formats: 14 bits
- Capacitive load C_L = 30 pF
- Measurement points done at CMOS levels: 0.5 V_{DD}
- I/O compensation cell activated
- HSLV activated when $V_{DD} \leq 2.7$ V
- Voltage scaling VOS0 selected

Table 93. DCMI characteristics(1)

Symbol	Parameter	Min	Max	Unit
-	Frequency ratio DCMI_PIXCLK/fHCLK	-	0.4	-
DCMI_PIXCLK	Pixel clock input	-	100	MHz
D_{PIXEL}	Pixel clock input duty cycle	30	70	%
$t_{su(DATA)}$	Data input setup time	2.5	-	ns
$t_{h(DATA)}$	Data hold time	2	-	
$t_{su(HSYNC)}$, $t_{su(VSYNC)}$	DCMI_HSYNC and DCMI_VSYNC input setup times	2.5	-	
$t_{h(HSYNC)}$, $t_{h(VSYNC)}$	DCMI_HSYNC and DCMI_VSYNC input hold times	1.5	-	

1. Evaluated by characterization - Not tested in production.

Figure 56. DCMI timing diagrams



5.3.23 PSSI interface characteristics

Unless otherwise specified, the parameters given in *Table 93* and *Table 94* are derived from tests performed under the ambient temperature, f_{HCLK} frequency, and V_{DD} supply voltage summarized in *Table 19* and *Section 5.3.1*, with the following configuration:

- PSSI_PDCK polarity: falling
- PSSI_RDY and PSSI_DE polarity: low
- Bus width: 16 lines
- DATA width: 32 bits
- Capacitive load C_L = 30 pF
- Measurement points are done at CMOS levels: 0.5 V_{DD}
- I/O compensation cell activated
- HSLV activated when $V_{DD} \leq 2.7$ V
- Voltage scaling VOS0 selected

Table 94. PSSI transmit characteristics(1)

Symbol	Parameter	Conditions	Min	Max	Unit
-	Frequency ratio PSSI_PDCK/f_{HCLK}	-	-	0.4	-
PSSI_PDCK	PSSI clock input	2.7 V ≤ V_{DD} ≤ 3.6 V	-	90(2)	MHz
		1.71 V ≤ V_{DD} ≤ 3.6 V	-	86(2)	
D_{pixel}	PSSI clock input duty cycle		30	70	%
t_{ov}(DATA)	Data output valid time	2.7 V ≤ V_{DD} ≤ 3.6 V	-	11.5	ns
		1.71 V ≤ V_{DD} ≤ 3.6 V	-	11.5	
t_{oh}(DATA)	Data output hold time	1.71 V ≤ V_{DD} ≤ 3.6 V	5.5	-	
$t_{ov(}$(DE)	DE output valid time		-	11.5	
t_{oh}(DE)	DE output hold time		5.5	-	
tsu(RDY)	RDY input setup time		0.5	-	
th(RDY)	RDY input hold time		0.5	-	

1. Evaluated by characterization - Not tested in production.
2. This maximal frequency does not consider receiver setup and hold timings.

Table 95. PSSI receive characteristics(1)

Symbol	Parameter	Conditions	Min	Max	Unit
-	Frequency ratio PSSI_PDCK/f_{HCLK}		-	0.4	-
PSSI_PDCK	PSSI clock input	1.71 V ≤ V_{DD} ≤ 3.6 V	-	100	MHz
D_{pixel}	PSSI clock input duty cycle	-	30	70	%
t_{su}(DATA)	Data input setup time	1.71 V ≤ V_{DD} ≤ 3.6 V	2	-	ns
t_{h}(DATA)	Data input hold time		2.5	-	
$t_{su(}$(DE)	DE input setup time		1.5	-	
t_{h}(DE)	DE input hold time		2	-	
t_{ov}(RDY)	RDY output valid time		-	16.5	
t_{oh}(RDY)	RDY output hold time		5.5	-	

1. Evaluated by characterization - Not tested in production.

Figure 57. PSSI transmit timing diagram

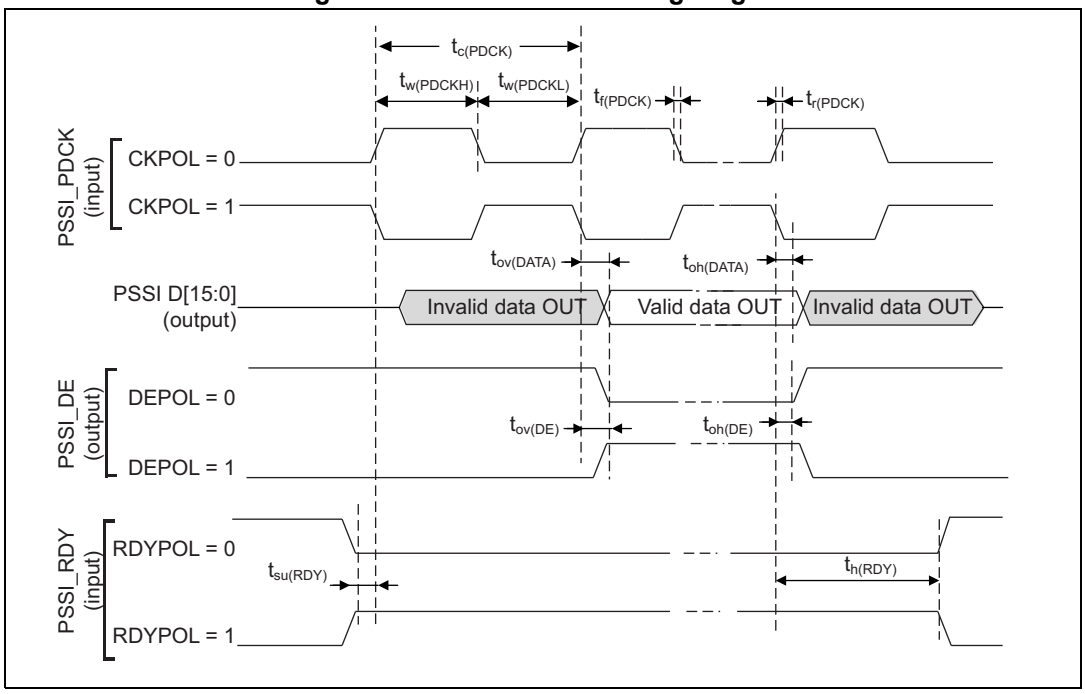
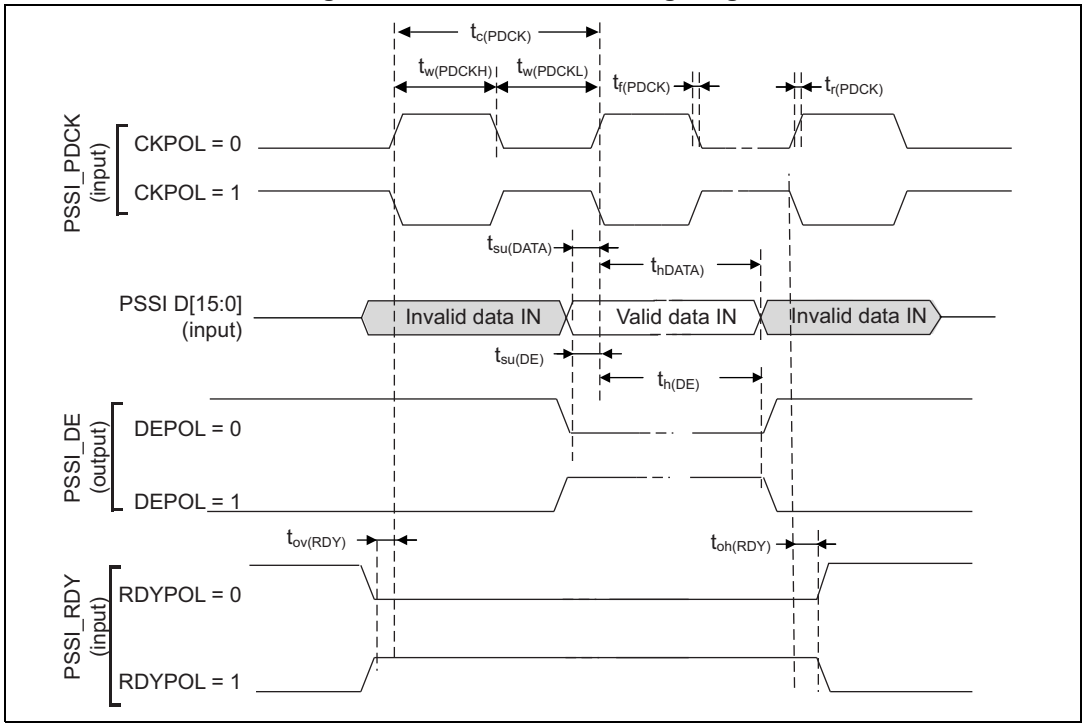


Figure 58. PSSI receive timing diagram



5.3.24 12-bit ADC characteristics

Unless otherwise specified, the parameters given in *Table 96* are derived from tests performed under the ambient temperature, f_{HCLK} frequency, and V_{DDA} supply voltage conditions summarized in *Table 19*.

Table 96. 12-bit ADC characteristics(1)(2)

Symbol	Parameter	Conditions						Min	Typ	Max	Unit
V_{DDA}	Analog supply voltage for ADC ON	-						1.62	-	3.6	V
V_{REF+}	Positive reference voltage	-						1.62	-	V_{DDA}	V
V_{REF-}	Negative reference voltage	-						V_{SSA}			V
$f_{adc\_ker\_ck}$(3)	Clock frequency	1.62 V ≤ V_{DDA} ≤ 3.6 V						1.5	-	75	MHz
f_S(4) with R_{AIN} = 47 Ω and C_{PCB} = 22 pF	Sampling rate for fast channels (VIN[0:5])	Resolution = 12 bits	Continuous mode	1.8V ≤ V_{DDA} ≤ 3.6V	-40°C ≤ T_J ≤ 130°C	$f_{adc\_ker\_ck}$ = 75 MHz	SMP =2.5	-	5.00	-	MSPS
				1.6V ≤ V_{DDA} ≤ 3.6V		$f_{adc\_ker\_ck}$ = 70 MHz		-	4.66	-	
			Single or Discontinuous mode	2.4V ≤ V_{DDA} ≤ 3.6V		$f_{adc\_ker\_ck}$ = 60 MHz		-	4.00	-	
				1.6V ≤ V_{DDA} ≤ 3.6V		$f_{adc\_ker\_ck}$ = 50 MHz		-	3.33	-	
		Resolution = 10 bits	Continuous mode	1.6V ≤ V_{DDA} ≤ 3.6V		$f_{adc\_ker\_ck}$ = 75 MHz		-	5.77	-	
			Single or Discontinuous mode	2.4V ≤ V_{DDA} ≤ 3.6V				-	5.77	-	
				1.6V ≤ V_{DDA} ≤ 3.6V		$f_{adc\_ker\_ck}$ = 65 MHz		-	5.00	-	
		Resolution = 8 bits	All modes	1.6V ≤ V_{DDA} ≤ 3.6V		$f_{adc\_ker\_ck}$ = 75 MHz		-	6.82	-	
		Resolution = 6 bits						-	8.33	-	
	Sampling rate for slow channels	Resolution = 12 bits	All modes(5)	1.6V ≤ V_{DDA} ≤ 3.6V		$f_{adc\_ker\_ck}$ = 35 MHz		-	2.30	-	
		Resolution = 10 bits						-	2.70	-	
		Resolution = 8 bits				$f_{adc\_ker\_ck}$ = 50 MHz		-	4.50	-	
		Resolution = 6 bits						-	5.50	-	
t_{TRIG}	External trigger period	Resolution = 12 bits						-	-	15	1/$f_{adc\_ker\_ck}$
V_{AIN}(2)	Conversion voltage range	-						0	-	V_{REF+}	V
V_{CMIV}	Common mode input voltage	-						V_{REF} / 2 − 10%	V_{REF} / 2	V_{REF} / 2 + 10%	V

Table 96. 12-bit ADC characteristics(1)(2) (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
R_{AIN}(6)	External input impedance	Resolution = 12 bits, T_J = 130°C (tolerance 4 LSBs)	-	-	321	Ω
		Resolution = 12 bits, T_J = 125°C	-	-	220	
		Resolution = 10 bits, T_J = 130°C	-	-	1039	
		Resolution = 10 bits, T_J = 125°C	-	-	2100	
		Resolution = 8 bits, T_J = 130°C	-	-	6327	
		Resolution = 8 bits, T_J = 125°C	-	-	12000	
		Resolution = 6 bits, T_J = 130°C	-	-	47620	
		Resolution = 6 bits, T_J = 125°C	-	-	80000	
C_{ADC}	Internal sample and hold capacitor	-	-	3	-	pF
$t_{ADCVREG\_STUP}$	LDO startup time	-	-	5	10	µs
t_{STAB}	Power-up time	LDO already started	1	-	-	Conversion cycle
t_{OFF_CAL}	Offset calibration time	-	1335			$1/f_{adc\_ker\_ck}$
t_{LATR}	Trigger conversion latency for regular and injected channels without aborting the conversion	CKMODE = 00	1.5	2	2.5	
		CKMODE = 01	-	-	2.5	
		CKMODE = 10	-	-	2.5	
		CKMODE = 11	-	-	2.25	
$t_{LATRINJ}$	Trigger conversion latency for regular and injected channels when a regular conversion is aborted	CKMODE = 00	2.5	3	3.5	
		CKMODE = 01	-	-	3.5	
		CKMODE = 10	-	-	3.5	
		CKMODE = 11	-	-	3.25	
t_S	Sampling time	-	2.5	-	640.5	
t_{CONV}	Total conversion time (including sampling)	N-bits resolution	t_S + 0.5 + N	-	-	
$I_{DDA\_D(ADC)}$	Consumption on V_{DDA} and V_{REF}, differential mode	fs = 5 MSPS	-	600	-	µA
		fs = 1 MSPS	-	190	-	
		fs = 0.1 MSPS	-	50	-	
$I_{DDA\_SE(ADC)}$	Consumption on V_{DDA} and V_{REF}, single-ended mode	fs = 5 MSPS	-	500	-	
		fs = 1 MSPS	-	150	-	
		fs = 0.1 MSPS	-	50	-	
$I_{DD(ADC)}$	Consumption on V_{DD}	$f_{adc\_ker\_ck}$ = 75 MHz	-	265	-	
		$f_{adc\_ker\_ck}$ = 50 MHz		175	-	
		$f_{adc\_ker\_ck}$ = 25 MHz	-	90	-	
		$f_{adc\_ker\_ck}$ = 12.5 MHz	-	45	-	
		$f_{adc\_ker\_ck}$ = 6.25 MHz	-	22	-	
		$f_{adc\_ker\_ck}$ = 3.125 MHz	-	11	-	

1. Specified by design - Not tested in production.
2. The voltage booster on ADC switches must be used for V_{DDA} < 2.7 V (embedded I/O switches).

3. This frequency is the analog ADC specification, it must respect the value in *Table 20*.
4. These values are valid on BGA package.
5. Depending upon the package, V_{REF+} can be internally connected to V_{DDA}, and V_{REF-} to V_{SSA}.
6. The tolerance is two LSBs for 12-, 10-, and 8-bit resolutions, if not otherwise specified.

Table 97. Minimum sampling time versus R_{AIN} (1)(2)

Resolution	R_{AIN} (Ω)	Minimum sampling time (s)	
		Fast channel	Slow channel(3)
12 bits	47	3.75E-08	6.12E-08
	68	3.94E-08	6.25E-08
	100	4.36E-08	6.51E-08
	150	5.11E-08	7.00E-08
	220	6.54E-08	7.86E-08
	330	8.80E-08	9.57E-08
	470	1.17E-07	1.23E-07
	680	1.60E-07	1.65E-07
10 bits	47	3.19E-08	5.17E-08
	68	3.35E-08	5.28E-08
	100	3.66E-08	5.45E-08
	150	4.35E-08	5.83E-08
	220	5.43E-08	6.50E-08
	330	7.18E-08	7.89E-08
	470	9.46E-08	1.00E-07
	680	1.28E-07	1.33E-07
	1000	1.81E-07	1.83E-07
	1500	2.63E-07	2.63E-07
	2200	3.79E-07	3.76E-07
	3300	5.57E-07	5.52E-07

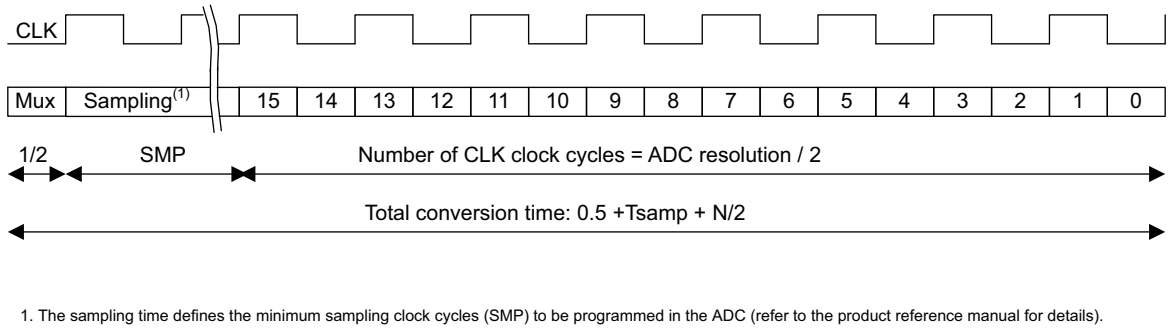
Table 97. Minimum sampling time versus R_{AIN} (1)(2) (continued)

Resolution	R_{AIN} (Ω)	Minimum sampling time (s)	
		Fast channel	Slow channel (3)
8 bits	47	2.64E-08	4.17E-08
	68	2.76E-08	4.24E-08
	100	3.02E-08	4.39E-08
	150	3.51E-08	4.66E-08
	220	4.27E-08	5.13E-08
	330	5.52E-08	6.19E-08
	470	7.17E-08	7.72E-08
	680	9.68E-08	1.00E-07
	1000	1.34E-07	1.37E-07
	1500	1.93E-07	1.94E-07
	2200	2.76E-07	2.74E-07
	3300	4.06E-07	4.01E-07
	4700	5.73E-07	5.62E-07
	6800	8.21E-07	7.99E-07
	10000	1.20E-06	1.17E-06
	15000	1.79E-06	1.74E-06
6 bits	47	2.14E-08	3.16E-08
	68	2.23E-08	3.21E-08
	100	2.40E-08	3.31E-08
	150	2.68E-08	3.52E-08
	220	3.13E-08	3.87E-08
	330	3.89E-08	4.51E-08
	470	4.88E-08	5.39E-08
	680	6.38E-08	6.79E-08
	1000	8.70E-08	8.97E-08
	1500	1.23E-07	1.24E-07
	2200	1.73E-07	1.73E-07
	3300	2.53E-07	2.49E-07
	4700	3.53E-07	3.45E-07
	6800	5.04E-07	4.90E-07
	10000	7.34E-07	7.11E-07
	15000	1.09E-06	1.05E-06

1. Specified by design - Not tested in production.
2. Data valid up to 130°C, with a 22 pF PCB capacitor, and V_{DDA} = 1.6 V.

3. Slow channels correspond to all ADC inputs except for the fast channels.

Figure 59. ADC conversion timing diagram



1. The sampling time defines the minimum sampling clock cycles (SMP) to be programmed in the ADC (refer to the product reference manual for details).

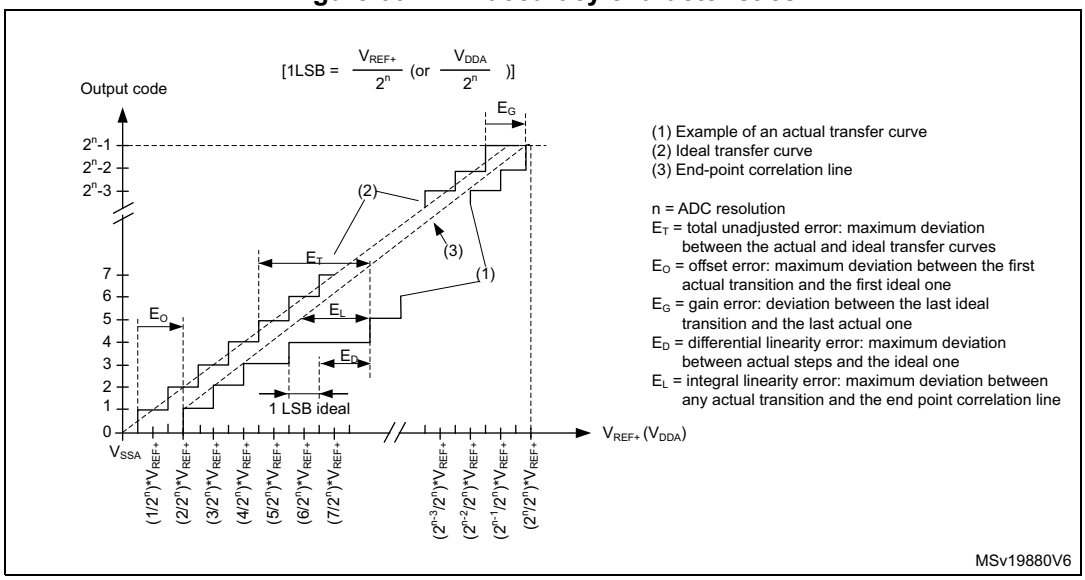
Table 98. ADC accuracy(1)(2)

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
ET	Total unadjusted error	Fast and slow channels	Single ended	-	±4	±10	LSB
			Differential	-	±2.5	±6	
EO	Offset error	-	Single ended	-	±2	±4.5	
		-	Differential	-	±2	±5.5	
EG	Gain error	-	Single ended	-	±2	±9.1	
		-	Differential		±3	±8	
ED	Differential linearity error	-	Single ended	-	+2.3/-1	+3/-1	
		-	Differential	-	+1.2/-1	+2/-1	
EL	Integral linearity error	Fast and slow channels	Single ended	-	±3	±5	
			Differential	-	±2	±2.5	
ENOB	Effective number of bits	Single ended		-	10.8	-	Bits
		Differential		-	11.3	-	
SINAD	Signal-to-noise and distortion ratio	Single ended		-	67	-	dB
		Differential		-	70	-	
SNR	Signal-to-noise ratio	Single ended		-	68	-	
		Differential		-	70	-	
THD	Total harmonic distortion	Single ended		-	-72	-	
		Differential		-	-82	-	

1. Evaluated by characterization for BGA packages. The values for LQFP package can differ. Not tested in production.
2. ADC DC accuracy values are measured after internal calibration in continuous mode.

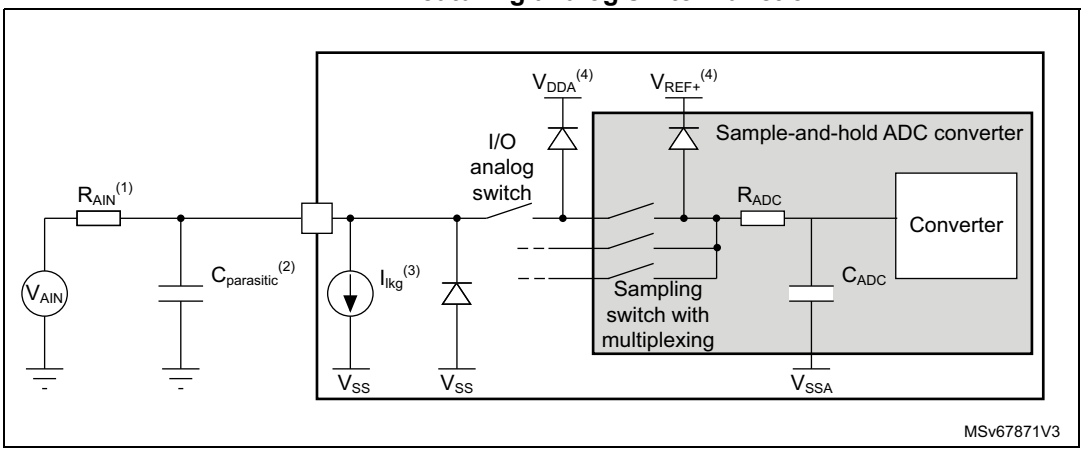
Note: ADC accuracy vs. negative injection current: injecting a negative current on any analog input pins should be avoided as this significantly reduces the accuracy of the conversion being performed on another analog input. It is recommended to add a Schottky diode (pin to ground) to analog pins, which may potentially inject negative currents.

Figure 60. ADC accuracy characteristics



1. Example of an actual transfer curve.
2. Ideal transfer curve.
3. End point correlation line.
4. E_T = Total unadjusted error: maximum deviation between the actual and the ideal transfer curves.
5. EO = Offset error: deviation between the first actual transition and the first ideal one.
6. EG = Gain error: deviation between the last ideal transition and the last actual one.
7. ED = Differential linearity error: maximum deviation between actual steps and the ideal one.
8. EL = Integral linearity error: maximum deviation between any actual transition and the end point correlation line.

Figure 61. Typical connection diagram when using the ADC with FT/TT pins featuring analog switch function



1. Refer to *Table 96* 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

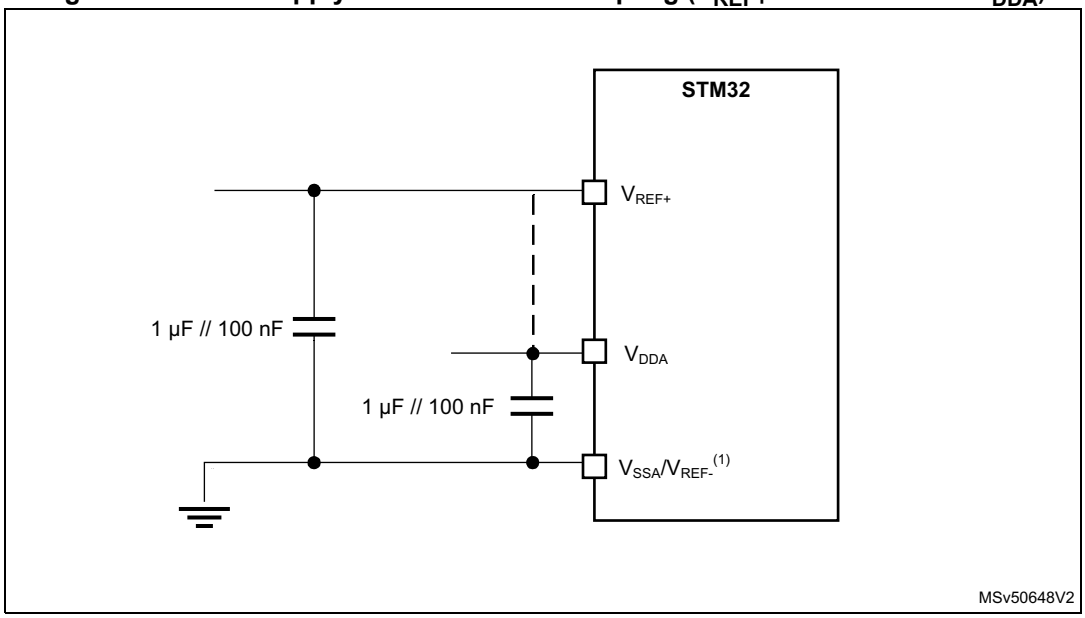
pad capacitance (refer to *Table 57*). A high $C_{parasitic}$ value downgrades conversion accuracy. To remedy this, f_{ADC} should be reduced.

3. Refer to *Table 57* for the value of I_{lkg}.
4. Refer to *Figure 23*.

General PCB design guidelines

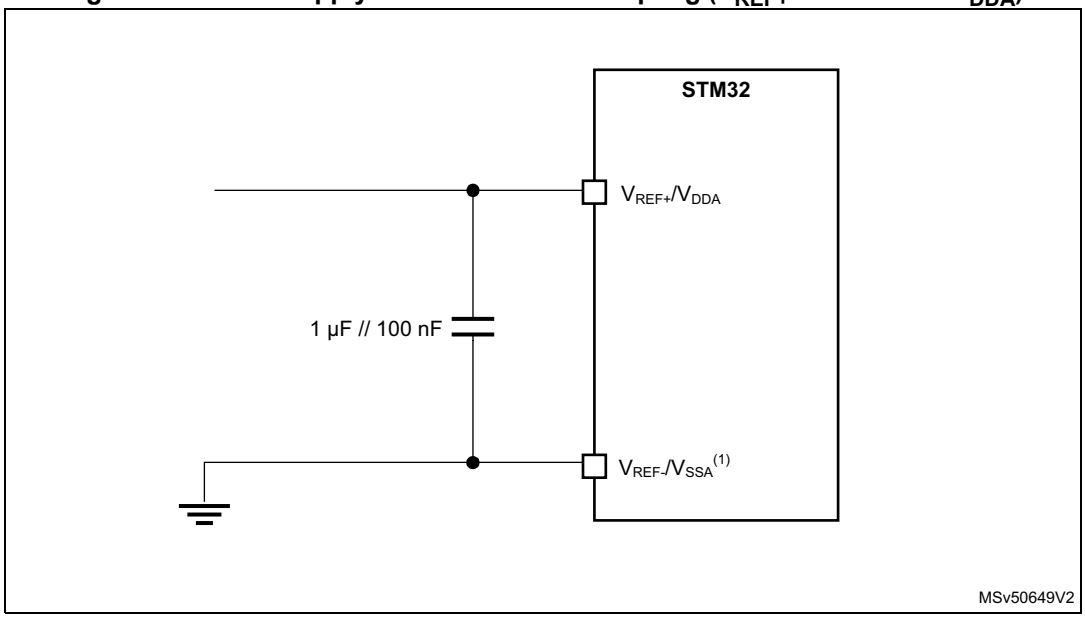
It is recommended to perform power supply decoupling as shown in *Figure 62* or *Figure 63*, depending on whether V_{REF+} is connected to V_{DDA} or not. The 100 nF capacitors must be ceramic (good quality), and placed as close as possible to the chip.

Figure 62. Power supply and reference decoupling (V_{REF+} not connected to V_{DDA})



1. VREF- is not available on LQFP100 with SMPS, LQFP144 and LQFP176 packages. When V_{REF-} is not available, it is internally connected to V_{SSA}. Refer to *Figure 23: Power supply scheme with SMPS* for more details.

Figure 63. Power supply and reference decoupling (V_{REF+} connected to V_{DDA})



1. VREF- is not available on LQFP100 with SMPS, LQFP144 and LQFP176 packages. When V_{REF-} is not available, it is internally connected to V_{SSA}. Refer to *Figure 23: Power supply scheme with SMPS* for more details.

5.3.25 DAC characteristics

Table 99. DAC characteristics(1)

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
V_{DDA}	Analog supply voltage	-		1.8	3.3	3.6	V
V_{REF+}	Positive reference voltage	-		1.8	-	V_{DDA}	
V_{REF-}	Negative reference voltage	-		-	V_{SSA}	-	
R_L	Resistive load	DAC output buffer ON	Connected to V_{SSA}	5	-	-	kΩ
			Connected to V_{DDA}	25	-	-	
R_O	Output impedance	DAC output buffer OFF		10.3	13	16	
R_{BON}	Output impedance sample and hold mode, output buffer ON	DAC output buffer ON	V_{DD} = 2.7 V	-	-	1.6	kΩ
			V_{DD} = 2.0 V	-	-	2.6	
R_{BOFF}	Output impedance sample and hold mode, output buffer OFF	DAC output buffer OFF	V_{DD} = 2.7 V	-	-	17.8	kΩ
			V_{DD} = 2.0 V	-	-	18.7	
C_L	Capacitive load	DAC output buffer OFF		-	-	50	pF
C_{SH}		Sample and hold mode		-	0.1	1	µF
V_{DAC_OUT}	Voltage on DAC_OUT output	DAC output buffer ON		0.2	-	V_{DDA} −0.2	V
		DAC output buffer OFF		0	-	V_{REF+}	

Table 99. DAC characteristics(1) (continued)

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
$t_{SETTLING}$	Settling time (full scale: for a 12-bit code transition between the lowest and the highest input codes when DAC_OUT reaches the final value of ±0.5LSB, ±1LSB, ±2LSB, ±4LSB, ±8LSB)	Normal mode, DAC output buffer ON, $C_L \leq 50$ pF, $R_L \geq 5$ kΩ	±0.5 LSB	-	2.05	3	µs
			±1 LSB	-	1.97	2.87	
			±2 LSB	-	1.67	2.84	
			±4 LSB	-	1.66	2.78	
			±8 LSB	-	1.65	2.7	
		Normal mode, DAC output buffer OFF, ±1LSB C_L= 10 pF		-	1.7	2	
t_{WAKEUP} (2)	Wake-up time from off state (setting the ENx bit in the DAC control register) until the final value of ±1LSB is reached	Normal mode, DAC output buffer ON, $C_L \leq 50$ pF, R_L = 5 kΩ		-	5	7.5	µs
		Normal mode, DAC output buffer OFF, $C_L \leq 10$ pF		-	2	5	
PSRR	DC V_{DDA} supply rejection ratio	Normal mode, DAC output buffer ON, $C_L \leq 50$ pF, R_L = 5 kΩ		-	-80	-28	dB
t_{SAMP}	Sampling time in Sample and hold mode, C_L= 100 nF (code transition between the lowest and the highest input code when DAC_OUT reaches the ±1LSB final value)	MODE<2:0>_V12 = 100/101 (BUFFER ON)		-	0.7	2.6	ms
		MODE<2:0>_V12 = 110 (BUFFER OFF)		-	11.5	18.7	
		MODE<2:0>_V12=111(3) (INTERNAL BUFFER OFF)		-	0.3	0.6	µs
I_{leak}	Output leakage current	-		-	-	(4)	nA
C_{lint}	Internal sample and hold capacitor	-		1.8	2.2	2.6	pF
t_{TRIM}	Middle code offset trim time	Minimum time to verify each code		50	-	-	µs
V_{offset}	Middle code offset for 1 trim code step	V_{REF+} = 3.6 V		-	850	-	µV
		V_{REF+} = 1.8 V		-	425	-	
$I_{DDA(DAC)}$	DAC quiescent consumption from V_{DDA}	DAC output buffer ON	No load, middle code (0x800)	-	360	-	µA
			No load, worst code (0xF1C)	-	490	-	
		DAC output buffer OFF	No load, middle/ worst code (0x800)	-	20	-	
		Sample and hold mode, C_{SH} = 100 nF		-	$360*T_{ON}/(T_{ON}+T_{OFF})$(5)	-	

Table 99. DAC characteristics(1) (continued)

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
$I_{DDV(DAC)}$	DAC consumption from V_{REF+}	DAC output buffer ON	No load, middle code (0x800)	-	170	-	µA
			No load, worst code (0xF1C)	-	170	-	
		DAC output buffer OFF	No load, middle/ worst code (0x800)	-	160	-	
		Sample and hold mode, buffer ON, C_{SH} = 100 nF (worst code)		-	$170*T_{ON}/(T_{ON}+T_{OFF})$(5)	-	
		Sample and hold mode, buffer OFF, C_{SH} = 100 nF (worst code)		-	$160*T_{ON}/(T_{ON}+T_{OFF})$(5)	-	

1. Specified by design - Not tested in production, unless otherwise specified.
2. In buffered mode, the output can overshoot above the final value for low input code (starting from the minimum value).
3. DACx_OUT pin is not connected externally (internal connection only).
4. Refer to *Table 57*.
5. T_{ON} is the refresh phase duration, T_{OFF} is the hold phase duration. Refer to the reference manual for more details.

Table 100. DAC accuracy(1)

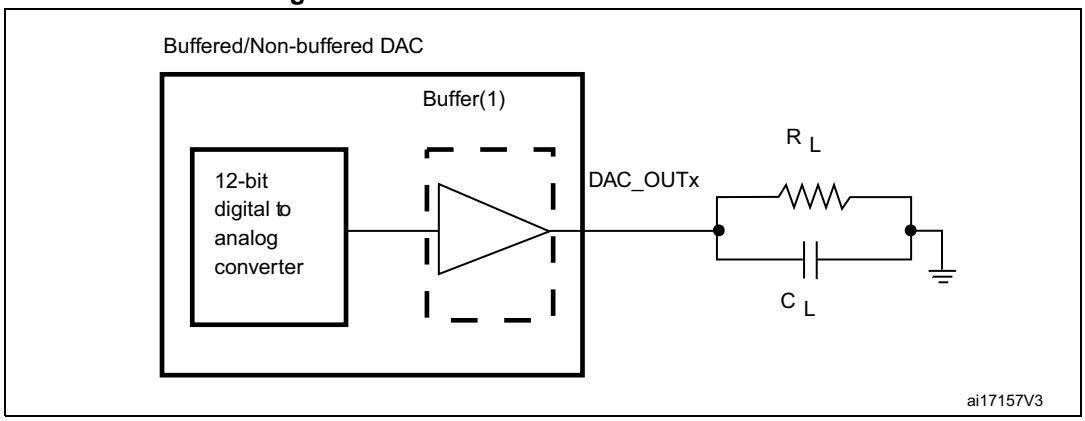
Symbol	Parameter	Conditions		Min	Typ	Max	Unit
DNL	Differential non linearity(2)	DAC output buffer ON		−2	-	2	LSB
		DAC output buffer OFF		−2	-	2	
-	Monotonicity	10 bits		-	-	-	-
INL	Integral non linearity(3)	DAC output buffer ON, $C_L \le 50$ pF, $R_L \ge 5$ kΩ		−4	-	4	LSB
		DAC output buffer OFF, $C_L \le 50$ pF, no R_L		−4	-	4	
Offset	Offset error at code 0x800 (3)	DAC output buffer ON, $C_L \le 50$ pF, $R_L \ge 5$ kΩ	V_{REF+} = 3.6 V	-	-	±12	
			V_{REF+} = 1.8 V	-	-	±25	
		DAC output buffer OFF, $C_L \le 50$ pF, no R_L		-	-	±8	
Offset1	Offset error at code 0x001(4)	DAC output buffer OFF, $C_L \le 50$ pF, no R_L		-	-	±5	
OffsetCal	Offset error at code 0x800 after factory calibration	DAC output buffer ON, $C_L \le 50$ pF, $R_L \ge 5$ kΩ	V_{REF+} = 3.6 V	-	-	±5	
			V_{REF+} = 1.8 V	-	-	±7	

Table 100. DAC accuracy(1) (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Gain	Gain error(5)	DAC output buffer ON, $C_L \le 50$ pF, $R_L \ge 5$ kΩ	-	-	±1	%
		DAC output buffer OFF, $C_L \le 50$ pF, no R_L	-	-	±1	
TUE	Total unadjusted error	DAC output buffer ON, $C_L \le 50$ pF, $R_L \ge 5$ kΩ	-	-	±30	LSB
		DAC output buffer OFF, $C_L \le 50$ pF, no R_L			±12	
TUECal	Total unadjusted error after calibration	DAC output buffer ON, $C_L \le 50$ pF, $R_L \ge 5$ kΩ	-	-	±23	
SNR	Signal-to-noise ratio(6)	DAC output buffer ON, $C_L \le 50$ pF, $R_L \ge 5$ kΩ, 1 kHz, BW = 500 kHz	-	67.8	-	dB
		DAC output buffer OFF, $C_L \le 50$ pF, no R_L,1 kHz, BW = 500 kHz	-	67.8	-	
THD	Total harmonic distortion(6)	DAC output buffer ON, $C_L \le 50$ pF, $R_L \ge 5$ kΩ, 1 kHz	-	−78.6	-	
		DAC output buffer OFF, $C_L \le 50$ pF, no R_L, 1 kHz	-	−78.6	-	
SINAD	Signal-to-noise and distortion ratio(6)	DAC output buffer ON, $C_L \le 50$ pF, $R_L \ge 5$ kΩ, 1 kHz	-	67.5	-	
		DAC output buffer OFF, $C_L \le 50$ pF, no R_L, 1 kHz	-	67.5	-	
ENOB	Effective number of bits	DAC output buffer ON, $C_L \le 50$ pF, $R_L \ge 5$ kΩ, 1 kHz	-	10.9	-	bits
		DAC output buffer OFF, $C_L \le 50$ pF, no R_L, 1 kHz	-	10.9	-	

1. Evaluated by characterization - Not tested in production.
2. Difference between two consecutive codes minus 1 LSB.
3. Difference between the value measured at Code i and the value measured at Code i on a line drawn between Code 0 and last Code 4095.
4. Difference between the value measured at Code (0x001) and the ideal value.
5. Difference between the ideal slope of the transfer function and the measured slope computed from code 0x000 and 0xFFF when the buffer is OFF, and from code giving 0.2 V and (V_{REF+} - 0.2 V) when the buffer is ON.
6. Signal is −0.5 dBFS with $F_{sampling}$ = 1 MHz.

Figure 64. 12-bit buffered/non-buffered DAC



1. The DAC integrates an output buffer that can be used to reduce the output impedance and to drive external loads directly, without the use of an external operational amplifier. The buffer can be bypassed by configuring the BOFFx bit in the DAC_CR register.

5.3.26 Analog temperature sensor characteristics

Table 101. Analog temperature sensor characteristics

Symbol	Parameter	Min	Typ	Max	Unit
T_L(1)	V_{SENSE} linearity with temperature (from V_{SENSOR} voltage)	-	-	3	°C
	V_{SENSE} linearity with temperature (from ADC counter)	-	-	3	
Avg_Slope(2)	Average slope (from V_{SENSOR} voltage)	-	2	-	mV/°C
	Average slope (from ADC counter)	-	2	-	
V_{30}(3)	Voltage at 30°C ± 5°C	-	0.62	-	V
t_{start_run}	Startup time in Run mode (buffer startup)	-	-	25.2	µs
t_{S_temp}(1)	ADC sampling time when reading the temperature	9	-	-	
I_{sens}(1)	Sensor consumption	-	0.18	0.31	µA
$I_{sensbuf}$(1)	Sensor buffer consumption	-	3.8	6.5	

1. Specified by design - Not tested in production.
2. Evaluated by characterization - Not tested in production.
3. Measured at V_{DDA} = 3.3 V ± 10 mV. The V_{30} ADC conversion result is stored in the TS_CAL1 bytes.

Table 102. Temperature sensor calibration values

Symbol	Parameter	Memory address
TS_CAL1	Temperature sensor raw data acquired value at 30°C, V_{DDA} = 3.3 V	0x08FF F814 -0x08FF F815
TS_CAL2	Temperature sensor raw data acquired value at 130°C, V_{DDA} = 3.3 V	0x08FF F818 - 0x08FF F819

5.3.27 Digital temperature sensor characteristics

Table 103. Digital temperature sensor characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{DTS}(2)	Output clock frequency	-	500	750	1150	kHz
T_{LC}(2)	Temperature linearity coefficient	VOS2	1660	2100	2750	Hz/°C
T_{TOTAL_ERROR}(2)	Temperature offset measurement, all VOS	T_J = −40 to 30°C	-13	-	4	°C
		T_J = 30°C to T_{Jmax}	-7	-	2	
T_{VDD_CORE}	Additional error due to supply variation	VOS2	0	-	0	°C
		VOS0, VOS1, VOS3	-1	-	1	
t_{TRIM}	Calibration time	-	-	-	2	ms
t_{WAKE_UP}	Wake-up time from off state until DTS ready bit is set	-	-	67	116	µs
I_{DDCORE_DTS}	DTS consumption on V_{DD_CORE}	-	8.5	30	70	µA

1. Specified by design - Not tested in production, unless otherwise specified.
2. Evaluated by characterization - Not tested in production.

5.3.28 V_{CORE} monitoring characteristics

Table 104. V_{CORE} monitoring characteristics(1)

Symbol	Parameter	Min	Typ	Max	Unit
T_{S_VCORE}	ADC sampling time when reading the V_{CORE} voltage	1	-	-	µs

1. Specified by design - Not tested in production.

5.3.29 Temperature and V_{BAT} monitoring

Table 105. V_{BAT} monitoring characteristics

Symbol	Parameter	Min	Typ	Max	Unit
R	Resistor bridge for V_{BAT}	-	4 x 26	-	kΩ
Q(1)	Ratio on V_{BAT} measurement	-	4	-	-
Er(2)	Error on Q	-10	-	+10	%
t_{S_vbat}(2)	ADC sampling time when reading V_{BAT} input	9	-	-	µs
$V_{BAThigh}$	High supply monitoring	3.50	3.575	3.63	V
V_{BATlow}	Low supply monitoring	-	1.36	-	
$I_{VBATbuf}$	Sensor buffer consumption	-	3.8	6.5	µA

1. 1.2 V ≤ V_{BAT} ≤ 3.63 V.
2. Specified by design - Not tested in production.

Table 106. V_{BAT} charging characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
R_{BC}	Battery charging resistor	VBRS in PWR_CR3 = 0	-	5	-	kΩ
		VBRS in PWR_CR3 = 1	-	1.5	-	

Table 107. Temperature monitoring characteristics

Symbol	Parameter	Min	Typ	Max	Unit
$TEMP_{high}$	High temperature monitoring	-	126	-	°C
$TEMP_{low}$	Low temperature monitoring	-	-37	-	

5.3.30 Voltage booster for analog switch

Table 108. Voltage booster for analog switch characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{DD}	Supply voltage	-	1.71	2.6	3.6	V
$t_{SU(BOOST)}$	Booster startup time	-	-	-	50	µs
$I_{DD(BOOST)}$	Booster consumption	1.71 V ≤ V_{DD} ≤ 2.7 V	-	-	125	µA
		2.7 V < V_{DD} < 3.6 V	-	-	250	

1. Evaluated by characterization - Not tested in production.

5.3.31 VREFBUF characteristics

Table 109. VREFBUF characteristics(1)

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
V_{DDA}	Analog supply voltage	Normal mode at V_{DDA} = 3.3 V	VRS = 000	2.8	3.3	3.6	V
			VRS = 001	2.4	-	3.6	
			VRS = 010	2.1	-	3.6	
		Degraded mode(2)	VRS = 000	1.62	-	2.80	
			VRS = 001	1.62	-	2.40	
			VRS = 010	1.62	-	2.10	
V_{REFBUF_OUT}	Voltage reference buffer output	Normal mode at 30°C, I_{LOAD} = 100 µA	VRS = 000	2.4980(3)	2.5000	2.5035(3)	V
			VRS = 001	2.0460	2.0490	2.0520	
			VRS = 010	1.8010	1.8040	1.8060	
		Degraded mode(2)	VRS = 000	V_{DDA} − 150 mV	-	2.5035	
			VRS = 001		-	2.0520	
			VRS = 010		-	1.8060	
TRIM	Trim step resolution	-	-	-	±0.05	±0.1	%

Table 109. VREFBUF characteristics(1) (continued)

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
C_L	Load capacitor	-	-	0.5	1	1.50	µF
esr	Equivalent serial resistor of C_L	-	-	-	-	2	Ω
I_{load}	Static load current	-	-	-	-	4	mA
I_{line_reg}	Line regulation	2.8 V ≤ V_{DDA} ≤ 3.6 V	I_{load} = 500 µA	-	200	-	ppm/V
			I_{load} = 4 mA	-	100	-	
I_{load_reg}	Load regulation	500 µA ≤ I_{load} ≤ 4 mA	Normal mode	-	50	-	ppm/mA
T_{coeff}	Temperature coefficient	-40°C < T_J < +130°C	-	-	-	100	ppm/°C
PSRR	Power supply rejection	DC	-	-	60	-	dB
		100 kHz	-	-	40	-	
t_{START}	Start-up time	C_L= 0.5 µF	-	-	300	-	µs
		C_L= 1 µF	-	-	500	-	
		C_L= 1.5 µF	-	-	650	-	
I_{INRUSH}	Control of maximum DC current drive on V_{REFBUF_OUT} during startup(4)	-		-	8	-	mA
$I_{DDA(VREFBUF)}$	Consumption from VDDA	I_{LOAD} = 0 µA	-	-	15	25	µA
		I_{LOAD} = 500 µA	-	-	16	30	
		I_{LOAD} = 4 mA	-	-	32	50	

1. Specified by design - Not tested in production, unless otherwise specified.
2. In degraded mode, the voltage reference buffer cannot accurately maintain the output voltage (V_{DDA}−drop voltage).
3. Evaluated by characterization - Not tested in production.
4. To properly control V_{REFBUF} I_{INRUSH} current during the startup phase and the change of scaling, V_{DDA} voltage must be in the range of 2.1 V - 3.6 V, 2.4 V -3.6 V, and 2.8 V - 3.6 V, respectively, for VRS = 010, 001, and 000.

5.3.32 Comparator characteristics

Table 110. COMP characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{DDA}	Analog supply voltage	-	1.62	3.3	3.6	V
V_{IN}	Comparator input voltage range	-	0	-	V_{DDA}	
V_{BG}(2)	Scaler input voltage	-	-			
V_{SC}	Scaler offset voltage	-	-	±5	±10	mV

Table 110. COMP characteristics(1) (continued)

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
$I_{DDA(SCALER)}$	Scaler static consumption from V_{DDA}	BRG_EN=0 (bridge disable)		-	0.2	0.3	µA
		BRG_EN=1 (bridge enable)		-	0.8	1	
t_{START_SCALER}	Scaler startup time	-		-	140	250	µs
t_{START}	Comparator startup time to reach propagation delay specification	High-speed mode		-	2	5	µs
		Medium mode		-	5	20	
		Ultra-low-power mode		-	15	80	
t_D(3)	Propagation delay for 200 mV step with 100 mV overdrive	High-speed mode		-	50	80	ns
		Medium mode		-	0.5	0.9	µs
		Ultra-low-power mode		-	2.5	7	
	Propagation delay for step > 200 mV with 100 mV overdrive only on positive inputs	High-speed mode		-	50	120	ns
		Medium mode		-	0.5	1.2	µs
		Ultra-low-power mode		-	2.5	7	
V_{offset}	Comparator offset error	Full common mode range		-	±5	±20	mV
V_{hys}	Comparator hysteresis	No hysteresis		-	0	-	mV
		Low hysteresis		4	10	22	
		Medium hysteresis		8	20	37	
		High hysteresis		16	30	52	
$I_{DDA(COMP)}$	Comparator consumption from V_{DDA}	Ultra-low-power mode	Static	-	400	600	nA
			With 50 kHz ±100 mV overdrive square signal	-	800	-	
		Medium mode	Static	-	5	7	µA
			With 50 kHz ±100 mV overdrive square signal	-	6	-	
		High-speed mode	Static	-	70	100	
			With 50 kHz ±100 mV overdrive square signal	-	75	-	

1. Specified by design - Not tested in production, unless otherwise specified.
2. Refer to *Section 5.3.6: Embedded reference voltage*.
3. Evaluated by characterization - Not tested in production.

5.3.33 Operational amplifier characteristics

Table 111. Operational amplifier characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{DDA}	Analog supply voltage Range	-	2	3.3	3.6	V
CMIR	Common Mode Input Range	-	0	-	V_{DDA}	
VI_{OFFSET}	Input offset voltage	25°C, no load on output	-	-	±1.5	mV
		All voltages and temperature, no load	-	-	±2.5	
ΔVI_{OFFSET}	Input offset voltage drift	-	-	±3.0	-	µV/°C
TRIMOFFSETP, TRIMLPOFFSETP	Offset trim step at low common input voltage ($0.1*V_{DDA}$)	-	-	1.1	1.5	mV
TRIMOFFSETN, TRIMLPOFFSETN	Offset trim step at high common input voltage ($0.9*V_{DDA}$)	-	-	1.1	1.5	
I_{LOAD}	Drive current	-	-	-	500	µA
I_{LOAD_PGA}	Drive current in PGA mode	-	-	-	270	
C_{LOAD}	Capacitive load	-	-	-	50	pF
CMRR	Common mode rejection ratio	-	-	80	-	dB
PSRR	Power supply rejection ratio	$C_{LOAD} \leq 50pf$ / $R_{LOAD} \geq 4\ k\Omega$(2) at 1 kHz, $V_{com}=V_{DDA}/2$	50	66	-	dB
GBW	Gain bandwidth for high supply range	200 mV ≤ Output dynamic range ≤ V_{DDA} - 200 mV	4	7.3	12.3	MHz
SR	Slew rate (from 10% and 90% of output voltage)	Normal mode	-	3	-	V/µs
		High-speed mode	-	24	-	
AO	Open loop gain	200 mV ≤ Output dynamic range ≤ V_{DDA} - 200 mV	59	90	129	dB
φm	Phase margin	-	-	55	-	°
GM	Gain margin	-	-	12	-	dB
V_{OHSAT}	High saturation voltage	I_{load}=max or R_{LOAD}=min, Input at V_{DDA}	V_{DDA} −100 mV	-	-	mV
V_{OLSAT}	Low saturation voltage	I_{load}=max or R_{LOAD}=min, Input at 0 V	-	-	100	

Table 111. Operational amplifier characteristics(1) (continued)

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
t_{WAKEUP}	Wake up time from OFF state	Normal mode	C_{LOAD} ≤ 50pf, R_{LOAD} ≥ 4 kΩ, follower configuration	-	0.8	3.2	µs
		High speed mode	C_{LOAD} ≤ 50pf, R_{LOAD} ≥ 4 kΩ, follower configuration	-	0.9	2.8	
PGA gain	Non inverting gain error value	PGA gain = 2		-1	-	1	%
		PGA gain = 4		-2	-	2	
		PGA gain = 8		-2.5	-	2.5	
		PGA gain = 16		-3	-	3	
	Inverting gain error value	PGA gain = -1		-1	-	1	
		PGA gain = -3		-1	-	1	
		PGA gain = -7		-2	-	2	
		PGA gain = -15		-3	-	3	
	External non-inverting gain error value	PGA gain = 2		-1	-	1	
		PGA gain = 4		-3	-	3	
		PGA gain = 8		-3.5	-	3.5	
		PGA gain = 16		-4	-	4	
$R_{network}$	R2/R1 internal resistance values in non-inverting PGA mode(3)	PGA Gain=2		-	10/10	-	kΩ/ kΩ
		PGA Gain=4		-	30/10	-	
		PGA Gain=8		-	70/10	-	
		PGA Gain=16		-	150/10	-	
	R2/R1 internal resistance values in inverting PGA mode(3)	PGA Gain = -1		-	10/10	-	
		PGA Gain = -3		-	30/10	-	
		PGA Gain = -7		-	70/10	-	
		PGA Gain = -15		-	150/10	-	
Delta R	Resistance variation (R1 or R2)	-		-15	-	15	%

Table 111. Operational amplifier characteristics(1) (continued)

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
PGA BW	PGA bandwidth for different non inverting gain	Gain=2		-	GBW/2	-	MHz
		Gain=4		-	GBW/4	-	
		Gain=8		-	GBW/8	-	
		Gain=16		-	GBW/16	-	
	PGA bandwidth for different inverting gain	Gain = -1		-	5.00	-	MHz
		Gain = -3		-	3.00	-	
		Gain = -7		-	1.50	-	
		Gain = -15		-	0.80	-	
en	Voltage noise density	at 1 KHz	output loaded with 4 kΩ	-	140	-	nV/√Hz
		at 10 KHz		-	55	-	
$I_{DDA(OPAMP)}$	OPAMP consumption from V_{DDA}	Normal mode	no Load, quiescent mode, follower	-	570	1000	µA
		High-speed mode		-	610	1200	

1. Specified by design - Not tested in production, unless otherwise specified.
2. R_{LOAD} is the resistive load connected to V_{SSA} or to V_{DDA}.
3. R2 is the internal resistance between the OPAMP output and th OPAMP inverting input. R1 is the internal resistance between the OPAMP inverting input and ground. PGA gain = 1 + R2/R1.

5.3.34 LTDC characteristics

Unless otherwise specified, the parameters given in *Table 112* for LCD-TFT are derived from tests performed under the ambient temperature, f_{HCLK} frequency and V_{DD} supply voltage summarized in *Table 112: LTDC characteristics*, with the following configuration:

- LCD_CLK polarity: low
- LCD_DE polarity: low
- LCD_VSYNC and LCD_HSYNC polarity: high
- Pixel formats: 24 bits
- Output speed is set to
  - LTDC clock: OSPEEDRy[1:0] = 10
- Capacitive load C_L=30 pF
- Measurement points are done at CMOS levels: 0.5 V_{DD}
- IO compensation cell enabled
- HSLV activated when $V_{DD} \leq 2.7$ V

Table 112. LTDC characteristics(1)

Symbol	Parameter		Min	Max	Unit
f_{CLK}	LTDC clock output frequency	1.71 < V_{DD} < 3.6 V, 30 pF	-	90	MHz
D_{CLK}	LTDC clock output duty cycle		45	55	%
$t_{w(CLKH)}$, $t_{w(CLKL)}$	Clock high time, low time		$t_{w(CLK)}$/ 2 − 0.5	$t_{w(CLK)}$ / 2 + 0.5	ns
$t_{v(DATA)}$	Data output valid time		-	3.5	
$t_{h(DATA)}$	Data output hold time		0	-	
$t_{v(HSYNC)}$, $t_{v(VSYNC)}$, $t_{v(DE)}$	HSYNC/VSYNC/DE output valid time		-	3	
$t_{h(HSYNC)}$, $t_{h(VSYNC)}$, $t_{h(DE)}$	HSYNC/VSYNC/DE output hold time		0	-	

1. Evaluated by characterization - not tested in production.

LCD-TFT timing diagrams

Figure 65. LCD-TFT horizontal timing diagram

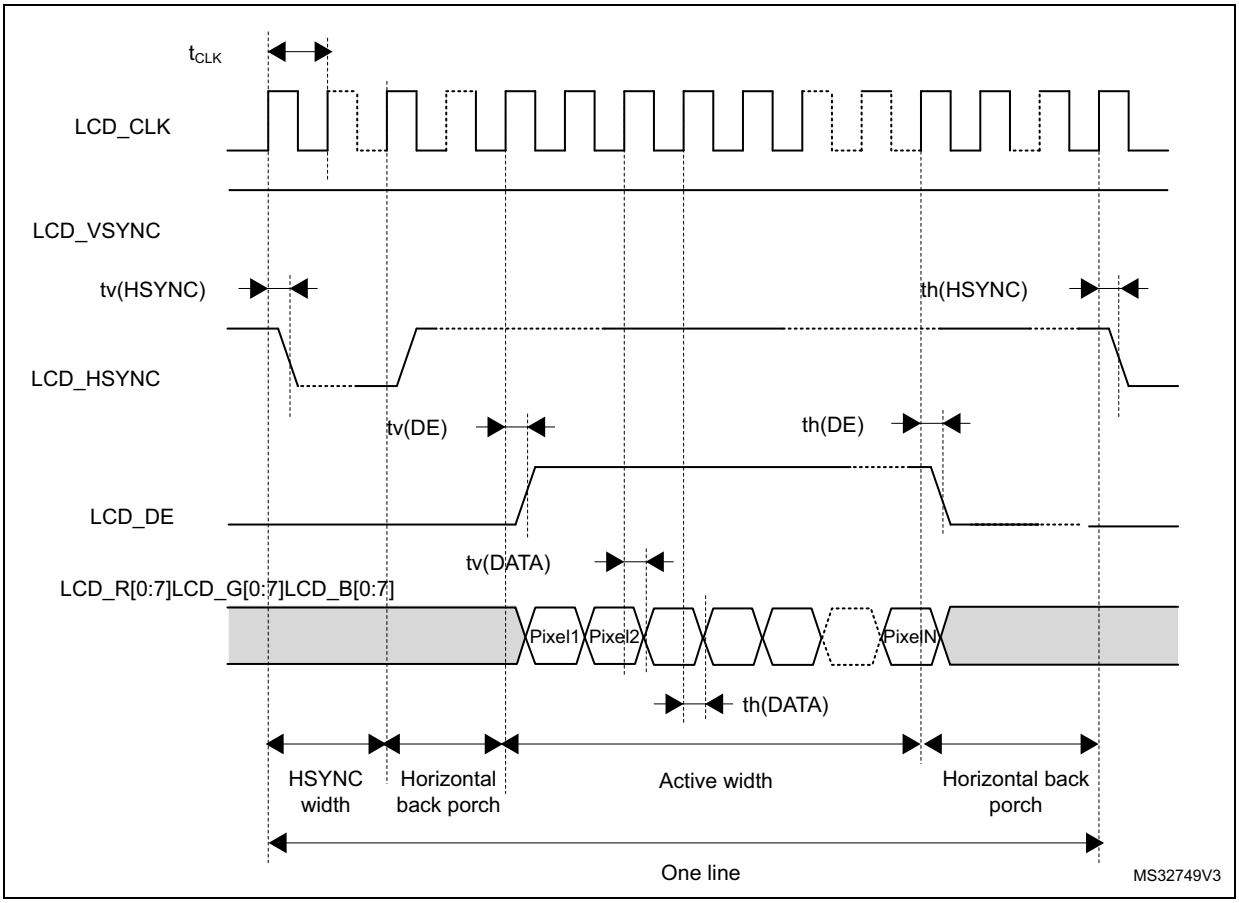
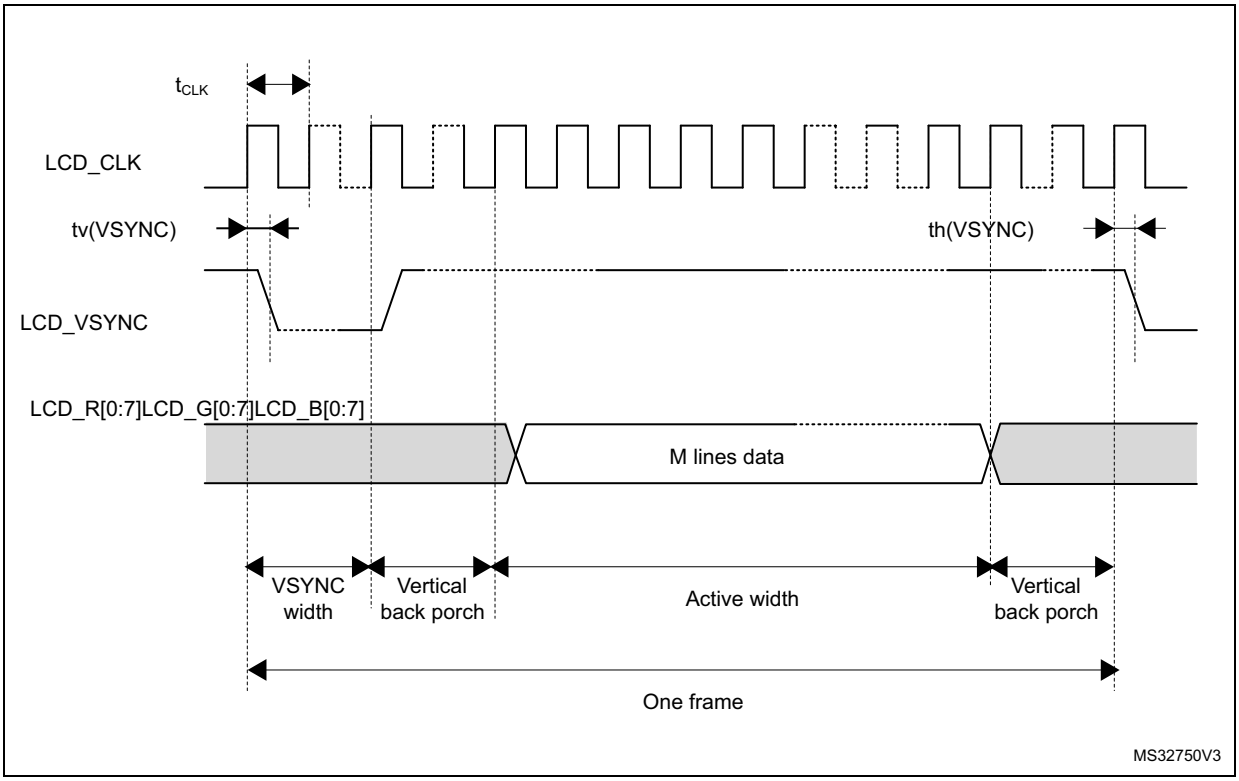


Figure 66. LTDC vertical timing diagram



5.3.35 ADF/MDF characteristics

Unless otherwise specified, the parameters given in the table below are derived from tests performed under the ambient temperature, f_{AHB} frequency and V_{DD} supply voltage conditions summarized in *Table 19*, with the following configuration:

- Output speed set to OSPEEDRy[1:0] = 10
- Capacitive load C_L = 30 pF
- Measurement points done at 0.5 × V_{DD} level
- I/O compensation cell activated
- HSLV activated when V_{DD} ≤ 2.7 V
- VOS level set to VOS0

Refer to *Section 5.3.15: I/O port characteristics* for more details on the input/output alternate function characteristics.

Table 113. ADF characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{CCKI}	Input clock frequency via ADF_CCK[1:0] pin, in SLAVE SPI mode	1.71 ≤ V_{DD} ≤ 3.6 V	-	-	25	MHz
f_{CCKO}	Output clock frequency in MASTER SPI mode		-	-	25	
f_{CCKOLF}	Output clock frequency in LF_MASTER SPI mode		-	-	5	
f_{SYMB}	Input symbol rate in Manchester mode		-	-	20	
t_{HCCKI} t_{LCCKI}	ADF_CCK[1:0] input clock high and low time	In SLAVE SPI mode	2 × Tadf_proc_ck(2)	-	-	ns
t_{HCCKO} t_{LCCKO}	ADF_CCK[1:0] output clock high and low time	In MASTER SPI mode	2 × Tadf_proc_ck	-	-	
$t_{HCCKOLF}$ $t_{LCCKOLF}$	ADF_CCK[1:0] output clock high and low time	In LF_MASTER SPI mode	Tadf_proc_ck	-	-	
t_{SUCCKI}	Data setup time with respect to ADF_CCK[1:0] input	In SLAVE SPI mode: ADF_CCK[1:0] configured in input, measured on rising and falling edge	4.5	-	-	
t_{HDCCKI}	Data hold time with respect to ADF_CCK[1:0] input		1	-	-	
t_{SUCCKO}	Data setup time with respect to ADF_CCK[1:0] output	In MASTER SPI mode: ADF_CCK[1:0] configured in output, measured on rising and falling edge	5.5	-	-	
t_{HDCCKO}	Data hold time with respect to ADF_CCK[1:0] output		0	-	-	
$t_{SUCCKOLF}$	Data setup time with respect to ADF_CCK[1:0] output	In LF_MASTER SPI mode: ADF_CCK[1:0] configured in output, measured on rising and falling edge	19.5	-	-	
$t_{HDCCKOLF}$	Data hold time with respect to ADF_CCK[1:0] output		0	-	-	

1. Evaluated by characterization. Not tested in production.
2. Tadf_proc_ck is the period of the ADF processing clock.

Figure 67. ADF timing diagram

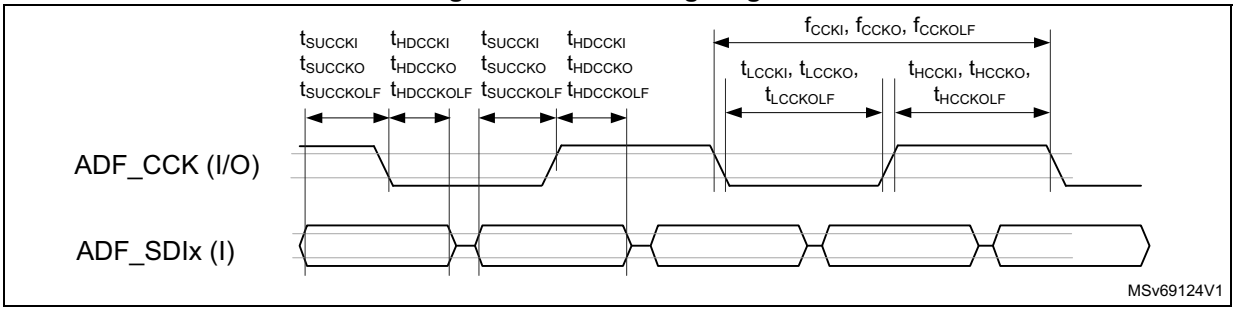
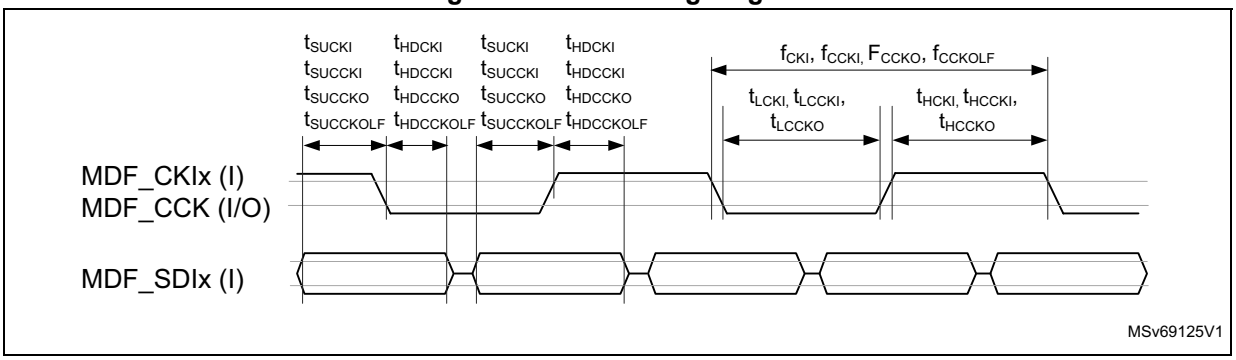


Table 114. MDF characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{CKI}	Input clock frequency via MDF_CKIx pin, in SLAVE SPI mode	1.71 ≤ V_{DD} ≤ 3.6 V	-	-	25	MHz
f_{CCKI}	Input clock frequency via MDF_CCK[1:0] pin, in SLAVE SPI mode		-	-	25	
f_{CCKO}	Output clock frequency in MASTER SPI mode		-	-	25	
f_{CCKOLF}	Output clock frequency in LF_MASTER SPI mode		-	-	5	
f_{SYMB}	Input symbol rate in Manchester mode		-	-	20	
t_{HCKI} t_{LCKI}	MDF_CKIx input clock high and low time	In SLAVE SPI mode	2 × Tmdf_proc_ck(2)	-	-	ns
t_{HCCKI} t_{LCCKI}	MDF_CCK[1:0] input clock high and low time	In SLAVE SPI mode	2 × Tmdf_proc_ck	-	-	
t_{HCCKO} t_{LCCKO}	MDF_CCK[1:0] output clock high and low time	In MASTER SPI mode	2 × Tmdf_proc_ck	-	-	
$t_{HCCKOLF}$ $t_{LCCKOLF}$	MDF_CCK[1:0] output clock high and low time	In LF_MASTER SPI mode	Tmdf_proc_ck	-	-	
t_{SUCKI}	Data setup time with respect to MDF_CKIx input	In SLAVE SPI mode, measured on rising and falling edge	1.5	-	-	
t_{HDCKI}	Data hold time with respect to MDF_CKIx input		0	-	-	
t_{SUCCKI}	Data setup time with respect to MDF_CCK[1:0] input	In SLAVE SPI mode: MDF_CCK[1:0] configured in input, measured on rising and falling edge	1.5	-	-	
t_{HDCCKI}	Data hold time with respect to MDF_CCK[1:0] input		0.5	-	-	
t_{SUCCKO}	Data setup time with respect to MDF_CCK[1:0] output	In MASTER SPI mode: MDF_CCK[1:0] configured in output, measured on rising and falling edge	3.5	-	-	
t_{HDCCKO}	Data hold time with respect to MDF_CCK[1:0] output		1.5	-	-	
$t_{SUCCKOLF}$	Data setup time with respect to MDF_CCK[1:0] output	In LF_MASTER SPI mode, MDF_CCK[1:0] configured in output, measured on rising and falling edge	19.5	-	-	
$t_{HDCCKOLF}$	Data hold time with respect to MDF_CCK[1:0] output		0	-	-	

1. Evaluated by characterization. Not tested in production.
2. Tmdf_proc_ck is the period of the MDF processing clock.

Figure 68. MDF timing diagram



5.3.36 Timer characteristics

The parameters given in *Table 115* are guaranteed by design.

Refer to *Section 5.3.15* for details on the input/output alternate function characteristics (output compare, input capture, external clock, PWM output).

Table 115. TIMx characteristics(1)(2)

Symbol	Parameter	Conditions	Min	Max	Unit
$t_{res(TIM)}$	Timer resolution time	-	1	-	$t_{TIMxCLK}$
		$f_{TIMxCLK}$ = 250 MHz	4	-	ns
f_{EXT}	Timer external clock frequency on CH1 to CH4	$f_{TIMxCLK}$ = 250 MHz	0	$f_{TIMxCLK}$ /4	MHz
Res_{TIM}	Timer resolution	-	-	16 / 32	bit
t_{MAX_COUNT}	Maximum possible count with 32-bit counter	-	-	65536 × 65536	$t_{TIMxCLK}$

1. TIMx is used as a general term to refer to the TIM1 to TIM17 timers.
2. Specified by design - Not tested in production.

Table 116. TIMx characteristics(1)(2)

Symbol	Parameter	Conditions(3)	Min	Max	Unit
$t_{res(TIM)}$	Timer resolution time	AHB/APBx prescaler = 1, 2, or 4, $f_{TIMxCLK}$ = 250 MHz	1	-	$t_{TIMxCLK}$
		AHB/APBx prescaler > 4, $f_{TIMxCLK}$ = 125 MHz	1	-	$t_{TIMxCLK}$
f_{EXT}	Timer external clock frequency on CH1 to CH4	$f_{TIMxCLK}$ = 250 MHz	0	$f_{TIMxCLK}$ /	MHz
Res_{TIM}	Timer resolution		-	16 / 32	bit
t_{MAX_COUNT}	Maximum possible count with 32-bit counter	-	-	65536 × 65536	$t_{TIMxCLK}$

1. TIMx is used as a general term to refer to the TIM1 to TIM17 timers.
2. Specified by design - Not tested in production.

3. The maximum timer frequency on APB1 or APB2 is up to 250 MHz, by setting the TIMPRE bit in the RCC_CFGR register, if APBx prescaler is 1 or 2 or 4, then TIMxCLK = rcc_hclk1, otherwise TIMxCLK = 4 x F_{rcc_pclkx1} or TIMxCLK = 4 x F_{rcc_pclkx2}.

5.3.37 Low-power timer characteristics

Table 117. LPTIMx characteristics(1)(2)

Symbol	Parameter	Min	Max	Unit
$t_{res(TIM)}$	Timer resolution time	1	-	$t_{lptim\_ker\_ck}$
$f_{lptim\_ker\_ck}$	Timer kernel clock	0	250	MHz
f_{EXT}	Timer external clock frequency on Input1 and Input2	0	$f_{lptim\_ker\_ck}$ /4	
Res_{TIM}	Timer resolution	-	16	bit
t_{MAX_COUNT}	Maximum possible count	-	65535	$t_{lptim\_ker\_ck}$

1. LPTIMx is used as a general term for LPTIM1 to LPTIM6 timers.
2. Specified by design - Not tested in production.

5.3.38 Communication interfaces

I²C interface characteristics

The I²C interface meets the timings requirements of the I²C-bus specification and user manual revision 03 for:

- Standard-mode (Sm): with a bit rate up to 100 kbit/s
- Fast-mode (Fm): with a bit rate up to 400 kbit/s
- Fast-mode Plus (Fm+): with a bit rate up to 1 Mbit/s.

The I²C timings requirements are specified by design, not tested in production, when the I²C peripheral is properly configured (refer to the product reference manual)

The SDA and SCL I/O requirements are met with the following restrictions:

- The SDA and SCL I/O pins are not “true” open-drain. When configured as open-drain, the PMOS connected between the I/O pin and V_{DD} is disabled, but still present. Only FT_f I/O pins support Fm+ low level output current maximum requirement. Refer to *Section 5.3.15* for the I2C I/Os characteristics

All I²C SDA and SCL I/Os embed an analog filter, refer to *Table 118* for its characteristics.

Table 118. I²C analog filter characteristics(1)(2)

Symbol	Parameter	Min	Max	Unit
t_{AF}	Maximum pulse width of spikes suppressed by analog filter	50(3)	160(4)	ns

1. Evaluated by characterization - Not tested in production.
2. Measurement points are done at 50% V_{DD}.
3. Spikes with widths below $t_{AF(min)}$ are filtered.
4. Spikes with widths above $t_{AF(max)}$ are not filtered.

USART interface characteristics

Unless otherwise specified, the parameters given in *Table 119* are derived from tests performed under the ambient temperature, f_{PCLKx} frequency, and V_{DD} supply voltage conditions summarized in *Table 19*, with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 10
- Capacitive load C_L = 30 pF
- Measurement points are done at CMOS levels: 0.5 V_{DD}
- I/O compensation cell activated
- VOS level set to VOS0
- HSLV activated when $V_{DD} \leq 2.7$ V

Refer to *Section 5.3.15* for more details on the input/output alternate function characteristics (NSS, CK, TX, RX for USART).

Table 119. USART characteristics(1)

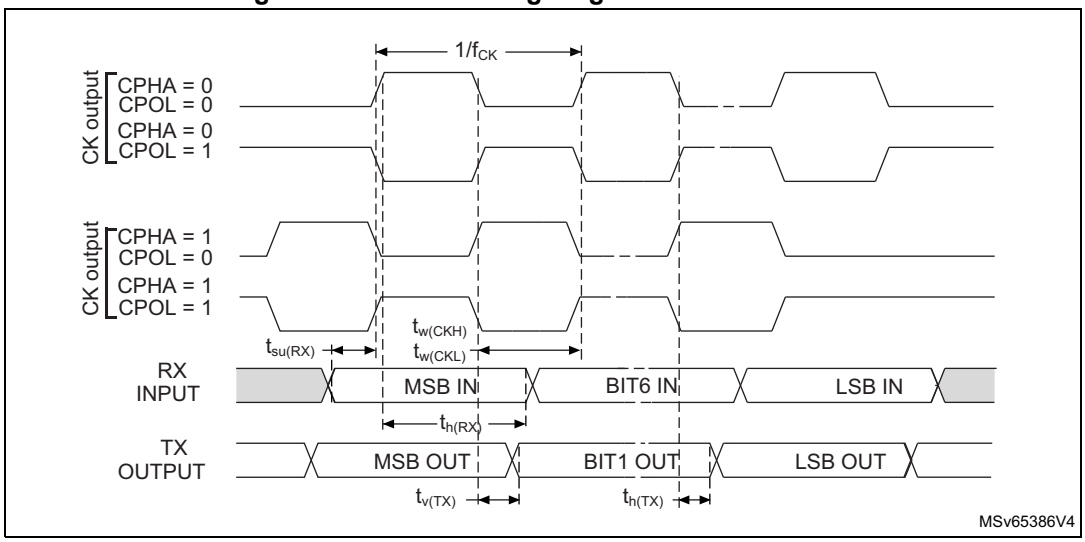
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{CK}	USART clock frequency	Master receiver 1.71 V < V_{DD} < 3.6 V	-	-	31	MHz
		Master transmitter 1.71 V < V_{DD} < 3.6 V			31/6(2)	
		Master transmitter 2.7 V < V_{DD} < 3.6 V			31/6(2)	
		Slave receiver 1.71 V < V_{DD} < 3.6 V			83	
		Slave transmitter 1.71 V < V_{DD} < 3.6 V			32/6(2)	
		Slave transmitter 2.7 V < V_{DD} < 3.6 V			35/6(2)	
$t_{su(NSS)}$	NSS setup time	Slave mode	t_{ker}(3) + 3.5	-	-	ns
$t_{h(NSS)}$	NSS hold time	Slave mode	2.5	-	-	
$t_{w(CKH)}$ $t_{w(CKL)}$	CK high and low time	Master mode	$1/f_{ck}/2$ -1	$1/f_{ck}/2$	$1/f_{ck}/2$ +1	
$t_{su(RX)}$	Data input setup time	Master mode	13	-	-	
		Slave mode	3.5	-	-	
$t_{h(RX)}$	Data input hold time	Master mode	0.5	-	-	
		Slave mode	1.5	-	-	
$t_{v(TX)}$	Data output valid time	Slave mode, 1.71 V < V_{DD} < 3.6 V	-	11.5	15.5/71(2)	
		Slave mode, 2.7 V < V_{DD} < 3.6 V	-		14/35(2)	
		Slave mode, 1.71 V < V_{DD} < 3.6 V	-	2.5	3/52(2)	
		Slave mode, 2.7 V < V_{DD} < 3.6 V	-		3/22(2)	

Table 119. USART characteristics(1) (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$t_{h(TX)}$	Data output hold time	Slave mode	7.5	-	-	ns
		Master mode	0	-	-	

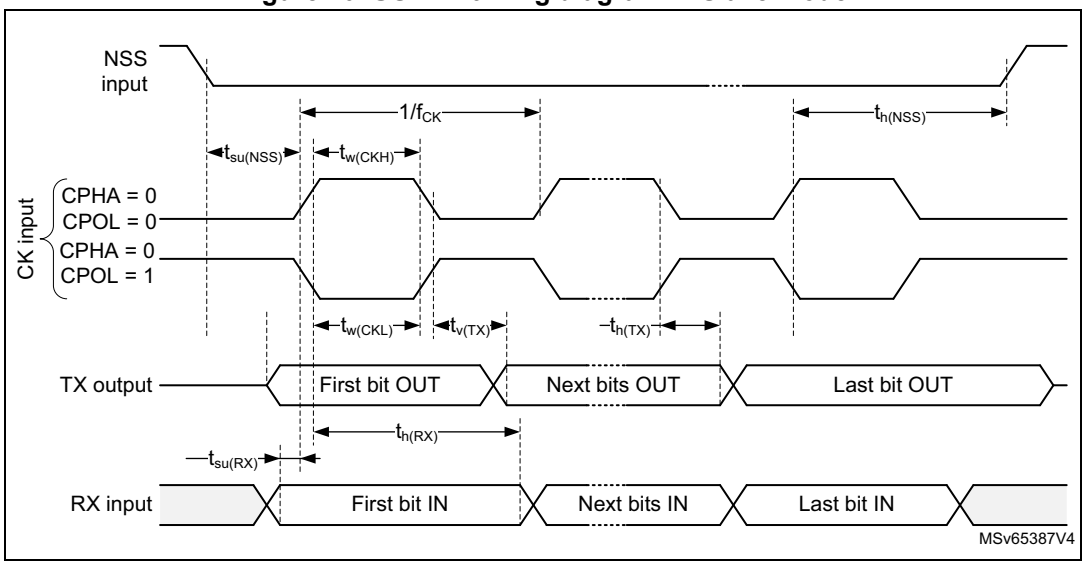
1. Evaluated by characterization - Not tested in production.
2. For PB14 with OSPEEDRy[1:0] = 01.
3. T_{ker} is the usart_ker_ck_pres clock period.

Figure 69. USART timing diagram in Master mode



1. Measurement points are done at $0.5V_{DD}$ and with external C_L = 30 pF.

Figure 70. USART timing diagram in Slave mode



I3C interface characteristics

The I3C interface meets the timings requirements of the MIPI® I3C specification v1.1.

The I3C peripheral supports:

- I3C SDR-only as controller
- I3C SDR-only as target
- I3C SCL bus clock frequency up to 12.5 MHz

The parameters given in *Table 120* are obtained with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 10
- I/O compensation cell activated
- HSLV activated when $V_{DD} \leq 2.7$ V
- VOS level set to VOS0

The timings are in line with MIPI specification, except for the ones given in *Table 120* and *Table 121*. For t_{SU_OD} and t_{SU_PP} this can be mitigated by increasing the corresponding SCL low duration in the I3C_TIMINGR0 register. For t_{SCO} this can be mitigated by enabling and adjusting the clock stall time both on the address ACK phase and on the data read Tbit phase in the I3C_TIMINGR2 register. This can also be mitigated by increasing the SCL low duration in the I3C_TIMINGR0 register. For further details, refer to AN5879.

Table 120. I3C open-drain measured timings

Symbol	Parameter	Conditions	Min	Unit
t_{SU_OD}	SDA data setup time during open drain mode	Controller 1.08 V < V_{DD} < 1.32 V	21(1)	ns
		Controller 1.71 V < V_{DD} < 3.6 V	24.5(1)	

1. SDA data setup time in open-drain mode must be at least 3 ns, as required by the MIPI specification.

Table 121. I3C push-pull measured timings

Symbol	Parameter	Conditions	Max	Unit
t_{SCO}	Clock in to data out for target	Target 1.71 V < V_{DD} < 3.6 V	9	ns
		Controller 1.2 V < V_{DDIO2} < 1.32 V	12	ns
		Controller 1.08 V < V_{DDIO2} < 1.2 V	14(1)	

1. The MIPI specification requires the t_{SCO} clock in to data out parameter to be a maximum of 12 ns.

SPI interface characteristics

Unless otherwise specified, the parameters given in *Table 122* are derived from tests performed under the ambient temperature, f_{PCLKx} frequency, and V_{DD} supply voltage conditions summarized in *Table 19*, with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 11
- Capacitive load C_L = 30 pF

- Measurement points are done at CMOS levels: 0.5 V_{DD}
- I/O compensation cell activated
- HSLV activated when $V_{DD} \leq 2.7$ V
- VOS level set to VOS0

Refer to *Section 5.3.15* for more details on the input/output alternate function characteristics (NSS, SCK, MOSI, MISO for SPI).

Table 122. SPI characteristics(1)

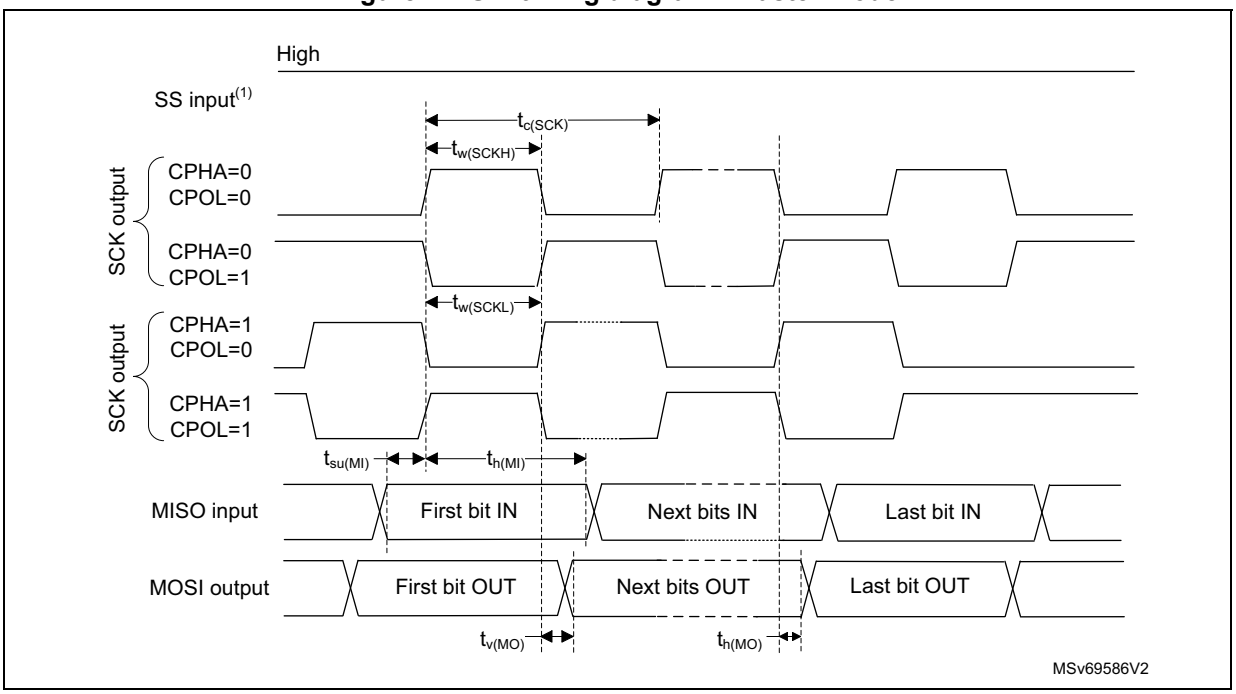
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{SCK} $1/t_{SCK}$	SPI clock frequency	Master receiver mode 2.7 V < V_{DD} < 3.6 V	-	-	125/3(2)/100(3)	MHz
		Master receiver mode 1.71 V < V_{DD} < 2.7 V	-	-	110/3(2)/88(3)	
		Master receiver mode 1.08 V < V_{DDIO2} < 1.32 V	-	-	44	
		Master transmitter mode 2.7 V < V_{DD} < 3.6 V			125/3(2)/100(3)	
		Master transmitter mode 1.71 V < V_{DD} < 2.7 V	-	-	120/3(2)/96(3)	
		Master transmitter mode 1.08 V < V_{DDIO2} < 1.32 V			44	
		Slave receiver mode 1.08 V < V_{DDIO2} < 1.32 V			125	
		Slave transmitter mode 2.7 V < V_{DD} < 3.6 V	-	-	43/6(4)	
		Slave transmitter mode 1.71 V < V_{DD} < 2.7 V	-	-	41/6(4)	
		Slave transmitter mode 1.08 V < V_{DDIO2} < 1.32 V	-	-	23	
$t_{su(NSS)}$	NSS setup time	Slave mode	3.5	-	-	ns
$t_{h(NSS)}$	NSS hold time	Slave mode	4.5	-	-	
$t_{w(SCKH)}$ $t_{w(SCKL)}$	SCK high and low time	Master mode	(t_{SCK}/2) - 1	(t_{SCK}/2	(t_{SCK}/2) + 1	ns
$t_{su(MI)}$	Data input setup time	Master mode	3.5	-	-	ns
$t_{su(SI)}$		Slave mode	2	-	-	
$t_{h(MI)}$	Data input hold time	Master mode	1	-	-	
$t_{h(SI)}$		Slave mode	1.5	-	-	
$t_{a(SO)}$	Data output access time	Slave mode	6.5	-	15	ns
$t_{dis(SO)}$	Data output disable time	Slave mode	7.5	-	18	

Table 122. SPI characteristics(1) (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$t_{v(SO)}$	Data output valid time	Slave mode.2.7 V < V_{DD} < 3.6 V	-	8.5/25(4)	11.5/33(4)	ns
		Slave mode1.71 V < V_{DD} < 2.7 V	-	10/59(4)	12/76(4)	
		Slave mode 1.08 V < V_{DDIO2} < 1.32 V		18	21.5	
$t_{v(MO)}$		Master mode	-	1.5	2	
$t_{h(SO)}$	Data output hold time	Slave mode 1.71 V < V_{DD} < 3.6 V	6.5/20.5(4)	-	-	ns
$t_{h(MO)}$		Master mode	0	-	-	

1. Evaluated by characterization - Not tested in production.
2. When using PB13.
3. Maximum speed for LQFP100 and LQFP100-SMPS packages.
4. When using PB14.

Figure 71. SPI timing diagram - Master mode



1. The SS input can be configured to active low or active high.

Figure 72. SPI timing diagram - Slave mode and CPHA = 0

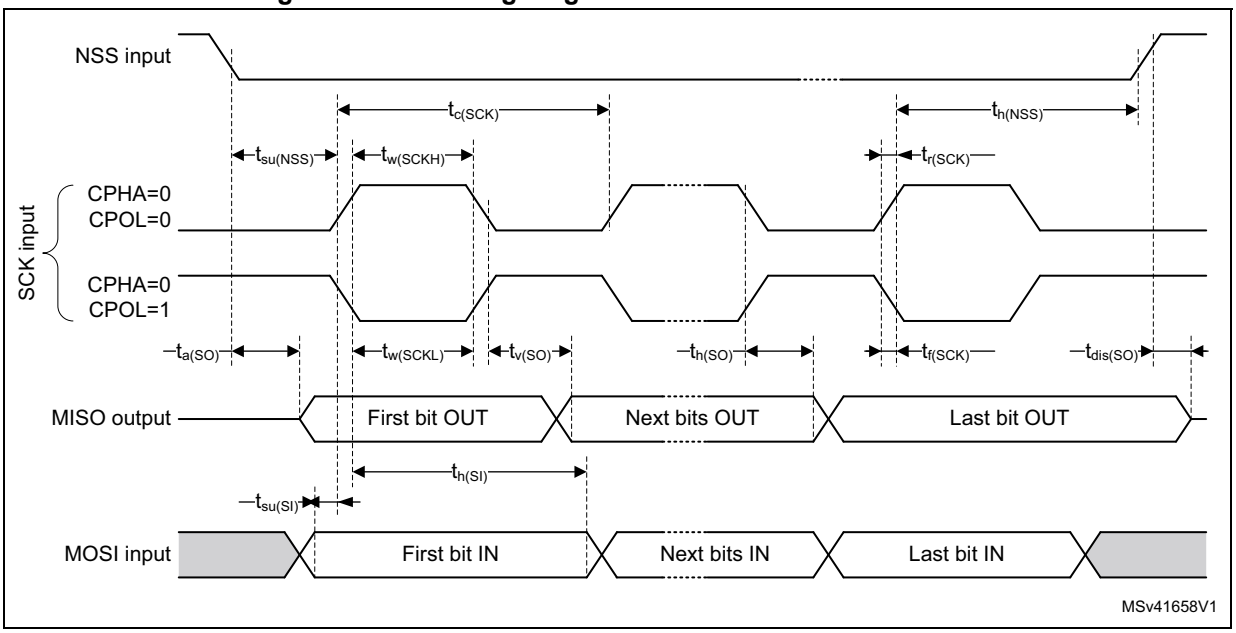
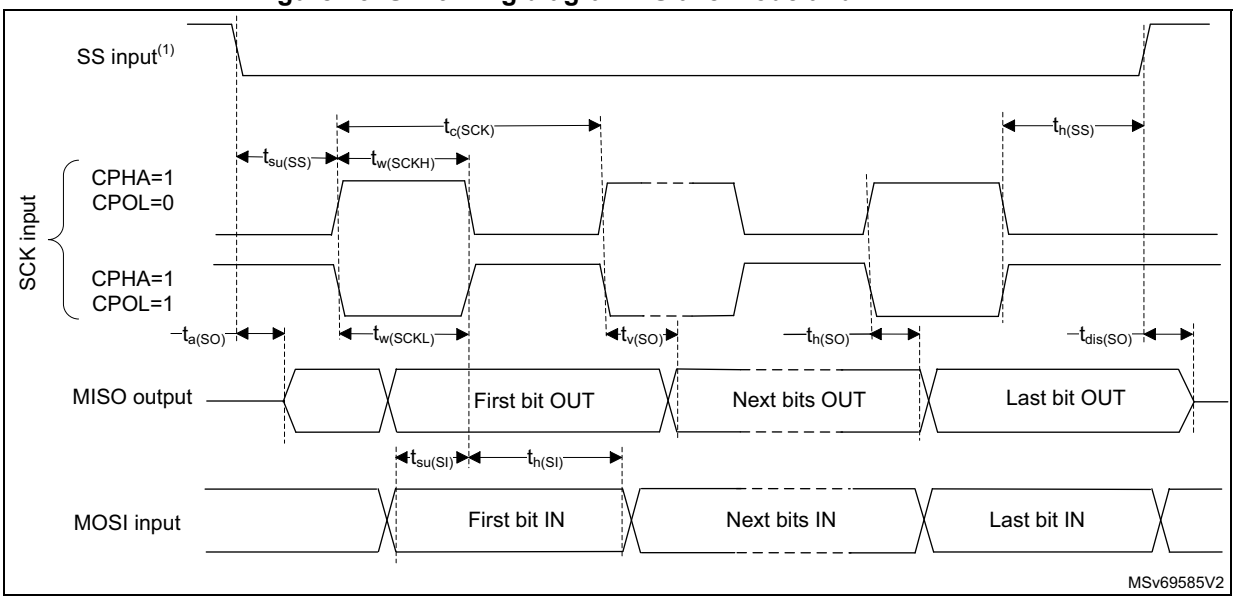


Figure 73. SPI timing diagram - Slave mode and CPHA = 1



1. The SS input can be configured to active low or active high.

I²S interface characteristics

Unless otherwise specified, the parameters given in *Table 123* are derived from tests performed under the ambient temperature, f_{PCLKx} frequency, and V_{DD} supply voltage conditions summarized in *Table 19*, with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 11
- Capacitive load C_L = 30 pF
- Measurement points are done at CMOS levels: 0.5 V_{DD}
- I/O compensation cell activated

- HSLV activated when $V_{DD} \leq 2.7$ V
- VOS level set to VOS0

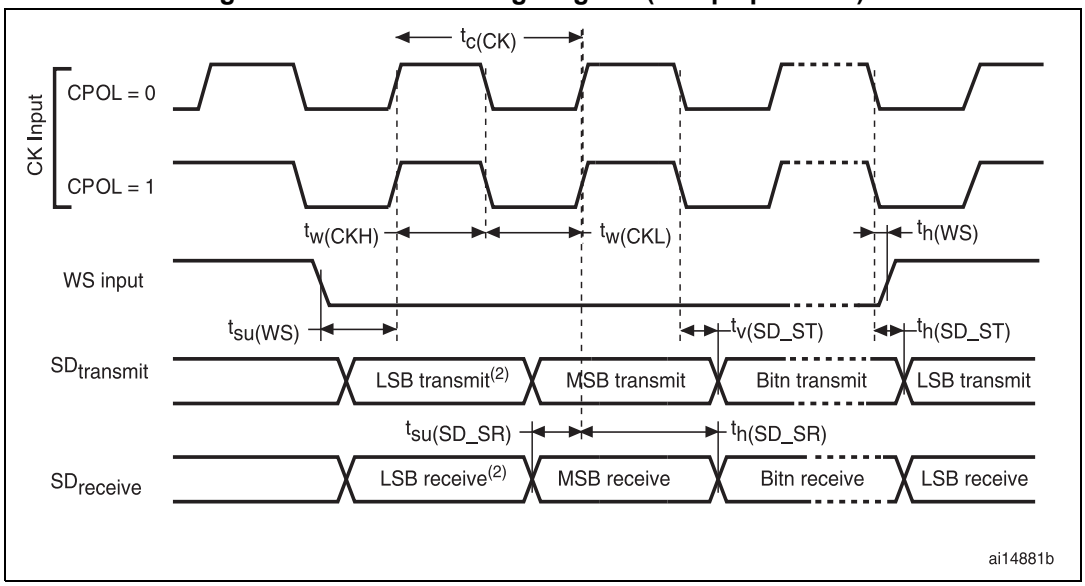
Refer to *Section 5.3.15* for more details on the input/output alternate function characteristics (CK,SD,WS).

Table 123. I²S dynamic characteristics(1)

Symbol	Parameter	Conditions	Min	Max	Unit
f_{MCK}	I²S main clock output	-	-	50	MHz
f_{CK}	I²S clock output	Master transmitter	-	50	
		Slave transmitter (TX)	-	21	
		Slave receiver (RX)	-	50	
$t_{v(WS)}$	WS valid time	Master mode	-	2	ns
$t_{h(WS)}$	WS hold time		0.5	-	
$t_{su(WS)}$	WS setup time	Slave mode	3	-	
$t_{h(WS)}$	WS hold time		1.5	-	
$t_{su(SD\_MR)}$	Data input setup time	Master receiver	4	-	
$t_{su(SD\_SR)}$		Slave receiver	2	-	
$t_{h(SD\_MR)}$	Data input hold time	Master receiver	1	-	
$t_{h(SD\_SR)}$		Slave receiver	1.5	-	
$t_{v(SD\_ST)}$	Data output valid time	Slave transmitter (after enable edge)	-	14	
$t_{v(SD\_MT)}$		Master transmitter (after enable edge)	-	1	
$t_{h(SD\_ST)}$	Data output hold time	Slave transmitter (after enable edge)	5.5	-	
$t_{h(SD\_MT)}$		Master transmitter (after enable edge)	0	-	

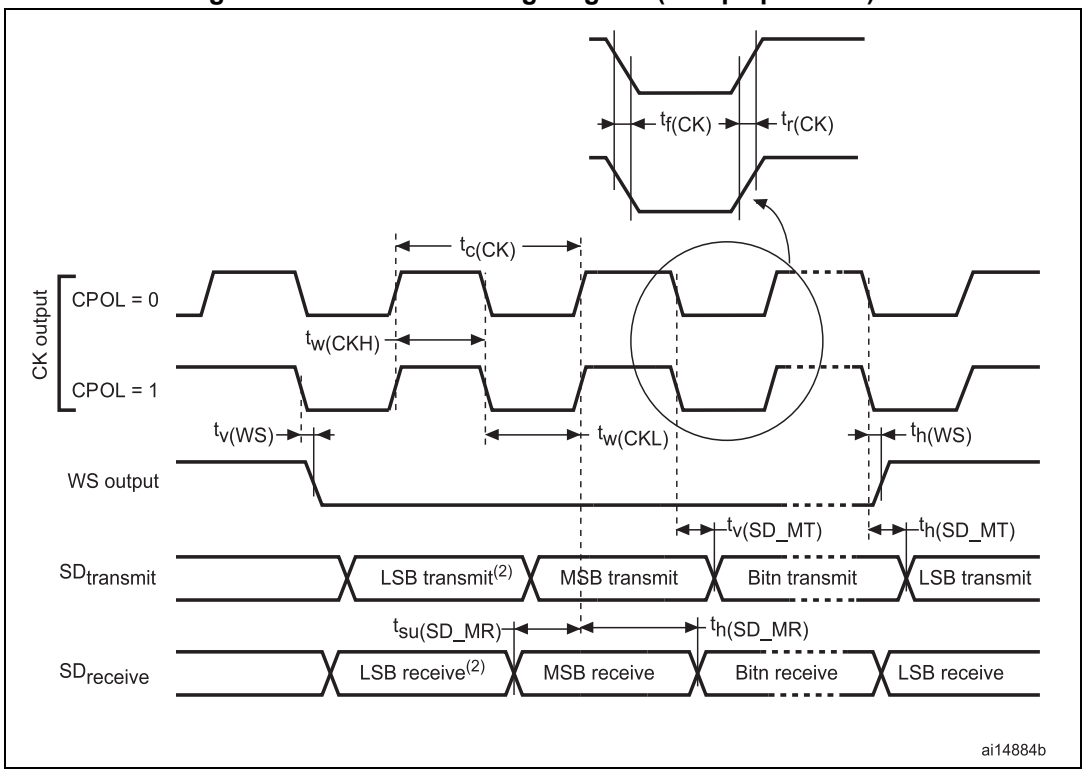
1. Evaluated by characterization - Not tested in production.

Figure 74. I²S slave timing diagram (Philips protocol)(1)



1. LSB transmit/receive of the previously transmitted byte. No LSB transmit/receive is sent before the first byte.

Figure 75. I²S master timing diagram (Philips protocol)(1)



1. LSB transmit/receive of the previously transmitted byte. No LSB transmit/receive is sent before the first byte.

USB full speed (OTG_FS) characteristics

The USB interface is fully compliant with the USB specification version 2.0.

Table 124. USB DC electrical characteristics

Symbol	Parameter	Conditions	Min(1)	Typ	Max(1)	Unit
V_{DD}	USB full speed transceiver operating voltage	-	3.0(2)(3)	-	3.6	V
V_{DI}(4)	Differential input sensitivity	Over VCM range	0.2	-	-	V
V_{CM}(4)	Differential input common mode range	Includes V_{DI} range	0.8	-	2.5	
V_{SE}(4)	Single ended receiver input threshold	-	0.8	-	2.0	
V_{OL}	Static output level low	R_L of 1.5 kΩ to 3.6 V	-	-	0.3	V
V_{OH}	Static output level high	R_L of 15 kΩ to V_{SS}	2.8	-	3.6	
RPUI	Embedded OTG_FS_DP pull-up value during idle	V_{IN} = V_{SS}, during idle	0.9	1.25	1.575	kΩ
R_{PUR}	Embedded OTG_FS_DP pull-up value during reception	V_{IN} = V_{SS}, during reception	1.425	2.25	3.09	-
R_{PD}(4)	Pull down resistor on PA11, PA12 (USB_FS_DP/DM)	V_{IN} = V_{DD}	14.25	-	24.8	kΩ
$t_{r(LS)}$	Rise time (low speed)	CL = 200 to 600 pF	75	-	300	ns
$t_{f(LS)}$	Fall time (low speed)	CL = 200 to 600 pF	75	-	300	ns
$t_{rfm(LS)}$	Rise/ fall time matching (low speed)	tr/tf	80	-	125	%
$t_{r(FS)}$	Rise time (full speed)	CL = 50 pF	4	-	20	ns
$t_{f(FS)}$	Fall time (full speed)	CL = 50 pF	4	-	20	ns
$t_{rfm(FS)}$	Rise/ fall time matching (full speed)	tr/tf	90	-	111	%
V_{CRS} (LS;FS)	Output signal cross-over voltage (low and full speeds)	-	1.3	-	2	V
Z_{DRV}	Output driver impedance(5)	Driver high and low	28	-	44	Ω

1. All the voltages are measured from the local ground potential.
2. The 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 voltage range.
3. It applies to V_{DDUSB} when V_{DDUSB} is independent from V_{DD}.
4. Specified by design - Not tested in production.
5. No external termination series resistors are required on USB_DP (D+) and USB_DM (D-); the matching impedance is already included in the embedded driver.

Figure 76. USB timings - definition of data signal rise and fall time

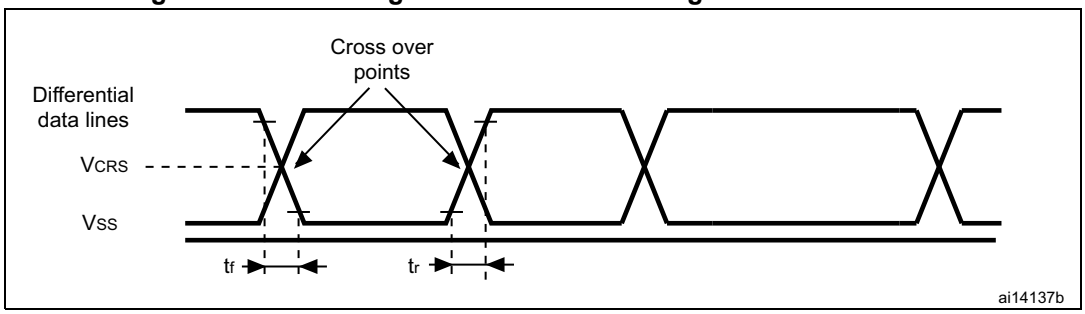


Table 125. USB startup time

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

1. Specified by design - Not tested in production.

Table 126. OTG_FS USB BCD electrical characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
RDAT_LKG	Data line leakage resistance	-	300	-	-	kΩ
VDAT_LKG	Data line leakage voltage	-	0.0	-	3.6	V
RDCP_DAT	Dedicated charging port resistance across D+/D-	-	-	-	200	Ω
VLGC_HI	Logic high	-	2.0	-	3.6	V
VLGC_LOW	Logic low	-	-	-	0.8	V
VLGC_HI	Logic high	-	2.0	-	3.6	V
VLGC_LOW	Logic low	-	-	-	0.8	
VLGC	Logic threshold	-	0.8	-	2.0	
VDAT_REF	Data detect voltage	-	0.25	-	0.4	
VDP_SRC	D+ source voltage	-	0.5	-	0.7	
VDM_SRC	D- source voltage	-	0.5	-	0.7	
IDP_SINK	D+ sink current	-	25	-	175	µA
IDM_SINK	D- sink current	-	25	-	175	

1. Specified by design - Not tested in production.

USB high-speed (OTG_HS) characteristics

The OTG_HS controller complies with the following specifications:

- USB On-The-Go supplement, revision 2.0
- Universal Serial Bus revision 2.0 specification
- Battery charging specification, revision 1.2

The parameters given in the tables below are derived from tests performed under temperature and V_{DD} supply voltage conditions summarized in *Table 19: General operating conditions*.

Table 127. USB OTG_HS electrical characteristics(1)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
V_{DDUSB}	USB transceiver operating voltage	-	3.12(2)	-	3.6	V
f_{HCLK}	f_{HCLK} value to guarantee proper operation of USB HS interface	-	30	-	-	MHz
V_{DI}	Differential input sensitivity	Over VCM range	0.2	-	-	V
V_{CM}	Differential common mode range	Includes VDI range	0.8	-	2.5	V
V_{SE}	Single ended receiver threshold	-	0.8	-	2	V
V_{OL}	Static output level low	R_L of 1.5 kΩ to 3.6 V	-	-	0.3	V
V_{OH}	Static output level high	R_L of 15 kΩ to V_{SS}	2.8	-	3.6	V
R_{PUI}	Embedded USB_DP pull-up value during idle	-	0.9	1.25	1.575	kΩ
R_{PUR}	Embedded USB_DP pull-up value during reception	-	1.425	2.25	3.090	
R_{PD}	Embedded USB_DP and USB_DM pull-down value	-	14.25	-	24.8	
$t_{r(LS)}$	Rise time (low speed)	C_L = 200 to 450 pF	75	-	300	ns
$t_{f(LS)}$	Fall time (low speed)	C_L = 200 to 450 pF	75	-	300	ns
$t_{rfm(LS)}$	Rise/ fall time matching (low speed)	tr/tf	80	-	125	%
$t_{r(FS)}$	Rise time (full speed)	C_L = 50 pF	4	-	20	ns
$t_{f(FS)}$	Fall time (full speed)	C_L = 50 pF	4	-	20	ns
$t_{rfm(FS)}$	Rise/ fall time matching (full speed)	tr/tf	90	-	111	%
$V_{CRS\ (LS;FS)}$	Output signal cross-over voltage (low and full speeds)	-	1.3	-	2.0	V
t_{lr}	Rise time	C_L < 5 pF	0.5	-	-	ns
t_{lf}	Fall time	C_L < 5 pF	0.5	-	-	
t_{lrfm}	Rise/fall time matching	-	80	-	125	%

Table 127. USB OTG_HS electrical characteristics(1) (continued)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
V_{hssq}	High speed squelch detection threshold	-	100	-	150	mV
V_{hsdsc}	High speed disconnect detection threshold	-	525	-	625	
V_{hsdif}	High speed differential detection threshold	-	100	-	-	
V_{hscm}	High speed data signaling common mode voltage range	-	-50	-	500	
V_{hsoi}	High speed idle level	-	-10	-	10	
V_{hsoh}	High speed data signaling high	-	360	-	440	
V_{hsol}	High speed data signaling low	-	-10	-	10	
$V_{hchirpj}$	Chirp J level	-	700	-	1100	
$V_{hchirpk}$	Chirp K level	-	-900	-	-500	
Z_{DRV}	Output driver impedance	Driving high or low	40.5	45	49.5	Ω

1. Evaluated by characterization. Not tested in production. Unless otherwise specified.
2. The USB functionality is ensured down to 3 V but not the full USB electrical characteristics which are degraded in the 3.0 to 3.12 V voltage range.

Table 128. USB HS PHY BCD electrical characteristics(1)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
$I_{DD\_USB\_BCD}$	Primary detection mode consumption on VDDUSB	-	-	5.67	-	mA
	Secondary detection mode consumption on VDDUSB	-	-	5.67	-	
$I_{DD11\_USB\_BCD}$	Primary detection mode consumption on VDD11USB	-	-	7.38	-	mA
	Secondary detection mode consumption on VDD11USB	-	-	7.38	-	
RDAT_LKG	Data line leakage resistance	-	300(2)	-	-	kΩ
VDAT_LKG	Data line leakage voltage	-	0.0	-	3.6(2)	V
RDCP_DAT	Dedicated charging port resistance across D+/D-	-	-	-	200(2)	Ω
VLGC_HI	Logic high	-	2.0	-	3.6	V
VLGC_LOW	Logic low	-	-	-	0.8	
VLGC	Logic threshold	-	0.8	-	2.0	
VDAT_REF	Data detect voltage	-	0.25(2)	-	0.4(2)	
VDP_SRC	D+ source voltage	-	0.5	-	0.7	
VDM_SRC	D- source voltage	-	0.5	-	0.7	

Table 128. USB HS PHY BCD electrical characteristics(1) (continued)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
IDM_SINK	D- sink current	-	25	-	175	µA
IDP_SINK	D+ sink current	-	25	-	175	
IDP_SRC	Data contact detect current source	-	7.0	-	13	

1. Evaluated by characterization. Not tested in production. Unless otherwise specified.
2. Specified by design - Not tested in production.

Table 129. OTG_HS current consumption characteristics(1)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
$I_{IDD(OTG\_HS)}$	USB (PLL and PHY) current consumption on VDDUSB	Full Speed Transmit (2)	-	5.84	-	mA
		High Speed Idle	-	5.64	-	
		High Speed Transmit(2)	-	13.77	-	
$I_{IDD11(OTG\_HS)}$	USB (PLL and PHY) current consumption on VDD11USB	Full Speed Transmit(2)	-	6.15	-	mA
		High Speed Idle	-	7.41	-	
		High Speed Transmit(2)	-	7.14	-	

1. Evaluated by characterization. Not tested in production. Unless otherwise specified.
2. Transfers consist of 70% transmit activity and 30% inter-packet delay.

UCPD characteristics

The UCPD controller complies with USB Type-C Rev 1.2 and USB Power Delivery Rev 3.0 specifications.

Table 130. UCPD electrical characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
V_{DD}	UCPD operating supply voltage	-	3.0	3.3	3.6	mA
V_{swing}	Output voltage swing	-	1.05	-	1.2	V
Z_{DRV}	Output driver impedance	-	33	-	75	Ω

SAI characteristics

Unless otherwise specified, the parameters given in *Table 131* are derived from tests performed under the ambient temperature, f_{PCLKx} frequency, and V_{DD} supply voltage conditions summarized in *Table 19*, with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 10
- Capacitive load C_L = 30 pF
- I/O compensation cell activated
- Measurement points are done at CMOS levels: 0.5 V_{DD}
- VOS level set to VOS0

Refer to *Section 5.3.15* for more details on the input/output alternate function characteristics (SCK, SD, WS).

Table 131. SAI characteristics(1)

Symbol	Parameter	Conditions	Min	Max	Unit
f_{MCK}	SAI main clock output	-	-	50	MHz
f_{CK}	SAI clock frequency	Master transmitter, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	38	
		Master transmitter, 1.71 V ≤ V_{DD} ≤ 3.6 V	-	38	
		Master receiver, 1.71 V ≤ V_{DD} ≤ 3.6 V	-	38	
		Slave transmitter, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	34	
		Slave transmitter, 1.71 V ≤ V_{DD} ≤ 3.6 V	-	33	
		Slave receiver, 1.71 V ≤ V_{DD} ≤ 3.6 V	-	50	
$t_{v(FS)}$	F_S valid time	Master mode, 2.7 V ≤ V_{DD} ≤ 3.6 V	-	13	ns
		Master mode, 1.71 V ≤ V_{DD} ≤ 3.6 V	-	13	
$t_{su(FS)}$	F_S setup time	Slave mode	5	-	
$t_{h(FS)}$	F_S hold time	Master mode	3	-	
		Slave mode	2	-	
$t_{su(SD\_A\_MR)}$	Data input setup time	Master receiver	4	-	
$t_{su(SD\_B\_SR)}$		Slave receiver	3.5	-	
$t_{h(SD\_A\_MR)}$	Data input hold time	Master receiver	1.5	-	
$t_{h(SD\_B\_SR)}$		Slave receiver	0.5	-	
$t_{v(SD\_B\_ST)}$	Data output valid time	Slave transmitter (after enable edge), 2.7 V ≤ V_{DD} ≤ 3.6 V	-	14.5	
		Slave transmitter (after enable edge), 1.71 V ≤ V_{DD} ≤ 3.6 V	-	15	
$t_{h(SD\_B\_ST)}$	Data output hold time	Slave transmitter (after enable edge)	7	-	
$t_{v(SD\_A\_MT)}$	Data output valid time	Master transmitter (after enable edge), 2.7 V ≤ V_{DD} ≤ 3.6 V	-	13	
		Master transmitter (after enable edge), 1.71 V ≤ V_{DD} ≤ 3.6 V	-	13	
$t_{h(SD\_A\_MT)}$	Data output hold time	Master transmitter (after enable edge)	5.5	-	

1. Evaluated by characterization - Not tested in production.

Figure 77. SAI master timing waveforms

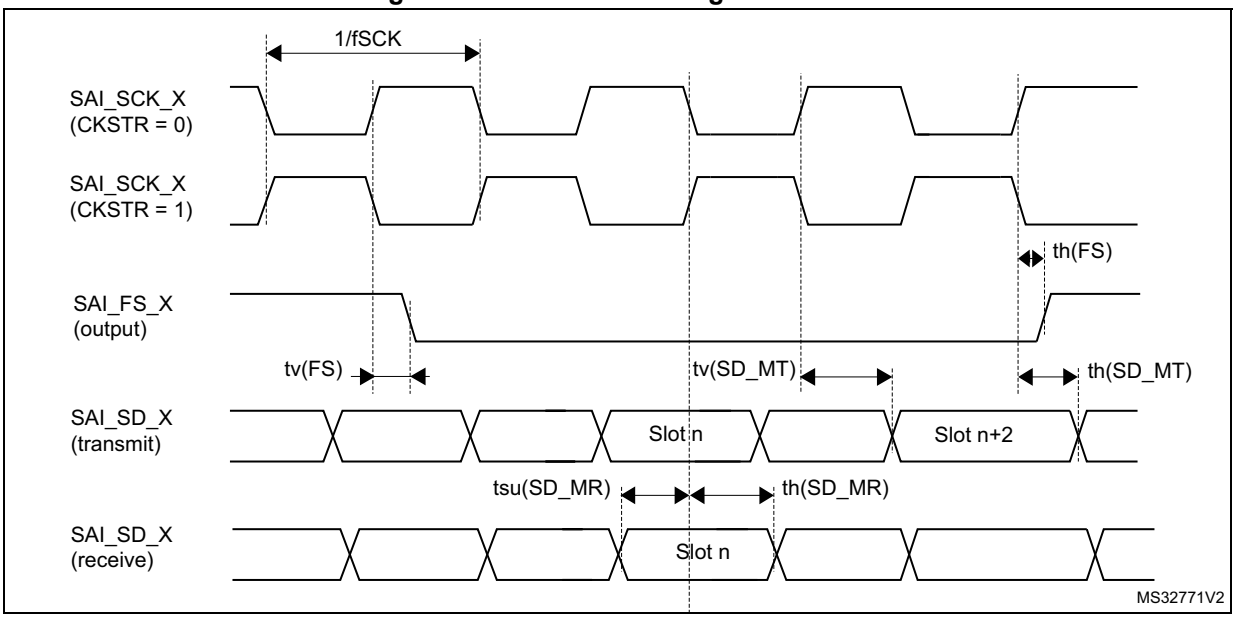
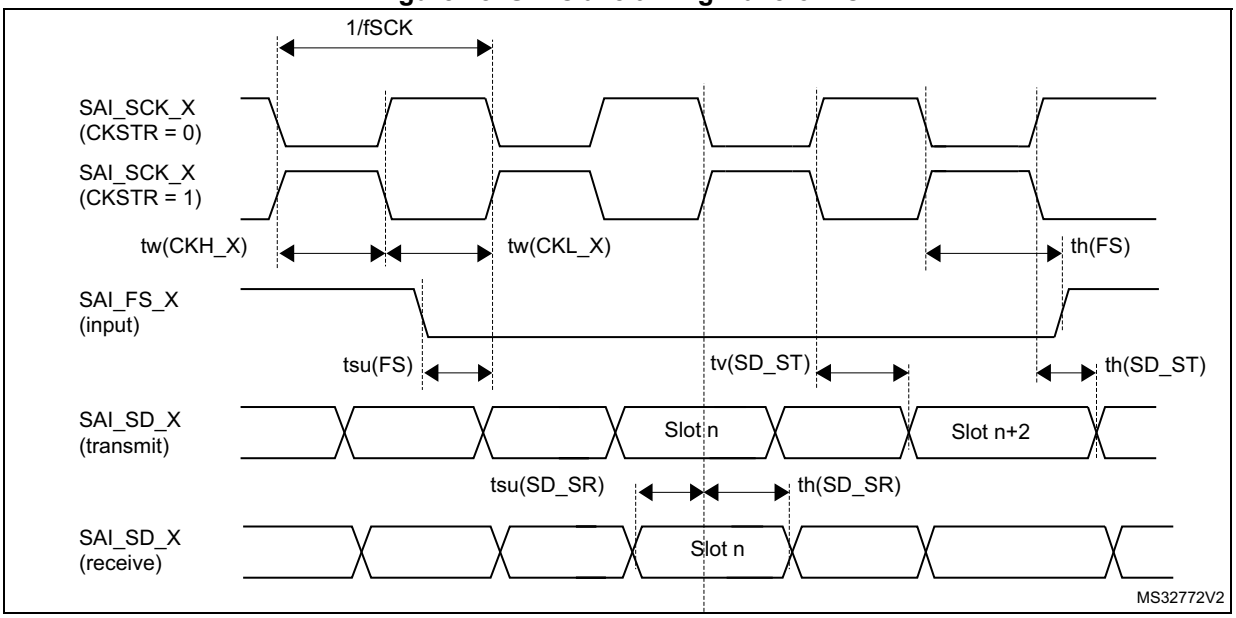


Figure 78. SAI slave timing waveforms



SD/SDIO MMC card host interface (SDMMC) characteristics

Unless otherwise specified, the parameters given in *Table 132* and *Table 133* are derived from tests performed under the ambient temperature, f_{PCLKx} frequency, and V_{DD} supply voltage summarized in *Table 19*, with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 11
- Capacitive load C_L= 30 pF
- Measurement points are done at CMOS levels: 0.5 V_{DD}
- I/O compensation cell activated
- HSLV activated when V_{DD} ≤ 2.7 V

Refer to *Section 5.3.15* for more details on the input/output characteristics.

Table 132. Dynamic characteristics: SD/MMC, V_{DD} = 2.7 to 3.6 V(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{PP}	Clock frequency in data transfer mode	-	0	-	130(2)/104(2)(3)	MHz
$t_{W(CKL)}$	Clock low time	f_{PP} = 52 MHz	8.5	9.5	-	ns
$t_{W(CKH)}$	Clock high time		8.5	9.5	-	
CMD, D inputs (referenced to CK) in eMMC legacy/SDR/DDR and SD HS/SDR(4)/DDR(4) mode						
t_{ISU}	Input setup time HS	-	3	-	-	ns
t_{IH}	Input hold time HS	-	1.5	-	-	
t_{IDW}(5)	Input valid window (variable window)	-	4.5	-	-	
CMD, D outputs (referenced to CK) in eMMC legacy/SDR/DDR and SD HS/SDR(4)/DDR(4) mode						
t_{OV}	Output valid time HS	-	-	(Tker / 2) + 1	(Tker / 2) + 1.5	ns
t_{OH}	Output hold time HS	-	(Tker / 2) - 0.5	-	-	
CMD, D inputs (referenced to CK) in SD default mode						
t_{ISUD}	Input setup time SD	-	3		-	ns
t_{IHD}	Input hold time SD	-	1.5		-	
CMD, D outputs (referenced to CK) in SD default mode						
t_{OVD}	Output valid default time SD	-	-	1	2	ns
t_{OHD}	Output hold default time SD	-	0	-	-	

1. Evaluated by characterization - Not tested in production.
2. C_L applied is 20 pF.
3. Maximum speed for LQFP100 and LQFP100-SMPS packages.
4. For SD 1.8 V support, an external voltage converter is needed.
5. The minimum window of time where the data needs to be stable for proper sampling in tuning mode.

Table 133. Dynamic characteristics: eMMC, V_{DD} = 1.71 to 1.9 V(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{PP}	Clock frequency in data transfer mode	-	0	-	110(2)/88(2)(3)	MHz
$t_{W(CKL)}$	Clock low time	f_{PP} = 52 MHz	8.5	9.5	-	ns
$t_{W(CKH)}$	Clock high time		8.5	9.5	-	
CMD, D inputs (referenced to CK) in eMMC mode						
t_{ISU}	Input setup time HS	-	2	-	-	ns
t_{IH}	Input hold time HS	-	2	-	-	
t_{IDW}(4)	Input valid window (variable window)	-	4	-	-	

Table 133. Dynamic characteristics: eMMC, V_{DD} = 1.71 to 1.9 V(1) (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
CMD, D outputs (referenced to CK) in eMMC mode						
t_{OV}	Output valid time HS	-	-	(Tker / 2) + 1	(Tker / 2) + 1.5	ns
t_{OH}	Output hold time HS	-	(Tker / 2) - 0.5	-	-	

1. Evaluated by characterization - Not tested in production.
2. C_L = 20 pF.
3. Maximum speed for LQFP100 and LQFP100-SMPS.
4. The minimum window of time where the data needs to be stable for proper sampling in tuning mode.

Figure 79. SDIO high-speed/eMMC timing

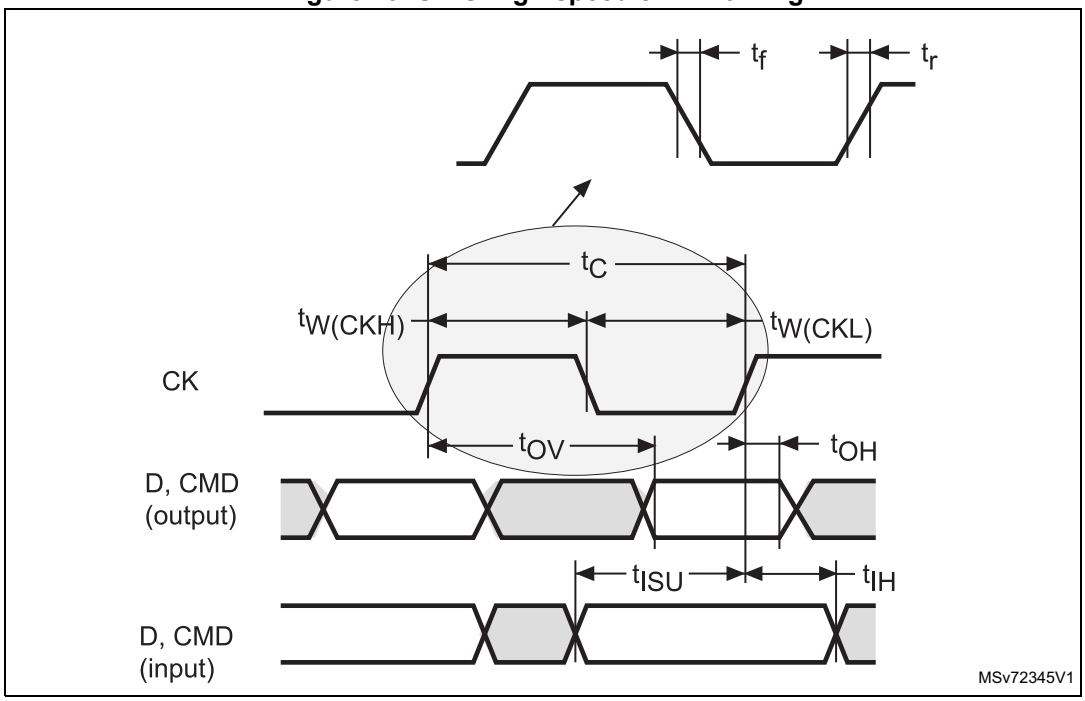


Figure 80. SD default speed timings

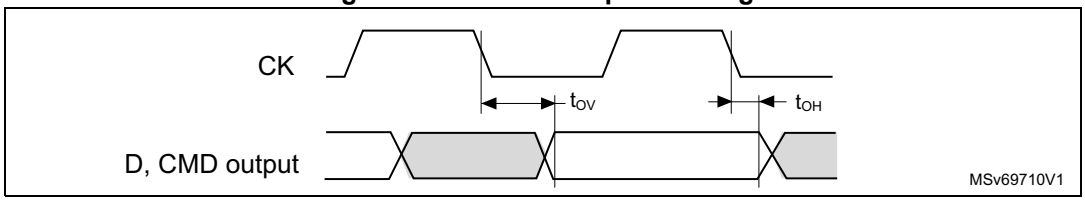
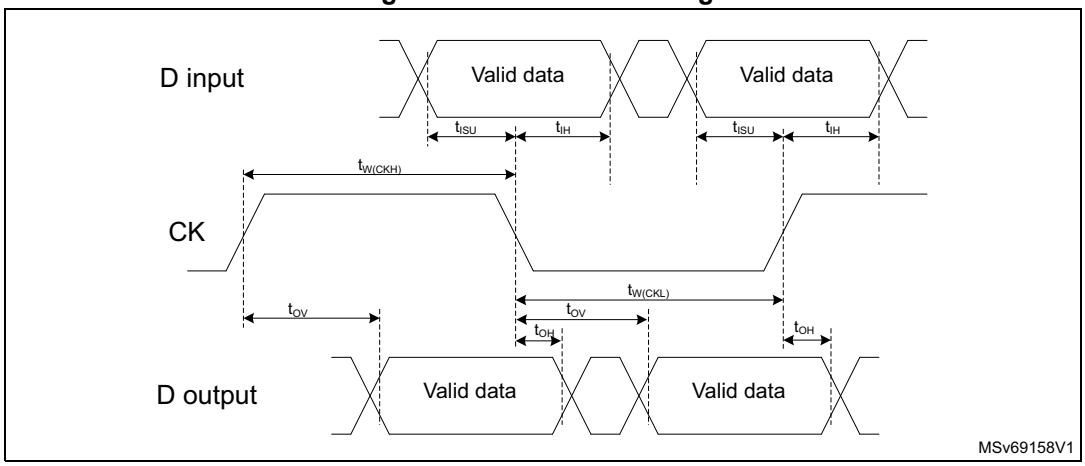


Figure 81. DDR mode timings



Ethernet interface characteristics

Unless otherwise specified, the parameters given in *Table 134*, *Table 135*, and *Table 136* are derived from tests performed under the ambient temperature, $f_{rcc\_c\_ck}$ frequency, and V_{DD} supply voltage conditions summarized in *Table 19*, with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 10
- Capacitive load C_L = 20 pF
- Measurement points are done at CMOS levels: 0.5 V_{DD}
- I/O compensation cell activated
- HSLV activated when $V_{DD} \leq 2.7$ V

Refer to *Section 5.3.15* for more details on the input/output characteristics.

Table 134. Dynamic characteristics: Ethernet MAC signals for SMI (1)

Symbol	Parameter	Min	Typ	Max	Unit
t_{MDC}	MDC cycle time (2.5 MHz)	399	400	401	ns
$T_{d(MDIO)}$	Write data valid time	0	0.5	1	
$t_{su(MDIO)}$	Read data setup time	12.5	-	-	
$t_{h(MDIO)}$	Read data hold time	0	-	-	

1. Evaluated by characterization - Not tested in production.

Table 135. Dynamic characteristics: Ethernet MAC signals for RMII (1)

Symbol	Parameter	Min	Typ	Max	Unit
$t_{su(RXD)}$	Receive data setup time	3	-	-	ns
$t_{ih(RXD)}$	Receive data hold time	1	-	-	
$t_{su(CRS)}$	Carrier sense setup time	2	-	-	
$t_{ih(CRS)}$	Carrier sense hold time	1	-	-	
$t_{d(TXEN)}$	Transmit enable valid delay time	7.5	9.5	15	
$t_{d(TXD)}$	Transmit data valid delay time	7.5	10	15.5	

1. Evaluated by characterization - Not tested in production.

Table 136. Dynamic characteristics: Ethernet MAC signals for MII (1)

Symbol	Parameter	Min	Typ	Max	Unit
$t_{su(RXD)}$	Receive data setup time	3	-	-	ns
$t_{ih(RXD)}$	Receive data hold time	1.5	-	-	
$t_{su(DV)}$	Data valid setup time	2	-	-	
$t_{ih(DV)}$	Data valid hold time	1	-	-	
$t_{su(ER)}$	Error setup time	3	-	-	
$t_{ih(ER)}$	Error hold time	1	-	-	
$t_{d(TXEN)}$	Transmit enable valid delay time	7.5	10	16	
$t_{d(TXD)}$	Transmit data valid delay time	8	10.5	16.5	

1. Evaluated by characterization - Not tested in production.

Figure 82. Ethernet RMII timing diagram

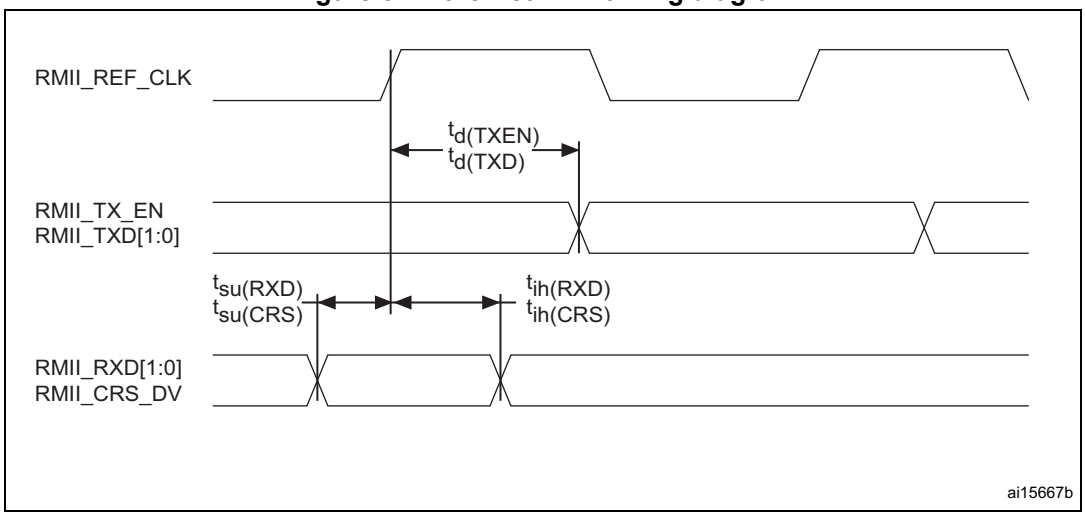


Figure 83. Ethernet MII timing diagram

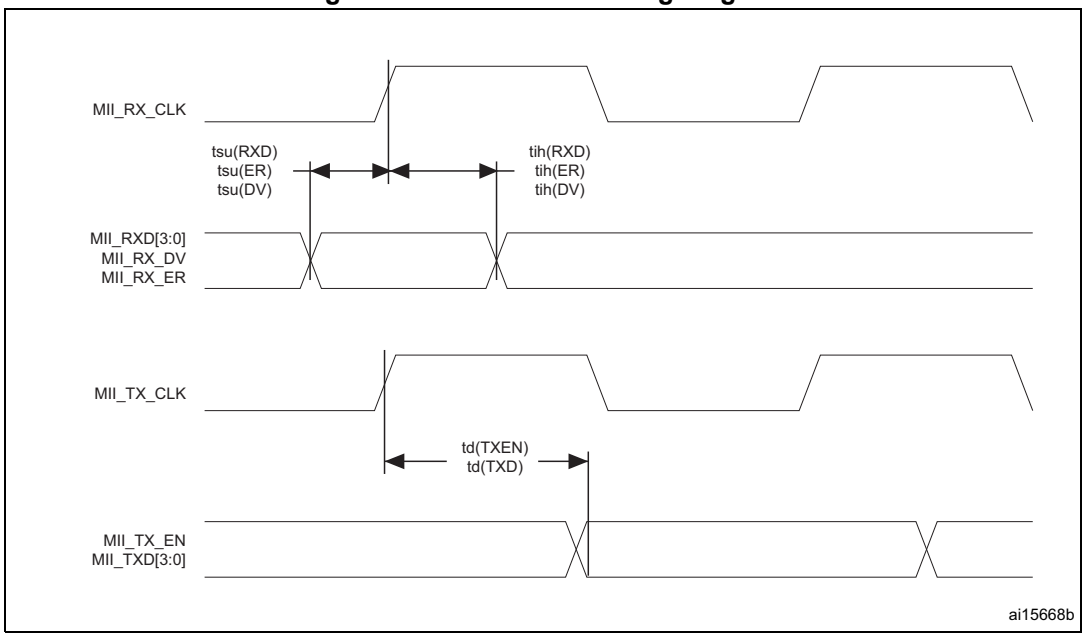
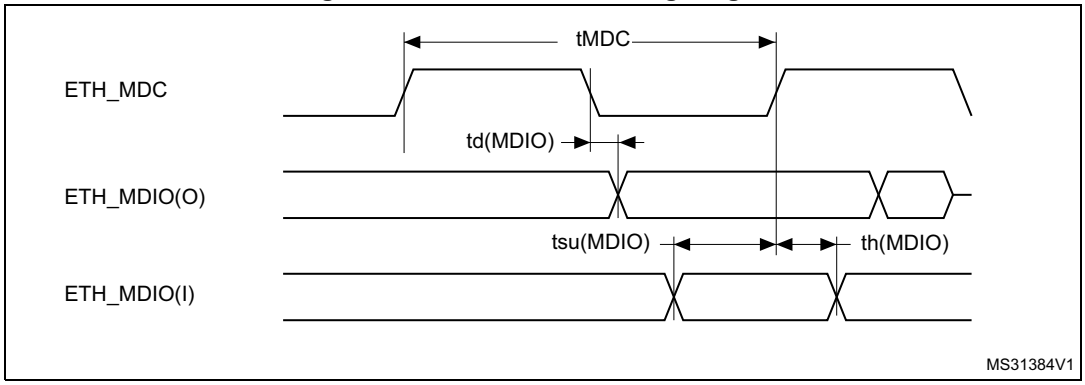


Figure 84. Ethernet SMI timing diagram



JTAG/SWD interface characteristics

Unless otherwise specified, the parameters given in *Table 137* and *Table 138* for JTAG/SWD are derived from tests performed under the ambient temperature, $f_{rcc\_c\_ck}$ frequency, and V_{DD} supply voltage summarized in *Table 19*, with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 1
- Capacitive load C_L = 30 pF
- HSLV activated when $V_{DD} \leq 2.7$ V
- Measurement points are done at CMOS levels: 0.5 V_{DD}

Refer to *Section 5.3.15* for more details on the input/output characteristics.

Table 137. Dynamic JTAG characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
F_{TCK}	T_{CK} clock frequency	2.7 V < V_{DD} < 3.6 V	-	-	50	MHz
$1/t_{c(TCK)}$		1.71 V < V_{DD} < 3.6 V	-	-	45	
$ti_{su(TMS)}$	TMS input setup time	-	2	-	-	ns
$ti_{h(TMS)}$	TMS input hold time	-	1.5	-	-	
$ti_{su(TDI)}$	TDI input setup time	-	1.5	-	-	
$ti_{h(TDI)}$	TDI input hold time	-	1.5	-	-	
$t_{ov(TDO)}$	TDO output valid time	2.7V < V_{DD} < 3.6 V	-	8	10	
		1.71 < V_{DD} < 3.6 V	-	8	11	
$t_{oh(TDO)}$	TDO output hold time	-	6.5	-	-	

Table 138. Dynamic SWD characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
F_{SWCLK}	SWCLK clock frequency	2.7 V < V_{DD} < 3.6 V	-	-	80	MHz
$1/t_{c(SWCLK)}$		1.71 V < V_{DD} < 3.6 V	-	-	71	
$ti_{su(SWDIO)}$	SWDIO input setup time	-	1.5	-	-	ns
$ti_{h(SWDIO)}$	SWDIO input hold time	-	1.5	-	-	
$t_{ov(SWDIO)}$	SWDIO output valid time	2.7 V < V_{DD} < 3.6 V	-	10.5	12.5	
		1.71 V < V_{DD} < 3.6 V	-	10.5	14.0	
$t_{oh(SWDIO)}$	SWDIO output hold time	-	8.5	-	-	

Figure 85. JTAG timing diagram

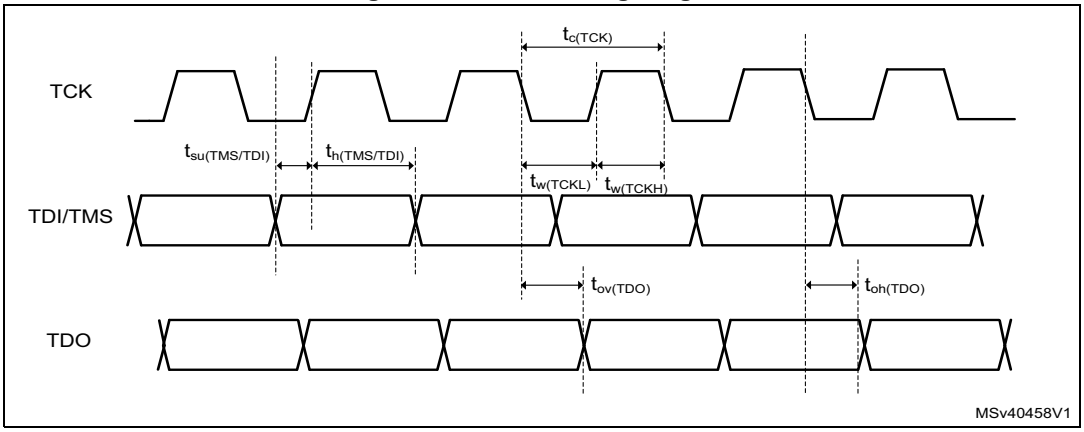
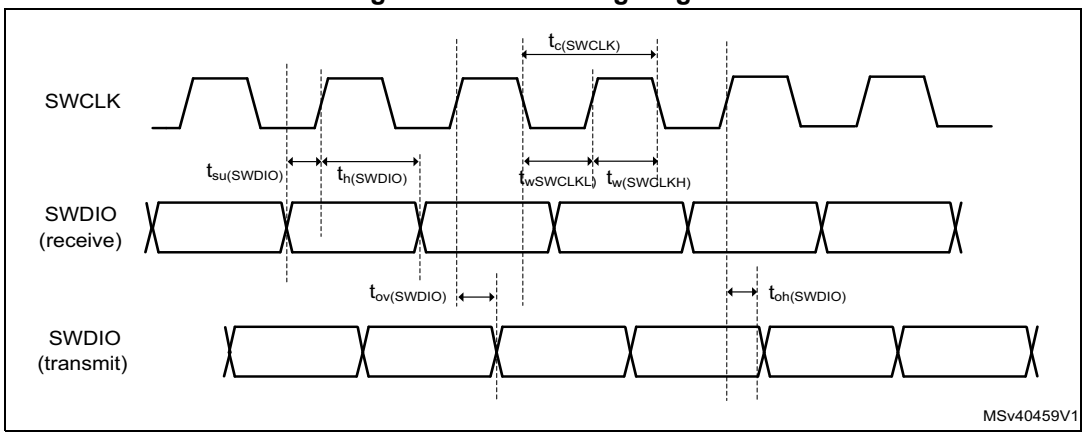


Figure 86. SWD timing diagram



6 Package information

To meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: *www.st.com*. ECOPACK is an ST trademark.

6.1 Device marking

Refer to "*Reference device marking schematics for STM32 microcontrollers and microprocessors*" (TN1433), available on *www.st.com*, for the location of pin 1 / ball A1 as well as the location and orientation of the marking areas versus pin 1 / ball A1.

Parts marked as "ES", "E" or accompanied by an engineering sample notification letter, are not yet qualified and therefore not approved for use in production. ST is not responsible for any consequences resulting from such use. In no event will ST be liable for the customer using any of these engineering samples in production. ST's Quality department must be contacted prior to any decision to use these engineering samples to run a qualification activity.

A WLCSP simplified marking example (if any) is provided in the corresponding package information subsection.

6.2 LQFP100 package information (1L)

This LQFP is a 100 lead, 14 x 14 mm low-profile quad flat package.

Note: See list of notes in the notes section.

Figure 87. LQFP100 - Outline(15)

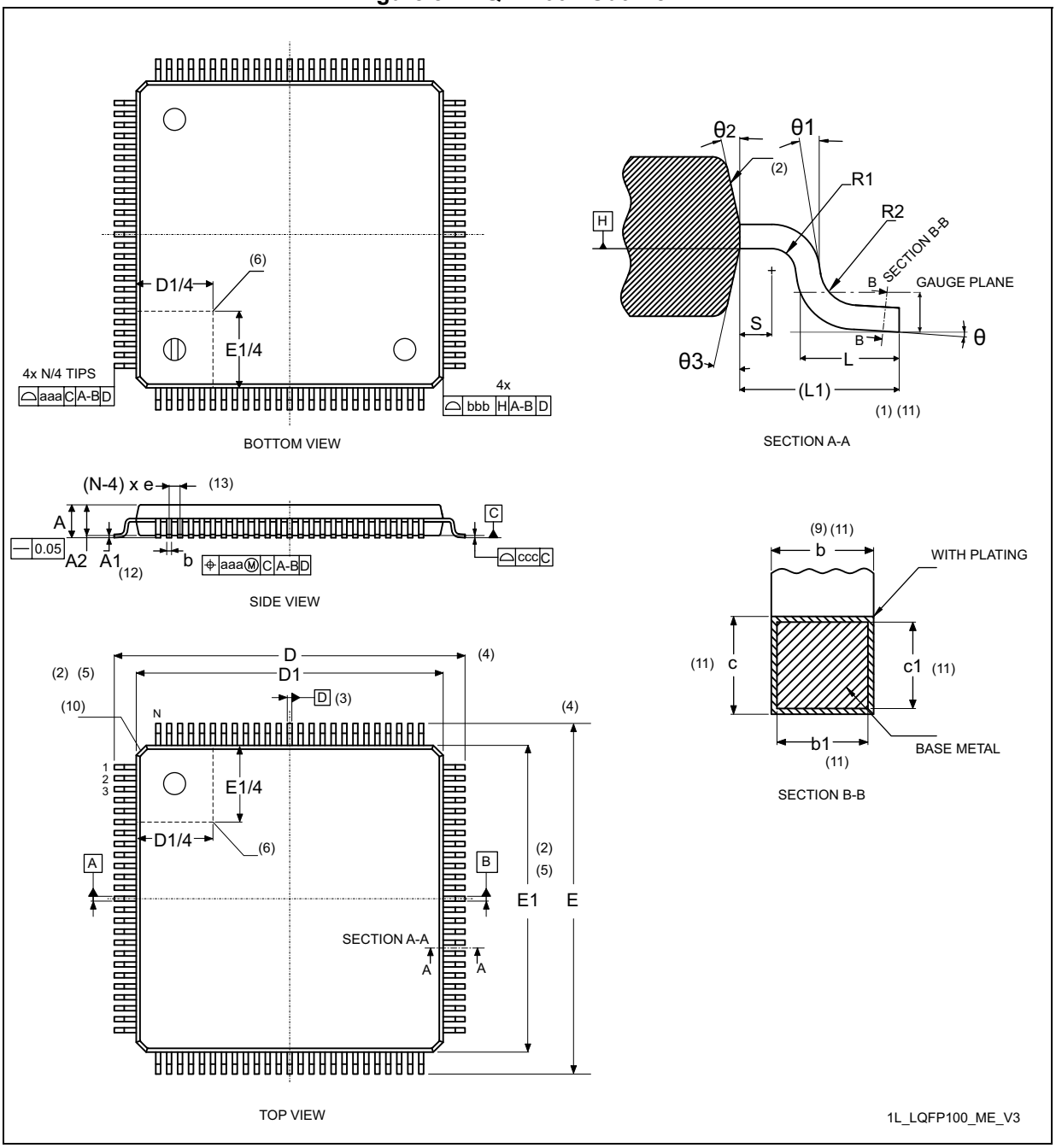


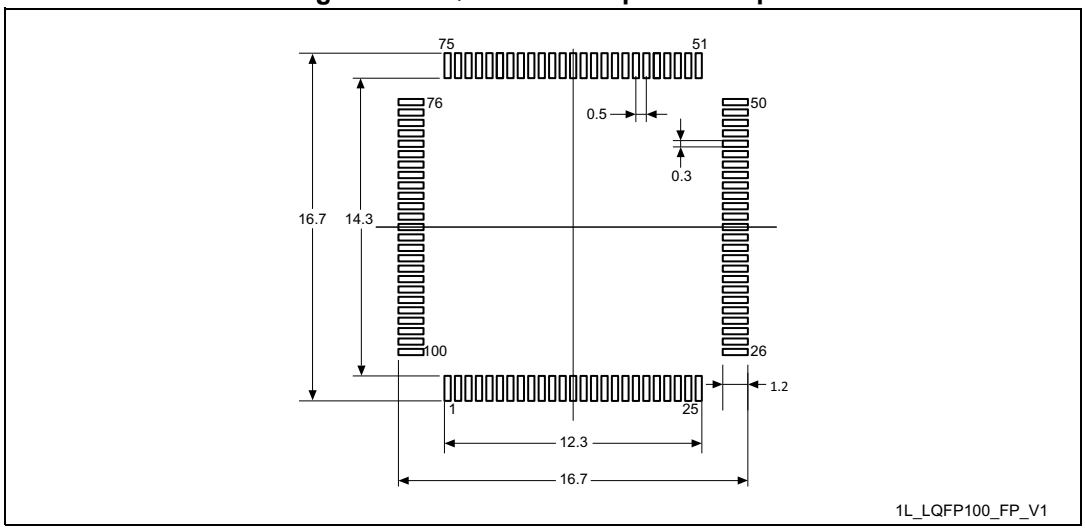
Table 139. LQFP100 - Mechanical data

Symbol	Millimeters			Inches[14]		
	Min	Typ	Max	Min	Typ	Max
A	-	1.50	1.60	-	0.0590	0.0630
A1[12]	0.05	-	0.15	0.0019	-	0.0059
A2	1.35	1.40	1.45	0.0531	0.0551	0.0570
b[9][11]	0.17	0.22	0.27	0.0067	0.0087	0.0106
b1[11]	0.17	0.20	0.23	0.0067	0.0079	0.0090
c[11]	0.09	-	0.20	0.0035	-	0.0079
c1[11]	0.09	-	0.16	0.0035	-	0.0063
D[4]	16.00 BSC			0.6299 BSC		
D1[2][5]	14.00 BSC			0.5512 BSC		
E[4]	16.00 BSC			0.6299 BSC		
E1[2][5]	14.00 BSC			0.5512 BSC		
e	0.50 BSC			0.0197 BSC		
L	0.45	0.60	0.75	0.177	0.0236	0.0295
L1[1][11]	1.00			-	0.0394	-
N[13]	100					
θ	0°	3.5°	7°	0°	3.5°	7°
θ1	0°	-	-	0°	-	-
θ2	10°	12°	14°	10°	12°	14°
θ3	10°	12°	14°	10°	12°	14°
R1	0.08	-	-	0.0031	-	-
R2	0.08	-	0.20	0.0031	-	0.0079
S	0.20	-	-	0.0079	-	-
aaa[1]	0.20			0.0079		
bbb[1]	0.20			0.0079		
ccc[1]	0.08			0.0031		
ddd[1]	0.08			0.0031		

Notes:

1. Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.
2. The top package body size may be smaller than the bottom package size by as much as 0.15 mm.
3. Datums A-B and D to be determined at datum plane H.
4. To be determined at seating datum plane C.
5. Dimensions D1 and E1 do not include mold flash or protrusions. Allowable mold flash or protrusions is 0.25 mm per side. D1 and E1 are Maximum plastic body size dimensions including mold mismatch.
6. Details of pin 1 identifier are optional but must be located within the zone indicated.
7. All dimensions are in millimeters.
8. No intrusion allowed inwards the leads.
9. Dimension “b” does not include dambar protrusion. Allowable dambar protrusion shall not cause the lead width to exceed the maximum “b” dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. Minimum space between protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.
10. Exact shape of each corner is optional.
11. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.
12. A1 is defined as the distance from the seating plane to the lowest point on the package body.
13. “N” is the number of terminal positions for the specified body size.
14. Values in inches are converted from mm and rounded to four decimal digits.
15. Drawing is not to scale.

Figure 88. LQFP100 - Footprint example

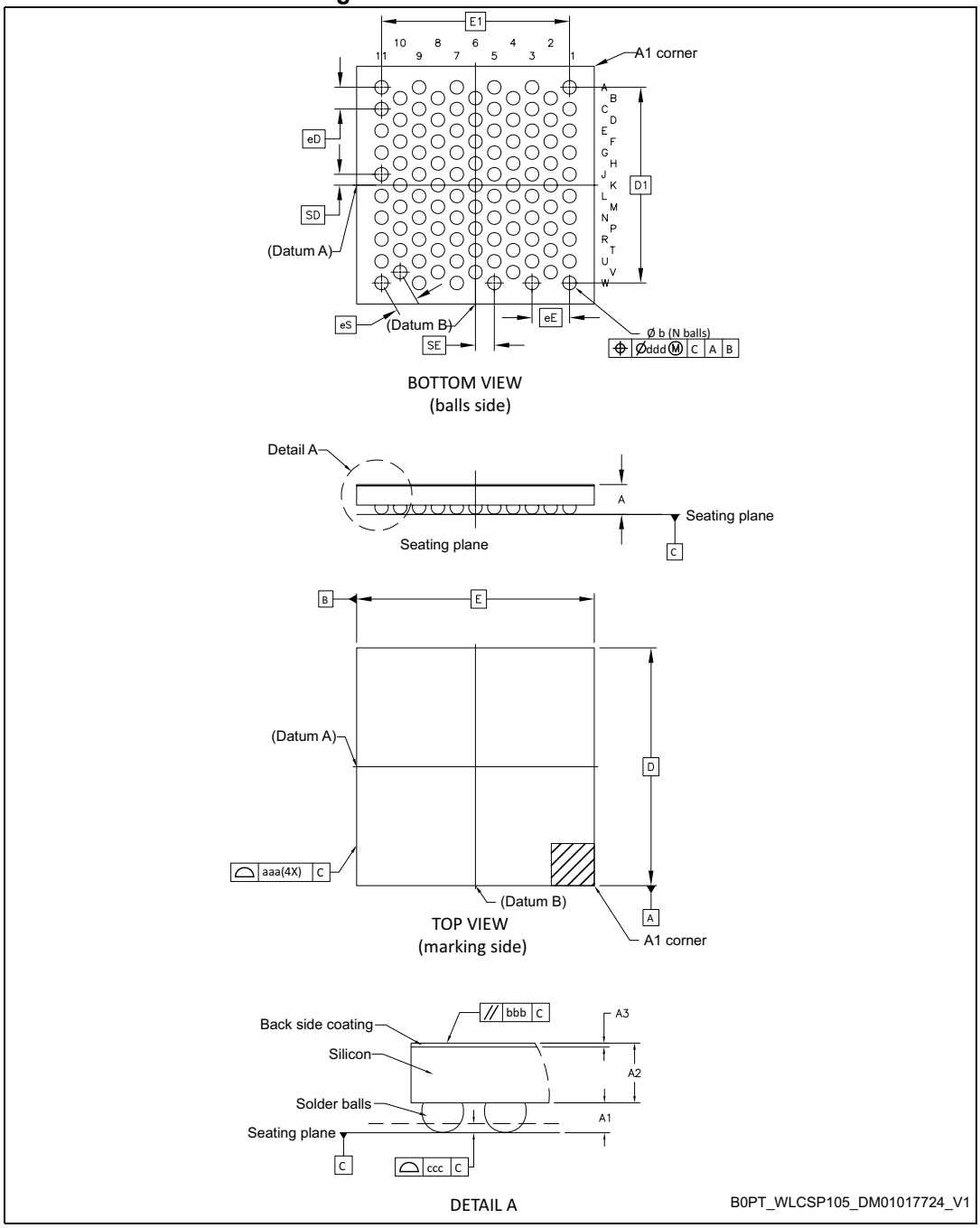


1. Dimensions are expressed in millimeters.

6.3 WLCSP105 package information (B0PT)

This WLCSP is a 105-ball, 4.38 x 4.38 mm, 0.4 mm pitch, wafer level chip scale package.

Figure 89. WLCSP105 - Outline



1. The drawing is not to scale.

Table 140. WLCSP105 - Mechanical data

Symbol	Millimeters			Inches[1]		
	Min	Typ	Max	Min	Typ	Max
A[2]	-	-	0.58	-	-	0.0228
A1[3]	0.14	-	-	0.0055	-	-
A2	-	0.38	-	-	0.0150	-
A3	-	0.025	-	-	0.0010	-
b[4]	0.22	0.26	0.29	0.0087	0.0102	0.0114
D[5]	4.38 BSC			0.1724 BSC		
D1[5]	3.60 BSC			0.1417 BSC		
E[5]	4.38 BSC			0.1724 BSC		
E1[5]	3.46 BSC			0.1362 BSC		
eD[5][6]	0.40 BSC			0.0157 BSC		
eE[5][6]	0.69 BSC			0.0272 BSC		
eS[5][6]	0.40 BSC			0.0157 BSC		
SD[5][7]	0.20 BSC			0.0079 BSC		
SE[5][7]	0.35 BSC			0.0138 BSC		
N[8]	105					
aaa[9]	0.02			0.0008		
bbb[9]	0.06			0.0024		
ccc[9]	0.03			0.0012		
ddd[9]	0.015			0.0006		

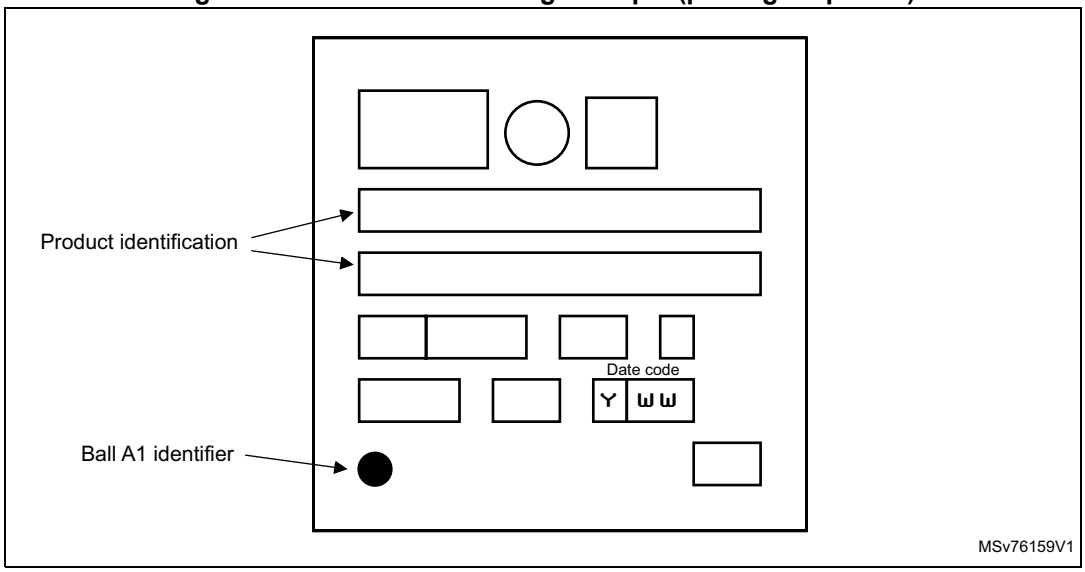
1. Values in inches are converted from mm and rounded to four decimal digits.
2. The profile height A is the distance from the seating plane to the highest point on the package. It is measured perpendicular to the seating plane.
3. A1 is defined as the distance from the seating plane to the lowest point on the package body.
4. Dimension b is measured at the maximum diameter of the terminal (ball) in a plane parallel to Datum C.
5. BSC stands for BASIC dimensions. It corresponds to the nominal value and has no tolerance.
6. e represents the solder balls grid pitch(es).
7. Basic dimensions SD and SE are defining the ball matrix position with respect to datums A and B.
8. N represents the total number of balls.
9. Tolerance of form and position drawing.

Example of device marking for WLCSP105

The following figure gives an example of the locations and orientation of the marking areas versus ball A1, and allows engineering samples to be identified.

With the device text markings oriented as in the figure, ball A1 is always located at top left.

Figure 90. WLCSP105 marking example (package top view)



6.4 LQFP144 package information (1A)

This LQFP is a 144-pin, 20 x 20 mm low-profile quad flat package.

Note: See list of notes in the notes section.

Figure 91. LQFP144 - Outline(15)

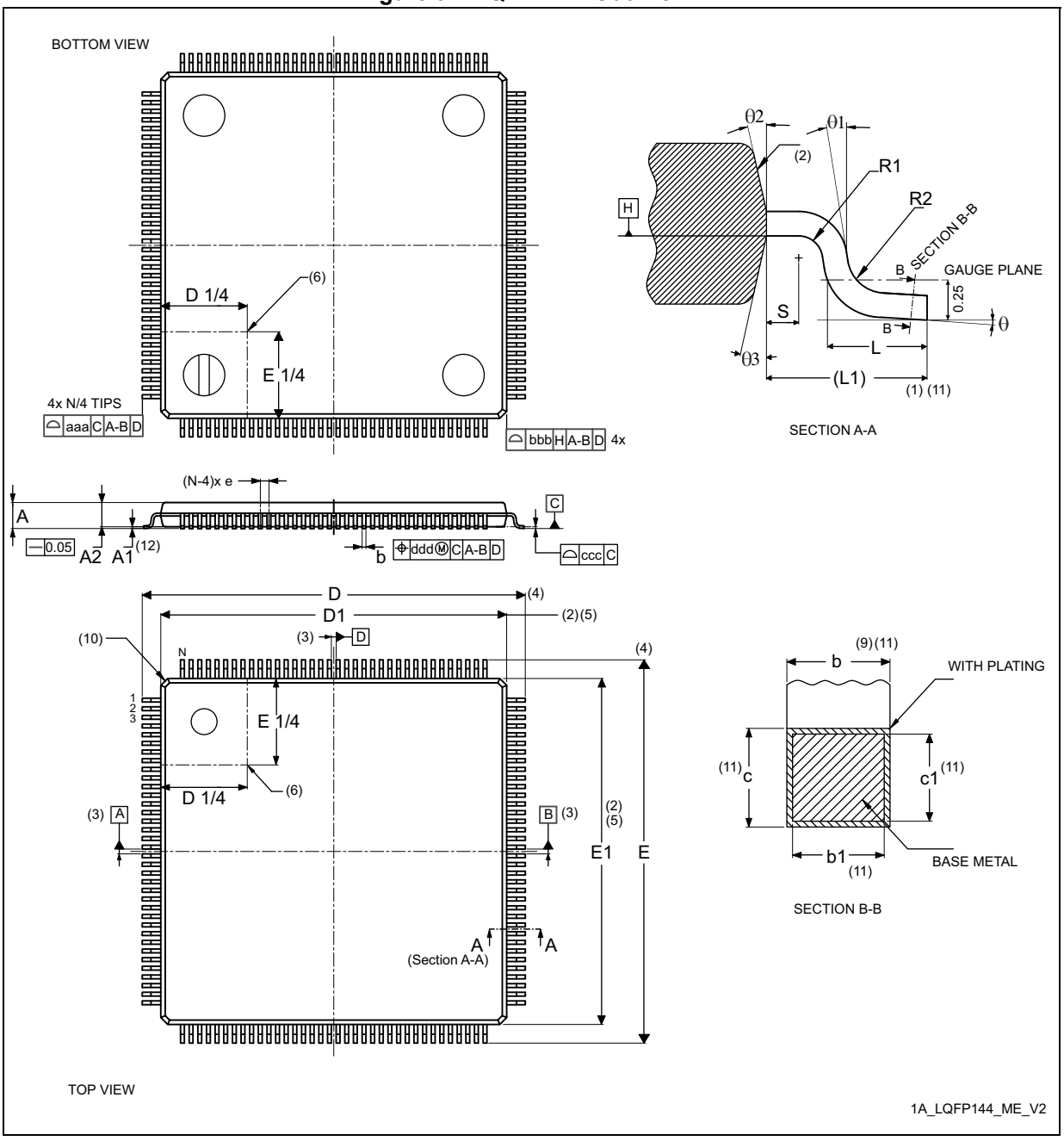


Table 141. LQFP144 - Mechanical data

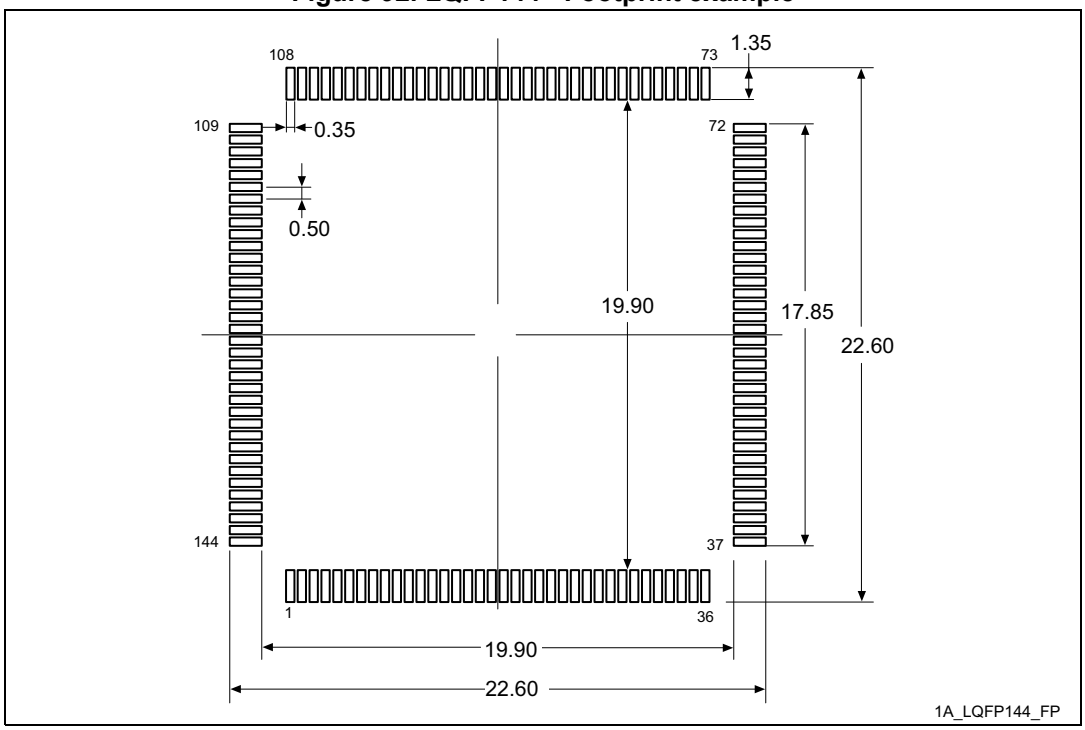
Symbol	Millimeters			Inches[14]		
	Min	Typ	Max	Min	Typ	Max
A	-	-	1.60	-	-	0.0630
A1[12]	0.05	-	0.15	0.0020	-	0.0059
A2	1.35	1.40	1.45	0.0531	0.0551	0.0571
b[9][11]	0.17	0.22	0.27	0.0067	0.0087	0.0106
b1[11]	0.17	0.20	0.23	0.0067	0.0079	0.0090
c[11]	0.09	-	0.20	0.0035	-	0.0079
c1[11]	0.09	-	0.16	0.0035	-	0.0063
D[4]	22.00 BSC			0.8661 BSC		
D1[2][5]	20.00 BSC			0.7874 BSC		
E[4]	22.00 BSC			0.8661 BSC		
E1[2][5]	20.00 BSC			0.7874 BSC		
e	0.50 BSC			0.0197 BSC		
L	0.45	0.60	0.75	0.0177	0.0236	0.0295
L1	1.00 REF			0.0394 REF		
N[13]	144					
θ	0°	3.5°	7°	0°	3.5°	7°
θ1	0°	-	-	0°	-	-
θ2	10°	12°	14°	10°	12°	14°
θ3	10°	12°	14°	10°	12°	14°
R1	0.08	-	-	0.0031	-	-
R2	0.08	-	0.20	0.0031	-	0.0079
S	0.20	-	-	0.0079	-	-
aaa	0.20			0.0079		
bbb	0.20			0.0079		
ccc	0.08			0.0031		
ddd	0.08			0.0031		

Notes:

1. Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.
2. The top package body size may be smaller than the bottom package size by as much as 0.15 mm.
3. Datums A-B and D to be determined at datum plane H.
4. To be determined at seating datum plane C.

5. Dimensions D1 and E1 do not include mold flash or protrusions. Allowable mold flash or protrusions is 0.25 mm per side. D1 and E1 are Maximum plastic body size dimensions including mold mismatch.
6. Details of pin 1 identifier are optional but must be located within the zone indicated.
7. All dimensions are in millimeters.
8. No intrusion allowed inwards the leads.
9. Dimension “b” does not include dambar protrusion. Allowable dambar protrusion shall not cause the lead width to exceed the maximum “b” dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. Minimum space between protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.
10. Exact shape of each corner is optional.
11. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.
12. A1 is defined as the distance from the seating plane to the lowest point on the package body.
13. “N” is the number of terminal positions for the specified body size.
14. Values in inches are converted from mm and rounded to four decimal digits.
15. Drawing is not to scale.

Figure 92. LQFP144 - Footprint example



1. Dimensions are expressed in millimeters.

6.5 UFBGA144 package information (A0Y2)

This UFBGA is a 144-pin, 10 x 10 mm, 0.80 mm pitch, ultra fine pitch ball grid array package.

Note: See list of notes in the notes section.

Figure 93. UFBGA144 - Outline(13)

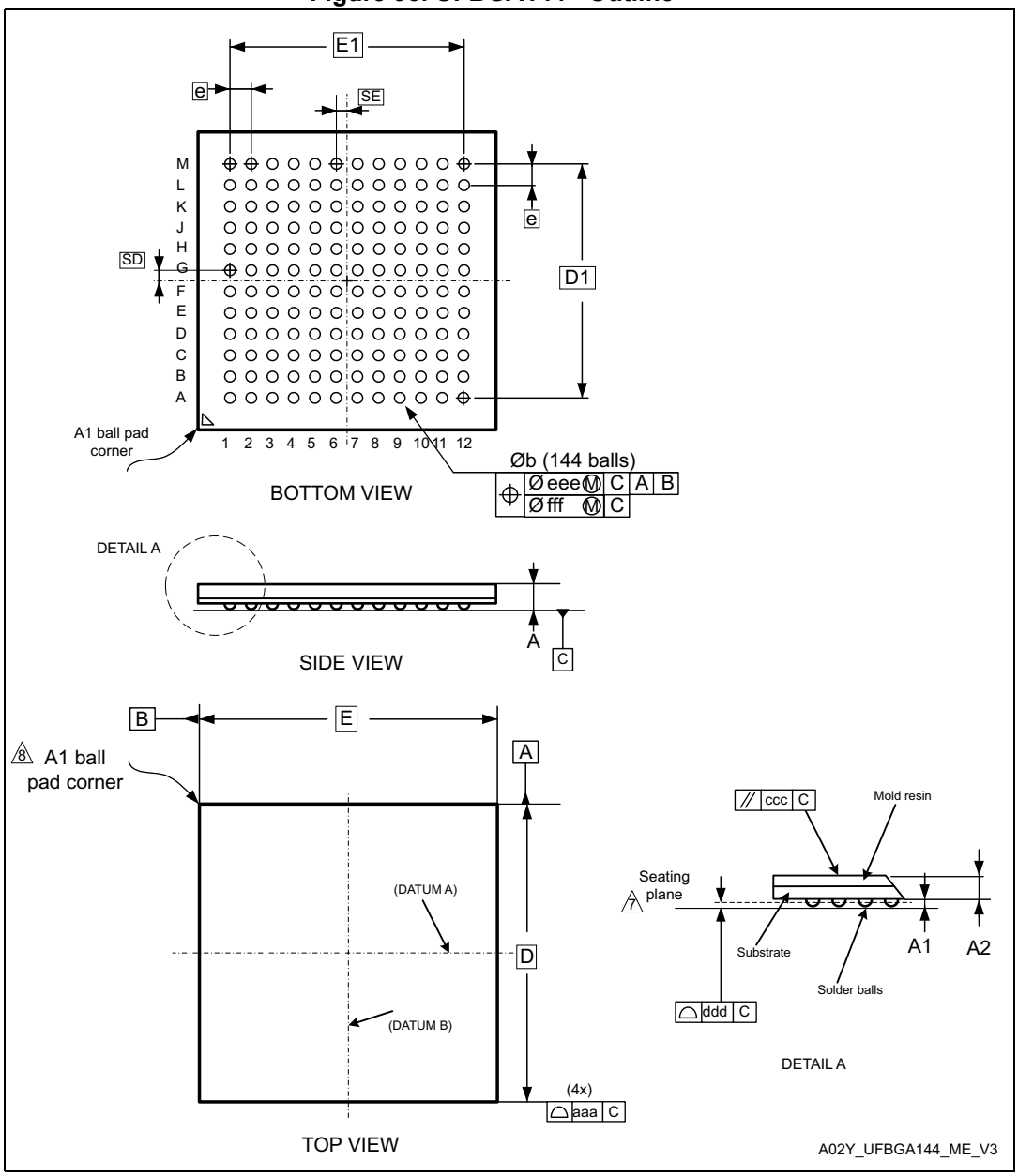


Table 142. UFBGA144 - Mechanical data

Symbol	Millimeters(1)			Inches(12)		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A(2)(3)	-	-	0.60	-	-	0.0236
A1(4)	0.05	-	-	0.0020	-	-
A2	-	0.43	-	-	0.0169	-
b(5)	0.35	0.40	0.45	0.0138	0.0157	0.0177
D	10.00 BSC(6)			0.3937 BSC		
D1	8.80 BSC			0.3465 BSC		
E	10.00 BSC			0.3937 BSC		
E1	8.80 BSC			0.3465 BSC		
e(9)	0.80 BSC			0.0315 BSC		
N(11)	144					
SD(12)	0.40 BSC			0.0157 BSC		
SE(12)	0.40 BSC			0.0157 BSC		
aaa	0.15			0.0059		
ccc	0.20			0.0079		
ddd	0.10			0.0039		
eee	0.15			0.0059		
fff	0.08			0.0031		

Notes:

1. Dimensioning and tolerancing schemes conform to ASME Y14.5M-2009 apart European projection.
2. UFBGA stands for ultra profile fine pitch ball grid array: 0.50 mm < A ≤ 0.65 mm / fine pitch e < 1.00 mm.
3. The profile height, A, is the distance from the seating plane to the highest point on the package. It is measured perpendicular to the seating plane.
4. A1 is defined as the distance from the seating plane to the lowest point on the package body.
5. Dimension b is measured at the maximum diameter of the terminal (ball) in a plane parallel to primary datum C.
6. BSC stands for BASIC dimensions. It corresponds to the nominal value and has no tolerance. For tolerances refer to form and position table. On the drawing these dimensions are framed.
7. Primary datum C is defined by the plane established by the contact points of three or more solder balls that support the device when it is placed on top of a planar surface.

8. The terminal (ball) A1 corner must be identified on the top surface of the package by using a corner chamfer, ink or metalized markings, or other feature of package body or integral heat slug. A distinguish feature is allowable on the bottom surface of the package to identify the terminal A1 corner. Exact shape of each corner is optional.
9. e represents the solder ball grid pitch.
10. N represents the total number of balls on the BGA.
11. Basic dimensions SD and SE are defined with respect to datums A and B. It defines the position of the center ball(s) in the outer row or column of a fully populated matrix.
12. Values in inches are converted from mm and rounded to four decimal digits.
13. Drawing is not to scale.

Figure 94. UFBGA144 - Footprint example

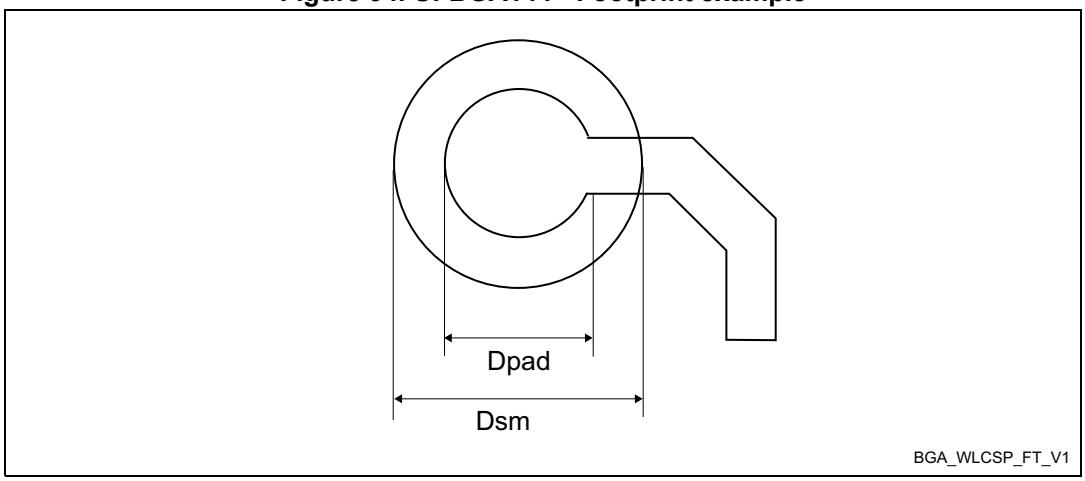


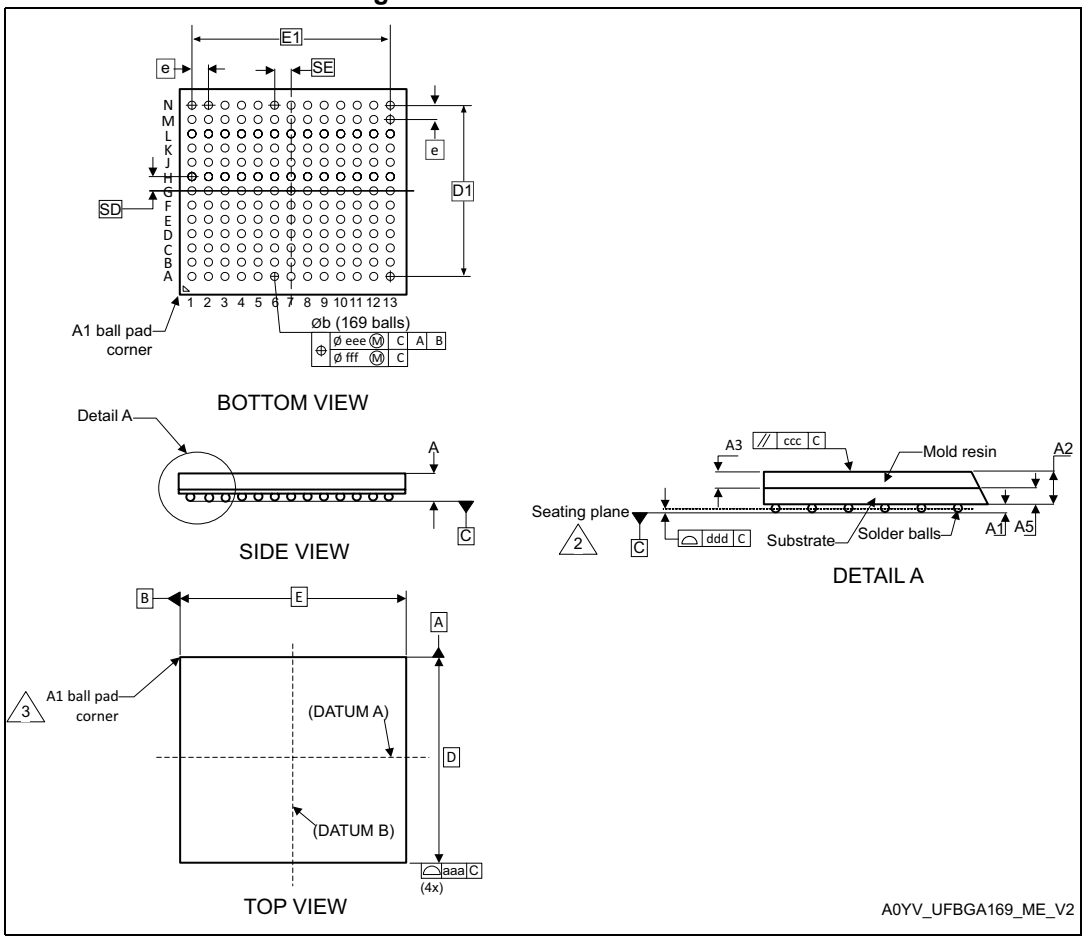
Table 143. UFBGA144 - Example of PCB design rules (0.80 mm pitch BGA)

Dimension	Values
Pitch	0.80 mm
Dpad	0.400 mm
Dsm	0.550 mm typical (depends on the soldermask registration tolerance)
Stencil opening	0.400 mm
Stencil thickness	Between 0.100 mm and 0.125 mm
Pad trace width	0.120 mm

6.6 UFBGA169 package information (A0YV)

This UFBGA is a 169-ball, 7 x 7 mm, 0.50 mm pitch, ultra fine pitch ball grid array package.

Figure 95. UFBGA169 - Outline



1. Drawing is not to scale.
2. Primary datum C is defined by the plane established by the contact points of three or more solder balls that support the device when it is placed on top of a planar surface.
3. The terminal (ball) A1 corner must be identified on the top surface of the package by using a corner chamfer, ink or metallized markings, or other feature of package body or integral heat slug. A distinguish feature is allowable on the bottom surface of the package to identify the terminal A1 corner. Exact shape of each corner is optional.

Table 144. UFBGA169 - Mechanical data

Symbol	Millimeters			Inches[1]		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A[2]	-	-	0.60	-	-	0.0236
A1[3]	0.05	-	-	0.0020	-	-
A2	-	0.43	-	-	0.0169	-
b[4]	0.23	0.28	0.33	0.0091	0.0110	0.0130
D[5]	7.00 BSC			0.2756 BSC		
D1[5]	6.00 BSC			0.2362 BSC		
E[5]	7.00 BSC			0.2756 BSC		
E1[5]	6.00 BSC			0.2362 BSC		
e[5][6]	0.50 BSC			0.0197 BSC		
N[7]	169					
SD[5][8]	0.50 BSC			0.0197 BSC		
SE[5][8]	0.50 BSC			0.0197 BSC		
aaa[9]	0.15			0.0059		
ccc[9]	0.20			0.0079		
ddd[9]	0.08			0.0031		
eee[9]	0.15			0.0059		
fff[9]	0.05			0.0020		

1. Values in inches are converted from mm and rounded to 4 decimal digits.
2. The profile height, A, is the distance from the seating plane to the highest point on the package. It is measured perpendicular to the seating plane.
3. A1 is defined as the distance from the seating plane to the lowest point on the package body.
4. Dimension b is measured at the maximum diameter of the terminal (ball) in a plane parallel to primary datum C.
5. BSC stands for BASIC dimensions. It corresponds to the nominal value and has no tolerance. For tolerances refer to form and position table.
6. e represents the solder ball grid pitch.
7. N represents the total number of balls on the BGA.
8. Basic dimensions SD and SE are defined with respect to datums A and B. It defines the position of the centre ball(s) in the outer row or column of a fully populated matrix.
9. Tolerance of form and position drawing

Figure 96. UFBGA169 - Footprint example

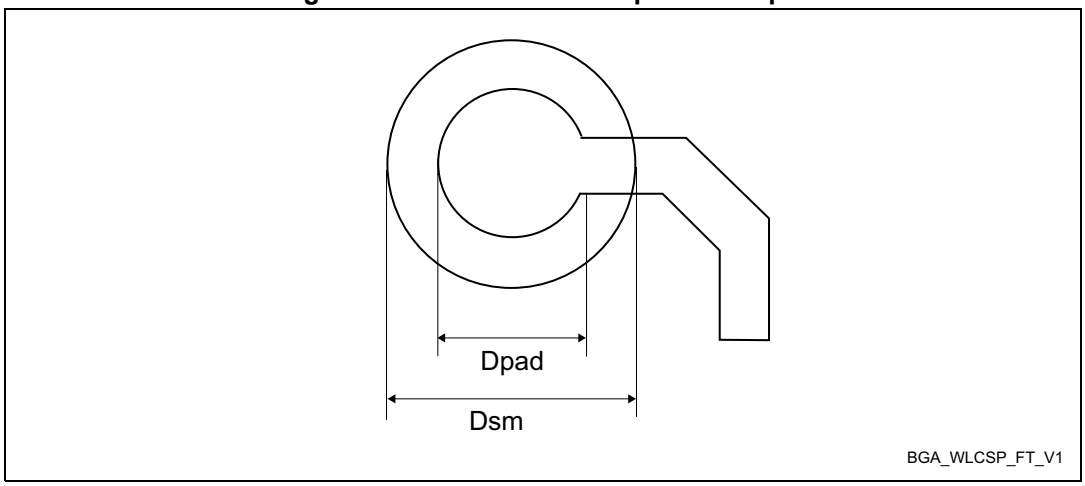


Table 145. UFBGA169 - Example of PCB design rules (0.5 mm pitch BGA)

Dimension	Values
Pitch	0.5 mm
Dpad	0.27 mm
Dsm	0.35 mm typical (depends on the solder mask registration tolerance)
Solder paste	0.27 mm aperture diameter.

Note: Non-solder mask defined (NSMD) pads are recommended.

Note: 4 to 6 mils solder paste screen printing process.

6.7 LQFP176 package information (1T)

This LQFP is a 176-pin, 24 x 24 mm, 0.5 mm pitch, low profile quad flat package.

Note: See list of notes in the notes section.

Figure 97. LQFP176 - Outline(15)

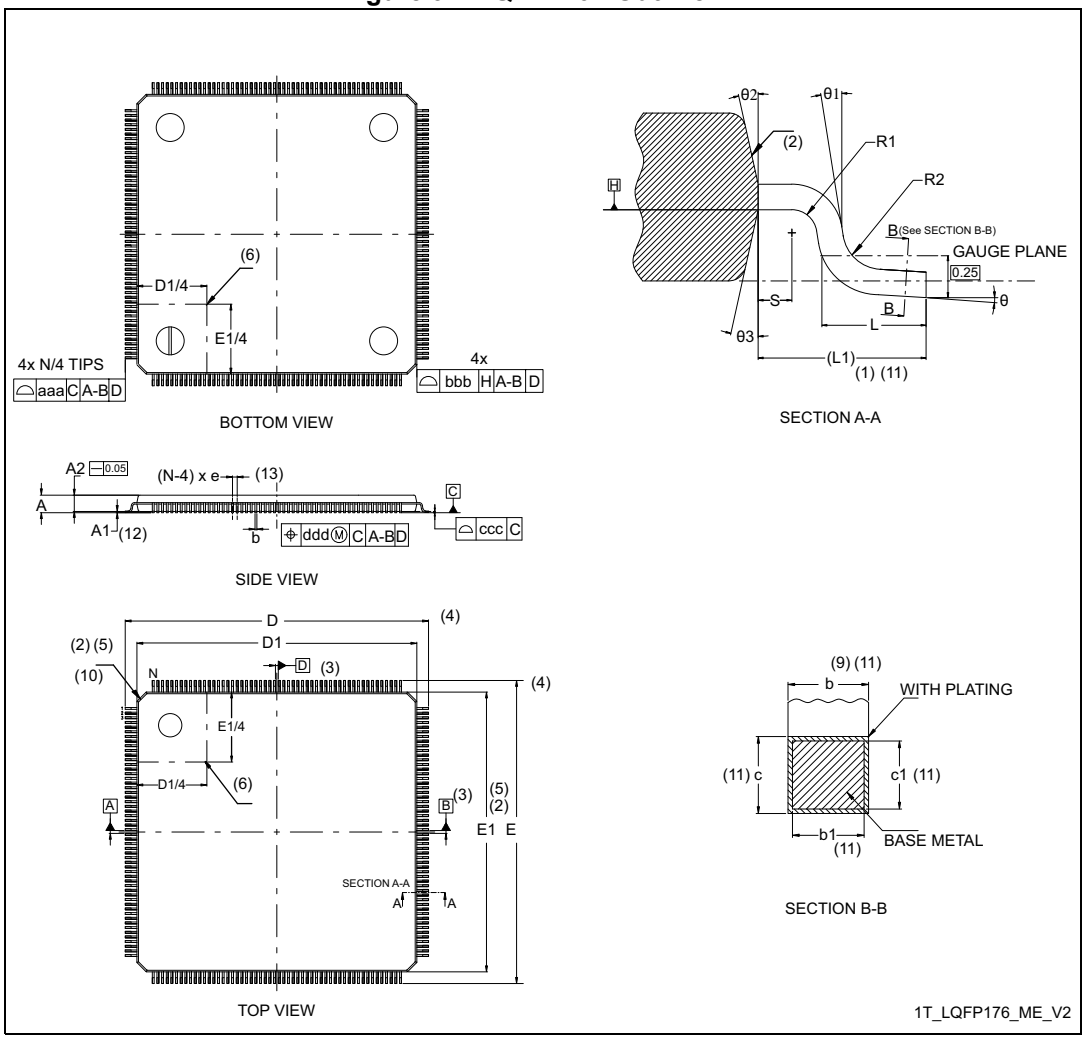


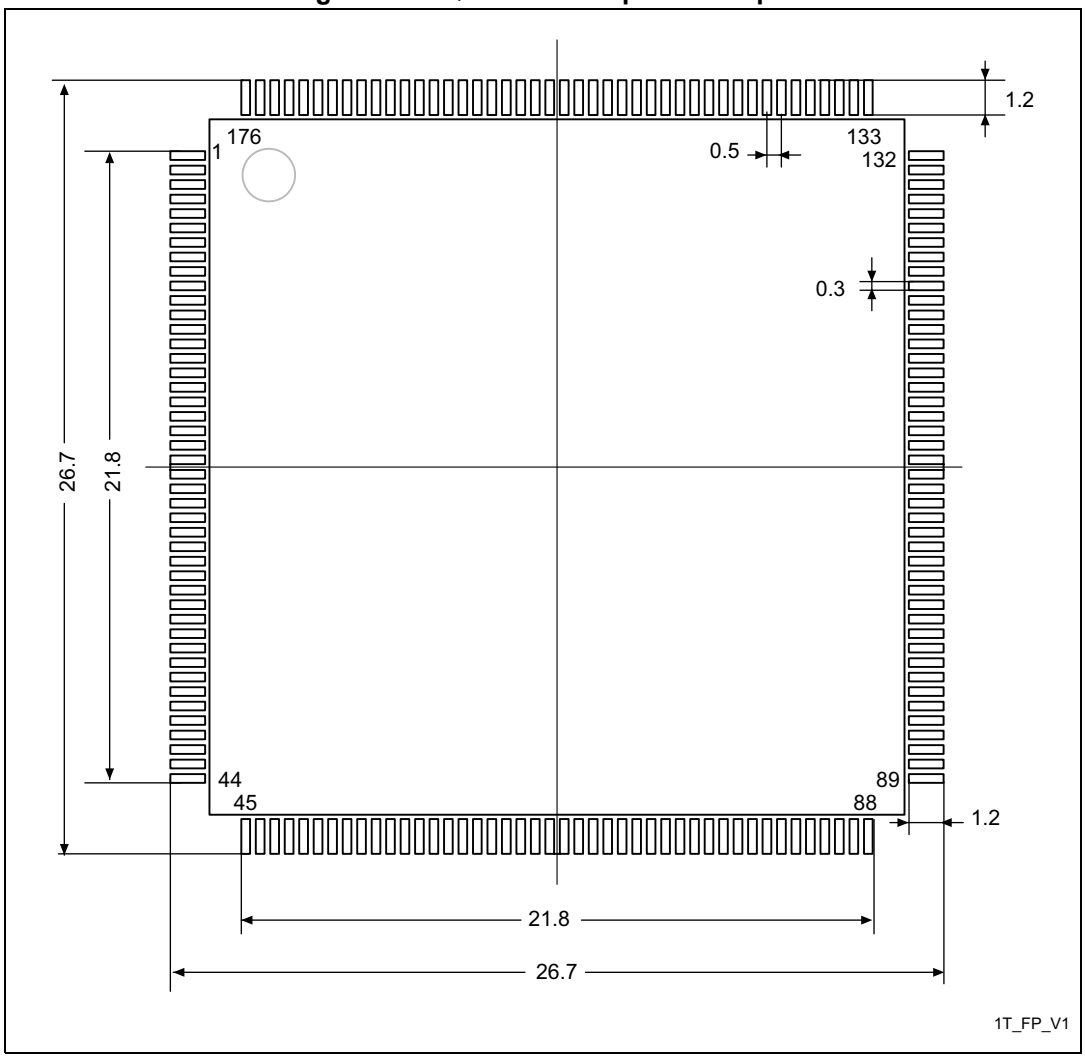
Table 146. LQFP176 - Mechanical data

Symbol	Millimeters			Inches[14]		
	Min	Typ	Max	Min	Typ	Max
A	-	-	1.600	-	-	0.0630
A1[12]	0.050	-	0.150	0.0020	-	0.0059
A2	1.350	1.400	1.450	0.0531	0.0551	0.0571
b[9][11]	0.170	0.220	0.270	0.0067	0.0087	0.0106
b1[11]	0.170	0.200	0.230	0.0067	0.0079	0.0091
c[11]	0.090	-	0.200	0.0035	-	0.0079
c1[11]	0.090	-	0.160	0.0035	-	0.063
D[4]	26.000			1.0236		
D1[2][5]	24.000			0.9449		
E[4]	26.000			0.0197		
E1[2][5]	24.000			0.9449		
e	0.500			0.1970		
L	0.450	0.600	0.750	0.0177	0.0236	0.0295
L1[1][11]	1			0.0394 REF		
N[13]	176					
θ	0°	3.5°	7°	0°	3.5°	7°
θ1	0°	-	-	0°	-	-
θ2	10°	12°	14°	10°	12°	14°
θ3	10°	12°	14°	10°	12°	14°
R1	0.080	-	-	0.0031	-	-
R2	0.080	-	0.200	0.0031	-	0.0079
S	0.200	-	-	0.0079	-	-
aaa[1]	0.200			0.0079		
bbb[1]	0.200			0.0079		
ccc[1]	0.080			0.0031		
ddd[1]	0.080			0.0031		

Notes:

1. Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.
2. The top package body size may be smaller than the bottom package size by as much as 0.15 mm.
3. Datums A-B and D to be determined at datum plane H.
4. To be determined at seating datum plane C.
5. Dimensions D1 and E1 do not include mold flash or protrusions. Allowable mold flash or protrusions is “0.25 mm” per side. D1 and E1 are Maximum plastic body size dimensions including mold mismatch.
6. Details of pin 1 identifier are optional but must be located within the zone indicated.
7. All dimensions are in millimeters.
8. No intrusion allowed inwards the leads.
9. Dimension “b” does not include dambar protrusion. Allowable dambar protrusion shall not cause the lead width to exceed the maximum “b” dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. Minimum space between protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.
10. Exact shape of each corner is optional.
11. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.
12. A1 is defined as the distance from the seating plane to the lowest point on the package body.
13. “N” is the number of terminal positions for the specified body size.
14. Values in inches are converted from mm and rounded to four decimal digits.
15. Drawing is not to scale.

Figure 98. LQFP176 - Footprint example

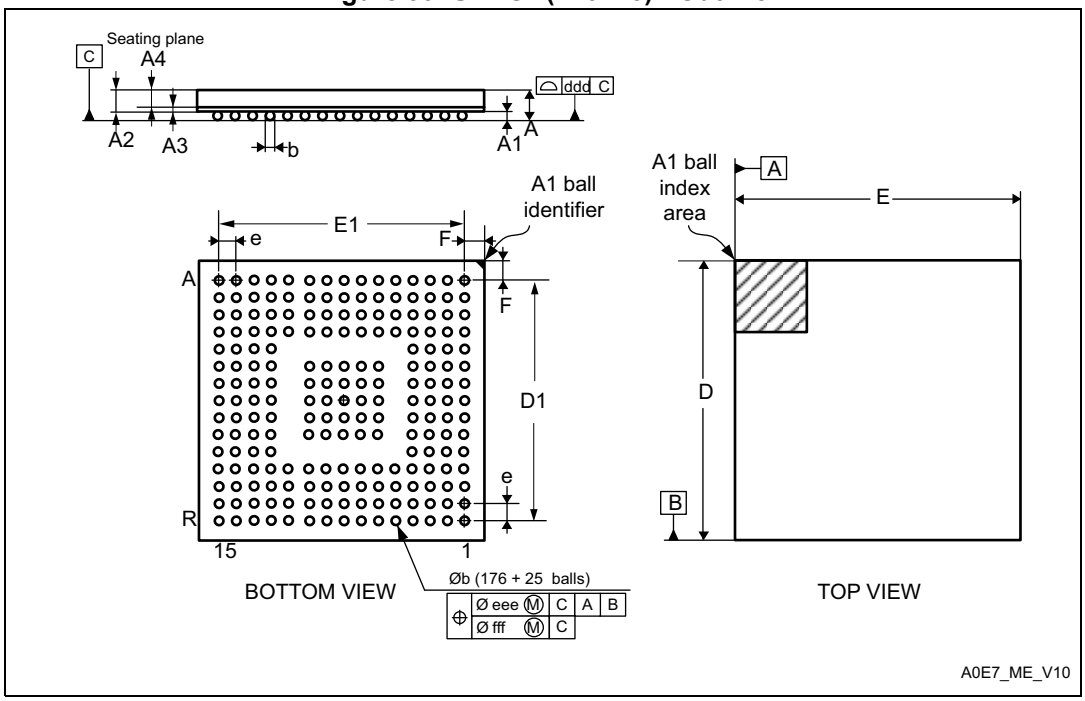


1. Dimensions are expressed in millimeters.

6.8 UFBGA(176+25) package information (A0E7)

This UFBGA is a 176+25-ball, 10 x 10 mm, 0.65 mm pitch, ultra fine pitch ball grid array package

Figure 99. UFBGA(176+25) - Outline



1. Drawing is not to scale.

Table 147. UFBGA(176+25) - Mechanical data

Symbol	Millimeters			Inches(1)		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	-	-	0.600	-	-	0.0236
A1	0.050	0.080	0.110	0.0020	0.0031	0.0043
A2	-	0.450	-	-	0.0177	-
A3	-	0.130	-	-	0.0051	-
A4	-	0.320	-	-	0.0126	-
b	0.240	0.290	0.340	0.0094	0.0114	0.0134
D	9.850	10.000	10.150	0.3878	0.3937	0.3996
D1	-	9.100	-	-	0.3583	-
E	9.850	10.000	10.150	0.3878	0.3937	0.3996
E1	-	9.100	-	-	0.3583	-
e	-	0.650	-	-	0.0256	-
F	-	0.450	-	-	0.0177	-
ddd	-	-	0.080	-	-	0.0031

Table 147. UFBGA(176+25) - Mechanical data (continued)

Symbol	Millimeters			Inches[1]		
	Min.	Typ.	Max.	Min.	Typ.	Max.
eee	-	-	0.150	-	-	0.0059
fff	-	-	0.050	-	-	0.0020

1. Values in inches are converted from mm and rounded to four decimal digits.

Figure 100. UFBGA(176+25) - Footprint example

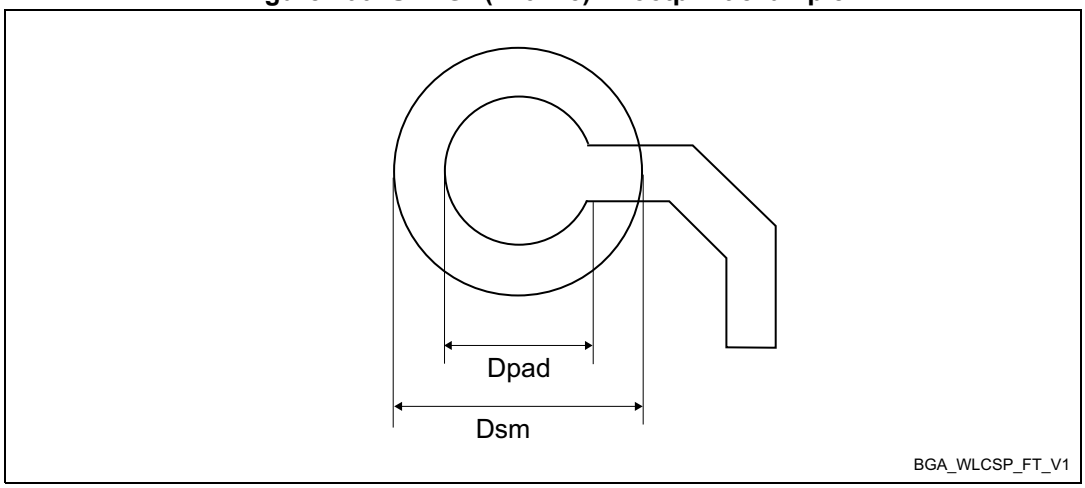


Table 148. UFBGA(176+25) - Example of PCB design rules (0.65 mm pitch BGA)

Dimension	Values
Pitch	0.65 mm
Dpad	0.300 mm
Dsm	0.400 mm typical (depends on the solder mask registration tolerance)
Stencil opening	0.300 mm
Stencil thickness	Between 0.100 mm and 0.125 mm
Pad trace width	0.100 mm

6.9 TFBGA225 package information (B04V)

This TFBGA is a 225-ball, 13 x 13 mm, 0.8 mm pitch, thin profile fine pitch ball grid array package.

Note: See list of notes in the notes section.

Figure 101. TFBGA225 - Outline(13)

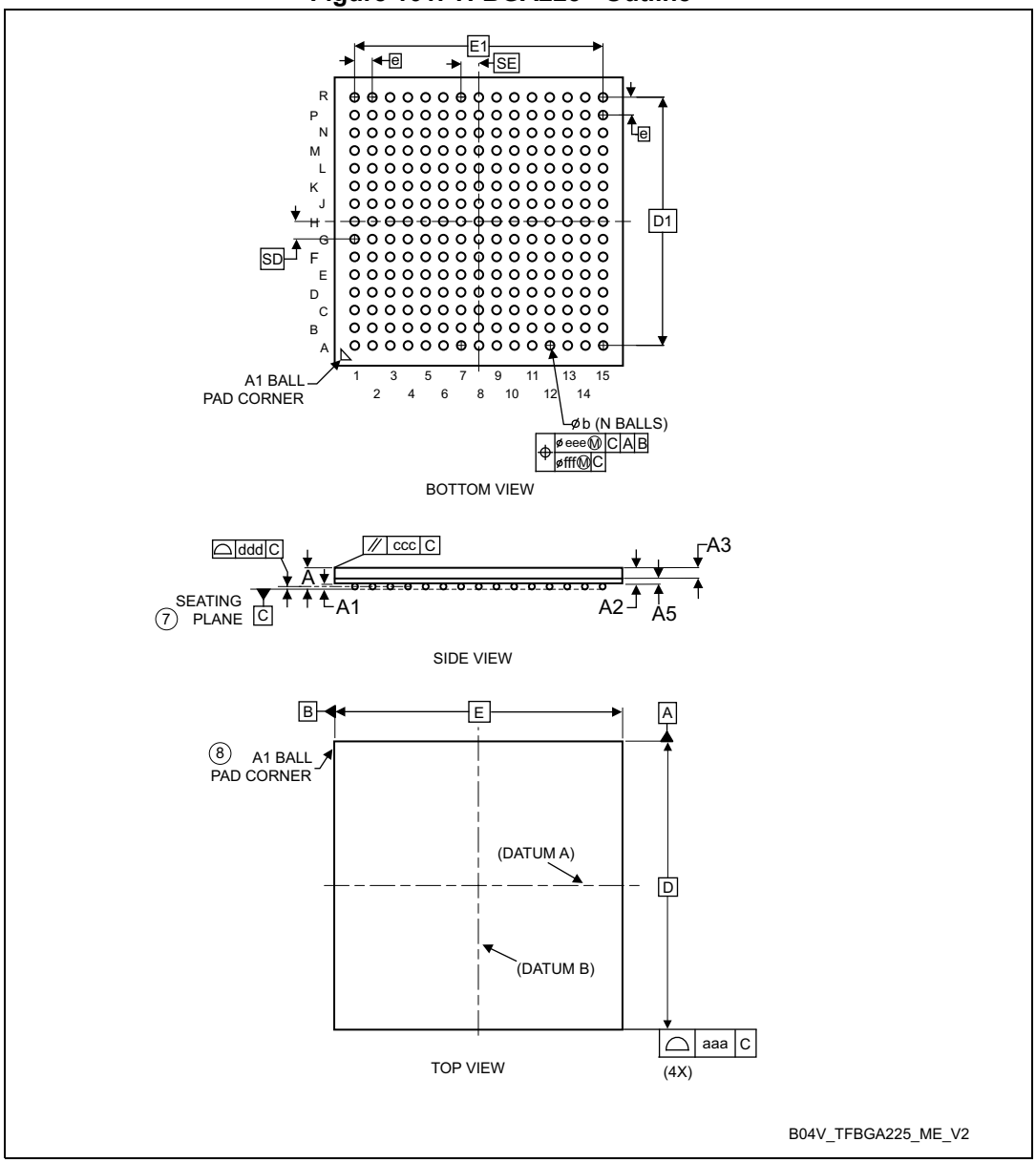


Table 149. TFBGA225 - Mechanical data

Symbol	Millimeters[1]			Inches[12]		
	Min	Typ	Max	Min	Typ	Max
A[2][3]	-	-	1.20	-	-	0.0472
A1[4]	0.15	-	-	0.0059	-	-
A2	-	0.76	-	-	0.0299	-
b[5]	0.35	0.40	0.45	0.0138	0.0157	0.0177
D[6]	13.00 BSC			0.5118 BSC		
D1	11.20 BSC			0.4409 BSC		
E	13.00 BSC			0.5118 BSC		
E1	11.20 BSC			0.4409 BSC		
e[9]	0.80 BSC			0.0315 BSC		
N[11]	225					
SD[12]	0.80 BSC			0.0315 BSC		
SE[12]	0.80 BSC			0.0315 BSC		
aaa	0.15			0.0059		
ccc	0.20			0.0079		
ddd	0.10			0.0039		
eee	0.15			0.0059		
fff	0.08			0.0031		

Notes:

1. Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.
2. TFBGA stands for Thin profile Fine pitch Ball Grid Array: 1.00mm < A ≤ 1.20mm / Fine pitch e < 1.00mm.
3. The profile height, A, is the distance from the seating plane to the highest point on the package. It is measured perpendicular to the seating plane.
4. A1 is defined as the distance from the seating plane to the lowest point on the package body.
5. Dimension b is measured at the maximum diameter of the terminal (ball) in a plane parallel to primary datum C.
6. BSC stands for BASIC dimensions. It corresponds to the nominal value and has no tolerance. For tolerances refer to form and position table.
7. Primary datum C is defined by the plane established by the contact points of three or more solder balls that support the device when it is placed on top of a planar surface.
8. The terminal (ball) A1 corner must be identified on the top surface of the package by using a corner chamfer, ink or metallized markings, or other feature of package body or

integral heat slug. A distinguish feature is allowable on the bottom surface of the package to identify the terminal A1 corner. Exact shape of each corner is optional.

9. e represents the solder ball grid pitch.
10. N represents the total number of balls on the BGA.
11. Basic dimensions SD and SE are defined with respect to datums A and B. It defines the position of the center ball(s) in the outer row or column of a fully populated matrix.
12. Values in inches are converted from millimeters and rounded to four decimal digits.
13. Drawing is not to scale.

Figure 102. TFBGA225 - Footprint example

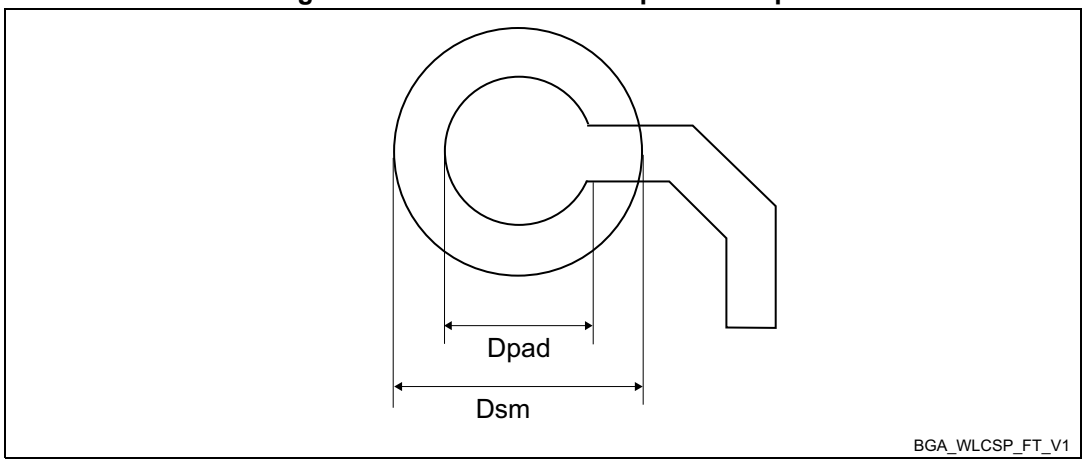


Table 150. TFBGA225 - Example of PCB design rules (0.8 mm pitch BGA)

Dimension	Values
Pitch	0.8 mm
Dpad	0.400 mm
Dsm	0.550 mm
Stencil opening	0.400 mm
Stencil thickness	0.125 to 0.100 mm

6.10 Package thermal characteristics

The maximum chip-junction temperature, T_{Jmax} in degrees Celsius, can be calculated using the following equation:

$$T_{Jmax} = T_{Amax} + (P_{Dmax} \times \Theta_{JA})$$

Where:

- T_{Amax} is the maximum ambient temperature in °C,
- Θ_{JA} is the package junction-to-ambient thermal resistance, in °C/W,
- P_{Dmax} is the sum of P_{INTmax} and $P_{I/Omax}$ ($P_{Dmax} = P_{INTmax} + P_{I/Omax}$),
- P_{INTmax} is the product of I_{DD} and V_{DD}, expressed in Watts. This is the maximum chip internal power.

$P_{I/Omax}$ represents the maximum power dissipation on output pins:

$$P_{I/Omax} = \sum (V_{OL} \times I_{OL}) + \sum((V_{DD} - V_{OH}) \times I_{OH}),$$

taking into account the actual V_{OL} / I_{OL} and V_{OH} / I_{OH} of the I/Os at low and high level in the application.

Table 151. Package thermal characteristic

Symbol	Parameter	Package	Value	Unit
Θ_{JA}	Thermal resistance junction-ambient	LQFP100 - 14 × 14 mm	31.9	°C/W
		WLCSP105 - 4.38 x 4.38 mm	38.9	
		LQFP144 - 20 × 20 mm	34.8	
		UFBGA144 - 10 x 10 mm	31.4	
		UFBGA169 - 7 x 7 mm	33.8	
		LQFP176 - 24 x 24 mm	33.5	
		UFBGA176 - 10 x 10 mm	32.1	
		TFBGA225 - 13 x 13 mm	29.6	
Θ_{JB}	Thermal resistance junction-board	LQFP100 - 14 × 14 mm	17.9	°C/W
		WLCSP105 - 4.38 x 4.38 mm	17.4	
		LQFP144 - 20 × 20 mm	23.6	
		UFBGA144 - 10 x 10 mm	19.1	
		UFBGA169 - 7 x 7 mm	19.2	
		LQFP176 - 24 x 24 mm	23.5	
		UFBGA176 - 10 x 10 mm	19.7	
		TFBGA225 - 13 x 13 mm	19	

Table 151. Package thermal characteristic (continued)

Symbol	Parameter	Package	Value	Unit
Θ_{JC}	Thermal resistance junction-case	LQFP100 - 14 × 14 mm	6.4	°C/W
		WLCSP105 - 4.38 x 4.38 mm	1.7	
		LQFP144 - 20 × 20 mm	7	
		UFBGA144 - 10 x 10 mm	7.4	
		UFBGA169 - 7 x 7 mm	7.8	
		LQFP176 - 24 x 24 mm	6.7	
		UFBGA176 - 10 x 10 mm	7.4	
		TFBGA225 - 13 x 13 mm	9.9	

6.10.1 Reference documents

- JESD51-2 Integrated Circuits Thermal Test Method Environment Conditions - Natural Convection (Still Air). Available from www.jedec.org.
- For information on thermal management, refer to "*Thermal management guidelines for STM32 32-bit Arm Cortex MCUs applications*" (AN5036) available from *www.st.com*.

7 Ordering information

Example: STM32 H 5E4 Z J T 7 Q TR

Device family

STM32 = Arm based 32-bit microcontroller

Product type

H = high performance

Device subfamily

5E4 = STM32H5E4xx without USB HS PHY
5E5 = STM32H5E5xx with USB HS PHY

Pin count

A = 169 balls
I = 176 pins / 176 +25 balls
L = 225 balls
V = 100 pins / 105 balls
Z = 144 pins / 144 balls

Flash memory size

J = 4 Mbytes
K = 3 Mbytes

Package

I = UFBGA, 7 x 7 mm, 0.50 mm pitch
H = TFBGA, 13 x 13 mm
K = UFBGA, 10 x 10 mm, 0.65 mm pitch
T = LQFP
Y = WLCSP

Temperature range

6 = Temperature range: -40 to 85 °C. Available only for the LDO option.

7 = Temperature range: -40 to 105 °C, and up to 125 °C at low dissipation. Available only for the SMPS option.

Dedicated topic

Q = dedicated pinout supporting SMPS step-down converter

Packing

TR = tape and reel

xxx = programmed parts

For a list of available options (such as speed or package) or for further information on any aspect of this device, contact the nearest ST sales office.

8 Important security notice

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9 Revision history

Table 152. Document revision history

Date	Revision	Changes
23-Feb-2026	1	Initial release.

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