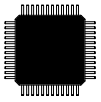
# STM32G56xxx

Datasheet

# Arm®Cortex®-M33 32-bit MCU + TrustZone® + FPU, 280 MHz, up to 512-Kbyte flash memory, 112-Kbyte RAM, cryptography, 111 ps 12 channel high-resolution timer, rich analog



TQFP48-EP (7 x 7 mm)
TQFP64-EP (10 x 10 mm)
LQFP80-EP (12 x 12 mm)
LQFP100-EP (14 x 14 mm)
LQFP128-EP (14 x 14 mm)

UFBGA121 (6 x 6 mm)

UFQFPN40 (5 x 5 mm)
UFQFPN48 (7 x 7 mm)

LQFP48 (7 x 7 mm)
LQFP64 (10 x 10 mm)
LQFP80 (12 x 12 mm)
LQFP100 (14 x 14 mm)
LQFP128 (14 x 14 mm)

| Product status | |
|---|---|
| STM32G564xx | STM32G563xx |
| STM32G564CC<br>STM32G564MC<br>STM32G564PC<br>STM32G564QC<br>STM32G564RC<br>STM32G564VC<br>STM32G564HC<br>STM32G564CB<br>STM32G564MB<br>STM32G564PB<br>STM32G564QB<br>STM32G564RB<br>STM32G564VB<br>STM32G564HB<br>STM32G564CE<br>STM32G564ME<br>STM32G564PE<br>STM32G564QE<br>STM32G564RE<br>STM32G564VE<br>STM32G564HE | STM32G563CE<br>STM32G563ME<br>STM32G563PE<br>STM32G563QE<br>STM32G563RE<br>STM32G563VE<br>STM32G563HE |

## Features

**Includes ST state-of-the-art patented technology.**

### Core

- Arm® Cortex®-M33 CPU with TrustZone®, FPU, frequency up to 280 MHz, MPU, 1136 CoreMark® (4.059 CoreMark®/MHz)

### Accelerators

- ART 8-Kbyte instruction cache allowing 0-wait-state execution from flash and external memories
- ART 4-Kbyte data cache for external memories
- Routine booster: SRAM1 (32-Kbyte) on instruction bus (CCM-SRAM)

### Memories

- Up to 512 Kbytes of embedded flash memory with ECC, 2 read-while-write banks
- Up to 48 Kbytes of flash memory per bank with high-cycling capability (100 Kcycles) for data flash
- 1 Kbyte OTP (one-time programmable)
- 112 Kbytes of SRAM with ECC (32-Kbyte SRAM1 (routine booster), 64-Kbyte SRAM2, 16-Kbyte SRAM3)
- One XSPI memory interface with on-the-fly decryption and support for serial PSRAM/NAND/NOR, hyper RAM / flash memory frame formats

### Mathematical acceleration

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

### Analog

- Three 12-bit ADCs with up to 5 Msps with 12-bit resolution (up to 39 channels) with hardware oversampling
- Eight 12-bit DAC channels
  - Two buffered external channels, 1 MSPS
  - Six unbuffered internal channels, 15 MSPS
- Eight ultrafast rail-to-rail analog comparators, 20 ns propagation delay
- Three operational amplifiers that can be used in PGA mode, all terminals accessible
- Internal voltage reference buffer (VREFBUF) supporting four output voltages (1.8 V, 2.048 V, 2.5 V, 2.9 V)
- Digital temperature sensor

**Programmable logic array (PLAY)**

- PLAY interface with 128 inputs and 16 outputs, 16 programmable logic elements (refer to PLAY specification in RM0514)

**Up to 26 timers**

- HRTIM (Hi-Resolution timer): 6 x 16-bit counters, 12 PWM outputs (12 outputs with 111 ps resolution)

  *Note: Only applicable for STM32G564xx devices.*
- 17 x 16-bit (including one low-power timer available in Stop mode and three motor control timers)
- 4 x 32-bit timers with up to four IC/OC/PWM or pulse counters and quadrature (incremental) encoder input
- Two watchdogs
- Two SysTick timers

**Security and cryptography**

- Arm® TrustZone® with Armv8-M mainline security extension
- Arm® TrustZone® and securable peripherals
- Flexible life cycle scheme with secure debug authentication
- Pre-configured immutable root of trust (STiRoT)
- SFI (secure firmware installation)
- Secure data storage with hardware unique key (HUK)
- Secure firmware upgrade support
- Live firmware upgrade
- Secure hide protection HDP (temporal isolation function)
- Two AES coprocessors including one with DPA resistance
- Public key accelerator, DPA resistant
- On-the-fly decryption of XSPI external memories (OTFDEC)
- HASH hardware accelerator
- True random number generator, NIST SP800-90B compliant
- CRC calculation unit, 96-bit unique ID
- Active tampers

**Communication interfaces**

- Up to four I2Cs, supporting Fm+ SMBUS 3.3(R)/PMBus®(R)
- One I3C
- Up to six U(S)ARTs (supporting ISO7816, LIN, IrDA, modem control modes, and up to three of them supporting SPI operating mode)
- One LPUART
- Up to three SPIs, two of which are capable to support audio-class-accuracy full-duplex I2S interface (using an internal audio PLL or external clock).

  *Note: Additional SPI interfaces can be supported if USART is configured in Synchronous mode (one additional SPI with XSPI).*
- Three FDCANs
- One USB Type-C® / USB Power Delivery r3.1
- Two position encoder interfaces POSENC (with Hiperface DSL, EnDAT 3 support)

**2 × DMA controllers to offload the CPU**

- Dual-port DMAs with FIFO

**Reset and supply management**

- 2.7 V to 3.6 V supply voltage
- POR, PDR, PVD, and AVD
- Embedded regulator (LDO) or SMPS step-down converter regulator with configurable scalable output to supply the digital circuitry

**Clock management**

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

**General-purpose inputs/outputs**

- Up to 103 fast I/Os with interrupt capability (most 5 V tolerant)

**Low-power modes**

- Sleep, Stop, and Standby modes
- 32 backup registers (32-bit)
- Calendar RTC with alarm, periodic wake-up from Stop/Standby

**Debug**

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

**Packages**

- ECOPACK2 compliant packages (all)
- Exposed pad option available for industrial applications (selected packages)
- Ambient temperature range: from -40°C up to 125°C (Tj = 140°C)

# 1 Introduction

This document provides information on STM32G56xxx devices, such as description, functional overview, pin assignment and definition, electrical characteristics, packaging, and ordering information.

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

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# 2 Description

The STM32G56xxx devices are high-performance microcontrollers of the STM32G5 series, based on the high-performance Arm® Cortex®-M33 32-bit RISC core. They operate at a frequency of up to 280 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.

The Cortex®-M33 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 512 Kbytes of dual bank flash memory and 112 Kbytes of SRAM), one XSPI memory interface (at least one XSPI available on all packages), and an extensive range of enhanced I/Os and peripherals connected to three APB buses, four 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®. It embeds 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: a fast AES coprocessor, a secure AES coprocessor with DPA resistance and hardware unique key that can be shared by hardware with fast AES, a public key accelerator (PKA), DPA resistant an on-the-fly decryption engine for XSPI external memories, a 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 erases in case of attack.

The devices offer three fast 12-bit ADCs, eight comparators, three operational amplifiers, eight DAC channels (two external, six internal), an internal voltage reference buffer, a low-power RTC, four 32-bit general-purpose timers, three 16-bit PWM timers dedicated to motor control, nine 16-bit general-purpose timers, four 16-bit basic timers, one 16-bit low-power timer and one high-resolution timer with 111 ps resolution.

The devices also feature standard and advanced communication interfaces, namely: four I2Cs, one I3C, three SPIs, two I2Ss, three USARTs, three UARTs and one low-power UART, three FDCANs, one USB full-speed, one USB Type-C® / USB power delivery controller, two position encoders POSENC, one programmable logic array PLAY.

The devices operate in the -40 to +85 °C (+140 °C junction), and -40 to +105°C (+140°junction) and -40 to +125 °C (+140 °C junction) temperature ranges from a 2.7 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 including an analog independent supply input for ADCs, DACs, OPAMPs and comparators. The RTC functionality and backup 32 x 32-bit registers are preserved in Standby mode.

The devices are offered in packages from 40 to 128 pins.

Packages are available with LDO or SMPS supply options for the $V_{CORE}$. (The SMPS option is available only for LQFP128 package.)

Refer to Table 1 for the list of peripherals available on each part number.

**Table 1. STM32G564xx device features and peripheral counts**

| Peripherals | | STM32G564HE | STM32G564CE | STM32G564RE | STM32G564ME | STM32G564VE | STM32G564QE | STM32G564PE |
|---|---|---|---|---|---|---|---|---|
| Flash memory (Kbytes) | | 512 = STM32G564xE<br>256 = STM32G564xC<br>128 = STM32G564xB | | | | | | |
| SRAM | System (Kbyte) | 112 (32 + 64 + 16) | | | | | | |
| | Backup 32-bit registers | 32 | | | | | | |
| XSPI | | 1 | | | | | | |
| Timers | HRTIM | 1 | | | | | | |
| | HRTIM high resolution channels (1) | 12 | 4/7/7 | 12 | | | | |
| | HRTIM standard resolution channels | 0 | | | | | | |
| | Advanced control | 3 (16-bit) | | | | | | |
| | General purpose | 4 (32-bit) and 9 (16-bit) | | | | | | |
| | Basic | 4 (16-bit) | | | | | | |
| | Lowpower | 1 (16-bit) | | | | | | |
| | SysTick timer | 2 | | | | | | |
| | Watchdog timers | 2 | | | | | | |
| Communication interfaces | SPI/I2S | 2/1 | 3/2 | | | | | |
| | I2C | 4 | | | | | | |
| | I3C | 1 | | | | | | |
| | USART | 3 | | | | | | |
| | UART | 3 | | | | | | |
| | LPUART | 1 | | | | | | |
| | POSENC | 2 | | | | | | |
| | FDCAN | 3 | | | | | | |
| | USB | No | Yes | | | | | |
| | UCPD | No | Yes | | | | | |
| PLAY | | 1 | | | | | | |
| CORDIC co-processor | | 1 | | | | | | |
| Filter mathematical accelerator (FMAC) | | 2 | | | | | | |
| Real time clock (RTC) | | Yes | | | | | | |
| Tamper pins | | 3 | 4 | | | | | |
| Active tampers | | 1 | 2 | | | | | |

| Peripherals | | STM32G564HE | STM32G564CE | STM32G564RE | STM32G564ME | STM32G564VE | STM32G564QE | STM32G564PE |
|---|---|---|---|---|---|---|---|---|
| True random number generator | | Yes | | | | | | |
| SAES, AES | | Yes | | | | | | |
| Public key accelerator (PKA) | | Yes | | | | | | |
| HASH (SHA-512) | | Yes | | | | | | |
| On-the-fly-decryption for XSPI (OTFDEC) | | Yes | | | | | | |
| GPIOs [1] | | 32 | 34/37/37 | 49/52 | 62/67 | 81/86 | 103/103/100 | 99 |
| Wake-up pins | | 2 | 4 | 6 | 6 | 7 | 7 | 7 |
| ADC | 12-bit ADCs | 3 | | | | | | |
| | Number of channels[1] ) | 16 | 19/19/19 | 25/29 | 33/35 | 37/37 | 39/39/39 | 38 |
| DAC | External channels | 2 | | | | | | |
| | Internal channels | 6 | | | | | | |
| COMP | | 5 | 8 | | | | | |
| OPAMP | | 3 | | | | | | |
| Internal voltage reference buffer | | Yes | | | | | | |
| Maximum CPU frequency | | 280 MHz | | | | | | |
| Operating voltage | | 2.7 to 3.6 V | | | | | | |
| Operating temperature | | Ambient operating temperature: – 40 to 85°C / – 40 to 105°C / – 40 to 125°C<br>Junction temperature: – 40 to 140°C | | | | | | |
| Package | | UFQFPN40 | LQFP48/ UFQFPN48/ TQFP48-EP | LQFP64/ TQFP64-EP | LQFP80/ LQFP80-EP | LQFP100/ LQFP100-EP | LQFP128/ LQFP128-EP/ LQFP128 SMPS | UFBGA121 |

1. *Depends on the package.*

**Table 2. STM32G563xx device features and peripheral counts**

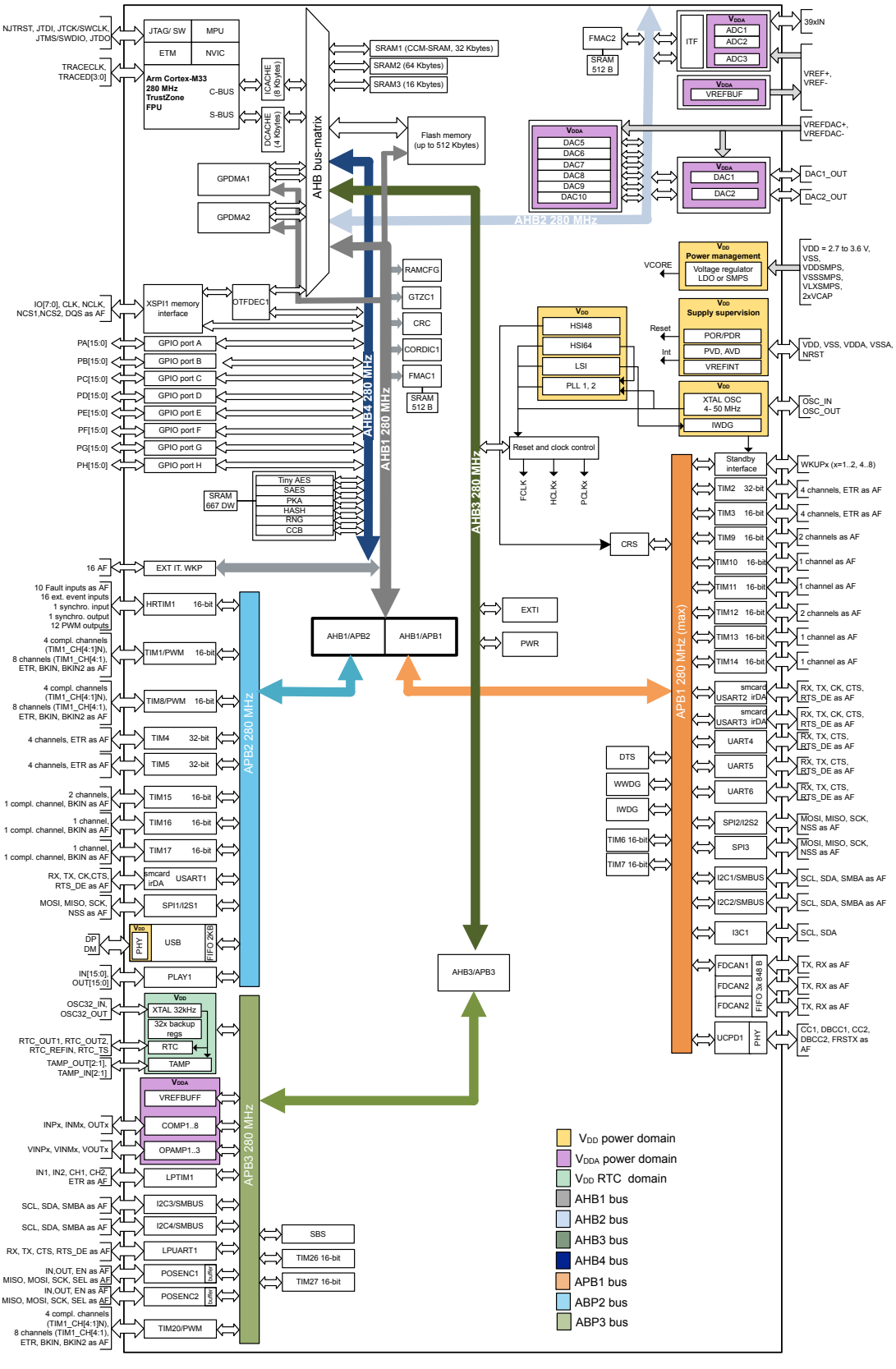
| Peripherals | | STM32G563HE | STM32G563CE | STM32G563RE | STM32G563ME | STM32G563VE | STM32G563QE | STM32G563PE |
|---|---|---|---|---|---|---|---|---|
| Flash memory (Kbytes) | | 512 = STM32G563xE<br>256 = STM32G563xC<br>128 = STM32G563xB | | | | | | |
| SRAM | System (Kbyte) | 112 (32 + 64 + 16) | | | | | | |
| | Backup 32-bit registers | 32 | | | | | | |
| XSPI | | 1 | | | | | | |
| Timers | HRTIM | 0 | | | | | | |
| | HRTIM high resolution channels | 0 | | | | | | |
| | HRTIM standard resolution channels | 0 | | | | | | |
| | Advanced control | 3 (16-bit) | | | | | | |
| | General purpose | 4 (32-bit) and 9 (16-bit) | | | | | | |
| | Basic | 4 (16-bit) | | | | | | |
| | Lowpower | 1 (16-bit) | | | | | | |
| | SysTick timer | 2 | | | | | | |
| | Watchdog timers | 2 | | | | | | |
| Communication interfaces | SPI/I2S | 2/1 | 3/2 | | | | | |
| | I2C | 4 | | | | | | |
| | I3C | 1 | | | | | | |
| | USART | 3 | | | | | | |
| | UART | 3 | | | | | | |
| | LPUART | 1 | | | | | | |
| | POSENC | 2 | | | | | | |
| | FDCAN | 3 | | | | | | |
| | USB | No | Yes | | | | | |
| | UCPD | No | Yes | | | | | |
| PLAY | | 1 | | | | | | |
| CORDIC co-processor | | 1 | | | | | | |
| Filter mathematical accelerator (FMAC) | | 2 | | | | | | |
| Real time clock (RTC) | | Yes | | | | | | |
| Tamper pins | | 3 | 4 | | | | | |
| Active tampers | | 1 | 2 | | | | | |

| Peripherals | | STM32G563HE | STM32G563CE | STM32G563RE | STM32G563ME | STM32G563VE | STM32G563QE | STM32G563PE |
|---|---|---|---|---|---|---|---|---|
| True random number generator | | Yes | | | | | | |
| SAES, AES | | Yes | | | | | | |
| Public key accelerator (PKA) | | Yes | | | | | | |
| HASH (SHA-512) | | Yes | | | | | | |
| On-the-fly-decryption for XSPI (OTFDEC) | | Yes | | | | | | |
| GPIOs (1) | | 32 | 34/37/37 | 49/52 | 62/67 | 81/86 | 103/103/100 | 99 |
| Wake-up pins | | 2 | 4 | 6 | 6 | 7 | 7 | 7 |
| ADC | 12-bit ADCs | 3 | | | | | | |
| | Number of channels (1) | 16 | 19/19/19 | 25/29 | 33/35 | 37/37 | 39/39/39 | 38 |
| DAC | External channels | 2 | | | | | | |
| | Internal channels | 6 | | | | | | |
| COMP | | 5 | 8 | | | | | |
| OPAMP | | 3 | | | | | | |
| Internal voltage reference buffer | | Yes | | | | | | |
| Maximum CPU frequency | | 280 MHz | | | | | | |
| Operating voltage | | 2.7 to 3.6 V | | | | | | |
| Operating temperature | | Ambient operating temperature: – 40 to 85°C / – 40 to 105°C / – 40 to 125°C<br>Junction temperature: – 40 to 140°C | | | | | | |
| Package | | UFQFPN40 | LQFP48/ UFQFPN48/ TQFP48-EP | LQFP64/ TQFP64-EP | LQFP80/ LQFP80-EP | LQFP100/ LQFP100-EP | LQFP128/ LQFP128-EP LQFP128 SMPS | UFBGA121 |

1. *Depends on the package.*

Figure 1 shows the general block diagram of the device family.

**Figure 1. STM32G56xxx block diagram**



# 3 Functional overview

## 3.1 Arm® Cortex®-M33 with FPU

The Cortex®-M33 with FPU is a highly energy-efficient processor designed for microcontrollers and deeply embedded applications, especially those requiring efficient security.

The Cortex®-M33 processor delivers a high-computational performance with low-power consumption and an advanced response to interrupts. It features:

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

Refer to Figure 1 for more details.

## 3.2 ART Accelerator (ICACHE and DCACHE)

### 3.2.1 Instruction cache (ICACHE)

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

Some specific features like dual controller ports, hit-under-miss, and critical-word-first refill policy, allow close to zero-wait-state performance in most use cases.

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)
  - One 32-bit AHB target port for control (input from AHB peripherals interconnect, for ICACHE register access)
  - Master2 port performing refill requests to external memories (external flash memory and RAMs through XSPI interface)
  - A second slave port dedicated to ICACHE registers access
- Close to zero wait states instructions/data access performance:
  - Zero wait-state on cache hit
  - Hit-under-miss capability, allowing to serve processor requests (access to cached data) 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 allowing to decouple internal and external memory traffic, respectively, on fast and slow buses, minimizing impact on interrupt latency
  - Optimum 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
- Memory address remap
- 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 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 DCACHE is introduced on S-AHB system bus of Cortex®-M33 processor to improve the performance of data traffic to/from external memories.

Some specific features like hit-under-miss and critical-word-first refill policy allow optimum performance on external memories data accesses.

DCACHE offers the following features:

- Multibus 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 XSPI interface)
  - A second slave port dedicated to DCACHE registers access
- Close to 0 wait-states instructions/data access performance:
  - 0 wait state on cache hit
  - Hit-under-miss capability, allowing to serve processor requests (access 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)
  - Hit-under-miss capability, allowing to serve processor requests (access to cached data) while a line refill (due to a previous cache miss) is still ongoing
  - Read and Write-back always allocated
  - Write-through always nonallocated (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 access to the memory and to prevent one task to accidentally corrupt the memory or the resources used by any other active task. This memory area is organized in 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 some critical or certified code must be protected against the interference of other tasks. It is usually managed by an RTOS (real-time operating system).

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

## 3.4 Embedded flash memory

The devices feature up to 512 Kbytes of embedded flash memory that is available for storing programs and data. The flash memory supports high-cycle data area of up to 100 Kcycles.

The flash memory interface features:

- Dual-bank operating modes
- Read-while-write (RWW)
- Bank swap remapping feature to facilitate firmware upgrade

This allows a read operation to be performed in one bank while an erase or program operation is performed in the other bank. Each bank contains up to 32 pages of 8 Kbytes.

The flash memory embeds 1-Kbyte OTP (one-time programmable) memory for user data and up to 96 Kbytes supporting high cycling capability (100 Kcycles) to be used for data (EEPROM emulation).

The whole nonvolatile 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 memory 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 pages, or malicious flash memory erasing.

For that purpose flash memory implements the following protection mechanisms:

- TrustZone backed watermark and block security protection
- Temporal isolation protection (HDP)
- Configuration protection
- User flash memory write protection
- Device nonvolatile security life cycle and application boot state management
- OTP locking
- Each flash memory page can be programmed on-the-fly as privileged or unprivileged.

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

## 3.5 Embedded SRAMs

Three SRAMs are embedded in the STM32G56xxx devices, each with specific features. SRAM1, SRAM2, and SRAM3 are the main SRAMs.

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

- SRAM1: 32-Kbyte with ECC (CCM-SRAM)
- SRAM2: 64-Kbyte with ECC
- SRAM3: 16-Kbyte with ECC

*Note: The ECC is supported by SRAM1, SRAM2, SRAM3 when enabled with the SRAM1_ECC, SRAM2_ECC, SRAM3_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, and SRAM3 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.

### 3.5.2 SRAM privilege protection

The SRAM1, SRAM2, and SRAM3 can be programmed as privileged or nonprivileged by blocks, using the MPCBB. The granularity of SRAM privilege block based is a page of 512 bytes.

## 3.6 Security overview

The STM32G56xxx devices 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.

The sensitive assets such as keys or secret code can be protected when opening the debug mode. The protection is enabled by code protection and hardware keys storage solutions where all *root of trust* can be protected thanks to hardware mechanisms.

Alternatively, a partial or a full regression can be launched in order to allow a debugging. Regressions are enabled by a debug authentication method.

STM32G56xxx devices feature a preconfigured immutable root of trust (STiRoT) which is hosted in the system flash memory. The STiRoT allows a reduction of development efforts and eases security certifications such as PSA or SESIP.

The STM32G56xxx devices design also permits the developers to introduce their own root of trust solution (OEMiRoT), including their installation in a nontrusted environment thanks to a secure firmware install (SFI) solution.

The STM32G56xxx devices 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), and applications execution.

STM32G56xxx devices embed a hardware key storage solution with the following characteristics:

- Feature a dedicated flash memory area per boot stages with access-control based on HDPL
- The protected assets can be stored encrypted with a derived key related to the current execution context (HDPL, regression counter called EPOCH).
- One crypto accelerator hardware DPA resistant (SAES), connected via hardware key bus to a non-DPA protected accelerator.

STM32G56xxx devices are powered by an Arm Cortex®-M33 microcontroller, which is associated with all the TrustZone® isolation infrastructure. This design permits to benefit from a runtime isolation to run secure applications.

## 3.7 Boot modes

At startup, a BOOT0 pin and BOOTADD/SBOOTADD 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
  - ST immutable root of trust (STiRoT)
  - 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, SPI, FDCAN, I2C, or USB in device mode through the DFU (device firmware upgrade).

Refer to the application note *Introduction to system memory boot mode on STM32 MCUs* (AN2606) for more details.

#### Embedded root security services (RSS)

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

Refer to the application note *Introduction to secure firmware install (SFI) for STM32 MCUs* (AN4992) for more details.

#### Embedded immutable root of trust (STiRoT)

The STiRoT embedded in the system memory, programmed by ST during production. STiRoT is the immutable root of trust managing the secure boot and secure install of the first updatable level to execute in a boot sequence.

#### Embedded debug authentication (ST-DA)

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

### 3.7.1 STM32G56xxx boot modes

Refer to Table 3 and Table 4, respectively, provide the detail of the boot mode when TrustZone is disabled (TZEN = 0xC3) and enabled (TZEN = 0xB4).

**Table 3. STM32G56xxx boot mode when TrustZone is disabled (TZEN = 0xC3)**

| PRODUCT_STATE | BOOT0 pin | BOOT_UBE FLASH_OP TSR[29:22] | Boot address option-byte selection | Bootarea | ST programmed default value |
|---|---|---|---|---|---|
| Open | 0 | NA | BOOTADD | Boot address defined by user option byte BOOTADD | Flash memory: 0x0800 0000 |
| | 1 | NA | NA | Bootloader | Bootloader |
| Provisioning | x | NA | NA | RSS | RSS |
| Provisioned, Closed, Locked | x | NA | BOOTADD | Boot address defined by user option byte BOOTADD | Flash memory: 0x0800 0000 |

When TrustZone is disabled (TZEN=0xC3), the BOOTADD is used to modify the boot address. A unique boot entry selection is supported by BOOT_LOCK option.

**Table 4. STM32G56xxx boot mode when TrustZone is enabled (TZEN = 0xB4)**

| PRODUCT_STATE | BOOT0 pin | BOOT_UBE FLASH_OP TSR[29:22] | Bootaddress option-byte selection | Boot area | ST programmed default value |
|---|---|---|---|---|---|
| Open | 0 | x | SBOOTADD | Bootaddress defined by user option byte SBOOTADD | Flash memory: 0x0C00 0000 |
| - | 1 | 0xB4 | NA | Bootloader | Bootloader |
| - | 1 | 0xC3 | NA | STiRoT | STiRoT |
| Provisioning | x | NA | NA | RSS | RSS |
| Provisioned, TZ_Closed, Closed, Locked | x x | 0xC3 | STiRoT | STiRoT | STiRoT |
| | | 0xB4 | SBOOTADD | Bootaddress defined by user option byte SBOOTADD | Flash memory: 0x0C00 0000 |

When TrustZone is enabled (TZEN=0xB4), the boot space must be in secure area. The SBOOTADD option bytes are used to select the boot secure memory address. A unique boot entry option can be selected by setting the SBOOT_LOCK option.

## 3.8 Global privilege controller (GTZC)

GTZC is used to configure TrustZone® and privileged attributes within the full system. The GTZC includes three different subblocks:

- TZSC:TrustZone security controller:
  This subblock 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:TTrustZone® illegal access controller:
  This subblock gathers all security illegal access events in the system and generates a secure interrupt towards NVIC.
- MPCBB:MPCBB: block-based memory protection controller:
  This subblock 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 are 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 peripheral memory space are aliased twice for secure and nonsecure states. However, the external memory space is not aliased

## 3.10 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

### 3.10.1 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, the 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:
  - XSPI 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 a secure and nonsecure state.
- TZIC: All illegal access interrupts are disabled after reset.

## 3.11 Power supply management

The PWR (power controller) main features are:

- Power supplies and supply domains
  - Core domain ($V_{CORE}$)
  - $V_{DD}$ domain
  - RTC domain (on $V_{DD}$) - active in Standby mode
  - Analog domain ($V_{DDA}$): ADC, DAC, COMP, OPAMP, VREFBUF (reference voltages for ADC and DAC: VREF+/VREF-, VREFDAC+/VREFDAC-)
  - SMPS power stage ($V_{DDSMPS}$, available only on SMPS packages)
- System supply voltage regulation
  - SMPS step-down converter
  - Voltage regulator (LDO)
- Power supply supervision
  - POR/PDR monitor
  - PVD monitor
  - AVD monitor
  - Out of functional range temperature monitoring
  - Maximum $V_{DD}$ voltage monitoring
- Power management
  - Operating modes
  - Voltage scaling control
  - Low-power modes
- TrustZone® security and privileged protection

### 3.11.1 Power supply schemes

The devices require a 2.7 V to 3.6 V $V_{DD}$ operating voltage supply. Several independent supplies can be provided for specific peripherals:

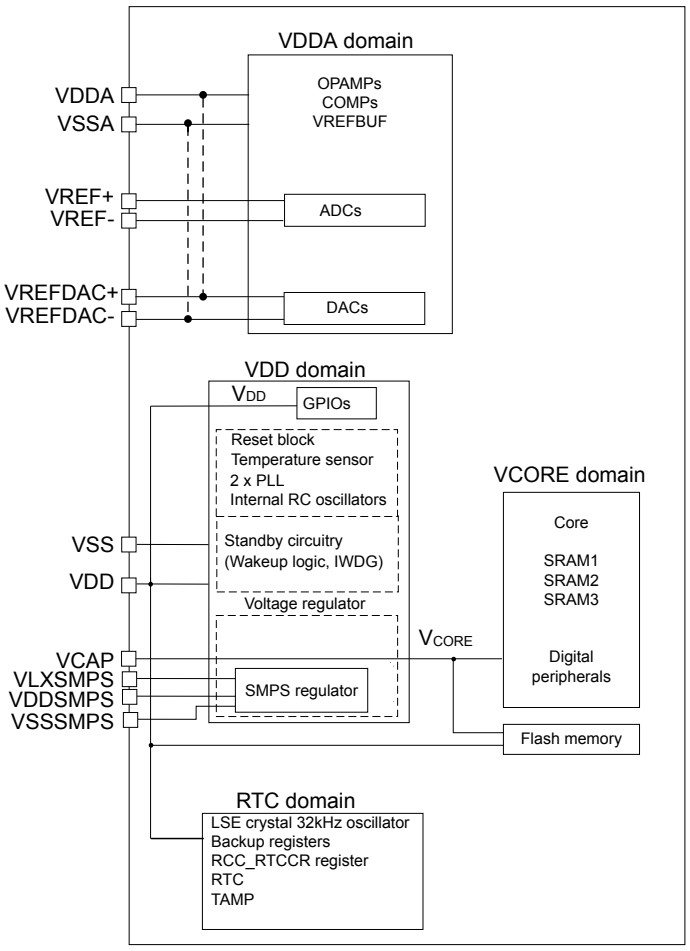
- $V_{DD}$ = 2.7 V to 3.6 V
  $V_{DD}$ is the external power supply for the I/Os, the internal regulator, and the system analog such as reset, power management and internal clocks. It is provided externally through the VDD/VSS pins.
  $V_{DD}$ is the power supply for RTC, LSE, external clock 32 kHz oscillator, and backup registers. Packages with exposed pad (TQFP-EP/LQFP-EP) have common connection to $V_{SS}$ on the exposed pad.
- $V_{DDA}$ = 2.7 V to 3.6 V
  $V_{DDA}$, $V_{SSA}$ are the external analog power supplies for ADCs, DACs, COMPs, OPAMPs, and VREFBUF. The $V_{DDA}$ voltage level is independent from the $V_{DD}$ voltage and must preferably be connected to $V_{DD}$ when these peripherals are not used.
- $V_{DDSMPS}$ = 2.7 V to 3.6 V
  $V_{DDSMPS}$, $V_{SSSMPS}$ are the external power supplies for the SMPS step-down converter. $V_{DDSMPS}$ is provided externally through the VDDSMPS supply pin and must be connected to the same supply as 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.
- $V_{REF+}$ / $V_{REF-}$
  $V_{REF+}$ / $V_{REF-}$ is the input reference voltage for ADCs. It is also the output of the internal voltage reference buffer when enabled (VREFBUF).
  $V_{REF+}$ can be grounded when ADCs are not active.
  VREF+ and VREF- pins are not available on all packages. When not available, they are bonded to VDDA and VSSA, 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 VSSA.
- $V_{REFDAC+}$ / $V_{REFDAC-}$
  $V_{REFDAC+}$ / $V_{REFDAC-}$ is the input reference voltage for DACs.
  $V_{REFDAC+}$ can be grounded when DACs are not active.
  VREFDAC+ and VREFDAC- pins are not available on all packages. When not available, they are bonded to VDDA and VSSA, respectively.
  $V_{REFDAC-}$ must always be equal to $V_{SSA}$

Depending upon the package, the devices embed an LDO regulator 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 pins, with an external capacitor of 10 µF for each VCAP pin (typical). The SMPS requires an external coil. The LDO regulator generates this voltage on VCAP pins connected to external capacitors of 2.2 µF each (typical). The SMPS requires an external capacitor 220 pF in series with an 18 Ω resitor between VLXSMPS and VSSSMPS pins.

Regulators can provide three different voltages (voltage scaling), and can operate in Stop modes.

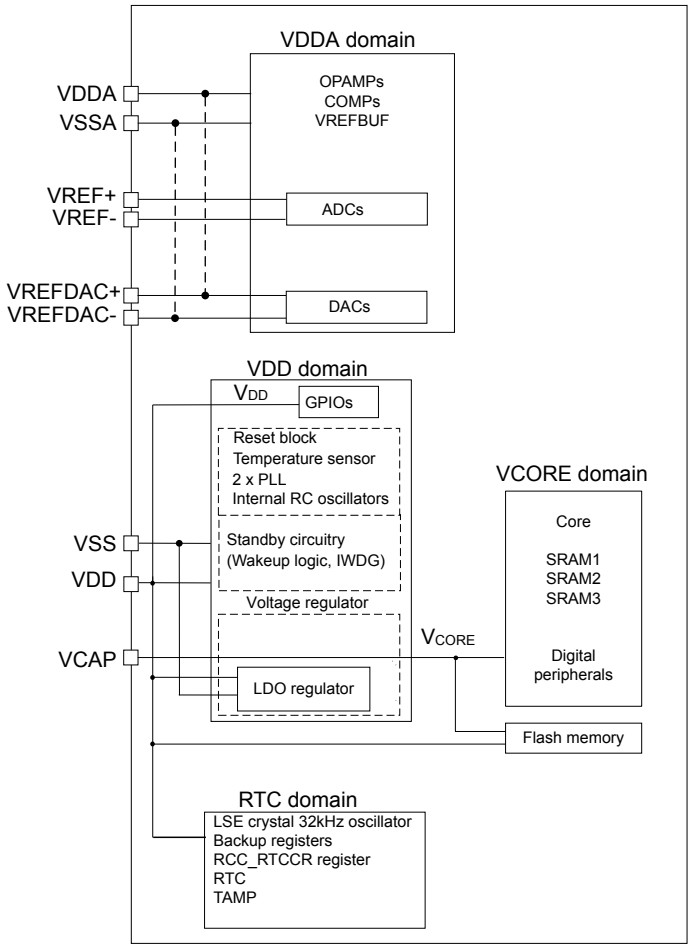
In addition to the LDO or SMPSregulator that provides the $V_{CORE}$ supply, the devices support LDO Bypass mode on all non-SMPS packages. In Bypass mode, the $V_{CORE}$ supply is provided from the external power supply to VCAP pins. In this configuration, the device is started in standard LDO mode but the external power supply must provide $V_{CORE}$ voltage to VCAP pins at a level always higher than the output from the internal LDO regulator. The default $V_{CORE}$ startup range is VOS2, therefore the external voltage during startup must be at higher $V_{COREEXT1}$ or $V_{COREEXT0}$ levels (refer to the product datasheet). The external supply voltage for $V_{CORE}$ must reach this correct level while $V_{DD}$ reaches the $V_{POR}$ threshold level + $t_{RSTTEMPO}$ temporization time. $V_{CORE}$ voltage must be always lower than $V_{DD}$ voltage (there is a recommendation to put Schottky diode between VCAP and VDD pins to avoid current injection from $V_{CORE}$ to $V_{DD}$). The firmware must then disable the internal LDO regulator by setting the BYPASS bit in the PWR_SCCR register and continue to supply $V_{CORE}$ only from the external power supply. The external power supply level must follow $V_{CORE}$ voltage requirements for the selected operation frequency ranges: $V_{COREEXT1}$ (for $f_{HCLK}$ < 220 MHz, $T_{jmax}$ = 140°C) or $V_{COREEXT0}$ (for $f_{HCLK}$ < 280 MHz, Tjmax = 105°C). VOS[1:0] bits (in PWR_VOSCR register) must be set to VOS0 range (VOS[1:0] = 3) after setting BYPASS = 1 and before increasing the system frequency above 170 MHz. This VOS0 setting must be used for any operating conditions in Bypass mode. Standby mode must not be used in Bypass mode. The lowest supported power mode in Bypass mode.

Figure 2. **STM32G56xxx power supply overview (with SMPS)**




DT72285V2

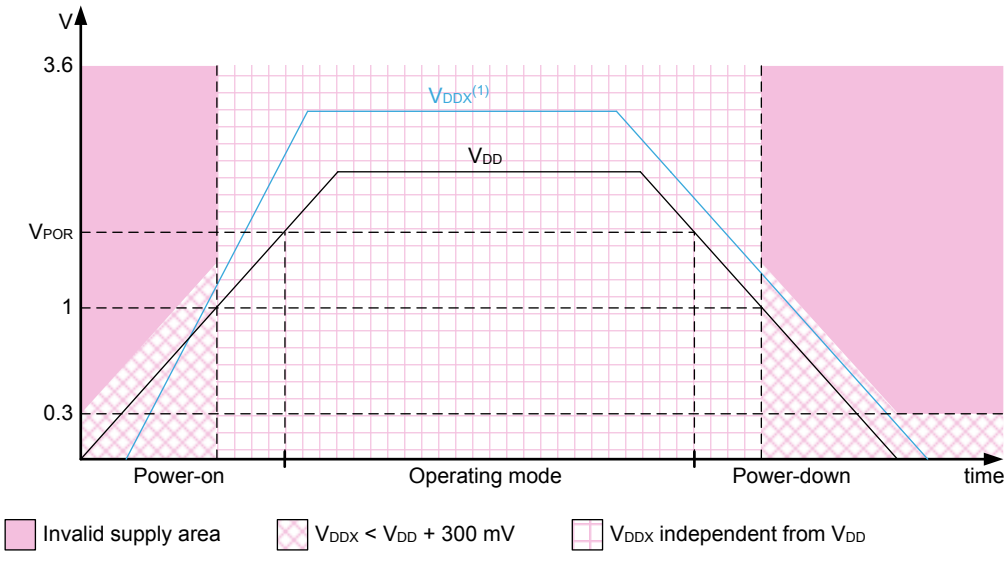
Figure 3. **STM32G56xxx power supply overview (with LDO)**




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 ($V_{DDA}$) 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 4. **Power-up/down sequence**




### 3.11.2 Power supply supervisor

The devices have an integrated ultra-low-power power-on reset (POR) active in all modes. The POR 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 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 (AVD) that compares the independent supply voltage $V_{DDA}$ 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($V_{CORE}$) with CPU and peripherals running at up to 280 MHz
- VOS1($V_{CORE}$) with CPU and peripherals running at up to 240 MHz
- VOS2($V_{CORE}$) with CPU and peripherals running at up to 170 MHz

### 3.11.3 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**

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

- **Stop modes**

Stop mode achieves the lowest power consumption while retaining the content of SRAMand registers. All clocks in the VCORE domain are stopped, the PLL, 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 is HSI up to 64 MHz, depending on software configuration.

- **Standby mode**

The Standby mode is used to achieve the lowest power consumption. The PLL, the HSI, 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 POR always remains active in Standby mode.

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

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

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

The system clock after wake-up is HSI at 64 MHz.

### 3.11.4 Reset mode

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

### 3.11.5 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

Some of the PWR configuration bits security is 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 RTC domain write protection is secure when the RTC is secure.

## 3.12 Peripheral interconnect matrix

Several peripherals have direct connections between them, that allow autonomous communication between them and 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.

## 3.13 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:** in order 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.
  - A 64 MHz high-speed internal RC oscillator (HSI), trimmable by software, can supply a PLL.
  - System PLL, which can be fed by HSE or HSI, with a maximum frequency at 280 MHz.

- **RC48 with clock recovery system (HSI48):** internal48 MHz clock source (HSI48) can be used to drive the USB or RNG.
- **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.
  - 32kHz 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. Two PLLs, each having three independent outputs allowing the highest flexibility, can generate independent clocks for the ADC, USB, RNG, FDCAN, and XSPI.
- **Startup clock:** after reset, the microcontroller restarts by default with an internal 32MHz 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 an 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):** it outputs one of the internal clocks for external use by the application.

Several prescalers allow AHB and APB frequency configuration. The maximum frequency of the AHB and the APB clock domains is 280 MHz.

### 3.13.1 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.

## 3.14 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. This automatic trimming is based on the external synchronization signal. This signal is either derived from usb SOF signalization, from the LSE oscillator, from an external signal on the CRS_SYNC pin or generated by user software. For faster lock-in during startup, automatic trimming and manual trimming action can be combined.

## 3.15 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.

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

### 3.15.1 GPIOs TrustZone® security

Each I/O pin of the 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.

## 3.16 Multi-AHB bus matrix

A 32-bit multi-AHB bus matrix interconnects all the masters (CPU, GPDMA1, GPDMA2) and the slaves (flash memory, XSPI, SRAMs, AHB, and APB) peripherals. It also ensures a seamless and efficient operation even when several high-speed peripherals work simultaneously.

## 3.17 General purpose direct memory access controller (GPDMA)

The GPDMA controller is a bus controller and system peripheral.

The GPDMA is 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 controller
- 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 nontime-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
- 8 concurrent DMA channels:
  - Per channel FIFO for queuing source and destination transfers
  - Intrachannel DMA transfers chaining via programmable linked-list into memory, supporting two execution modes: run-to-completion and link step mode
  - Intrachannel and interchannel 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
  - 12 channels with linear source and destination addressing: either fixed or contiguously incremented addressing, programmed at a block level, between successive single transfers
  - 4 channels with 2D source and destination addressing: programmable signed address offsets between successive burst transfers (noncontiguous addressing within a block, combined with programmable signed address offsets between successive blocks, at a second 2D/repeated block level)
  - Support for scatter-gather (multibuffer transfers), data interleaving and deinterleaving 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
  - Channel abort and restart
  - Channel terminate with FIFO draining
- 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 sublevels
  - 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

## 3.18 Interrupts and events

### 3.18.1 Nested vectored interrupt controller (NVIC)

The devices embed an NVIC that is able to manage 16 priority levels and to handle up to 148 maskable interrupt channels plus the 16 interrupt channels 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.

### 3.18.2 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 are allowed to wake up the system
- Configurable events (signals from I/Os or peripherals able to generate a pulse)
  - Select able 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

## 3.19 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, that can be ulteriorly compared with a reference signature generated at link-time and that can be stored at a given memory location.

## 3.20 CORDIC coprocessor (CORDIC1)

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 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, at an, 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

## 3.21 Filter math accelerator (FMAC1, FMAC2)

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
- 26-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 (Inputand output buffers can be circular)
- Filter functions: FIR and IIR (direct form 1)
- Vector functions: dot product, convolution, and correlation
- AHB slave interface
- DMA read and write data channels

## 3.22 Programmable logic array (PLAY1)

The programmable logic array allows the user to create custom logic and state machines without the need for external programmable logic devices, such as FPGAs. The PLAY provides 16 programmable logic elements, in the form of look-up tables (LUTs), each of which has four inputs and one output. The output can be programmed to be any logical function of the four inputs. More complex functions can be created by cascading logic elements.

Inputs to and outputs from the logic array can be selected from a choice of external I/Os, internal signals or software programmable register bits. External inputs can be synchronized to the internal clock and filtered to remove short pulses, or connected directly to the logic array if purely combinatorial or asynchronous functions are required.

Each logic element output can be registered using the internal clock, or another signal. Registered outputs can be fed back to the logic array inputs to create finite state machines. Transitions on the outputs can set flags, which can generate interrupts to the processor. The state of the flags can be read and reset by software. The raw states of the logic element outputs can also be read by software or by an external debugger. This provides visibility of the logic array state to simplify debugging of the programmed logic functions.

The array is configured via memory-mapped registers. The configuration is simple and intuitive. Configuration registers are protected against accidental programming by a lock bit. The configuration is maintained in case of a warm system reset.

## 3.23 Octo-SPI interface (XSPI1)

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

- Indirect mode: all the operations are performed using the XSPI 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 XSPI supports the following protocols with associated frame formats:

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

The XSPI offers the following features:

- Three functional modes: indirect, automatic 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-bit, 16-bit, and 32-bit data accesses allowed
- DMA channel for indirect mode operations
- Interrupt generation on FIFO threshold, timeout, operation complete, and access error

### 3.23.1 XSPI TrustZone®security

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

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

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

## 3.24 Delay block (DLYBXS1)

The delay block (DLYB) is used to generate an output clock that is 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 XSPI interface.

The delay is voltage and temperature dependent, that may require the application to reconfigure and recenter the output clock phase with the received data.

The delay block main features are:

- Input clock frequency ranging from 25 to 280 MHz
- Up to 12 oversampling phases

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

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

Table 5. **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 | | |
| Over sampling | X | | |
| Data register | 32-bit | | |
| Data register FIFO depth | 8 stages | | |
| DMA support | X | | |
| Offset compensation | X | | |
| Gain compensation | X | | |
| Number of analog watchdogs | 3 | | |
| Option register | X | | |

### 3.25.1 Analog temperature sensor

This sensor generates a voltage ($V_{SENSE}$) that varies linearly with temperature. It is internally connected 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 of the temperature sensor varies from chip to chip due to 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 is stored in the system memory area, accessible in read-only mode.

### 3.25.2 Internal voltage reference ($V_{REFINT}$)

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

The precise voltage of VREFINT is individually measured for each part by STMicroelectronics during production test and stored in the system memory area. It is accessible in read-only mode.

### 3.25.3 $V_{CORE}$ voltage sensor

This embedded hardware enables the application to measure the CPU core voltage $V_{CORE}$ using the ADC input channel.

## 3.26 Digital temperature sensor (DTS)

The devices embed 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 a 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.

## 3.27 Digital-to-analog converter (DAC1, DAC2, DAC5 to DAC10)

Eight 12-bit DAC channels (two external buffered (DAC1, DAC2) and six internal unbuffered (DAC5 to DAC10) can be used to convert digital signals into analog voltage signal outputs. The selected design structure is composed of integrated resistor strings and an amplifier in an inverting configuration.

This digital interface supports the following features:

- One DAC interface, one output channel
- 8-bit or 12-bit output mode
- Buffer offset calibration, factory and user trimming (for DAC1 and DAC2 only)
- Left or right data alignment in 12-bit mode
- Synchronized update capability
- Noise-wave and triangular-wave generation
- Saw tooth wave generation
- DMA capability for each channel
- External triggers for conversion
- Possibility to disconnect the DAC1 and DAC2 output from DAC1_OUT1 and DAC2_OUT1 pin, respectively
- DAC output connection to on-chip peripherals
- Voltage reference input VREFDAC+/VREFDAC
- Sample and hold low-power mode, with internal or external capacitor (for DAC1 and DAC2 only)
- Up to 1 Msps for external output (for DAC1 and DAC2) and 15 Msps for internal output (for DAC5 to DAC10)

## 3.28 Voltage reference buffer (VREFBUF)

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

The internal voltage reference buffer supports four voltages: 1.8 V, 2.048 V, 2.5 V, and 2.9 V.

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

## 3.29 Operational amplifier (OPAMP1, OPAMP2, OPAMP3)

The devices embed three operational amplifiers with external or internal follower routing and PGA capability.

The operational amplifier features:

- 13 MHz bandwidth
- Rail-to-rail input
- PGA with a noninverting gain of 2, 4, 8, or 16, and inverting gain of -1, -3, -7, or -15

The OPAMPx (x = 1, 2, or 3) internal output OPAMPxINT can be sampled using an ADCx (x = 1, 2, or 3) internal input channel. In this case, the I/O on which the OPAMPx output is mapped can be used as a GPIO.

## 3.30 Comparators (COMP1 to COMP8)

The devices embed eight rail-to-rail comparators with 17 ns propagation delay, programmable internal or external reference voltage, and hysteresis.

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)

All comparators can wake up from Stop mode, generate interrupts, and breaks for the timers.

## 3.31 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 (digital) and an internal conditioning component.

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

The true random generator:

- Delivers 32-bit true random numbers, produced by a digital entropy source conditioned by a NIST SP800-90B approved conditioning stage
- Can be used as entropy source to construct a nondeterministic random bit generator (NDRBG)
- Produces four 32-bit random samples every 412 AHB clock cycles if $f_{AHB}$ < 77 MHz and 256 RNG clock cycles otherwise
- Embeds startup 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)

## 3.32 Encryption standard hardware accelerator (AES) and secure advanced encryption standard hardware accelerator (SAES)

The devices embed two AES accelerators: SAES and AES. The SAES with hardware unique key embeds protection against differential power analysis (DPA) and related side channel attacks. The SAES can share its current key register information with the faster AES using a dedicated hardware bus.

The SAES and the AES can be used to both encrypt and decrypt data using the AES algorithm. It is a fully compliant implementation of the advanced encryption standard (AES) as defined by Federal Information Processing Standards Publication (FIPS PUB 197, Nov 2001).

Multiple chaining modes are supported for key sizes of 128 or 256 bits. ECB, CBC, CTR, CCM, GCM, and GMAC chaining are supported by the AES and SAES.

SAES and AES support DMA single transfers for incoming and outgoing data (two DMA channels required).

The SAES supports the selection of all the following key sources, while the AES support only the first:

- 256 bits of software key, written by the application in the key registers (write only)
- 256-bit derived by hardware secure key management.

The SAES and AES peripherals support:

- Compliant implementation of standard NIST *Special Publication 197, Advanced Encryption Standard (AES)* and *SpecialPublication 800-38A, Recommendation for Block Cipher Modes of Operation*
- 128-bit data block processing
- Support for cipher keys length of 128-bit and 256-bit
- Encryption and decryption with multiple chaining modes:
  - Electronic codebook (ECB) mode
  - Cipher block chaining (CBC) mode
  - Counter(CTR) mode
  - Galois counter mode (GCM)
  - Galois message authentication code (GMAC) mode
  - Counter with CBC-MAC (CCM) mode
- 528 or 743 clock cycle latency in ECB encryption mode for SAES processing one 128-bit block of data with, respectively, 128-bit or 256-bit key
- 51 or 75 clock cycle latency in ECB encryption mode for AES processing one 128-bit block of data with, respectively, 128-bit or 256-bit key
- Integrated round key scheduler to compute the last round key for AES ECB/CBC decryption
- 256-bit register for storing the cryptographic key (four 32-bit registers), with key atomicity enforcement
- 128-bit registers for storing initialization vectors (four 32-bit registers)
- One 32-bit INPUT buffer and one 32-bit OUTPUT buffer
- Automatic data flow control with support of single-transfer direct memory access (DMA) using two channels (one for incoming data, one for processed data)
- Data swapping logic to support 1-, 8-, 16- or 32-bit data
- Possibility for software to suspend a message if the SAES/AES needs to process another message with a higher priority (suspend/resume operation)

Table 6. **SAES/AES features**

| AES/SAES modes/feature[1]s | AES | SAES |
|---|---|---|
| ECB, CBC chaining | X | X |
| CTR, CCM, GCM chaining | X | X |
| AES 128-bit ECB encryption in cycles | 51 | 528 |
| DHUK and BHK key selection | - | X |
| Side-channel attacks resistance | - | X |
| Shared key between SAES and AES | X | |

1. *X = supported*

## 3.33 HASH hardware accelerator (HASH)

HASH is a fully compliant implementation of the secure hash, (SHA-1, SHA-224, or SHA-256) and HMAC (keyed-hash message authentication code) algorithms. HMAC is suitable for applications requiring message authentication.

HASH computes FIPS (Federal information processing standards) approved digests of any length of less than 264 bits (for SHA-1, SHA-224, and SHA-256) or of less than 2128 bits (for SHA-384 and SHA-512).

The HASH main features are:

- Suitable for data authentication applications compliant with:
  - Federal information processing standards, publication *FIPS PUB 180-4 Secure hash standard* (SHA-1 and SHA-2 family)
  - Federal information processing standards, publication *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)*
- Fast computation of SHA-1, SHA-224, and SHA-256
  - 82 (or 66 clock cycles, respectively) for processing one 512-bit block of data using SHA-1 (or SHA-256 algorithm, respectively)
- 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
  - Supported word swapping formats: bit, byte, half-word, and 32-bit word
- Automatic padding to complete the input bit string to fit digest minimum block size of 512 bits (16 × 32 bits)
- Single 32-bit input register associated to an internal input FIFO of 16 × 32-bit words, corresponding to one block size
- AHB slave peripheral, accessible through 32-bit word accesses only (else an AHB error is generated)
- 8 × 32-bit words (H0 to H7) for output message digest
- Automatic data flow control with support of direct memory access (DMA) using one channel. Single or fixed burst of four supported.
- Interruptible message digest computation, on a per-32-bit word basis
  - Reloadable digest registers
  - Hashing computation suspend/resume mechanism, including using DMA

## 3.34 On-the-fly decryption engine (OTFDEC1)

The OTFDEC allows the decryption of the on-the-fly AHB traffic based on the read request address information, for example execute-in-place of a code stored encrypted. Four independent and nonoverlapping encrypted regions can be defined in OTFDEC.

OTFDEC uses AES-128 in counter mode to achieve the lowest possible latency. As a consequence, each time the content of one encrypted region is changed the entire region must be reencrypted with a different cryptographic context (key or initialization vector). This constraint makes OTFDEC suitable to decrypt read-only data or code stored in external NOR flash.

*Note: When OTFDEC is used with XSPI, it is mandatory to access the flash memory using the Memory-mapped mode of the flash memory controller.*

When security is enabled in the product, OTFDEC can be programmed only by a secure host.

The OTFDEC main features are the following:

- On-the-fly 128-bit decryption during XSPI memory-mapped read operations (single or multiple)
  - Use of AES in counter (CTR) mode, with two 128-bit key stream buffers
  - Support for any read size
  - Physical address of the reads is used for the encryption/decryption
- Up to 4 independent encrypted regions
  - Granularity of the region definition: 4096 bytes
  - Region configuration write locking mechanism
  - Each region has its own 128-bit key, two-bytes firmware version, and eight bytes application-defined nonce. At least one of those must be changed each time an encryption is performed by the application.
- Encryption keys confidentiality and integrity protection
  - Write-only registers, with software locking mechanism
  - Availability of 8-bit CRC as public key information
- Support for XSPI prefetching mechanism
- Possibility to select an enhanced encryption mode to add a proprietary layer of protection on top of AES stream cipher (execute only)
- AMBA®AHB slave peripheral, accessible through 32-bit word single accesses only (otherwise an AHB bus error is generated, and write accesses are ignored)
- Secure programming only if TrustZone® security is enabled
- Encryption mode

## 3.35 Public key accelerator (PKA)

The PKA is used for the computation of cryptographic public key primitives, specifically those related to RSA, Diffie-Hellmann, or ECC (elliptic curve cryptography) over GF(p) (Galois fields). To achieve high performance at a reasonable cost, these operations are executed in the Montgomery domain.

All needed computations are performed within the accelerator, so no further hardware/softwareelaboration is needed to process the inputs or the outputs.

The PKA main features are:

- Acceleration of RSA, DH, and ECC over GF(p) operations, based on the Montgomery method for fast modular multiplications. More specifically:
  - RSA modular exponentiation, RSA Chinese remainder theorem (CRT) exponentiation
  - ECC scalar multiplication, point on curve check, complete addition, double base ladder, projective to affine
  - ECDSA signature generation and verification
- Capability to handle operands up to 4160 bits for RSA/DH and 640 bits for ECC
- Arithmetic and modular operations such as addition, subtraction, multiplication, modular reduction, modular inversion, comparison, and Montgomery multiplication
- Built-in Montgomery domain inward and outward transformations
- Protection against differential power analysis (DPA) and related side-channel attacks.

## 3.36 Coupling and chaining bridge (CCB)

The CCB is capable of wrapping the private keys used by the PKA accelerator using a concealed link between PKA, SAES, and RNG peripherals. The private key value can be prevented from being exposed in CPU-accessible memory space, preventing a range of potential vulnerabilities.

## 3.37 Timers and watchdogs

The devices include one high-resolution timer, three advanced control timers, up to thirteen general-purpose timers (9 x 16-bit, 4 x 32-bit), four basic timers, one low-power timer, two watchdog timers and two SysTick timers.

Table 7. Timer features compares the features of the advanced control, general-purpose and basic timers.

**Table 7. Timer features**

| Type | Timer | Counter resolution | Counter type | Prescaler factor | DMA request generation | Capture/ compare channels | Complementary outputs |
|---|---|---|---|---|---|---|---|
| High resolution timer | HRTIM | 16 bits | Up | /1 /2 /4 (x2 x4 x8 x16 x32, with DLL) | Yes | 12(1) | Yes |
| Advanced control | TIM1,TIM8, TIM20 | 16 bits | Up, down, up/down | Any integer between 1 and 65536 | Yes | 4 | 4 |
| General purpose | TIM2,TIM3 TIM4,TIM5 | 32 bits | | | | 4 | 0 |
| | TIM15 | 16 bits | Up, down, up/down | | | 2 | 1 |
| | TIM16,TIM17 | | | | | 1 | 1 |
| | TIM9, TIM12 | | Up | | | 2 | 0 |
| | TIM10, TIM11, TIM13, TIM14 | | | | | 1 | 0 |
| Basic | TIM6,TIM7, TIM26, TIM27 | 16 bits | Up | | | 0 | 0 |

1. .There are 12 high resolution channels.

### 3.37.1 High-resolution timer (HRTIM1)

The high-resolution timer (HRTIM) allows generating digital signals with high-accuracy timings, such as PWM or phase-shifted pulses.

It consists of 12 high-resolution outputs (channels CHA1/CHA2 to CHF1/CHF2), which can be coupled by pairs for deadtime insertion. It also features eight fault inputs for protection purposes and 16 inputs to handle external events such as current limitation, zero voltage, or zero current switching.

HRTIM timer is a digital kernel clocked at 280 MHz followed by delay lines. Delay lines with closed loop control guarantee a 111 ps resolution that does not depend on the voltage, temperature, or chip-to-chip manufacturing process deviation. The high resolution is available on the 12 outputs (channels CHA1/CHA2 to CHF1/CHF2) in all operating modes: variable duty cycle, variable frequency, and constant ON time.

The slave timers can be combined to control multiswitch complex converters or operate independently to manage multiple independent converters. The waveforms are defined by a combination of user-defined timings and external events such as analog or digital feedback signals.

HRTIM timer includes options for blanking and filtering out spurious events or faults. It also offers specific modes and features to offload the CPU: DMA requests, burst mode controller, push-pull, and resonant mode. It supports many topologies including LLC, full bridge phase shifted, buck or boost converters, either in voltage or current mode, as well as lighting application (fluorescent or LED). It can also be used as a general-purpose timer, for instance to achieve high-resolution PWM-emulated DAC.

In debug mode, the HRTIM counters can be frozen and the PWM outputs enter safe state.

### 3.37.2 Advanced-control timers (TIM1, TIM8, TIM20)

The advanced-control timers can each 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.

### 3.37.3 General-purpose timers (TIM2 to TIM5, TIM9 to TIM17)

The devices embed up to nine synchronizable general-purpose timers (see Table 7. Timer features), each of them can be used to generate PWM outputs, or act as a simple time base.

- TIM2, TIM3, TIM4, TIM5
  Full-featured general-purpose timers with 32-bit auto-reload up/downcounter and 32-bit prescaler.
  These timers feature 4 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.
- TIM15, TIM16, TIM17
  They are general-purpose timers with midrange features.
  They have 16-bit auto-reload up/downcounter and 16-bit prescalers.
  - TIM15 has two channels and one complementary channel.
  - TIM16, TIM17 have one channel and one complementary channel.

  All channels can be used for input capture/output compare, PWM, or one-pulse mode output.
  The 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.
- TIM9, TIM10, TIM11, TIM12, TIM13, TIM14
  General-purpose timers with midrange features.
  They have 16-bit auto-reload upcounters and 16-bit prescalers.
  - TIM9, TIM12 have two channels.
  - TIM10, TIM11, TIM13, TIM14 have one channel.

  All channels can be used for input capture/output compare, PWM, or one-pulse mode output.
  The timers can work together via the *TimerLink* feature for synchronization or event chaining.
  The counters can be frozen in Debug mode.

### 3.37.4 Basic timers (TIM6, TIM7, TIM26, TIM27)

These timers are mainly used for DAC trigger generation. They can also be used as a generic 16-bit timebase.
The timers have independent DMA request generation.

### 3.37.5 Low-power timer (LPTIM1)

The devices embed one low-power timer. 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 timer supports the following features:

- 16-bit up counter with 16-bit auto reload 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 auto reload 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 10 events
- DMA request generation on the following events:
  - Update event
  - Input capture

### 3.37.6 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.

### 3.37.7 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.

### 3.37.8 SysTick timer

The Cortex®-M33 embeds two SysTick timers.

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
- Auto reload capability
- Maskable system interrupt generation when the counter reaches zero
- Programmable clock source

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

### 3.38.1 Real-time clock (RTC)

The RTC supports the following features:

- Calendar with subsecond, seconds, minutes, hours (12- or 24-hour 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 controller 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.
- 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 from the $V_{DD}$ supply.

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 all low-power modes when it is clocked by the LSE or by LSI.

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

### 3.38.2 Tamper and backup registers (TAMP)

The anti-tamper detection circuit is used to protect sensitive data from external attacks. 32 x 32-bit backup registers are retained in all low-power modes. The backup registers, as well as other secrets in the device, are protected by this anti-tamper detection circuit with two 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, SRAM1, SRAM2, caches, and cryptographic peripherals.
- 32 x 32-bit backup registers:
  - The backup registers (TAMP_BKPxR) are implemented in the RTC domain that remains powered-on in Standby mode.
- Up to 4 tamper pins for 2 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 2 meshes (each input associated to its own exclusive output) to 2 meshes (single output shared for up to 2 tamper inputs)
  - Passive tampers: Ultralow power edge or level detection with internal pull-up hardware management
  - Configurable digital filter

*Note: As input, only PC13, PA0, and PA1 are functional in Standby mode. As output, only PC13 is functional in Standby mode.*

- 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 3 configurable-size areas:
    - 1 read/write secure area
    - 1 write secure/read nonsecure area
    - 1 read/write nonsecure area
  - Boot secret key (BHK) is only usable by secure AES peripheral, stored in backup registers, protected against read and write access
- Tamper configuration and backup registers privilege protection
- Monotonic counter

## 3.39 Inter-integrated circuit peripheral (I2C)

The device embeds four I2C. Refer to Table 8 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-bit and 10-bit addressing mode
  - Multiple 7-bit target addresses
  - Programmable setup and hold times
  - Optional clock stretching
- System management bus (SMBus) specification rev 3.3 compatibility:
  - Hardware PEC (packet error checking) generation and verification with ACK control
  - Address resolution protocol (ARP) support
  - SMBus alert
  - Specific I/Os thresholds for SMbus rev 3.3 on I/Os with SMBUS 3.3 capability (see Table 1)
- Power system management protocol (PMBus) specification rev 1.3 compatibility
- Independent clock: a choice of independent clock sources allowing the $I^2C$-bus communication speed to be independent from the PCLK reprogramming
- Wake-up from Stop capability
- Programmable analog and digital noise filters
  1-byte buffer with DMA capability

**Table 8. I2C implementation**

| Features(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 (Fm+) with 20 mA output drive I/Os (up to 1 Mbit/s) | X | X | X | X |

| Features(1) | I2C1 | I2C2 | I2C3 | I2C4 |
|---|---|---|---|---|
| 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.*

## 3.40 Improved inter-integrated circuit interface (I3C)

The I3C interface handles communication between this device and others, such as sensors and host processor(s), connected on an I3C bus. An I3C bus.

The peripheral implements all the features required by the MIPI® I3C specification v1.1. It can control all 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 a controller, the I3C peripheral improves the features of the $I^2C$ 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 offload the CPU.

**Table 9. I3C peripheral controller/target features versus MIPI® v1.1**

| Features | MIPI® I3C v1.1 | I3C peripheral when controller | I3C peripheral when target | Comments |
|---|---|---|---|---|
| I3CSDR 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 CCCs and some optional CCCs are 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 | - | |
| Asynchronous timing control 1, 2, 3 | X | - | - | |
| Device-to-device tunneling | X | X | - | |
| Multilane data transfer | X | X | - | |
| Monitoring device early termination | X | - | - | |

1. *X = supported.*

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

The devices have three embedded universal synchronous/asynchronous receiver transmitters (USART1/ USART2/USART3), three universal asynchronous receiver transmitters (UART4/UART5/UART6), and one low-power universal asynchronous receiver transmitter (LPUART1).

**Table 10. USART, UART, and LPUART features (continued)**

| Mode/feature[1] | USART 1/2/3 | UART 4/5/6 | LPUART 1 |
|---|---|---|---|
| Hardware flow control for modem | X | X | X |
| Continuous communication using DMA | X | X | X |
| Multiprocessor communication | X | X | X |
| Synchronous mode (master/slave) | X | - | - |
| Smart cardmode | 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-baudrate detection | X | X | - |
| Driver enable | X | X | X |
| USART data length | 7, 8, and 9 bits | | |
| Tx/Rx FIFO | X | X | X |
| Tx/RxFIFO size | 8 bytes | | |

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

### 3.41.1 Universal synchronous/asynchronous receiver transmitter (USART/UART)

The USART offers a flexible means to perform full-duplex data exchange with external equipment 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 communications up to 35 Mbauds are 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 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 controller/target mode and clock output/input for synchronous communications
- SPI target 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 controller synchronous break send capability and LIN target 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

### 3.41.2 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 bauds. Therefore, even in Stop mode, the LPUART can wait for an incoming frame while having an extremely low energy consumption. Higher-speed clocks can be used to reach a higher baud rate.

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 bauds 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

## 3.42 Serial peripheral interface (SPI) / inter-integrated sound interfaces (I2S)

The devices embed three 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 a 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 a 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 asynchronous 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/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 a 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 16 x 8-bit embedded Rx and TxFIFOs with DMA capability
- Programmable number of data in a 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 is ready to handle the data flow.

Two standard I2S interfaces (multiplexed with SPI1 and SPI2) 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 of 16, 24, or 32 bits
- Channel length of 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 (jeft-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 11. **SPI features**

| Feature | SPI1, SPI2 (full feature set instances) | SPI3 |
|---|---|---|
| Data size | Configurable from 4 to 32-bit | Configurable from 4 to 32-bit |
| CRC computation | CRC polynomial length configurable from 5 to 33-bit | CRC polynomial length configurable from 5 to 33-bit |
| Size of FIFOs | 16 x 8-bit | 16 x 8-bit |
| Number of transferred data | Unlimited, expandable | Unlimited, expandable |
| I2S feature | Yes | No |

## 3.43 Controller area network (FDCAN1, FDCAN2, FDCAN3)

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

The modules (FDCAN1, FDCAN2, FDCAN3) are compliant with ISO 11898-1: 2015 (CAN protocol specification version 2.0 part A, B) and CAN FD protocol specification version 1.0.

An 848-byte 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
- 2 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 payloads (up to 64 bytes per payload)
- Configurable transmit Event FIFO
- Programmable loop-back test mode
- Maskable module interrupts
- End-of-frame transmission/reception event generation
- Two clock domains: APB bus interface and CAN core kernel clock
- Power-down support

## 3.44 Position encoder interface (POSENC)

The POSENC peripheral is a multiprotocol digital position encoder master interface. It includes interface cores from several vendors and provides an interface for unifying register and memory access, as well as interrupt and input/output management. It features:

- EnDat3 master interface
  - HEIDENHAIN design-core based
  - Support for FID-based memory
  - Support for one safety packet
- Hiperface DSL
  - SICK design-core based
  - Safety variants of the DSL Master interface core
  - Safe channel 2 accessible via SPI-based interface (for external Safe Control Unit)
- Direct or indirect design core memory and registers interfaces
- Posted write and indirect read commands mechanisms for minimizing APB bus stall
- Strobe interface for synchronizing communication with on-chip peripherals (e.g timers) or off-chip peripheral or host (via the EXTI external interrupt interface)
- Interrupt interface
- APB interface

## 3.45 USB full speed (USB)

USB main features

- USB specification version 2.0 full-speed compliant
- Host and device functions
- 2048 bytes of dedicated SRAM data buffer memory with 32-bit access
- USB clock recovery
- Configurable number of endpoints from 1 to 8
- Cyclic redundancy check (CRC) generation/checking, non-return-to-zero inverted (NRZI) encoding/decoding and bit-stuffing
- Isochronous transfers support
- Double-buffered bulk/isochronous endpoint support
- USB suspend/resume operations
- Frame-locked clock pulse generation
- USB2.0 Link power management support
- Battery charging specification revision 1.2 support in device

## 3.46 USB Type-C® / USB Power Delivery controller (UCPD)

The device embeds 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
- “Deadbattery” support
- USB Power Delivery message transmission and reception
- FRS (fast role swap) support

The digital controller handles notably:

- 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 prescaler)
- 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.

## 3.47 Development support

### 3.47.1 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 the five required by the JTAG (JTAG pins can be reused 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.

### 3.47.2 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 thehost computer that runs the debugger software. TPA hardware is commercially available from common development tool vendors.

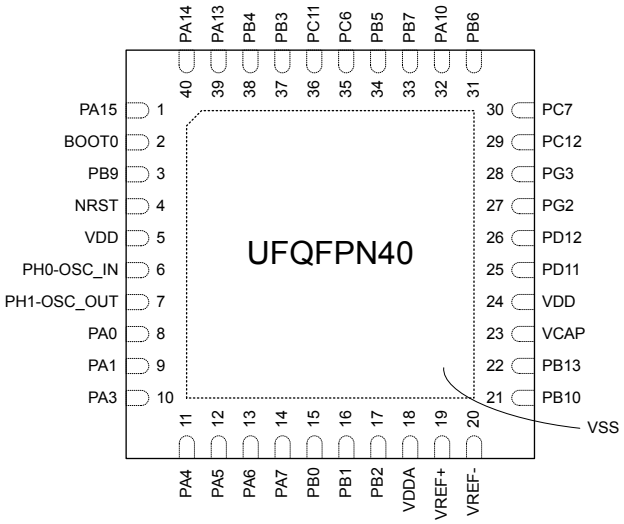
The ETM operates with third party debugger software tools.

# 4 Pinouts/ballouts, pin description, and alternate functions

## 4.1 Pinout/ballout schematics

**Figure 5. UFQFPN40 pinout**

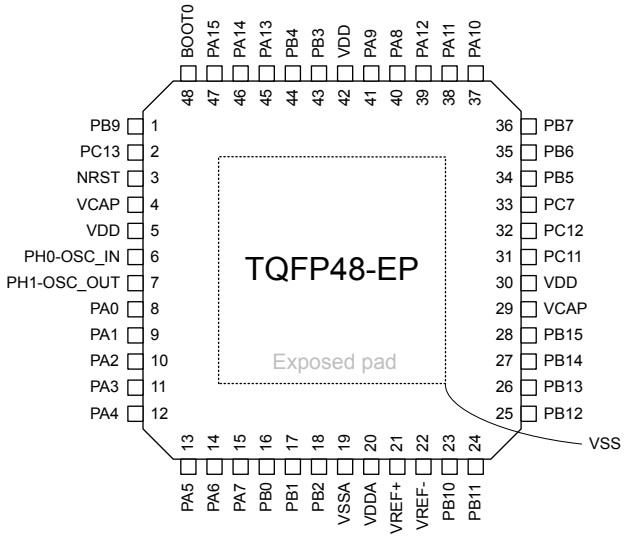
Package top view




DT80680V1

**Figure 6. TQFP48-EP pinout**

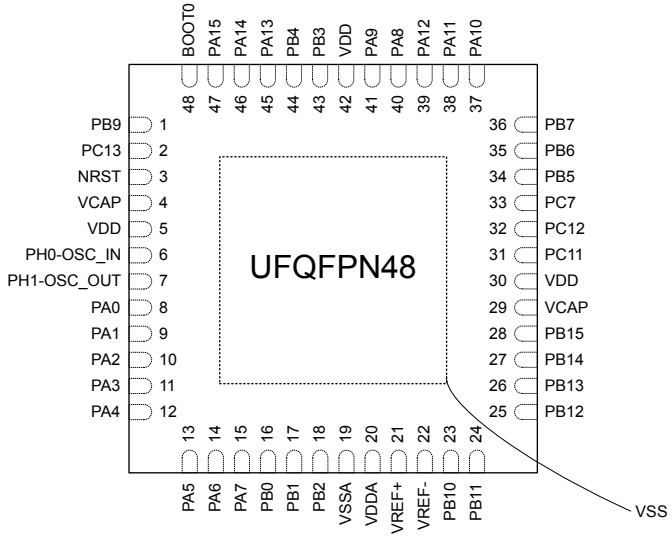
Package top view




DT75472V1

**Figure 7. UFQFPN48 pinout**

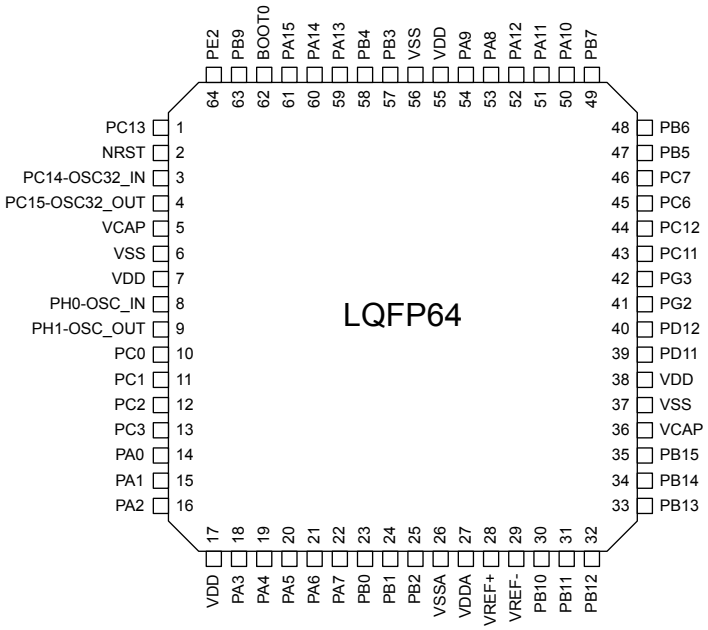
Package top view




DT72264V1

**Figure 8. LQFP64 pinout**

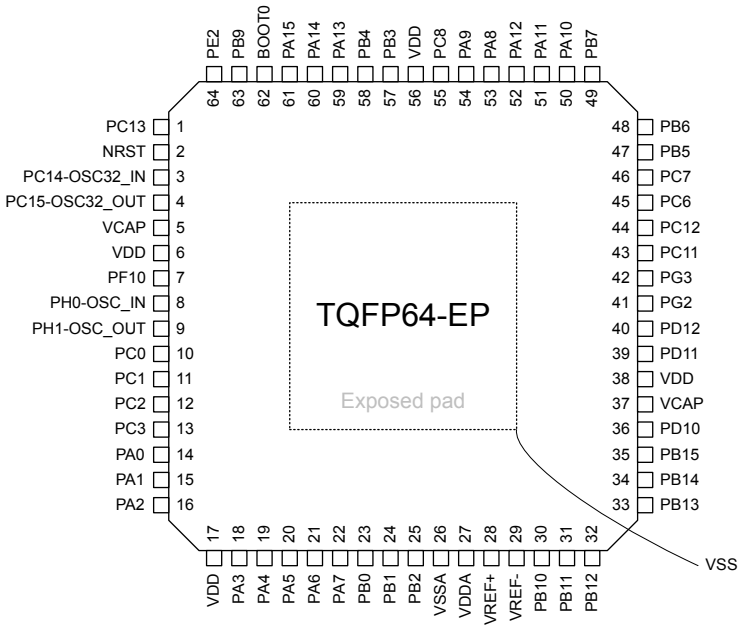
Package top view




DT72260V1

**Figure 9. TQFP64-EP pinout**

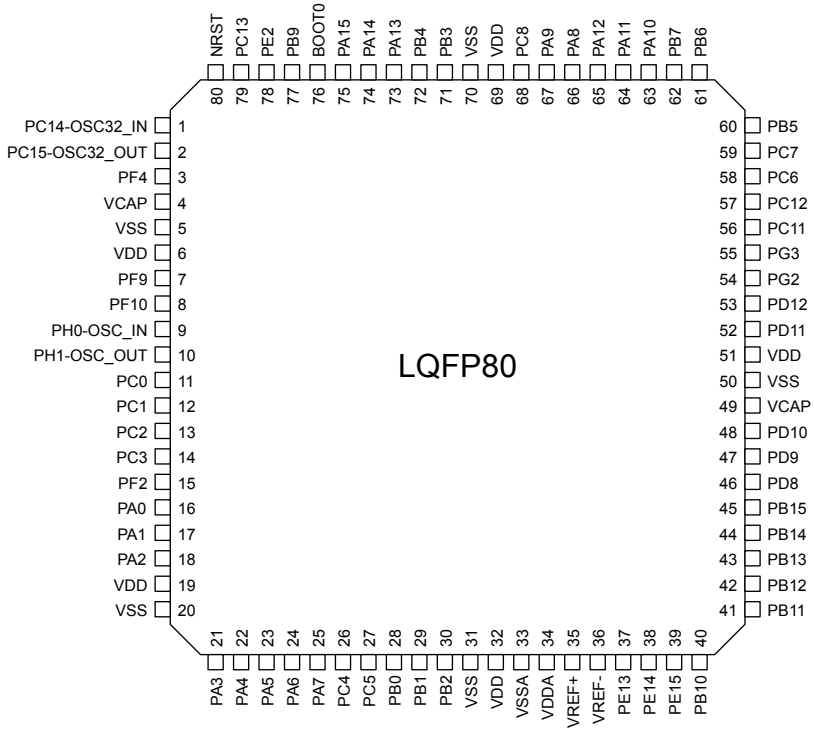
Package top view




DT75473V1

**Figure 10. LQFP80 pinout**

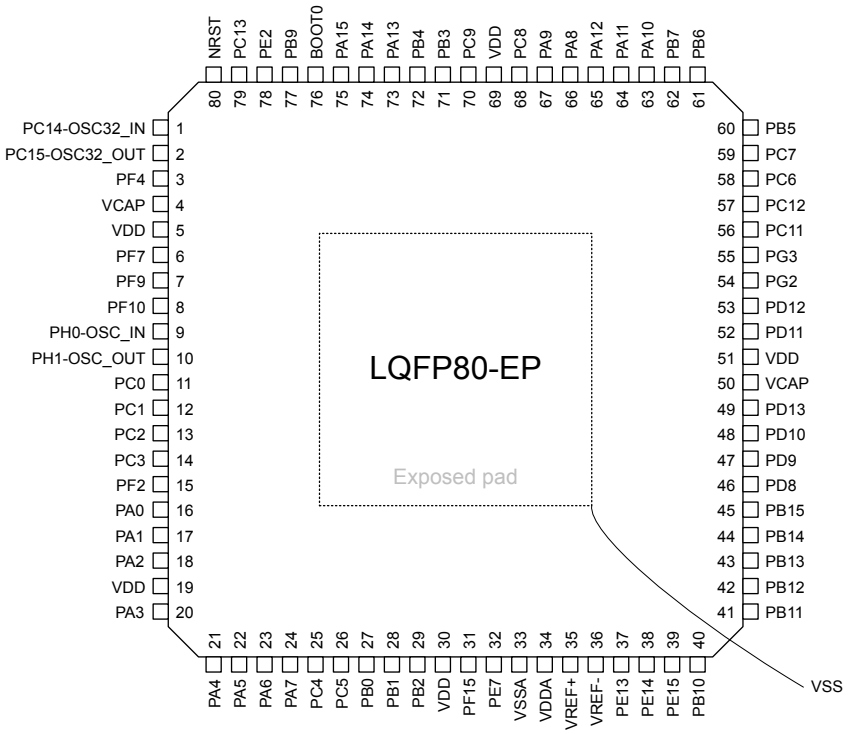
Package top view




DT72261V1

**Figure 11. LQFP80-EP pinout**

Package top view




DT80678V1

**Figure 12. LQFP100 pinout**

Package top view

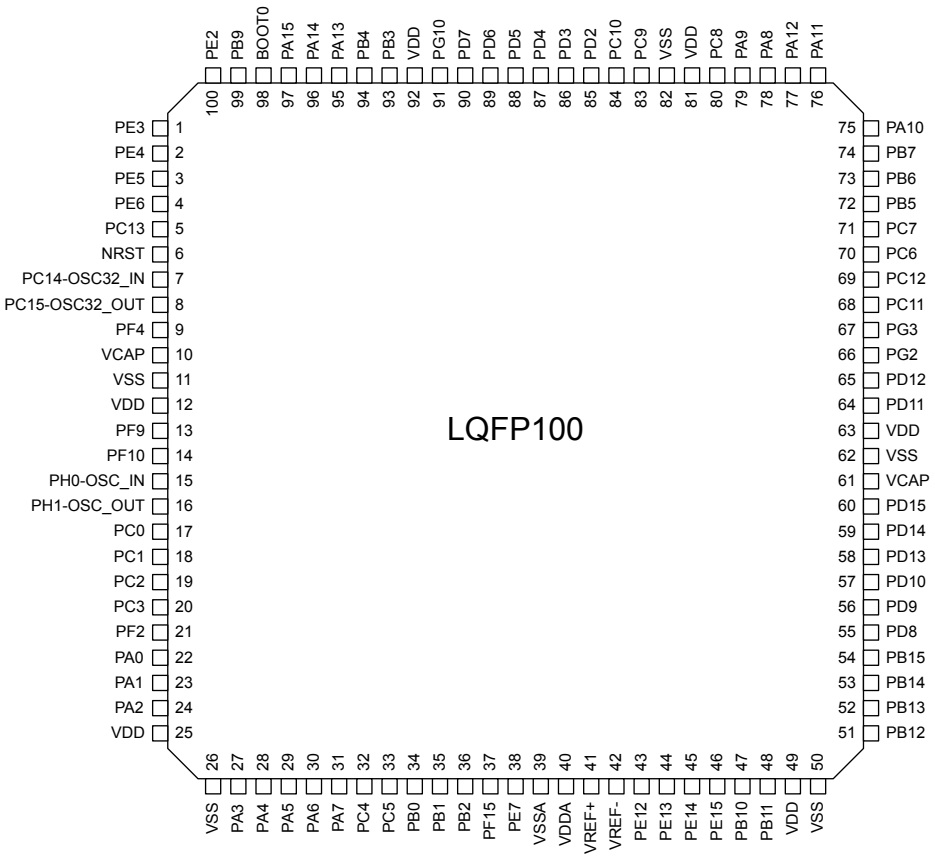
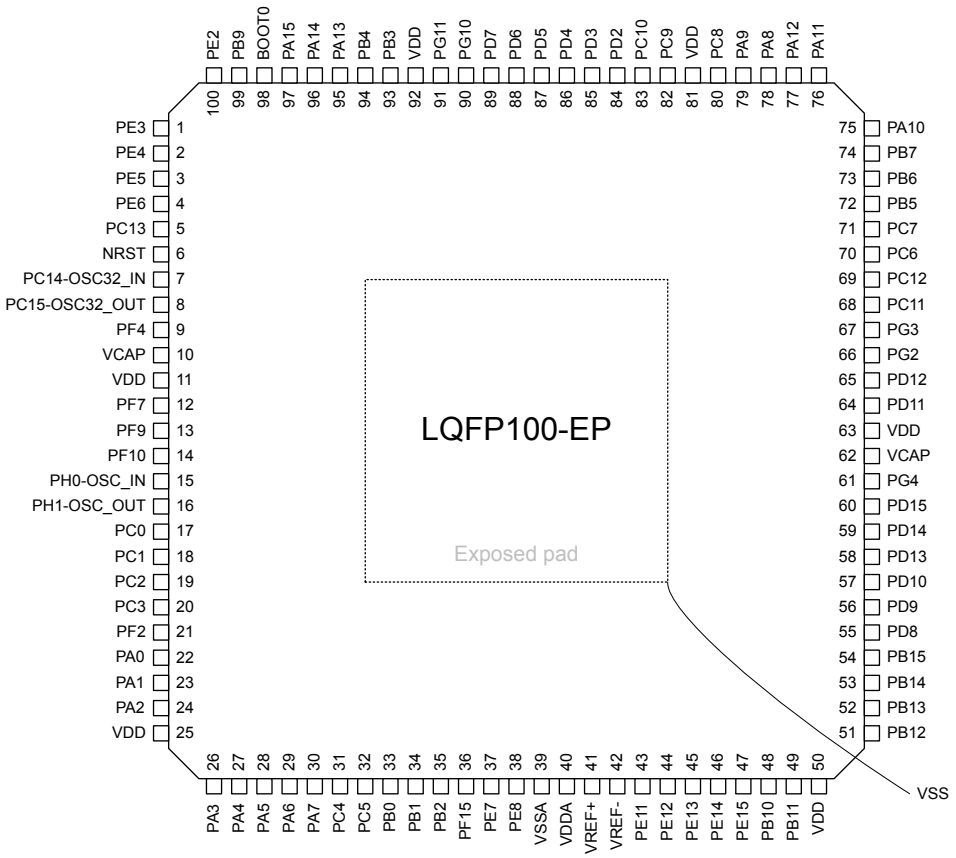


**Figure 13. LQFP100-EP pinout**

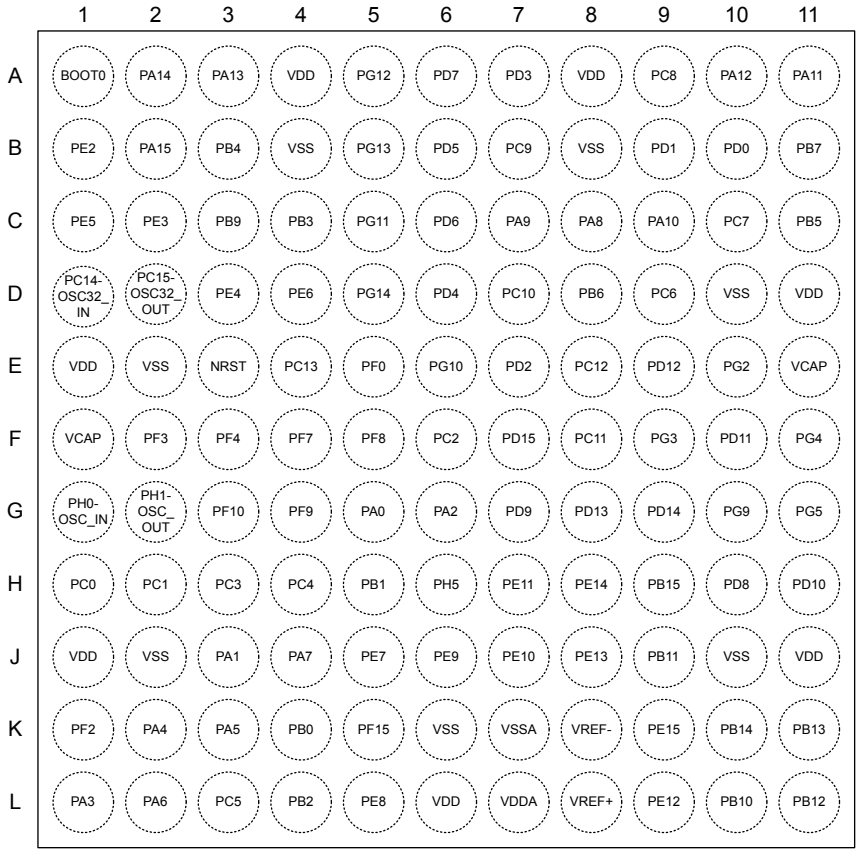
Package top view




DT75474V1

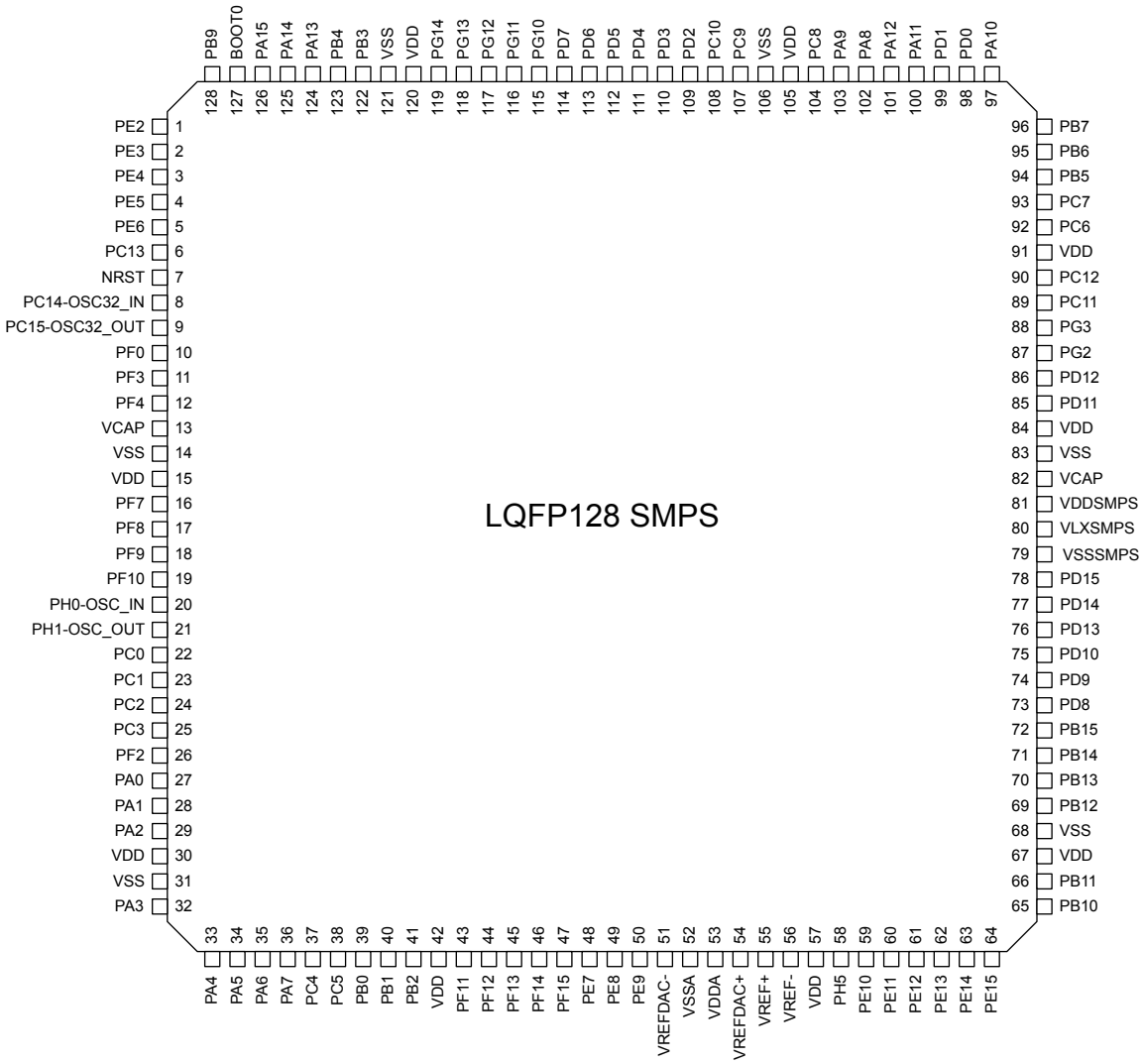
**Figure 14. UFBGA121 ballout**

Package top view




DT75476V1

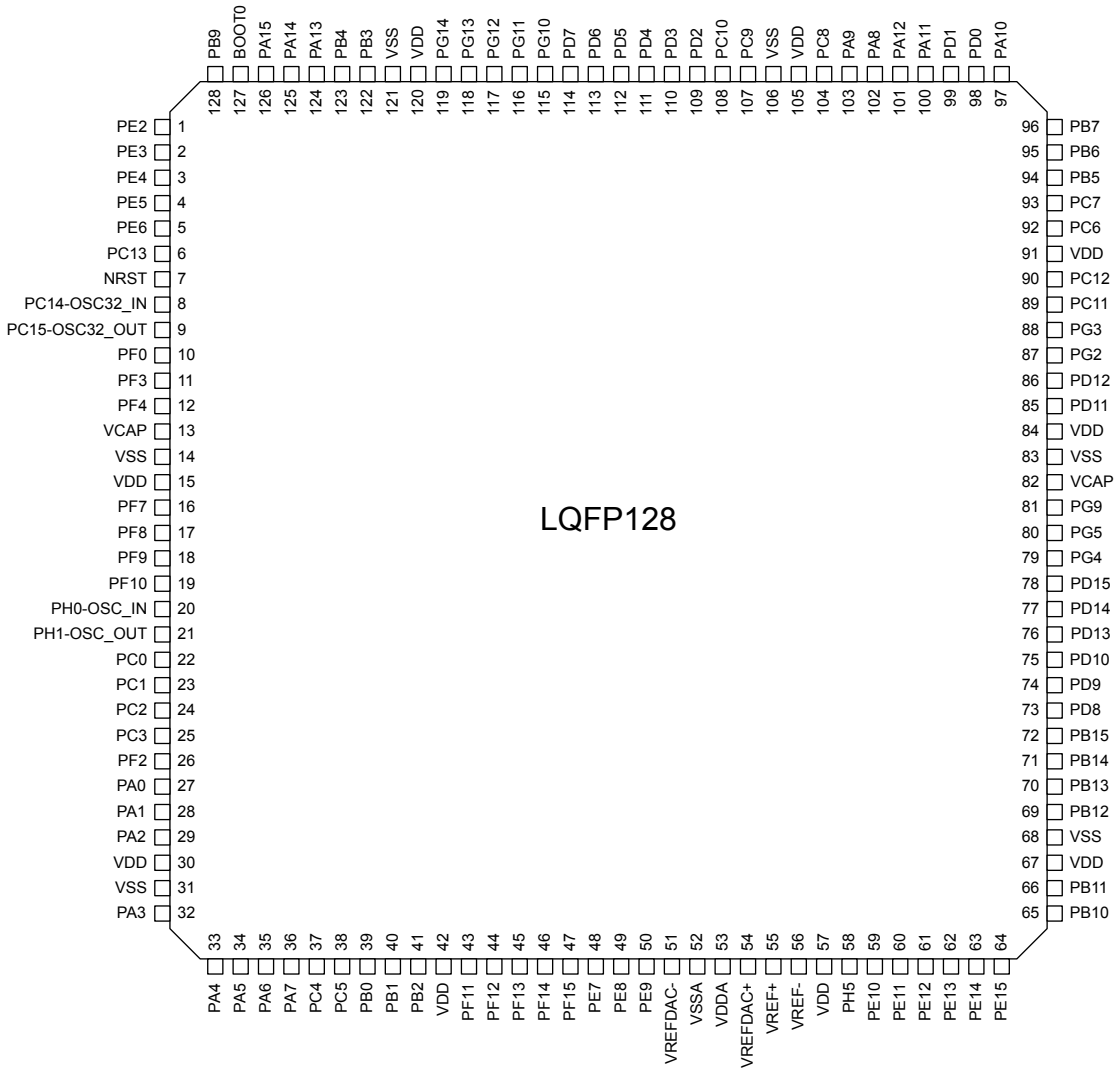
**Figure 15. LQFP128 SMPS pinout**




DT72258V1

**Figure 16. LQFP128 pinout**

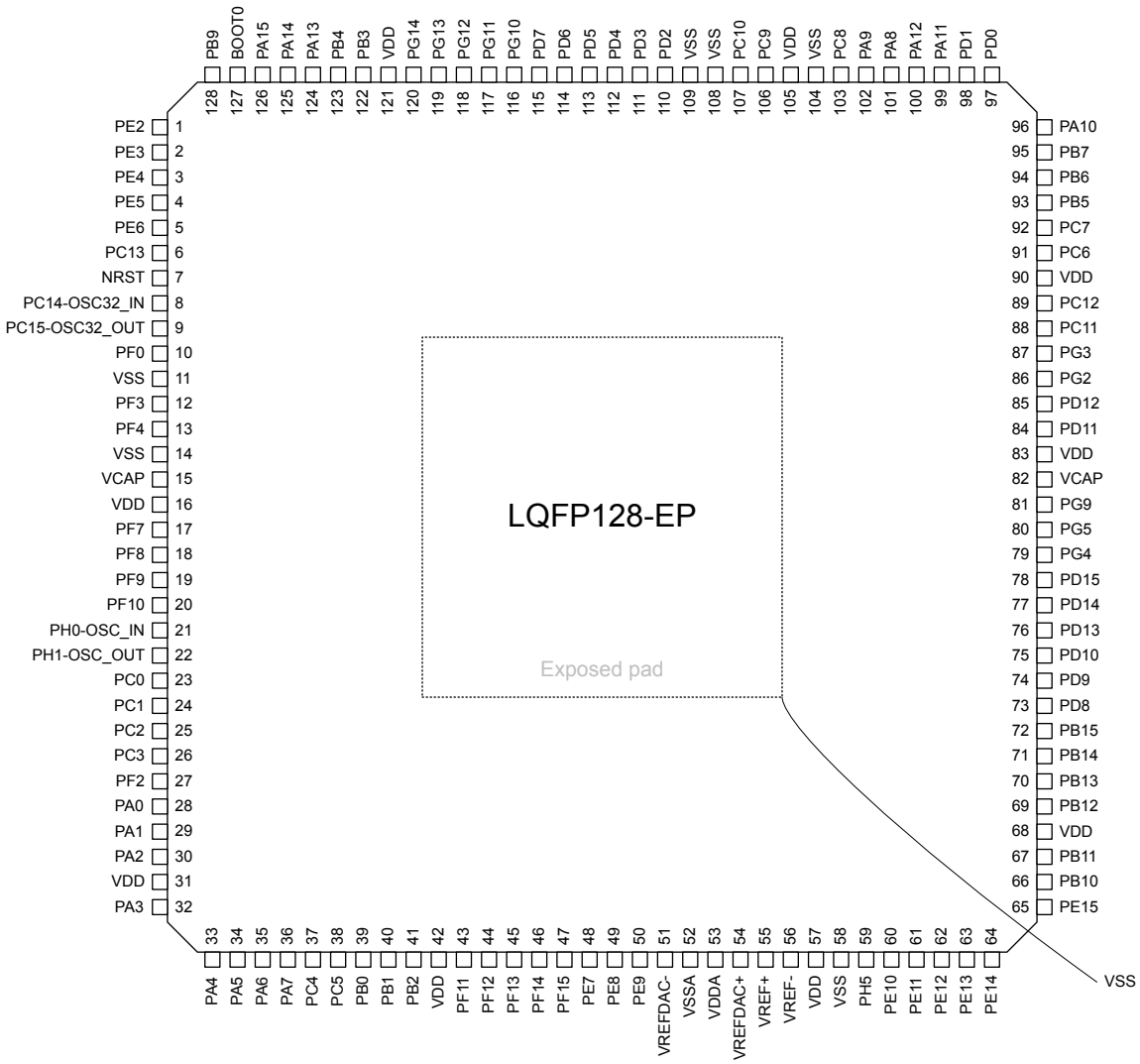
Package top view




DT72263V1

**Figure 17. LQFP128-EP pinout**

Package top view




DT80679V1

## 4.2 Pin/ball 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 | | I | Input-only pin |
| | | I/O | Input/output pin |
| | | O | Output-only pin |
| | | S | Supply pin |
| I/O structure | | FT | 5 V-tolerant I/O |
| | | TT | 3.6 V-tolerant I/O |
| | | TTa | 3.6 V-tolerant I/O with internal clamping to $V_{DDA}$ |
| | | B | Dedicated BOOT0 pin |
| | | RST | Bidirectional reset pin with embedded weak pull-up resistor |
| | | **Options for TT and FT I/Os**(1) | |
| | | _a | I/O with analog switch function supplied by $V_{DDA}$ |
| | | _b | I/O with SMBUS 3.3 capability |
| | | _c | USB Type-C power delivery capable I/O |
| | | _d | USB Type-C power delivery dead battery function I/O |
| | | _f | I2C Fm+ capable I/O |
| | | _t | Tamper I/O functional in Standby mode |
| Notes | | Unless otherwise specified by a note, all I/Os are set as floating 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_at, FT_f, FT_c, TT_a.*

**Table 13. STM32G56xxx pin/ball definition**

NA = Not available

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | - | - | - | 64 | 64 | 78 | 78 | 100 | 100 | B1 | 1 | 1 | 1 | PE2 | I/O | FT_f | - | TRACECLK, LPTIM1_IN2, TIM3_CH1, XSPI1_IO0, TIM11_CH1, TIM8_CH4N, UART6_TX, TIM20_CH1, I2C4_SCL, HRTIM1_EEV12, PLAY1_IN6, EVENTOUT | - |
| - | - | - | - | - | - | - | - | 1 | 1 | C2 | 2 | 2 | 2 | PE3 | I/O | FT_ft | (1) | TRACED0, HRTIM1_EEV8, TIM3_CH2, XSPI1_IO1, TIM20_CH2, I2C1_SDA, I2C4_SDA, PLAY1_IN7, EVENTOUT | TAMP_OUT2 |
| - | - | - | - | - | - | - | - | 2 | 2 | D3 | 3 | 3 | 3 | PE4 | I/O | FT_fb | (2) | TRACED1, TIM3_CH3, I2C3_SDA(boot), SPI1_NSS/I2S1_WS, TIM20_CH1N, I2C1_SMBA, I2C4_SMBA, PLAY1_OUT7, EVENTOUT | - |
| - | - | - | - | - | - | - | - | 3 | 3 | C1 | 4 | 4 | 4 | PE5 | I/O | FT_fb | (2) | TRACED2, TIM3_CH4, I3C1_SCL, I2C3_SCL(boot), XSPI1_NCS1, TIM20_CH2N, I2C4_SCL, XSPI1_IO2, PLAY1_OUT8, EVENTOUT | - |
| - | - | - | - | - | - | - | - | 4 | 4 | D4 | 5 | 5 | 5 | PE6 | I/O | FT_fb | (2) | TRACED3, TIM4_CH3, I3C1_SDA, TIM20_CH3N, I2C3_SMBA, I2C1_SCL, I2C4_SDA, XSPI1_IO3, PLAY1_IN8, EVENTOUT | - |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | 2 | 2 | 2 | 1 | 1 | 79 | 79 | 5 | 5 | E4 | 6 | 6 | 6 | PC13 | I/O | FT_t | (1) | TIM1_BKIN, LPUART1_TX, TIM8_BKIN, SPI2_NSS/ I2S2_WS, TIM20_CH3, TIM17_BKIN, UART4_TX, POSENC1_OUT, HRTIM1_EEV14, FDCAN1_RX, PLAY1_IN4, EVENTOUT | RTC_OUT1/RTC_TS, WKUP4, TAMP_IN2/ TAMP_OUT1 |
| 4 | 3 | 3 | 3 | 2 | 2 | 80 | 80 | 6 | 6 | E3 | 7 | 7 | 7 | NRST | I/O | RST | - | - | NRST |
| - | - | - | - | 3 | 3 | 1 | 1 | 7 | 7 | D1 | 8 | 8 | 8 | PC14-OSC32_IN(OSC32_IN) | I/O | FT | (3) | TIM16_BKIN, TIM1_BKIN, LPUART1_RX, LPTIM1_IN1, USART2_RX, UART4_RX, UART5_RX(boot), HRTIM1_FLT7, PLAY1_IN1 | OSC32_IN |
| - | - | - | - | 4 | 4 | 2 | 2 | 8 | 8 | D2 | 9 | 9 | 9 | PC15-OSC32_OUT(OSC32_OUT) | I/O | FT | (3) | TIM15_BKIN, LPUART1_TX, TIM8_BKIN, LPTIM1_IN2, USART2_TX, UART4_TX, UART5_TX(boot), HRTIM1_FLT8, PLAY1_IN13 | OSC32_OUT |
| - | - | - | - | - | - | - | - | - | - | E5 | 10 | 10 | 10 | PF0 | I/O | FT | - | HRTIM1_SCIN, XSPI1_IO3, SPI2_MISO, POSENC1_MISO, USART1_TX, HRTIM1_EEV4, PLAY1_OUT6, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - | 11 | VSS | S | - | (4) | - | - |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | - | - | - | - | - | - | - | - | - | F2 | 11 | 11 | 12 | PF3 | I/O | FT | - | HRTIM1_EEV1, SPI2_SCK/I2S2_CK, SPI3_NSS, USART2_TX, TIM20_CH4, POSENC1_SCK, PLAY1_OUT15, EVENTOUT | - |
| - | - | - | - | - | - | 3 | 3 | 9 | 9 | F3 | 12 | 12 | 13 | PF4 | I/O | FT | - | HRTIM1_EEV2, XSPI1_NCS1, SPI2_MOSI/I2S2_SDO, POSENC1_MOSI, USART2_RX, XSPI1_NCS2, TIM20_CH1N, COMP1_OUT, TIM10_CH1, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - | 14 | VSS | S | - | (4) | - | - |
| - | 4 | 4 | 4 | 5 | 5 | 4 | 4 | 10 | 10 | F1 | 13 | 13 | 15 | VCAP | S | - | - | - | - |
| - | 5 | - | - | 6 | - | 5 | - | 11 | - | E2 | 14 | 14 | - | VSS | S | - | - | - | - |
| 5 | 6 | 5 | 5 | 7 | 6 | 6 | 5 | 12 | 11 | E1 | 15 | 15 | 16 | VDD | S | - | - | - | - |
| - | - | - | - | - | - | - | 6 | - | 12 | F4 | 16 | 16 | 17 | PF7 | I/O | FT | - | TIM4_CH3, XSPI1_NCS1, TIM5_CH2, SPI3_SCK, TIM20_BKIN, POSENC2_SCK, PLAY1_IN0, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | - | F5 | 17 | 17 | 18 | PF8 | I/O | FT | - | TIM4_CH2, XSPI1_NCS2, TIM5_CH3, SPI3_MISO, TIM20_BKIN2, POSENC2_MISO, PLAY1_OUT1, EVENTOUT | - |
| - | - | - | - | - | - | 7 | 7 | 13 | 13 | G4 | 18 | 18 | 19 | PF9 | I/O | FT | - | TIM4_CH1, TIM15_CH1, TIM5_CH4, SPI2_SCK/ I2S2_CK, UART4_RX, TIM20_BKIN, XSPI1_DQS0, PLAY1_IN9, EVENTOUT | - |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | - | - | - | - | 7 | 8 | 8 | 14 | 14 | G3 | 19 | 19 | 20 | PF10 | I/O | FT | - | HRTIM1_SCOUT, TIM15_CH2, TIM14_CH1, SPI2_NSS/ I2S2_WS, TIM20_BKIN2, POSENC1_SEL, XSPI1_CLK, EVENTOUT | - |
| 6 | 7 | 6 | 6 | 8 | 8 | 9 | 9 | 15 | 15 | G1 | 20 | 20 | 21 | PH0-OSC_IN(PH0) | I/O | FT_a | - | HRTIM1_EEV7, TIM1_CH3N, TIM8_CH3, TIM5_CH1, SPI2_SCK/ I2S2_CK, USART1_TX, XSPI1_IO2, POSENC2_SCK, XSPI1_NCS1, TIM13_CH1, EVENTOUT | ADC1_INP10, ADC1_INN9, OSC_IN |
| 7 | 8 | 7 | 7 | 9 | 9 | 10 | 10 | 16 | 16 | G2 | 21 | 21 | 22 | PH1-OSC_OUT(PH1) | I/O | FT_a | - | HRTIM1_EEV11, TIM1_ETR, XSPI1_NCS2, TIM8_CH4, SPI2_SCK/ I2S2_CK, POSENC1_SCK, USART1_RX, XSPI1_DQS0, POSENC2_MISO, HRTIM1_FLT1, TIM10_CH1, EVENTOUT | ADC2_INP10, ADC2_INN9, OSC_OUT |
| - | - | - | - | 10 | 10 | 11 | 11 | 17 | 17 | H1 | 22 | 22 | 23 | PC0 | I/O | FT_a | - | AUDIOCLK, HRTIM1_EEV8, XSPI1_IO3, TIM11_CH1, LPTIM1_CH1, TIM1_CH1, SPI2_RDY, LPUART1_RX, XSPI1_IO7, COMP7_OUT, PLAY1_IN3, EVENTOUT | ADC1_INP6, ADC1_INN5, ADC2_INP6, ADC2_INN5, COMP3_INM2, WKUP7 |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | - | - | - | 11 | 11 | 12 | 12 | 18 | 18 | H2 | 23 | 23 | 24 | PC1 | I/O | TT_a | - | TRACED0, TIM1_CH2, XSPI1_IO2, TIM14_CH1, SPI2_MOSI/I2S2_SDO, USART1_RTS, LPUART1_TX, POSENC2_MISO, XSPI1_IO6, HRTIM1_EEV5, PLAY1_OUT3, EVENTOUT | ADC1_INP7, ADC1_INN6, ADC2_INP7, ADC2_INN6, OPAMP2_VINP3, COMP3_INP2, WKUP6 |
| - | - | - | - | 12 | 12 | 13 | 13 | 19 | 19 | F6 | 24 | 24 | 25 | PC2 | I/O | FT_a | - | PWR_CSTOP, TIM1_CH3, TIM2_ETR, XSPI1_IO1, SPI2_MOSI/I2S2_SDO, POSENC1_SCK, UART6_CTS, TIM20_CH2, XSPI1_IO5, COMP3_OUT, EVENTOUT | ADC1_INP8, ADC1_INN7, ADC2_INP8, ADC2_INN7 |
| - | - | - | - | 13 | 13 | 14 | 14 | 20 | 20 | H3 | 25 | 25 | 26 | PC3 | I/O | TT_a | - | PWR_CSLEEP, HRTIM1_EEV9, TIM1_CH4, XSPI1_IO0, SPI2_MISO/I2S2_SDI, SPI3_NSS, UART6_RTS, TIM20_CH2N, POSENC2_SEL, XSPI1_IO4, COMP8_OUT, EVENTOUT | ADC1_INP9, ADC1_INN8, ADC2_INP9, ADC2_INN8 |
| - | - | - | - | - | - | 15 | 15 | 21 | 21 | K1 | 26 | 26 | 27 | PF2 | I/O | FT | - | XSPI1_NCS1, TIM16_CH1N, SPI3_MOSI, TIM17_CH1, TIM20_CH3, POSENC2_MOSI, TIM2_CH4, PLAY1_OUT9, EVENTOUT | - |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| 8 | 9 | 8 | 8 | 14 | 14 | 16 | 16 | 22 | 22 | G5 | 27 | 27 | 28 | PA0 | I/O | TT_at | (1) | TRACECLK, TIM2_CH1, TIM5_CH1, TIM11_CH1, SPI3_RDY, USART2_CTS/ USART2_NSS, UART4_TX(boot), POSENC1_MOSI, XSPI1_NCS2, COMP1_OUT, TIM8_BKIN, EVENTOUT | ADC1_INP1, ADC1_INN0, ADC2_INP1, ADC2_INN0, COMP1_INM2, COMP3_INP1, WKUP1, TAMP_IN1 |
| 9 | 10 | 9 | 9 | 15 | 15 | 17 | 17 | 23 | 23 | J3 | 28 | 28 | 29 | PA1 | I/O | TT_at | (1) | RTC_REFIN, TIM2_CH2, TIM5_CH2, LPTIM1_IN1, POSENC1_MISO, USART2_RTS, UART4_RX(boot), TIM15_CH1N, XSPI1_DQS0, TIM10_CH1, EVENTOUT | ADC1_INP2, ADC1_INN1, ADC2_INP2, ADC2_INN1, OPAMP1_VINP0, OPAMP3_VINP2, COMP1_INP1, TAMP_IN2 |
| - | 11 | 10 | 10 | 16 | 16 | 18 | 18 | 24 | 24 | G6 | 29 | 29 | 30 | PA2 | I/O | TT_at | (1) | TIM2_CH3, TIM5_CH3, LPUART1_TX, LPTIM1_IN2, POSENC1_SEL, USART2_TX(boot), UART4_CTS, TIM15_CH1, HRTIM1_EEV3, COMP2_OUT, EVENTOUT | ADC1_INP3, ADC1_INN2, OPAMP1_VOUT, COMP2_INM2, COMP3_INM1, WKUP2, TAMP_OUT1 |
| - | - | - | - | 17 | 17 | 19 | 19 | 25 | 25 | J1 | 30 | 30 | 31 | VDD | S | - | - | - | - |
| - | - | - | - | - | - | 20 | - | 26 | - | J2 | 31 | 31 | - | VSS | S | - | - | - | - |
| 10 | 12 | 11 | 11 | 18 | 18 | 21 | 20 | 27 | 26 | L1 | 32 | 32 | 32 | PA3 | I/O | TT_a | - | TIM2_CH4, TIM5_CH4, LPUART1_RX, POSENC1_IN, USART2_RX(boot), TIM15_CH2, PLAY1_IN0, EVENTOUT | ADC1_INP4, ADC1_INN3, OPAMP1_VINP1/ OPAMP1_VINM0, COMP2_INP2 |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| 11 | 13 | 12 | 12 | 19 | 19 | 22 | 21 | 28 | 27 | K2 | 33 | 33 | 33 | PA4 | I/O | TT_a | - | TIM3_CH4, SPI1_NSS(boot)/ I2S1_WS, USART2_CK, POSENC1_OUT, FDCAN2_RX, PLAY1_OUT12, EVENTOUT | ADC2_INP17, ADC2_INN15, DAC1_OUT1, COMP1_INM1 |
| 12 | 14 | 13 | 13 | 20 | 20 | 23 | 22 | 29 | 28 | K3 | 34 | 34 | 34 | PA5 | I/O | TT_a | - | TIM2_CH1, TIM8_CH4, POSENC1_EN, LPTIM1_CH2, TIM9_CH1, FDCAN2_TX, UART5_RX, EVENTOUT | ADC2_INP13, ADC2_INN12, DAC2_OUT1, OPAMP2_VINM0, COMP2_INM1 |
| 13 | 15 | 14 | 14 | 21 | 21 | 24 | 23 | 30 | 29 | L2 | 35 | 35 | 35 | PA6 | I/O | TT_a | - | TIM16_CH1, TIM3_CH1, TIM8_BKIN, TIM1_BKIN, FDCAN1_RX(boot), TIM8_CH2, COMP1_OUT, UART5_TX, EVENTOUT | ADC2_INP3, ADC2_INN2, OPAMP2_VOUT |
| 14 | 16 | 15 | 15 | 22 | 22 | 25 | 24 | 31 | 30 | J4 | 36 | 36 | 36 | PA7 | I/O | TT_a | - | TIM17_CH1, TIM3_CH2, TIM8_CH1N, SPI1_RDY, TIM1_CH1N, USART1_CK, FDCAN1_TX(boot), HRTIM1_EEV10, COMP2_OUT, EVENTOUT | ADC2_INP4, ADC2_INN3, OPAMP1_VINP2, OPAMP2_VINP0, COMP2_INP1 |
| - | - | - | - | - | - | 26 | 25 | 32 | 31 | H4 | 37 | 37 | 37 | PC4 | I/O | FT_a | - | HRTIM1_FLT1, TIM1_ETR, USART1_TX, I2S1_MCK, TIM8_CH2, LPTIM1_CH1, PLAY1_OUT4, EVENTOUT | ADC2_INP5, ADC2_INN4 |
| - | - | - | - | - | - | 27 | 26 | 33 | 32 | L3 | 38 | 38 | 38 | PC5 | I/O | TT_a | - | HRTIM1_EEV10, TIM15_BKIN, USART1_RX, LPTIM1_IN2, TIM1_CH4N, SPI3_NSS, TIM1_BKIN2, TIM12_CH2, EVENTOUT | ADC2_INP11, ADC2_INN10, OPAMP1_VINM1, OPAMP2_VINM1 |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| 15 | 17 | 16 | 16 | 23 | 23 | 28 | 27 | 34 | 33 | K4 | 39 | 39 | 39 | PB0 | I/O | TT_a | - | TIM16_BKIN, TIM1_CH4, TIM8_CH2N, SPI1_SCK(boot)/ I2S1_CK, TIM1_CH2N, TIM17_CH1N, SPI3_SCK, HRTIM1_FLT5, COMP5_OUT, EVENTOUT | ADC1_INP15, ADC1_INN14, ADC3_INP12, ADC3_INN11, OPAMP2_VINP2, OPAMP3_VINP0, COMP4_INP1 |
| 16 | 18 | 17 | 17 | 24 | 24 | 29 | 28 | 35 | 34 | H5 | 40 | 40 | 40 | PB1 | I/O | TT_a | - | HRTIM1_SCOUT, TIM3_CH3, TIM8_CH3N, SPI1_MISO(boot)/ I2S1_SDI, TIM1_CH3N, USART2_RX, SPI3_MISO, HRTIM1_EEV6, COMP4_OUT, PLAY1_OUT5, EVENTOUT | ADC1_INP12, ADC1_INN11, ADC3_INP1, ADC3_INN0, OPAMP3_VOUT, COMP1_INP2 |
| 17 | 19 | 18 | 18 | 25 | 25 | 30 | 29 | 36 | 35 | L4 | 41 | 41 | 41 | PB2 | I/O | TT_a | - | RTC_OUT2, TIM5_CH1, TIM3_CH4, SPI1_MOSI(boot)/ I2S1_SDO, TIM20_CH1, LPTIM1_CH1, HRTIM1_SCIN, HRTIM1_FLT6, COMP8_OUT, EVENTOUT | ADC2_INP12, ADC2_INN11, OPAMP3_VINM0, PVD_IN |
| - | - | - | - | - | - | 31 | - | - | - | K6 | - | - | - | VSS | S | - | - | - | - |
| - | - | - | - | - | - | 32 | 30 | - | - | L6 | 42 | 42 | 42 | VDD | S | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | 43 | 43 | 43 | PF11 | I/O | FT | - | POSENC1_OUT, TIM20_ETR, HRTIM1_EEV12, PLAY1_IN2, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | - | - | 44 | 44 | 44 | PF12 | I/O | FT | - | TIM1_CH4N, LPTIM1_ETR, POSENC1_IN, TIM20_CH1, HRTIM1_EEV13, PLAY1_OUT2, EVENTOUT | - |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | - | - | - | - | - | - | - | - | - | - | 45 | 45 | 45 | PF13 | I/O | TT_a | - | LPTIM1_CH2, TIM20_CH2, HRTIM1_EEV15, PLAY1_IN3, EVENTOUT | ADC2_INP0 |
| - | - | - | - | - | - | - | - | - | - | - | 46 | 46 | 46 | PF14 | I/O | FT | - | TIM5_CH1, POSENC1_EN, UART6_RTS, TIM20_CH3N, HRTIM1_EEV14, PLAY1_OUT3, EVENTOUT | - |
| - | - | - | - | - | - | - | 31 | 37 | 36 | K5 | 47 | 47 | 47 | PF15 | I/O | TT_a | - | TIM5_CH2, UART6_CTS, TIM20_CH4, HRTIM1_EEV16, PLAY1_OUT4, EVENTOUT | ADC1_INP0 |
| - | - | - | - | - | - | - | 32 | 38 | 37 | J5 | 48 | 48 | 48 | PE7 | I/O | TT_a | - | TIM1_ETR, HRTIM1_EEV4, PLAY1_IN1, EVENTOUT | COMP4_INP2 |
| - | - | - | - | - | - | - | - | - | 38 | L5 | 49 | 49 | 49 | PE8 | I/O | FT_a | - | TIM5_CH3, TIM1_CH1N, TIM20_CH4N, FDCAN1_RX, HRTIM1_EEV10, PLAY1_OUT7, EVENTOUT | COMP4_INM1 |
| - | - | - | - | - | - | - | - | - | - | J6 | 50 | 50 | 50 | PE9 | I/O | FT | - | TIM5_ETR, TIM1_CH1, FDCAN1_TX, HRTIM1_FLT3, PLAY1_IN7, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | - | - | 51 | 51 | 51 | VREFDAC- | S | - | - | - | - |
| - | 20 | 19 | 19 | 26 | 26 | 33 | 33 | 39 | 39 | K7 | 52 | 52 | 52 | VSSA | S | - | - | - | - |
| 18 | 21 | 20 | 20 | 27 | 27 | 34 | 34 | 40 | 40 | L7 | 53 | 53 | 53 | VDDA | S | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | 54 | 54 | 54 | VREFDAC+ | S | - | - | - | - |
| 19 | 22 | 21 | 21 | 28 | 28 | 35 | 35 | 41 | 41 | L8 | 55 | 55 | 55 | VREF+ | S | - | - | - | - |
| 20 | 23 | 22 | 22 | 29 | 29 | 36 | 36 | 42 | 42 | K8 | 56 | 56 | 56 | VREF- | S | - | - | - | - |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | - | - | - | - | - | - | - | - | - | - | 57 | 57 | 57 | VDD | S | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - | 58 | VSS | S | - | (4) | - | - |
| - | - | - | - | - | - | - | - | - | - | H6 | 58 | 58 | 59 | PH5 | I/O | FT | - | TIM17_CH1, TIM20_CH2N, HRTIM1_SCOUT, PLAY1_OUT5, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | - | J7 | 59 | 59 | 60 | PE10 | I/O | FT_a | - | TIM1_CH2N, HRTIM1_FLT7, PLAY1_OUT8, EVENTOUT | ADC3_INP14, ADC3_INN12, COMP8_INM2 |
| - | - | - | - | - | - | - | - | - | 43 | H7 | 60 | 60 | 61 | PE11 | I/O | FT | - | TIM1_CH2, HRTIM1_FLT8, FDCAN2_TX, PLAY1_IN8, EVENTOUT | - |
| - | - | - | - | - | - | - | - | 43 | 44 | L9 | 61 | 61 | 62 | PE12 | I/O | FT_a | - | TIM1_CH3N, FDCAN2_RX, PLAY1_OUT10, EVENTOUT | ADC3_INP16, ADC3_INN15, COMP8_INM1 |
| - | - | - | - | - | - | 37 | 37 | 44 | 45 | J8 | 62 | 62 | 63 | PE13 | I/O | FT_a | - | TIM1_CH3, TIM20_BKIN2, UART5_RTS, HRTIM1_FLT6, PLAY1_OUT11, EVENTOUT | ADC3_INP3, ADC3_INN2 |
| - | - | - | - | - | - | 38 | 38 | 45 | 46 | H8 | 63 | 63 | 64 | PE14 | I/O | FT_a | - | TIM1_CH4, TIM1_BKIN2, UART5_CTS, HRTIM1_EEV3, PLAY1_IN5, EVENTOUT | ADC3_INP4, ADC3_INN3 |
| - | - | - | - | - | - | 39 | 39 | 46 | 47 | K9 | 64 | 64 | 65 | PE15 | I/O | TT_a | - | TIM1_BKIN, TIM1_CH4N, USART3_RX, HRTIM1_FLT2, PLAY1_OUT6, EVENTOUT | ADC3_INP2, ADC3_INN1, COMP8_INP1 |
| 21 | 24 | 23 | 23 | 30 | 30 | 40 | 40 | 47 | 48 | L10 | 65 | 65 | 66 | PB10 | I/O | TT_a | - | HRTIM1_FLT3, TIM2_CH3, USART3_TX, LPUART1_RX, TIM1_BKIN, CRS_SYNC, EVENTOUT | ADC3_INP0, OPAMP3_VINM1, COMP5_INM1 |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | 25 | 24 | 24 | 31 | 31 | 41 | 41 | 48 | 49 | J9 | 66 | 66 | 67 | PB11 | I/O | TT_a | - | HRTIM1_FLT4, TIM1_CH3N, SPI2_RDY, USART3_RX, LPUART1_TX, TIM2_CH4, TIM9_CH1, PLAY1_IN2, EVENTOUT | ADC1_INP14, ADC1_INN12, ADC2_INP14, ADC2_INN13, COMP6_INP1 |
| - | - | - | - | - | - | - | - | 49 | 50 | J11 | 67 | 67 | 68 | VDD | S | - | - | - | - |
| - | - | - | - | - | - | - | - | 50 | - | J10 | 68 | 68 | - | VSS | S | - | - | - | - |
| - | 26 | 25 | 25 | 32 | 32 | 42 | 42 | 51 | 51 | L11 | 69 | 69 | 69 | PB12 | I/O | TT_a | - | HRTIM1_FLT2, TIM5_CH4, TIM8_BKIN2, TIM14_CH1, SPI2_NSS(boot)/ I2S2_WS, USART3_CK, LPUART1_RTS, TIM1_BKIN, TIM9_CH2, UCPD1_FRSTX, FDCAN1_RX, UART5_RX, EVENTOUT | ADC1_INP11, ADC1_INN10, COMP7_INM2, COMP8_INP2 |
| 22 | 27 | 26 | 26 | 33 | 33 | 43 | 43 | 52 | 52 | K11 | 70 | 70 | 70 | PB13 | I/O | TT_a | - | HRTIM1_FLT6, TIM1_CH1, TIM14_CH1, SPI2_SCK(boot)/ I2S2_CK, USART3_CTS/ USART3_NSS, LPUART1_CTS, LPTIM1_ETR, TIM8_CH4, FDCAN1_TX, UART5_TX, EVENTOUT | ADC3_INP5, ADC3_INN4, OPAMP3_VINP1, COMP5_INP1 |
| - | 28 | 27 | 27 | 34 | 34 | 44 | 44 | 53 | 53 | K10 | 71 | 71 | 71 | PB14 | I/O | TT_a | - | MCO2, TIM15_CH1, TIM1_CH2, USART1_TX, SPI2_MISO(boot)/ I2S2_SDI, USART3_RTS, UART4_RTS, LPTIM1_CH2, TIM8_CH4N, HRTIM1_EEV1, COMP4_OUT, PLAY1_OUT2, EVENTOUT | ADC1_INP5, ADC1_INN4, OPAMP2_VINP1, COMP7_INP1 |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | 29 | 28 | 28 | 35 | 35 | 45 | 45 | 54 | 54 | H9 | 72 | 72 | 72 | PB15 | I/O | FT_a | - | MCO2, TIM15_CH2, TIM15_CH1N, XSPI1_CLK, USART1_RX, SPI2_MOSI(boot)/ I2S2_SDO, TIM1_CH3, UART6_TX, UART4_CTS, UART5_RX, HRTIM1_EEV2, COMP3_OUT, EVENTOUT | ADC2_INP15, ADC2_INN14, COMP4_INM2, COMP6_INM2 |
| - | - | - | - | - | - | 46 | 46 | 55 | 55 | H10 | 73 | 73 | 73 | PD8 | I/O | FT_a | - | HRTIM1_EEV4, TIM4_ETR, XSPI1_IO3, POSENC2_MOSI, USART3_TX, TIM20_ETR, CRS_SYNC, EVENTOUT | ADC3_INP6, ADC3_INN5 |
| - | - | - | - | - | - | 47 | 47 | 56 | 56 | G7 | 74 | 74 | 74 | PD9 | I/O | FT_a | - | HRTIM1_EEV6, XSPI1_NCS2, POSENC2_MISO, USART3_RX, XSPI1_IO2, TIM20_CH3N, TIM9_CH2, PLAY1_IN11, EVENTOUT | ADC3_INP15, ADC3_INN14 |
| - | - | - | - | - | 36 | 48 | 48 | 57 | 57 | H11 | 75 | 75 | 75 | PD10 | I/O | FT_a | - | HRTIM1_SCOUT, POSENC2_SEL, USART3_CK, XSPI1_IO1, TIM20_CH3, HRTIM1_EEV9, EVENTOUT | ADC3_INP7, ADC3_INN6, COMP6_INM1 |
| - | - | - | - | - | - | - | 49 | 58 | 58 | G8 | 76 | 76 | 76 | PD13 | I/O | FT_a | - | LPTIM1_CH1, TIM4_CH2, POSENC2_IN, SPI3_RDY, XSPI1_DQS0, HRTIM1_FLT1, PLAY1_OUT13, EVENTOUT | ADC3_INP10, ADC3_INN9, COMP5_INM2 |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | - | - | - | - | - | - | - | 59 | 59 | G9 | 77 | 77 | 77 | PD14 | I/O | TT_a | - | HRTIM1_EEV11, TIM4_CH3, XSPI1_NCS1, POSENC2_OUT, POSENC1_OUT, PLAY1_IN14, EVENTOUT | ADC3_INP11, ADC3_INN10, COMP7_INP2 |
| - | - | - | - | - | - | - | - | 60 | 60 | F7 | 78 | 78 | 78 | PD15 | I/O | FT_a | - | TIM16_BKIN, TIM4_CH4, XSPI1_IO0, POSENC2_EN, SPI2_NSS/I2S2_WS, TIM1_CH1, HRTIM1_FLT4, PLAY1_OUT14, EVENTOUT | COMP7_INM1 |
| - | - | - | - | - | - | - | - | - | 61 | F11 | 79 | - | 79 | PG4 | I/O | FT_f | - | HRTIM1_EEV2, SPI1_MISO/I2S1_SDI, XSPI1_IO1, TIM5_CH1, POSENC2_EN, TIM20_BKIN2, PLAY1_OUT1, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | - | G11 | 80 | - | 80 | PG5 | I/O | FT_f | - | HRTIM1_EEV7, SPI1_MOSI/I2S1_SDO, XSPI1_IO2, TIM5_CH3, LPUART1_CTS, TIM20_ETR, PLAY1_IN1, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | - | G10 | 81 | - | 81 | PG9 | I/O | FT | - | HRTIM1_FLT1, SPI1_SCK/I2S1_CK, XSPI1_IO3, TIM5_CH4, SPI3_SCK, UART6_RX, TIM15_CH1N, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | - | - | - | 79 | - | VSSSMPS | S | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | 80 | - | VLXSMPS | S | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | 81 | - | VDDSMPS | S | - | - | - | - |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| 23 | 30 | 29 | 29 | 36 | 37 | 49 | 50 | 61 | 62 | E11 | 82 | 82 | 82 | VCAP | S | - | - | - | - |
| - | 31 | - | - | 37 | - | 50 | - | 62 | - | D10 | 83 | 83 | - | VSS | S | - | - | - | - |
| 24 | 32 | 30 | 30 | 38 | 38 | 51 | 51 | 63 | 63 | D11 | 84 | 84 | 83 | VDD | S | - | - | - | - |
| 25 | - | - | - | 39 | 39 | 52 | 52 | 64 | 64 | F10 | 85 | 85 | 84 | PD11 | I/O | TT_a | - | TIM5_ETR, TIM4_CH2, TIM8_ETR, USART3_CTS/ USART3_NSS, UART4_RX, POSENC2_MOSI, XSPI1_IO0, HRTIM1_CHE1, PLAY1_OUT0, EVENTOUT | ADC3_INP8, ADC3_INN7, COMP6_INP2 |
| 26 | - | - | - | 40 | 40 | 53 | 53 | 65 | 65 | E9 | 86 | 86 | 85 | PD12 | I/O | TT_a | - | TIM4_CH3, POSENC2_SCK, USART3_RTS, UART4_TX, LPTIM1_IN1, HRTIM1_CHE2, PLAY1_OUT1, EVENTOUT | ADC3_INP9, ADC3_INN8, COMP5_INP2 |
| 27 | - | - | - | 41 | 41 | 54 | 54 | 66 | 66 | E10 | 87 | 87 | 86 | PG2 | I/O | FT_f | - | TIM15_BKIN, SPI1_MOSI/I2S1_SDO, XSPI1_IO1, I2C2_SCL, USART2_TX, TIM20_CH4, TIM8_BKIN2, HRTIM1_CHD1, COMP5_OUT, EVENTOUT | - |
| 28 | - | - | - | 42 | 42 | 55 | 55 | 67 | 67 | F9 | 88 | 88 | 87 | PG3 | I/O | FT_f | - | SPI1_SCK/I2S1_CK, XSPI1_IO2, I2C2_SDA, TIM20_CH4N, USART3_RX, TIM20_BKIN, TIM8_ETR, HRTIM1_CHD2, COMP7_OUT, PLAY1_IN10, EVENTOUT | - |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| 36 | - | 31 | 31 | 43 | 43 | 56 | 56 | 68 | 68 | F8 | 89 | 89 | 88 | PC11 | I/O | FT_f | - | TRACED1, HRTIM1_CHC1, TIM1_ETR, XSPI1_IO3, TIM8_CH2N, SPI1_MISO/I2S1_SDI, SPI3_MISO, USART3_RX, UART4_RX, POSENC1_IN, TIM4_CH1, TIM12_CH1, EVENTOUT | - |
| 29 | - | 32 | 32 | 44 | 44 | 57 | 57 | 69 | 69 | E8 | 90 | 90 | 89 | PC12 | I/O | FT_f | - | TRACED3, HRTIM1_CHC2, TIM5_CH2, LPUART1_RTS, I2C2_SDA, SPI3_MOSI, USART3_CK, POSENC1_OUT, TIM8_CH3N, XSPI1_IO0, TIM13_CH1, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | - | - | 91 | 91 | 90 | VDD | S | - | - | - | - |
| 35 | - | - | - | 45 | 45 | 58 | 58 | 70 | 70 | D9 | 92 | 92 | 91 | PC6 | I/O | FT_f | - | HRTIM1_EEV10, TIM3_CH1, I3C1_SCL, TIM8_CH1, I2S2_MCK, UART6_TX, I2C4_SCL, HRTIM1_CHF1, XSPI1_IO3, COMP6_OUT, EVENTOUT | - |
| 30 | - | 33 | 33 | 46 | 46 | 59 | 59 | 71 | 71 | C10 | 93 | 93 | 92 | PC7 | I/O | FT_f | - | TRACED2, HRTIM1_FLT5, TIM3_CH2, I3C1_SDA, TIM8_CH3, USART3_RTS, UART6_RX, POSENC1_EN, I2C4_SDA, HRTIM1_CHF2, XSPI1_IO2, COMP5_OUT, EVENTOUT | - |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| 34 | 33 | 34 | 34 | 47 | 47 | 60 | 60 | 72 | 72 | C11 | 94 | 94 | 93 | PB5 | I/O | FT_f | - | TIM16_CH1, TIM4_CH3, XSPI1_IO1, TIM8_CH2N, POSENC1_SCK, I2S2_MCK, I2C3_SDA, I2C1_SCL, I2C4_SCL, HRTIM1_CHA1, COMP4_OUT, CRS_SYNC, EVENTOUT | - |
| 31 | 34 | 35 | 35 | 48 | 48 | 61 | 61 | 73 | 73 | D8 | 95 | 95 | 94 | PB6 | I/O | FT_f | - | TIM1_BKIN2, TIM4_CH4, XSPI1_IO0, I2C1_SDA, TIM8_CH2, USART2_TX, UART4_CTS, SPI3_SCK, I2C4_SDA, HRTIM1_CHA2, UCPD1_FRSTX, COMP7_OUT, TIM12_CH1, EVENTOUT | - |
| 33 | 35 | 36 | 36 | 49 | 49 | 62 | 62 | 74 | 74 | B11 | 96 | 96 | 95 | PB7 | I/O | FT_f | (13) | HRTIM1_CHB1, TIM2_CH1, TIM8_CH1, I2C1_SCL, SPI1_NSS/ I2S1_WS, SPI3_NSS, FDCAN3_TX, TIM1_BKIN, TIM2_ETR, COMP1_OUT, TIM12_CH2, EVENTOUT | - |
| 32 | 36 | 37 | 37 | 50 | 50 | 63 | 63 | 75 | 75 | C9 | 97 | 97 | 96 | PA10 | I/O | FT | (13) | TIM17_BKIN, TIM2_CH1, LPUART1_TX, I2C2_SMBA, TIM8_CH1N, TIM1_CH3, USART1_RX, UART4_RX, POSENC2_IN, TIM8_BKIN, HRTIM1_CHB2, FDCAN2_TX, COMP6_OUT, EVENTOUT | - |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | - | - | - | - | - | - | - | - | - | B10 | 98 | 98 | 97 | PD0 | I/O | FT_fd | (5) | HRTIM1_EEV5, I2C2_SMBA, XSPI1_DQS0, I2C3_SCL, SPI1_MOSI/I2S1_SDO, UART4_RX, FDCAN1_RX, I2C4_SMBA, TIM8_CH4N, EVENTOUT | UCPD1_DBCC2 |
| - | - | - | - | - | - | - | - | - | - | B9 | 99 | 99 | 98 | PD1 | I/O | FT_fd | (5) | HRTIM1_EEV8, SPI1_MISO/I2S1_SDI, XSPI1_NCS2, I2C3_SDA, UART4_TX, FDCAN1_TX, TIM8_CH4, TIM8_BKIN2, EVENTOUT | UCPD1_DBCC1 |
| - | 37 | 38 | 38 | 51 | 51 | 64 | 64 | 76 | 76 | A11 | 100 | 100 | 99 | PA11 | I/O | FT_fu | - | TIM1_CH4N, TIM1_BKIN2, I3C1_SCL, I2C2_SCL, SPI2_MISO/I2S2_SDI, TIM1_CH1N, USART1_CTS/USART1_NSS, UART4_RX, FDCAN1_RX, XSPI1_NCS1, HRTIM1_FLT1, FDCAN2_RX, TIM13_CH1, EVENTOUT | USB_DM(boot) |
| - | 38 | 39 | 39 | 52 | 52 | 65 | 65 | 77 | 77 | A10 | 101 | 101 | 100 | PA12 | I/O | FT_fu | - | MCO1, TIM16_CH1N, I3C1_SDA, I2C2_SDA, SPI2_MOSI/I2S2_SDO, TIM1_CH2N, USART1_RTS, UART4_TX, FDCAN1_TX, XSPI1_CLK, HRTIM1_EEV7, COMP2_OUT, EVENTOUT | USB_DP(boot) |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | 39 | 40 | 40 | 53 | 53 | 66 | 66 | 78 | 78 | C8 | 102 | 102 | 101 | PA8 | I/O | FT_c | (6) | TIM1_ETR, TIM4_ETR, LPUART1_RX, USART1_CK, SPI1_RDY, FDCAN3_RX, USART2_RX, UART6_RX, TIM1_CH3N, HRTIM1_EEV4, TIM15_BKIN, EVENTOUT | UCPD1_CC1 |
| - | 40 | 41 | 41 | 54 | 54 | 67 | 67 | 79 | 79 | C7 | 103 | 103 | 102 | PA9 | I/O | FT_c | (6) | TIM2_CH3, TIM2_ETR, LPUART1_TX, TIM8_ETR, TIM16_BKIN, USART1_TX, UART4_RTS, POSENC2_EN, HRTIM1_EEV9, HRTIM1_FLT3, PLAY1_IN12, EVENTOUT | UCPD1_CC2 |
| - | - | - | - | - | 55 | 68 | 68 | 80 | 80 | A9 | 104 | 104 | 103 | PC8 | I/O | FT_f | - | TIM3_CH3, I3C1_SCL, TIM8_CH3, TIM20_CH3, I2C3_SCL, XSPI1_IO7, HRTIM1_EEV15, TIM10_CH1, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - | 104 | VSS | S | - | (4) | - | - |
| - | 41 | 42 | 42 | 55 | 56 | 69 | 69 | 81 | 81 | A8 | 105 | 105 | 105 | VDD | S | - | - | - | - |
| - | 42 | - | - | 56 | - | 70 | - | 82 | - | B8 | 106 | 106 | - | VSS | S | - | - | - | - |
| - | - | - | - | - | - | - | 70 | 83 | 82 | B7 | 107 | 107 | 106 | PC9 | I/O | FT_f | - | TIM3_CH2, I3C1_SDA, TIM8_CH4, TIM8_BKIN2, UART6_TX, I2C3_SDA, HRTIM1_EEV16, EVENTOUT | - |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | - | - | - | - | - | - | - | 84 | 83 | D7 | 108 | 108 | 107 | PC10 | I/O | FT | - | HRTIM1_EEV1, I2C2_SMBA, TIM8_CH1N, I2C3_SMBA, SPI1_RDY, TIM20_CH4N, USART3_TX, UART4_TX, XSPI1_IO4, UCPD1_FRSTX, COMP8_OUT, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - | 108 | VSS | S | - | (4) | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - | 109 | VSS | S | - | (4) | - | - |
| - | - | - | - | - | - | - | - | 85 | 84 | E7 | 109 | 109 | 110 | PD2 | I/O | FT | - | TRACED2, TIM3_ETR, XSPI1_IO5, TIM8_BKIN, SPI1_SCK/I2S1_CK, POSENC2_SCK, TIM20_ETR, UART5_RX, HRTIM1_EEV12, PLAY1_IN15, EVENTOUT | WKUP8 |
| - | - | - | - | - | - | - | - | 86 | 85 | A7 | 110 | 110 | 111 | PD3 | I/O | FT | - | TIM1_CH1, XSPI1_IO6, TIM8_BKIN2, SPI2_SCK/I2S2_CK, USART2_CTS/USART2_NSS, UART5_TX, TIM2_CH4, HRTIM1_EEV3, PLAY1_IN13, EVENTOUT | - |
| - | - | - | - | - | - | - | - | 87 | 86 | D6 | 111 | 111 | 112 | PD4 | I/O | FT_f | - | TIM1_CH2, TIM2_CH2, I3C1_SCL, USART1_CTS/USART1_NSS, USART2_RTS, XSPI1_IO7, I2C4_SCL, HRTIM1_FLT3, EVENTOUT | - |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | - | - | - | - | - | - | - | 88 | 87 | B6 | 112 | 112 | 113 | PD5 | I/O | FT | - | TIM4_CH4, TIM8_ETR, SPI2_RDY, TIM1_BKIN2, USART2_TX, XSPI1_IO4, TIM1_BKIN, I2C4_SMBA, HRTIM1_EEV10, EVENTOUT | - |
| - | - | - | - | - | - | - | - | 89 | 88 | C6 | 113 | 113 | 114 | PD6 | I/O | FT_f | - | I3C1_SCL, SPI1_MISO/ I2S1_SDI, I2C4_SCL, USART2_RX, XSPI1_IO5, SPI3_MISO, TIM2_CH1, HRTIM1_FLT5, EVENTOUT | - |
| - | - | - | - | - | - | - | - | 90 | 89 | A6 | 114 | 114 | 115 | PD7 | I/O | FT_f | - | TIM2_ETR, I3C1_SDA, SPI1_MOSI/I2S1_SDO, I2C4_SDA, USART2_CK, XSPI1_IO6, FDCAN1_RX, TIM2_CH3, TIM9_CH1, EVENTOUT | - |
| - | - | - | - | - | - | - | - | 91 | 90 | E6 | 115 | 115 | 116 | PG10 | I/O | FT_f | - | SPI1_NSS/I2S1_WS, XSPI1_IO7, I2C2_SDA, POSENC1_IN, SPI3_SCK, LPUART1_TX, FDCAN1_TX, TIM8_CH2, TIM9_CH2, PLAY1_IN1, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | 91 | C5 | 116 | 116 | 117 | PG11 | I/O | FT_f | - | SPI1_SCK/I2S1_CK, XSPI1_NCS2, I2C2_SCL, I2C4_SCL, SPI3_NSS, TIM20_CH1, LPTIM1_IN2, TIM8_CH1, TIM12_CH2, EVENTOUT | - |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| - | - | - | - | - | - | - | - | - | - | A5 | 117 | 117 | 118 | PG12 | I/O | FT | - | TIM15_CH1N, XSPI1_NCS1, POSENC1_OUT, UART6_RTS, LPUART1_RX, LPTIM1_IN1, TIM8_CH3N, PLAY1_IN4, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | - | B5 | 118 | 118 | 119 | PG13 | I/O | FT | - | TRACED0, XSPI1_CLK, POSENC1_EN, UART6_CTS, LPTIM1_CH1, COMP6_OUT, EVENTOUT | - |
| - | - | - | - | - | - | - | - | - | - | D5 | 119 | 119 | 120 | PG14 | I/O | FT_f | - | TRACED1, LPTIM1_ETR, SPI3_MOSI, UART6_TX, TIM20_CH1N, LPTIM1_CH2, HRTIM1_FLT4, PLAY1_IN5, EVENTOUT | - |
| - | - | - | - | - | - | - | - | 92 | 92 | A4 | 120 | 120 | 121 | VDD | S | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | B4 | 121 | 121 | - | VSS | S | - | - | - | - |
| 37 | 43 | 43 | 43 | 57 | 57 | 71 | 71 | 93 | 93 | C4 | 122 | 122 | 122 | PB3(JTDO/ TRACESWO) | I/O | FT_f | (7) | JTDO/TRACESWO, TIM2_CH2, TIM3_ETR, XSPI1_CLK, I2C2_SDA(boot), TIM8_CH1N, FDCAN3_RX, USART3_TX, I2C3_SDA, POSENC2_OUT, TIM4_ETR, HRTIM1_FLT5, HRTIM1_EEV11, UART5_RTS, EVENTOUT | - |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| 38 | 44 | 44 | 44 | 58 | 58 | 72 | 72 | 94 | 94 | B3 | 123 | 123 | 123 | PB4(NJTRST) | I/O | FT_fb | (8) | NJTRST, TIM16_CH1, TIM3_CH1, I3C1_SDA, I2C2_SCL(boot), TIM8_CH2N, FDCAN3_TX, TIM17_BKIN, I2C3_SCL, I2C1_SMBA, TIM2_CH1, XSPI1_DQS0, HRTIM1_EEV15, UART5_CTS, EVENTOUT | - |
| 39 | 45 | 45 | 45 | 59 | 59 | 73 | 73 | 95 | 95 | A3 | 124 | 124 | 124 | PA13(JTMS/SWDIO) | I/O | FT_f | (9) | JTMS/SWDIO, HRTIM1_FLT7, TIM3_CH4, I3C1_SCL, I2C3_SCL, I2C4_SMBA, SPI3_MOSI, TIM15_BKIN, FDCAN2_RX, TIM8_CH3N, EVENTOUT | - |
| 40 | 46 | 46 | 46 | 60 | 60 | 74 | 74 | 96 | 96 | A2 | 125 | 125 | 125 | PA14(JTCK/SWCLK) | I/O | FT_f | (10) | JTCK/SWCLK, TIM16_CH1N, TIM4_CH1, LPUART1_CTS, SPI1_NSS/I2S1_WS, XSPI1_IO3, TIM15_CH1, XSPI1_NCS1, FDCAN2_TX, TIM8_CH1, EVENTOUT | - |
| 1 | 47 | 47 | 47 | 61 | 61 | 75 | 75 | 97 | 97 | B2 | 126 | 126 | 126 | PA15(JTDI) | I/O | FT_fb | (11) | JTDI, HRTIM1_SCIN, TIM3_ETR, I3C1_SCL, I2C1_SCL, TIM8_BKIN, I2C4_SCL, TIM17_CH1N, TIM3_CH3, POSENC1_IN, TIM4_CH2, HRTIM1_EEV6, TIM15_BKIN, EVENTOUT | - |
| 2 | 48 | 48 | 48 | 62 | 62 | 76 | 76 | 98 | 98 | A1 | 127 | 127 | 127 | BOOT0 | I | B | - | - | BOOT0 |

| Pin Number | | | | | | | | | | | | | | Pin name (function after reset) | Pin type | I/O structure | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UFQFPN40 | LQFP48 | TQFP48-EP | UFQFPN48 | LQFP64 | TQFP64-EP | LQFP80 | LQFP80-EP | LQFP100 | LQFP100-EP | UFBGA121 | LQFP128 | LQFP128 SMPS | LQFP128-EP | | | | | | |
| 3 | 1 | 1 | 1 | 63 | 63 | 77 | 77 | 99 | 99 | C3 | 128 | 128 | 128 | PB9 | I/O | FT_fbt | (12) | MCO1, TIM1_CH2, TIM4_CH4, I3C1_SDA, I2C1_SDA, I2C4_SDA, TIM17_CH1, POSENC1_EN, TIM8_CH3, HRTIM1_EEV5, FDCAN1_TX, COMP3_OUT, EVENTOUT | WKUP5, TAMP_IN1/ TAMP_OUT2 |
| 41 | - | 49 | 49 | - | 65 | - | 81 | - | 101 | - | - | - | 129 | VSS | S | - | (4) | - | - |

1. *Active tamper pin (input/output). As a tamper input, only PC13, PA0, PA1 are functional in Standby mode. As a tamper output, only PC13 is functional in Standby mode.*
2. *SMBus 3.3 compliant pin.*
3. *LSE pin. PC14, PC15 are LSE pins. The use of PC14, PC15 GPIOs in output mode is limited. The speed must not exceed 500 kHz with a maximum load of 30 pF. Speed in input mode must not exceed 1 MHz. These GPIOs must not be used as current sources (max +/- 0.5 mA).*
4. *VSS pin connected to exposed pad.*
5. *UCPD_DBCC pins*
6. *UCPD_CC pins. Maximum speed - 10 MHz as output, 100 MHz as input. Driving capability - 2 mA output max. After reset, a pull-down resistor (Rd = 5.1 kΩ from UCPD peripheral) can be activated on UCPD1_CC1, UCPD1_CC2 pins (PA8, PA9). The pull-down on UCPD1_CC1 (PA8) is activated by high level on UCPD1_DBCC1 (PD0). The pull-down on UCPD1_CC2 (PA9) is activated by high level on UCPD1_DBCC2 (PD1). This pull-down control (dead battery support on UCPD peripheral) can be disabled by setting bit UCPD1_DBDIS = 1 in the PWR_UCPDR register.*
7. *JTDO default debug pin.*
8. *NJTRST default debug pin. The internal pull-up is activated after reset. SMBus 3.3 compliant pin.*
9. *SWDIO default debug pin. The internal pull-up is activated after reset.*
10. *SWCLK default debug pin. The internal pull-down is activated after reset.*
11. *JTDI default debug pin. The internal pull-up is activated after reset. SMBus 3.3 compliant pin.*
12. *Active tamper pin (input/output). As a tamper input, only PC13, PA0, PA1 are functional in Standby mode. As a tamper output, only PC13 is functional in Standby mode. SMBus 3.3 compliant pin.*
13. *UFQFPN40 pinout is not compatible with STM32G54x/53x devices: pins 32 (PA10) and 33 (PB7) are exchanged.*

*Note: All alternate functions with "(boot)" suffix can be activated after entering into embedded bootloader. This activation can be disabled/enabled by configuring the active bootloader interfaces in the BL_COM_CFG option byte (see the FLASH_BL_COM_CFG_PRG register).*

## 4.3 Alternate functions

**Table 14. Alternate functions**

| Port | | AF0 | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 | AF7 | AF8 | AF9 | AF10 | AF11 | AF12 | AF13 | AF14 | AF 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SYS | HRTIM1/ LPTIM1/ TIM1/2/5/15/16/ 17 | I2C2/SPI1/ I2S1/ TIM1/2/3/4/5/ 15 | I3C1/ LPUART1/ TIM8/15/XSPI1 | I2C1/2/3/ TIM5/8/11/14/ USART1 | LPTIM1/SPI1/ I2S1/SPI2/I2S2/ TIM8/16 | FDCAN3/I2C4/ POSENC1/2/ SPI3/ TIM1/8/20 | SPI2/I2S2/ SPI3/TIM17/ UART6/U SART1/2/3 | FDCAN3/I2C3 /LPUART1/ TIM3/20/ UART4/6/ XSPI1 | FDCAN1/I2C1/ LPTIM1/ POSENC1/2/ SPI3/ TIM1/15/20/ UART5 | I2C4/ TIM2/4/8/ XSPI1 | HRTIM1/ TIM9 | HRTIM1/ USB_PD/ XSPI1 | COMP1/4/7/ FDCAN1/2/ HRTIM1 | COMP2/3/5/6/8/ CRS/PLAY1_IN/ PLAY1_OUT/ TIM8/10/12/13/15/ UART5 | EVENTOUT |
| Port A | PA0 | TRACE CLK | TIM2_CH1 | TIM5_CH1 | - | TIM11_CH1 | - | SPI3_RDY | USART2_CTS/ USART2_NSS | UART4_TX | POSENC1_MO SI | XSPI1_NCS2 | - | - | COMP1_OUT | TIM8_BKIN | EVENTOUT |
| | PA1 | RTC_RE FIN | TIM2_CH2 | TIM5_CH2 | - | - | LPTIM1_IN1 | POSENC1_MISO | USART2_RTS | UART4_RX | TIM15_CH1N | XSPI1_DQS0 | - | - | - | TIM10_CH1 | |
| | PA2 | - | TIM2_CH3 | TIM5_CH3 | LPUART1_TX | - | LPTIM1_IN2 | POSENC1_SEL | USART2_TX | UART4_CTS | TIM15_CH1 | - | - | HRTIM1_EEV3 | - | COMP2_OUT | |
| | PA3 | - | TIM2_CH4 | TIM5_CH4 | LPUART1_RX | - | - | POSENC1_IN | USART2_RX | - | TIM15_CH2 | - | - | - | - | PLAY1_IN0 | |
| | PA4 | - | - | TIM3_CH4 | - | - | SPI1_NSS/ I2S1_WS | - | USART2_CK | - | POSENC1_OU T | - | - | - | FDCAN2_RX | PLAY1_OUT12 | |
| | PA5 | - | - | TIM2_CH1 | - | TIM8_CH4 | - | POSENC1_EN | - | - | LPTIM1_CH2 | - | TIM9_CH1 | - | FDCAN2_TX | UART5_RX | |
| | PA6 | - | TIM16_CH1 | TIM3_CH1 | - | TIM8_BKIN | - | TIM1_BKIN | - | - | FDCAN1_RX | TIM8_CH2 | - | - | COMP1_OUT | UART5_TX | |
| | PA7 | - | TIM17_CH1 | TIM3_CH2 | - | TIM8_CH1N | SPI1_RDY | TIM1_CH1N | USART1_CK | - | FDCAN1_TX | - | HRTIM1_EEV1 0 | - | - | COMP2_OUT | |
| | PA8 | - | TIM1_ETR | TIM4_ETR | LPUART1_RX | USART1_CK | SPI1_RDY | FDCAN3_RX | USART2_RX | UART6_RX | TIM1_CH3N | - | - | HRTIM1_EEV4 | - | TIM15_BKIN | |
| | PA9 | - | TIM2_CH3 | TIM2_ETR | LPUART1_TX | TIM8_ETR | TIM16_BKIN | - | USART1_TX | UART4_RTS | POSENC2_EN | - | - | HRTIM1_EEV9 | HRTIM1_FLT3 | PLAY1_IN12 | |
| | PA10 | - | TIM17_BKIN | TIM2_CH1 | LPUART1_TX | I2C2_SMBA | TIM8_CH1N | TIM1_CH3 | USART1_RX | UART4_RX | POSENC2_IN | TIM8_BKIN | - | HRTIM1_CHB2 | FDCAN2_TX | COMP6_OUT | |
| | PA11 | - | TIM1_CH4N | TIM1_BKIN2 | I3C1_SCL | I2C2_SCL | SPI2_MISO/ I2S2_SDI | TIM1_CH1N | USART1_CTS/ USART1_NSS | UART4_RX | FDCAN1_RX | XSPI1_NCS1 | - | HRTIM1_FLT1 | FDCAN2_RX | TIM13_CH1 | |
| | PA12 | MCO1 | TIM16_CH1N | - | I3C1_SDA | I2C2_SDA | SPI2_MOSI/ I2S2_SDO | TIM1_CH2N | USART1_RTS | UART4_TX | FDCAN1_TX | XSPI1_CLK | - | HRTIM1_EEV7 | - | COMP2_OUT | |
| | PA13 | JTMS/ SWDIO | HRTIM1_FLT7 | TIM3_CH4 | I3C1_SCL | I2C3_SCL | - | I2C4_SMBA | SPI3_MOSI | - | TIM15_BKIN | - | - | - | FDCAN2_RX | TIM8_CH3N | |
| | PA14 | JTCK/ SWCLK | TIM16_CH1N | TIM4_CH1 | LPUART1_CTS | - | SPI1_NSS/ I2S1_WS | - | - | XSPI1_IO3 | TIM15_CH1 | XSPI1_NCS1 | - | - | FDCAN2_TX | TIM8_CH1 | |
| | PA15 | JTDI | HRTIM1_SCIN | TIM3_ETR | I3C1_SCL | I2C1_SCL | TIM8_BKIN | I2C4_SCL | TIM17_CH1N | TIM3_CH3 | POSENC1_IN | TIM4_CH2 | - | HRTIM1_EEV6 | - | TIM15_BKIN | |
| Port B | PB0 | - | TIM16_BKIN | TIM1_CH4 | - | TIM8_CH2N | SPI1_SCK/ I2S1_CK | TIM1_CH2N | TIM17_CH1N | - | SPI3_SCK | - | HRTIM1_FLT5 | - | - | COMP5_OUT | EVENTOUT |
| | PB1 | - | HRTIM1_SCOU T | TIM3_CH3 | - | TIM8_CH3N | SPI1_MISO/ I2S1_SDI | TIM1_CH3N | USART2_RX | - | SPI3_MISO | - | HRTIM1_EEV6 | - | COMP4_OUT | PLAY1_OUT5 | |
| | PB2 | RTC_O UT2 | TIM5_CH1 | TIM3_CH4 | - | - | SPI1_MOSI/ I2S1_SDO | TIM20_CH1 | - | - | LPTIM1_CH1 | - | HRTIM1_SCIN | HRTIM1_FLT6 | - | COMP8_OUT | |
| | PB3 | JTDO/ TRACES WO | TIM2_CH2 | TIM3_ETR | XSPI1_CLK | I2C2_SDA | TIM8_CH1N | FDCAN3_RX | USART3_TX | I2C3_SDA | POSENC2_OU T | TIM4_ETR | - | HRTIM1_FLT5 | HRTIM1_EEV1 1 | UART5_RTS | |
| | PB4 | NJTRST | TIM16_CH1 | TIM3_CH1 | I3C1_SDA | I2C2_SCL | TIM8_CH2N | FDCAN3_TX | TIM17_BKIN | I2C3_SCL | I2C1_SMBA | TIM2_CH1 | - | XSPI1_DQS0 | HRTIM1_EEV1 5 | UART5_CTS | |
| | PB5 | - | TIM16_CH1 | TIM4_CH3 | XSPI1_IO1 | - | TIM8_CH2N | POSENC1_SCK | I2S2_MCK | I2C3_SDA | I2C1_SCL | I2C4_SCL | - | HRTIM1_CHA1 | COMP4_OUT | CRS_SYNC | |
| | PB6 | - | TIM1_BKIN2 | TIM4_CH4 | XSPI1_IO0 | I2C1_SDA | TIM8_CH2 | - | USART2_TX | UART4_CTS | SPI3_SCK | I2C4_SDA | HRTIM1_CHA2 | UCPD1_FRSTX | COMP7_OUT | TIM12_CH1 | |
| | PB7 | - | HRTIM1_CHB1 | TIM2_CH1 | TIM8_CH1 | I2C1_SCL | SPI1_NSS/ I2S1_WS | SPI3_NSS | - | FDCAN3_TX | TIM1_BKIN | TIM2_ETR | - | - | COMP1_OUT | TIM12_CH2 | |
| | PB9 | MCO1 | TIM1_CH2 | TIM4_CH4 | I3C1_SDA | I2C1_SDA | - | I2C4_SDA | TIM17_CH1 | - | POSENC1_EN | TIM8_CH3 | - | HRTIM1_EEV5 | FDCAN1_TX | COMP3_OUT | |
| | PB10 | - | HRTIM1_FLT3 | TIM2_CH3 | - | - | - | - | USART3_TX | LPUART1_RX | TIM1_BKIN | - | - | - | - | CRS_SYNC | |

| Port | | AF0 | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 | AF7 | AF8 | AF9 | AF10 | AF11 | AF12 | AF13 | AF14 | AF 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SYS | HRTIM1/ LPTIM1/ TIM1/2/5/15/16/ 17 | I2C2/SPI1/ I2S1/ TIM1/2/3/4/5/ 15 | I3C1/ LPUART1/ TIM8/15/XSPI1 | I2C1/2/3/ TIM5/8/11/14/ USART1 | LPTIM1/SPI1/ I2S1/SPI2/I2S2/ TIM8/16 | FDCAN3/I2C4/ POSENC1/2/ SPI3/ TIM1/8/20 | SPI2/I2S2/ SPI3/TIM17/ UART6/U SART1/2/3 | FDCAN3/I2C3 /LPUART1/ TIM3/20/ UART4/6/ XSPI1 | FDCAN1/I2C1/ LPTIM1/ POSENC1/2/ SPI3/ TIM1/15/20/ UART5 | I2C4/ TIM2/4/8/ XSPI1 | HRTIM1/ TIM9 | HRTIM1/ USB_PD/ XSPI1 | COMP1/4/7/ FDCAN1/2/ HRTIM1 | COMP2/3/5/6/8/ CRS/PLAY1_IN/ PLAY1_OUT/ TIM8/10/12/13/15/ UART5 | EVENTOUT |
| Port B | PB11 | - | HRTIM1_FLT4 | TIM1_CH3N | - | - | SPI2_RDY | - | USART3_RX | LPUART1_TX | - | TIM2_CH4 | TIM9_CH1 | - | - | PLAY1_IN2 | |
| | PB12 | - | HRTIM1_FLT2 | TIM5_CH4 | TIM8_BKIN2 | TIM14_CH1 | SPI2_NSS/ I2S2_WS | - | USART3_CK | LPUART1_RT S | TIM1_BKIN | - | TIM9_CH2 | UCPD1_FRSTX | FDCAN1_RX | UART5_RX | EVENTOUT |
| | PB13 | - | HRTIM1_FLT6 | TIM1_CH1 | - | TIM14_CH1 | SPI2_SCK/ I2S2_CK | - | USART3_CTS/ USART3_NSS | LPUART1_CT S | LPTIM1_ETR | TIM8_CH4 | - | - | FDCAN1_TX | UART5_TX | EVENTOUT |
| | PB14 | MCO2 | TIM15_CH1 | TIM1_CH2 | - | USART1_TX | SPI2_MISO/ I2S2_SDI | - | USART3_RTS | UART4_RTS | LPTIM1_CH2 | TIM8_CH4N | HRTIM1_EEV1 | - | COMP4_OUT | PLAY1_OUT2 | |
| | PB15 | MCO2 | TIM15_CH2 | TIM15_CH1 N | XSPI1_CLK | USART1_RX | SPI2_MOSI/ I2S2_SDO | TIM1_CH3 | UART6_TX | UART4_CTS | UART5_RX | - | HRTIM1_EEV2 | - | - | COMP3_OUT | |
| Port C | PC0 | AUDIOC LK | HRTIM1_EEV8 | - | XSPI1_IO3 | TIM11_CH1 | LPTIM1_CH1 | TIM1_CH1 | SPI2_RDY | LPUART1_RX | - | XSPI1_IO7 | - | - | COMP7_OUT | PLAY1_IN3 | |
| | PC1 | TRACE D0 | TIM1_CH2 | - | XSPI1_IO2 | TIM14_CH1 | SPI2_MOSI/ I2S2_SDO | - | USART1_RTS | LPUART1_TX | POSENC2_MIS O | XSPI1_IO6 | - | - | HRTIM1_EEV5 | PLAY1_OUT3 | |
| | PC2 | PWR_C STOP | TIM1_CH3 | TIM2_ETR | XSPI1_IO1 | - | SPI2_MOSI/ I2S2_SDO | POSENC1_SCK | UART6_CTS | - | TIM20_CH2 | XSPI1_IO5 | - | - | - | COMP3_OUT | |
| | PC3 | PWR_C SLEEP | HRTIM1_EEV9 | TIM1_CH4 | XSPI1_IO0 | - | SPI2_MISO/ I2S2_SDI | SPI3_NSS | UART6_RTS | TIM20_CH2N | POSENC2_SE L | XSPI1_IO4 | - | - | - | COMP8_OUT | |
| | PC4 | - | HRTIM1_FLT1 | TIM1_ETR | - | USART1_TX | I2S1_MCK | TIM8_CH2 | - | - | LPTIM1_CH1 | - | - | - | - | PLAY1_OUT4 | |
| | PC5 | - | HRTIM1_EEV1 0 | TIM15_BKIN | - | USART1_RX | LPTIM1_IN2 | TIM1_CH4N | SPI3_NSS | - | TIM1_BKIN2 | - | - | - | - | TIM12_CH2 | |
| | PC6 | - | HRTIM1_EEV1 0 | TIM3_CH1 | I3C1_SCL | TIM8_CH1 | - | - | I2S2_MCK | UART6_TX | - | I2C4_SCL | HRTIM1_CHF1 | XSPI1_IO3 | - | COMP6_OUT | |
| | PC7 | TRACE D2 | HRTIM1_FLT5 | TIM3_CH2 | I3C1_SDA | TIM8_CH3 | - | - | USART3_RTS | UART6_RX | POSENC1_EN | I2C4_SDA | HRTIM1_CHF2 | XSPI1_IO2 | - | COMP5_OUT | |
| | PC8 | - | - | TIM3_CH3 | I3C1_SCL | TIM8_CH3 | - | TIM20_CH3 | - | I2C3_SCL | - | XSPI1_IO7 | - | - | HRTIM1_EEV1 5 | TIM10_CH1 | |
| | PC9 | - | - | TIM3_CH2 | I3C1_SDA | TIM8_CH4 | - | TIM8_BKIN2 | UART6_TX | I2C3_SDA | - | - | - | - | HRTIM1_EEV1 6 | - | |
| | PC10 | - | HRTIM1_EEV1 | I2C2_SMBA | TIM8_CH1N | I2C3_SMBA | SPI1_RDY | TIM20_CH4N | USART3_TX | UART4_TX | - | XSPI1_IO4 | - | UCPD1_FRSTX | - | COMP8_OUT | |
| | PC11 | TRACE D1 | HRTIM1_CHC1 | TIM1_ETR | XSPI1_IO3 | TIM8_CH2N | SPI1_MISO/ I2S1_SDI | SPI3_MISO | USART3_RX | UART4_RX | POSENC1_IN | TIM4_CH1 | - | - | - | TIM12_CH1 | |
| | PC12 | TRACE D3 | HRTIM1_CHC2 | TIM5_CH2 | LPUART1_RTS | I2C2_SDA | - | SPI3_MOSI | USART3_CK | - | POSENC1_OU T | TIM8_CH3N | - | XSPI1_IO0 | - | TIM13_CH1 | |
| | PC13 | - | - | TIM1_BKIN | LPUART1_TX | TIM8_BKIN | SPI2_NSS/ I2S2_WS | TIM20_CH3 | TIM17_BKIN | UART4_TX | POSENC1_OU T | - | HRTIM1_EEV1 4 | - | FDCAN1_RX | PLAY1_IN4 | |
| | PC14 | - | TIM16_BKIN | TIM1_BKIN | LPUART1_RX | - | LPTIM1_IN1 | - | USART2_RX | UART4_RX | UART5_RX | - | HRTIM1_FLT7 | - | - | PLAY1_IN1 | |
| | PC15 | - | - | TIM15_BKIN | LPUART1_TX | TIM8_BKIN | LPTIM1_IN2 | - | USART2_TX | UART4_TX | UART5_TX | - | HRTIM1_FLT8 | - | - | PLAY1_IN13 | |
| Port D | PD0 | - | HRTIM1_EEV5 | I2C2_SMBA | XSPI1_DQS0 | I2C3_SCL | SPI1_MOSI/ I2S1_SDO | - | - | UART4_RX | FDCAN1_RX | I2C4_SMBA | - | - | - | TIM8_CH4N | - |
| | PD1 | - | HRTIM1_EEV8 | SPI1_MISO/ I2S1_SDI | XSPI1_NCS2 | I2C3_SDA | - | - | - | UART4_TX | FDCAN1_TX | TIM8_CH4 | - | - | - | TIM8_BKIN2 | |
| | PD2 | TRACE D2 | - | TIM3_ETR | XSPI1_IO5 | TIM8_BKIN | SPI1_SCK/ I2S1_CK | POSENC2_SCK | - | TIM20_ETR | UART5_RX | - | - | - | HRTIM1_EEV1 2 | PLAY1_IN15 | |
| | PD3 | - | - | TIM1_CH1 | XSPI1_IO6 | TIM8_BKIN2 | SPI2_SCK/ I2S2_CK | - | USART2_CTS/ USART2_NSS | - | UART5_TX | TIM2_CH4 | HRTIM1_EEV3 | - | - | PLAY1_IN13 | |
| | PD4 | - | TIM1_CH2 | TIM2_CH2 | I3C1_SCL | USART1_CT S/ USART1_NS S | - | - | USART2_RTS | XSPI1_IO7 | - | I2C4_SCL | HRTIM1_FLT3 | - | - | - | |

| Port | | AF0 | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 | AF7 | AF8 | AF9 | AF10 | AF11 | AF12 | AF13 | AF14 | AF 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SYS | HRTIM1/ LPTIM1/ TIM1/2/5/15/16/ 17 | I2C2/SPI1/ I2S1/ TIM1/2/3/4/5/ 15 | I3C1/ LPUART1/ TIM8/15/XSPI1 | I2C1/2/3/ TIM5/8/11/14/ USART1 | LPTIM1/SPI1/ I2S1/SPI2/I2S2/ TIM8/16 | FDCAN3/I2C4/ POSENC1/2/ SPI3/ TIM1/8/20 | SPI2/I2S2/ SPI3/TIM17/ UART6/U SART1/2/3 | FDCAN3/I2C3 /LPUART1/ TIM3/20/ UART4/6/ XSPI1 | FDCAN1/I2C1/ LPTIM1/ POSENC1/2/ SPI3/ TIM1/15/20/ UART5 | I2C4/ TIM2/4/8/ XSPI1 | HRTIM1/ TIM9 | HRTIM1/ USB_PD/ XSPI1 | COMP1/4/7/ FDCAN1/2/ HRTIM1 | COMP2/3/5/6/8/ CRS/PLAY1_IN/ PLAY1_OUT/ TIM8/10/12/13/15/ UART5 | EVENTOUT |
| Port D | PD5 | - | - | TIM4_CH4 | - | TIM8_ETR | SPI2_RDY | TIM1_BKIN2 | USART2_TX | XSPI1_IO4 | TIM1_BKIN | I2C4_SMBA | HRTIM1_EEV1 0 | - | - | - | - |
| | PD6 | - | - | - | I3C1_SCL | - | SPI1_MISO/ I2S1_SDI | I2C4_SCL | USART2_RX | XSPI1_IO5 | SPI3_MISO | TIM2_CH1 | HRTIM1_FLT5 | - | - | - | |
| | PD7 | - | - | TIM2_ETR | I3C1_SDA | - | SPI1_MOSI/ I2S1_SDO | I2C4_SDA | USART2_CK | XSPI1_IO6 | FDCAN1_RX | TIM2_CH3 | TIM9_CH1 | - | - | - | |
| | PD8 | - | HRTIM1_EEV4 | TIM4_ETR | XSPI1_IO3 | - | - | POSENC2_MOSI | USART3_TX | - | TIM20_ETR | - | - | - | - | CRS_SYNC | |
| | PD9 | - | HRTIM1_EEV6 | - | XSPI1_NCS2 | - | - | POSENC2_MISO | USART3_RX | XSPI1_IO2 | TIM20_CH3N | - | TIM9_CH2 | - | - | PLAY1_IN11 | |
| | PD10 | - | HRTIM1_SCOU T | - | - | - | - | POSENC2_SEL | USART3_CK | XSPI1_IO1 | TIM20_CH3 | - | HRTIM1_EEV9 | - | - | - | - |
| | PD11 | - | TIM5_ETR | TIM4_CH2 | - | - | - | TIM8_ETR | USART3_CTS/ USART3_NSS | UART4_RX | POSENC2_MO SI | XSPI1_IO0 | HRTIM1_CHE1 | - | - | PLAY1_OUT0 | |
| | PD12 | - | - | TIM4_CH3 | - | - | - | POSENC2_SCK | USART3_RTS | UART4_TX | LPTIM1_IN1 | - | HRTIM1_CHE2 | - | - | PLAY1_OUT1 | |
| | PD13 | - | LPTIM1_CH1 | TIM4_CH2 | - | - | - | POSENC2_IN | - | - | SPI3_RDY | XSPI1_DQS0 | - | HRTIM1_FLT1 | - | PLAY1_OUT13 | |
| | PD14 | - | HRTIM1_EEV1 1 | TIM4_CH3 | XSPI1_NCS1 | - | - | POSENC2_OUT | - | - | POSENC1_OU T | - | - | - | - | PLAY1_IN14 | |
| | PD15 | - | TIM16_BKIN | TIM4_CH4 | XSPI1_IO0 | - | - | POSENC2_EN | SPI2_NSS/ I2S2_WS | - | TIM1_CH1 | - | HRTIM1_FLT4 | - | - | PLAY1_OUT14 | |
| Port E | PE2 | TRACE CLK | LPTIM1_IN2 | TIM3_CH1 | XSPI1_IO0 | TIM11_CH1 | - | TIM8_CH4N | UART6_TX | - | TIM20_CH1 | I2C4_SCL | - | - | HRTIM1_EEV1 2 | PLAY1_IN6 | EVENTOUT |
| | PE3 | TRACE D0 | HRTIM1_EEV8 | TIM3_CH2 | XSPI1_IO1 | - | - | - | - | TIM20_CH2 | I2C1_SDA | I2C4_SDA | - | - | - | PLAY1_IN7 | |
| | PE4 | TRACE D1 | - | TIM3_CH3 | - | I2C3_SDA | SPI1_NSS/ I2S1_WS | - | - | TIM20_CH1N | I2C1_SMBA | I2C4_SMBA | - | - | - | PLAY1_OUT7 | |
| | PE5 | TRACE D2 | - | TIM3_CH4 | I3C1_SCL | I2C3_SCL | - | - | - | XSPI1_NCS1 | TIM20_CH2N | I2C4_SCL | - | XSPI1_IO2 | - | PLAY1_OUT8 | |
| | PE6 | TRACE D3 | - | TIM4_CH3 | I3C1_SDA | - | - | TIM20_CH3N | - | I2C3_SMBA | I2C1_SCL | I2C4_SDA | - | XSPI1_IO3 | - | PLAY1_IN8 | |
| | PE7 | - | - | TIM1_ETR | - | - | - | - | - | - | - | - | HRTIM1_EEV4 | - | - | PLAY1_IN1 | |
| | PE8 | - | TIM5_CH3 | TIM1_CH1N | - | - | - | - | - | TIM20_CH4N | FDCAN1_RX | - | HRTIM1_EEV1 0 | - | - | PLAY1_OUT7 | |
| | PE9 | - | TIM5_ETR | TIM1_CH1 | - | - | - | - | - | - | FDCAN1_TX | - | HRTIM1_FLT3 | - | - | PLAY1_IN7 | |
| | PE10 | - | - | TIM1_CH2N | - | - | - | - | - | - | - | - | HRTIM1_FLT7 | - | - | PLAY1_OUT8 | |
| | PE11 | - | - | TIM1_CH2 | - | - | - | - | - | - | - | - | HRTIM1_FLT8 | - | FDCAN2_TX | PLAY1_IN8 | |
| | PE12 | - | - | TIM1_CH3N | - | - | - | - | - | - | - | - | - | - | FDCAN2_RX | PLAY1_OUT10 | |
| | PE13 | - | - | TIM1_CH3 | - | - | - | - | - | TIM20_BKIN2 | UART5_RTS | - | HRTIM1_FLT6 | - | - | PLAY1_OUT11 | |
| | PE14 | - | - | TIM1_CH4 | - | - | - | TIM1_BKIN2 | - | - | UART5_CTS | - | HRTIM1_EEV3 | - | - | PLAY1_IN5 | |
| | PE15 | - | - | TIM1_BKIN | - | - | - | TIM1_CH4N | USART3_RX | - | - | - | HRTIM1_FLT2 | - | - | PLAY1_OUT6 | |
| Port F | PF0 | - | HRTIM1_SCIN | - | XSPI1_IO3 | - | SPI2_MISO | POSENC1_MISO | USART1_TX | - | - | - | - | HRTIM1_EEV4 | - | PLAY1_OUT6 | EVENTOUT |
| | PF2 | - | - | - | XSPI1_NCS1 | - | TIM16_CH1N | SPI3_MOSI | TIM17_CH1 | TIM20_CH3 | POSENC2_MO SI | TIM2_CH4 | - | - | - | PLAY1_OUT9 | |
| | PF3 | - | HRTIM1_EEV1 | - | - | - | SPI2_SCK/ I2S2_CK | SPI3_NSS | USART2_TX | TIM20_CH4 | POSENC1_SC K | - | - | - | - | PLAY1_OUT15 | |
| | PF4 | - | HRTIM1_EEV2 | - | XSPI1_NCS1 | - | SPI2_MOSI/ I2S2_SDO | POSENC1_MOSI | USART2_RX | XSPI1_NCS2 | TIM20_CH1N | - | - | - | COMP1_OUT | TIM10_CH1 | |

| Port | | AF0 | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 | AF7 | AF8 | AF9 | AF10 | AF11 | AF12 | AF13 | AF14 | AF 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SYS | HRTIM1/ LPTIM1/ TIM1/2/5/15/16/ 17 | I2C2/SPI1/ I2S1/ TIM1/2/3/4/5/ 15 | I3C1/ LPUART1/ TIM8/15/XSPI1 | I2C1/2/3/ TIM5/8/11/14/ USART1 | LPTIM1/SPI1/ I2S1/SPI2/I2S2/ TIM8/16 | FDCAN3/I2C4/ POSENC1/2/ SPI3/ TIM1/8/20 | SPI2/I2S2/ SPI3/TIM17/ UART6/U SART1/2/3 | FDCAN3/I2C3 /LPUART1/ TIM3/20/ UART4/6/ XSPI1 | FDCAN1/I2C1/ LPTIM1/ POSENC1/2/ SPI3/ TIM1/15/20/ UART5 | I2C4/ TIM2/4/8/ XSPI1 | HRTIM1/ TIM9 | HRTIM1/ USB_PD/ XSPI1 | COMP1/4/7/ FDCAN1/2/ HRTIM1 | COMP2/3/5/6/8/ CRS/PLAY1_IN/ PLAY1_OUT/ TIM8/10/12/13/15/ UART5 | EVENTOUT |
| Port F | PF7 | - | - | TIM4_CH3 | XSPI1_NCS1 | TIM5_CH2 | - | SPI3_SCK | - | TIM20_BKIN | POSENC2_SCK | - | - | - | - | PLAY1_IN0 | EVENTOUT |
| | PF8 | - | - | TIM4_CH2 | XSPI1_NCS2 | TIM5_CH3 | - | SPI3_MISO | - | TIM20_BKIN2 | POSENC2_MISO | - | - | - | - | PLAY1_OUT1 | |
| | PF9 | - | - | TIM4_CH1 | TIM15_CH1 | TIM5_CH4 | - | - | SPI2_SCK/ I2S2_CK | UART4_RX | TIM20_BKIN | XSPI1_DQS0 | - | - | - | PLAY1_IN9 | |
| | PF10 | - | HRTIM1_SCOUT | - | TIM15_CH2 | TIM14_CH1 | SPI2_NSS/ I2S2_WS | - | - | TIM20_BKIN2 | POSENC1_SEL | XSPI1_CLK | - | - | - | - | |
| | PF11 | - | - | - | - | - | - | POSENC1_OUT | - | - | TIM20_ETR | - | HRTIM1_EEV12 | - | - | PLAY1_IN2 | |
| | PF12 | - | TIM1_CH4N | - | - | - | LPTIM1_ETR | POSENC1_IN | - | - | TIM20_CH1 | - | HRTIM1_EEV13 | - | - | PLAY1_OUT2 | |
| | PF13 | - | - | - | - | - | LPTIM1_CH2 | - | - | - | TIM20_CH2 | - | HRTIM1_EEV15 | - | - | PLAY1_IN3 | |
| | PF14 | - | - | - | - | TIM5_CH1 | - | POSENC1_EN | UART6_RTS | - | TIM20_CH3N | - | HRTIM1_EEV14 | - | - | PLAY1_OUT3 | |
| | PF15 | - | - | - | - | TIM5_CH2 | - | - | UART6_CTS | - | TIM20_CH4 | - | HRTIM1_EEV16 | - | - | PLAY1_OUT4 | |
| Port G | PG2 | - | TIM15_BKIN | SPI1_MOSI/ I2S1_SDO | XSPI1_IO1 | I2C2_SCL | - | - | USART2_TX | - | TIM20_CH4 | TIM8_BKIN2 | HRTIM1_CHD1 | - | - | COMP5_OUT | EVENTOUT |
| | PG3 | - | - | SPI1_SCK/ I2S1_CK | XSPI1_IO2 | I2C2_SDA | - | TIM20_CH4N | USART3_RX | - | TIM20_BKIN | TIM8_ETR | HRTIM1_CHD2 | - | COMP7_OUT | PLAY1_IN10 | |
| | PG4 | - | HRTIM1_EEV2 | SPI1_MISO/ I2S1_SDI | XSPI1_IO1 | TIM5_CH1 | - | POSENC2_EN | - | TIM20_BKIN2 | - | - | - | - | - | PLAY1_OUT1 | |
| | PG5 | - | HRTIM1_EEV7 | SPI1_MOSI/ I2S1_SDO | XSPI1_IO2 | TIM5_CH3 | - | - | - | LPUART1_CTS | TIM20_ETR | - | - | - | - | PLAY1_IN1 | |
| | PG9 | - | HRTIM1_FLT1 | SPI1_SCK/ I2S1_CK | XSPI1_IO3 | TIM5_CH4 | - | SPI3_SCK | UART6_RX | - | - | - | - | - | - | TIM15_CH1N | |
| | PG10 | - | - | SPI1_NSS/ I2S1_WS | XSPI1_IO7 | I2C2_SDA | - | POSENC1_IN | SPI3_SCK | LPUART1_TX | FDCAN1_TX | TIM8_CH2 | TIM9_CH2 | - | - | PLAY1_IN1 | |
| | PG11 | - | - | SPI1_SCK/ I2S1_CK | XSPI1_NCS2 | I2C2_SCL | - | I2C4_SCL | SPI3_NSS | TIM20_CH1 | LPTIM1_IN2 | TIM8_CH1 | - | - | - | TIM12_CH2 | |
| | PG12 | - | - | TIM15_CH1N | XSPI1_NCS1 | - | - | POSENC1_OUT | UART6_RTS | LPUART1_RX | LPTIM1_IN1 | TIM8_CH3N | - | - | - | PLAY1_IN4 | |
| | PG13 | TRACED0 | - | - | XSPI1_CLK | - | - | POSENC1_EN | UART6_CTS | - | LPTIM1_CH1 | - | - | - | - | COMP6_OUT | |
| | PG14 | TRACED1 | LPTIM1_ETR | - | - | - | - | SPI3_MOSI | UART6_TX | TIM20_CH1N | LPTIM1_CH2 | - | - | HRTIM1_FLT4 | - | PLAY1_IN5 | |
| Port H | PH0 | - | HRTIM1_EEV7 | TIM1_CH3N | TIM8_CH3 | TIM5_CH1 | SPI2_SCK/ I2S2_CK | - | USART1_TX | XSPI1_IO2 | POSENC2_SCK | XSPI1_NCS1 | - | - | - | TIM13_CH1 | EVENTOUT |
| | PH1 | - | HRTIM1_EEV11 | TIM1_ETR | XSPI1_NCS2 | TIM8_CH4 | SPI2_SCK/ I2S2_CK | POSENC1_SCK | USART1_RX | XSPI1_DQS0 | POSENC2_MISO | - | - | HRTIM1_FLT1 | - | TIM10_CH1 | |
| | PH5 | - | TIM17_CH1 | - | - | - | - | - | - | TIM20_CH2N | - | - | - | - | HRTIM1_SCOUT | PLAY1_OUT5 | |

# 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 junction temperature, supply voltage and frequencies by tests in production on 100 % of the devices with an junction 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. 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 2.7 ≤ $V_{DD}$ ≤ 3.6 V 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 and supply voltage 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 18.

### 5.1.5 Pin input voltage

The input voltage measurement on a pin of the device is described in Figure 19.

**Figure 18. Pin loading conditions**

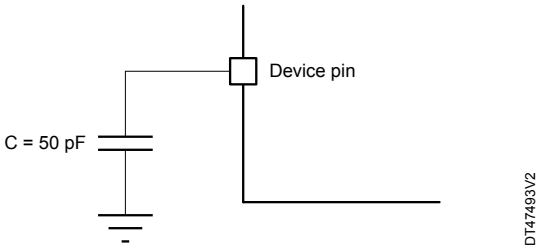
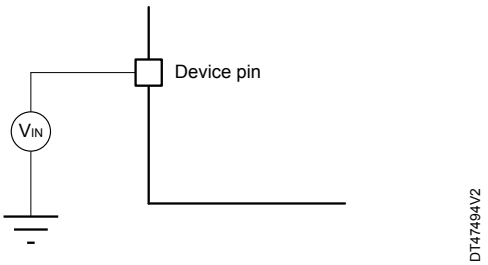



**Figure 19. Pin input voltage**




### 5.1.6 Power supply scheme

Each power supply pair (such as $V_{DD}/V_{SS}$ or $V_{DDA}/V_{SSA}$) must be decoupled with filtering ceramic capacitors as shown in the following figures. These capacitors must be placed as close as possible to, or below, the appropriate pins on the underside of the PCB to ensure the proper functionality of the device.

Figure 20. **STM32G56xxx power supply scheme (with SMPS)**

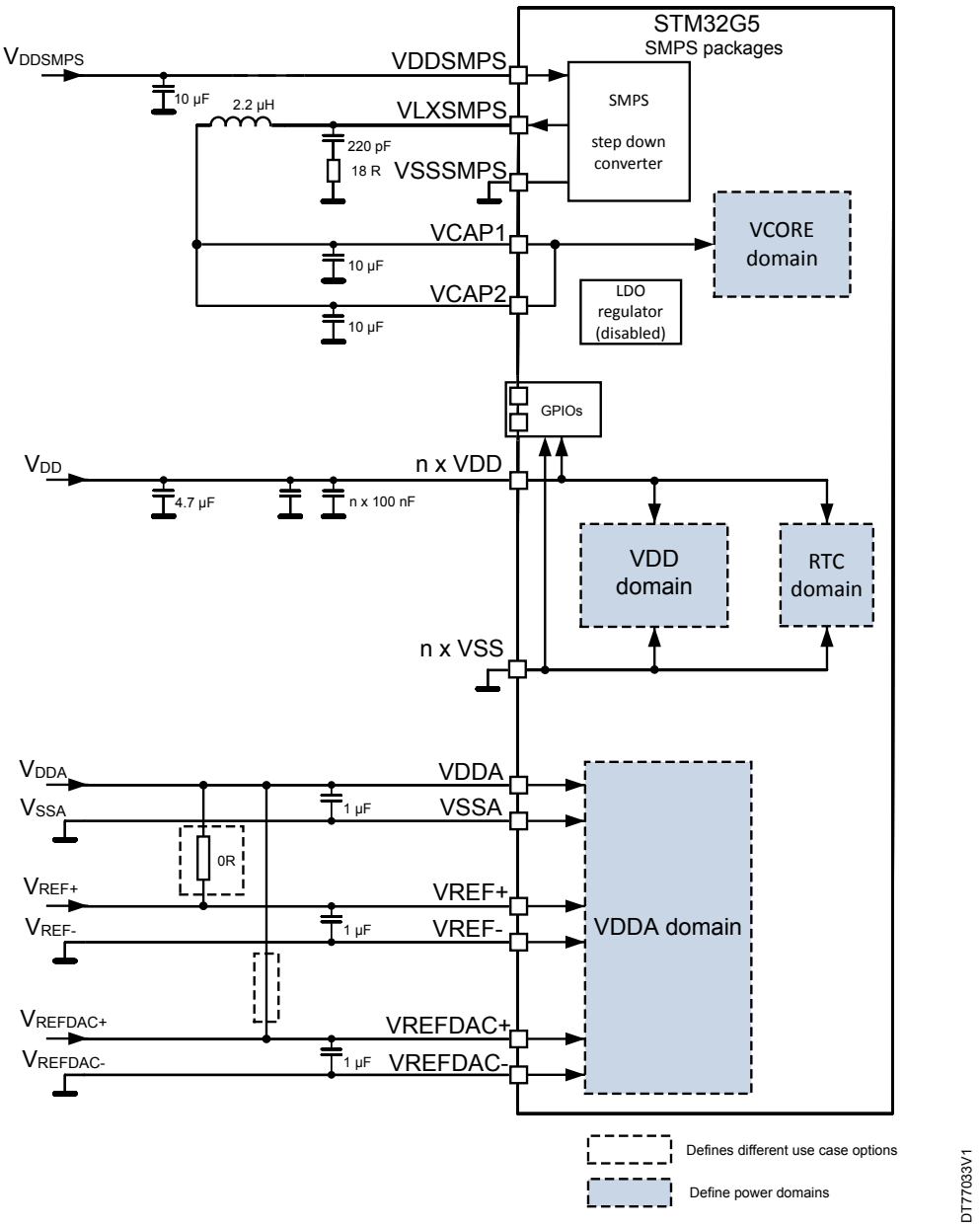
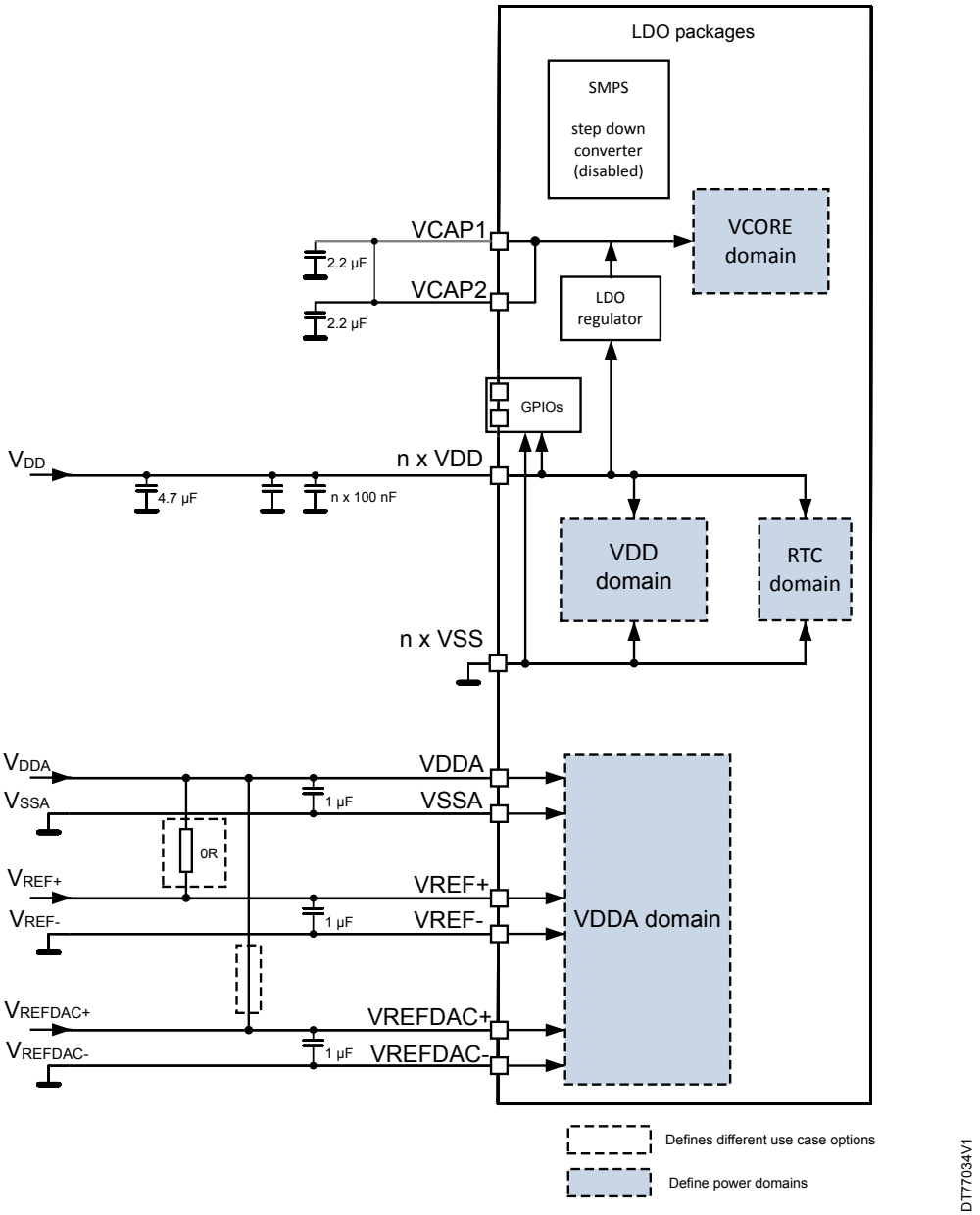


Figure 21. **STM32G56xxx power supply scheme (with LDO)**




*Note: SMPS and LDO regulators provide, in a concurrent way, the $V_{CORE}$ supply depending on application requirements. However, only one of them is active at the same time. When SMPS is active, it feeds the $V_{CORE}$ on the two VCAP pins supplied by the filtered VLXSMPS output pin. A 2.2 µH coil and a 10 µF capacitor on each VCAP pin are then required. When LDO is active, it supplies the $V_{CORE}$ and regulates it using the 2.2 µF decoupling capacitors on VCAP pins. Refer to Table 20 and Table 21 for used components.*

*Note: It is recommended to add a decoupling capacitor of 100 nF near each VCAP pin/ball, but it is not mandatory.*

## 5.2 Absolute maximum ratings

Stresses above the absolute maximum ratings listed in Table 15. Voltage characteristics, Table 16. Current characteristics, and Table 17. Thermal characteristics 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 15. Voltage characteristics

All main power (VDD, VDDSMPS, VDDA, VREF+, and VREFDAC+) and ground (VSS, VSSA, VREF+, and VREFDAC+) pins must always be connected to the external power supply, in the permitted range.

| Symbol | Ratings | Min | Max | Unit |
|---|---|---|---|---|
| $V_{DDx}$ - $V_{SS}$ | External main supply voltage (including $V_{DD}$, $V_{DDSMPS}$, $V_{DDA}$, $V_{REFDAC+}$, and $V_{REF+}$) | -0.3 | 4.0 | V |
| $V_{CAP}$ | External $V_{CORE}$ supply voltage (bypass mode operation) | $V_{SS}$ - 0.3 | min ($V_{DD}$, $V_{DDA}$, 1.40 V) | V |
| $V_{IN}$(1) | Input voltage on FT_xxx pins except FT_c pins | $V_{SS}$ -0.3 | min (min($V_{DD}$, $V_{DDA}$) + 4.0, 6.0 V) (2)(3) | V |
| | Input voltage on TT_xx pins | $V_{SS}$ -0.3 | 4.0 | V |
| | Input voltage on BOOT0 pin | $V_{SS}$ -0.3 | min (min($V_{DD}$, $V_{DDA}$) + 4.0, 6.0 V) (2)(3) | |
| | Input voltage on FT_c pins | $V_{SS}$ -0.3 | 5.5 | |
| | Input voltage on FT_fb pins | $V_{SS}$ -0.3 | 5.5 | |
| | Input voltage on COMP and OPAMP inputs | $V_{SSA}$ -0.3 | $V_{DDA}$ + 0.3 | |
| | Input voltage on any other pins | $V_{SS}$-0.3 | 4.0 | |
| $V_{AIN}$ | Input voltage on ADC inputs | $V_{SSA}$-0.3 | min ( $V_{DDA}$, $V_{REF+}$) + 0.3V | |
| $V_{REF+}$-$V_{DDA}$ | Allowed voltage difference for $V_{REF+}$ > $V_{DDA}$ or $V_{REFDAC+,}$ > $V_{DDA}$ | - | 0.4 | |
| $\|\Delta V_{DDx}\|$ | Variations between different $V_{DDX}$ power pins of the same domain | - | 50.0 | mV |
| $\|V_{SSx}-V_{SS}\|$ | Variations between all the different ground pins | - | 50.0 | |

1. *$V_{IN}$ maximum must always be respected. Refer to Table 16. Current characteristics for the maximum allowed injected current values.*
2. *This formula must be applied on power supplies related to the I/O structure described by the pin definition table.*
3. *To sustain a voltage higher than 4 V the internal pull-up/pull-down resistors must be disabled. Internal analog switch must also be disabled.*

### Table 16. Current characteristics

| Symbol | Ratings | Max | Unit |
|---|---|---|---|
| $\sum IV_{DD}$ | Total current into sum of all $V_{DD}$ power lines (source)(1) | 350 | mA |
| $\sum IV_{SS}$ | Total current out of sum of all $V_{SS}$ ground lines (sink)(1) | 350 | |
| $IV_{DD}$ | 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 and analog blocks | -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) 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. *A negative injection is induced by $V_{IN} < V_{SS}$. $I_{INJ(PIN)}$ must never be exceeded. Refer to Table 15. Voltage characteristics for the minimum allowed input voltage values.*
4. *Positive injection ((when $V_{IN} > V_{DD}$, resp. $V_{AIN} >$ min ($V_{DDA}$, $V_{REF+}$) for ADC and $V_{IN} > V_{DDA}$ for other analog blocks) is not possible on these I/Os, and does not occur for input voltages lower than the maximum ammowed voltage value specified in .Table 15. Voltage characteristics*
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 17. Thermal characteristics**

| Symbol | Ratings | Value | Unit |
|---|---|---|---|
| $T_{STG}$ | Storage temperature range | -65 to +150 | °C |
| $T_J$ | Maximum junction temperature | 140(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 18. General operating conditions**

| Symbol | Parameter | Operating conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{DD}$ | Standard operating voltage | USB not used | 2.7(1) | - | 3.6 | V |
| | | USB used | 3.0 | - | 3.6 | |
| $V_{DDSMPS}$ | Supply voltage for the internal SMPS step-down converter | - | $V_{DD}$ | | | |
| $V_{DDA}$ | Analog supply voltage | COMP used | 2.70 | - | 3.6 | |
| | | DAC used | 2.70 | - | | |
| | | OPAMP used | 2.70 | - | | |
| | | ADC used | 2.70 | - | | |
| | | VREFBUF used | 2.70 | - | | |
| | | ADC, DAC, OPAMP, COMP, VREFBUF not used | 0 | - | | |
| $V_{IN}$(2) | I/O Input voltage | All I/O except FT_c and TT_xx | −0.3 | - | min (min ( $V_{DD}$, $V_{DDA}$) + 3.6 V , 5.5 V)(3)(4) | |
| | | FT_c I/O | −0.3 | - | 5.0 | |
| | | TT_xx I/O | −0.3 | - | $V_{DD}$ + 0.3 | |
| $V_{CORE}$ | Internal regulator ON | VOS0(5) | 1.30 | 1.36 | 1.40 | |
| | | VOS1 | 1.15 | 1.21 | 1.26 | |

| Symbol | Parameter | Operating conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{CORE}$ | Internal regulator ON | VOS2 | 1.05 | 1.11 | 1.15 | V |
| | | SVOS3 (Stop mode) | - | 0.95 | - | |
| $V_{COREEXT0}$ | Internal regulator OFF: external $V_{CORE}$ voltage must be supplied from external regulator on VCAP pins | $f_{HCLK}$ < 280 MHz, Tjmax = 105°C | 1.35 | 1.37 | 1.40 | |
| $V_{COREEXT1}$ | | $f_{HCLK}$ < 220 MHz, Tjmax = 140°C | 1.20 | 1.23 | 1.26 | |
| $f_{HCLK}$ | AHB clock frequency internal regulator ON | VOS0(5) | - | - | 280 | |
| | | VOS1 | - | - | 240 | |
| | | VOS2 | - | - | 170 | |
| $f_{PCLKx}$ (x=1,2,3) | APB1, APB2, APB3 clock frequency internal regulator ON | VOS0(5) | - | - | 280 | |
| | | VOS1 | - | - | 240 | |
| | | VOS2 | - | - | 170 | |
| $P_D$ | Power dissipation at $T_A$ = 125°C for suffix 3(6) | All packages | See Section 6.15: Package thermal characteristics for application appropriate thermal resistance and package. Power dissipation is then calculated according ambient temperature ($T_A$) and maximum junction temperature ($T_J$) and selected thermal resistance. | | | mW |
| | Power dissipation at $T_A$ = 105°C for suffix 7(6) | All packages | | | | |
| | Power dissipation at $T_A$ = 85°C for suffix 6(6) | All packages | | | | |
| $T_A$ | Ambient temperature for the suffix 3 version | Maximum power dissipation | –40 | - | 125 | °C |
| | Ambient temperature for the suffix 7 version | Maximum power dissipation | -40 | - | 105 | |
| | | In LDO bypass mode | -40 | - | 125 | |
| | Ambient temperature for the suffix 6 version | Maximum power dissipation | –40 | - | 85 | |
| | | In LDO bypass mode | –40 | - | 125 | |
| $T_J$ | Junction temperature range | VOS0, $V_{COREEXT0}$ | -40 | - | 105 | |
| | | VOS1,VOS2, $V_{COREEXT1}$ | –40 | - | 140 | |

1. *When RESET is released functionality is guaranteed down to PDR level minimum voltage.*
2. *Operating conditions for analog peripherals must be respected when connection between this peripheral and GPIO is active. Refer to parameters of given peripheral.*
3. *For operations with voltage higher than Min ($V_{DD}$, $V_{DDA}$) +0.3 V, the internal Pull-up and Pull-Down resistors must be disabled.*
4. *This formula has to be applied on power supplies related to the IO structure described by the pin definition table. Maximum I/O input voltage is the smallest value between Min ($V_{DD}$, $V_{DDA}$) + 3.6 V and 5.5 V.*
5. *In VOS0 mode, the max Tj 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 Section 6.15: Package thermal characteristics).*

**Table 19. Maximum allowed clock frequencies**

| Symbol[1][2] | Parameter | VOS0[3] | VOS1[4] | VOS2 | Unit |
|---|---|---|---|---|---|
| $f_{CPU}$ | CPU | 280 | 240 | 170 | MHz |
| $f_{HCLK}$ | AHB | 280 | 240 | 170 | |
| $f_{PCLK}$ | APB | 280 | 240 | 170 | |
| $f_{octospi_ker_ck}$ | OCTOSPI | 280 | 240 | 170 | |
| $f_{fdcan_ker_ck}$ | FDCAN | 280 | 240 | 170 | |
| $f_{I2C_ker_ck}$ | I2C | 280 | 240 | 170 | |
| $f_{I3C_ker_ck}$ | I3C | 280 | 240 | 170 | |
| $f_{lptim_ker_ck}$ | LPTIM | 280 | 240 | 170 | |
| $f_{tim_ker_ck}$ | TIM | 280 | 240 | 170 | |
| $f_{rng_clk}$ | RNG | 48 | 48 | 48 | |
| $f_{spi_ker_ck}$ | SPI(I2S) | 280 | 240 | 170 | |
| $f_{lpuart_ker_ck}$ | LPUART1 | 280 | 240 | 170 | |
| $f_{usart_ker_ck}$ | USART/UART | 280 | 240 | 170 | |
| $f_{usb_ker_ck}$ | USB | 48 | 48 | 48 | |
| $f_{adc_ker_ck}$[5] | ADC | 80 | 80 | 80 | |
| $f_{dac_ker_ck}$ | DAC | 280 | 240 | 170 | |
| $f_{ucpd_ker_ck}$ | UCPD | 280 | 240 | 170 | |
| $f_{rtc_ker_ck}$ | RTC | 1 | 1 | 1 | |
| $f_{play_clk}$ | PLAY | 280 | 240 | 170 | |
| $f_{posenc_ker_ck}$ | POSENC | 200 | 200 | 200 | |

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 characteristic.)*
3. *Maximum allowed clock frequency while using external regulator at $V_{COREEXT0}$ range is 280 MHz.*
4. *Maximum allowed clock frequency while using external regulator at $V_{COREEXT1}$ range is 220 MHz.*
5. *This maximum kernel clock frequency does not consider the maximum ADC clock frequency (refer to Section 5.3.20).*

## 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 20. Characteristics of LDO regulator external components) to the VCAPx (one or two pins, depending upon the package). Two external capacitors must be connected to VCAP pins.

**Figure 22. External capacitor $C_{EXT}$**

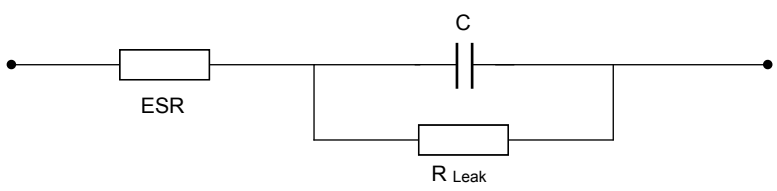


**Table 20. Characteristics of LDO regulator external components**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $C_{EXT}$ | Capacitance of external capacitor on VCAP pin | LDO or bypass mode | - | 2.2(1) | - | µF |
| | ESR of the external capacitor | 2.4 MHz | - | - | 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 requiring external components.

**Table 21. Characteristics of SMPS step-down converter external components**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $C_{in}$ | Capacitance of external capacitor on VDDSMPS pins | - | - | 10(1) | - | µF |
| | ESR of external capacitor | 2.4 MHz | - | - | 10 | mΩ |
| $C_{filt}$ | Capacitance of external capacitor on VLXSMPS pin | - | - | 220 | - | pF |
| $R_{filt}$ | Resistance of external resistor on VLXSMPS pin | - | - | 18 | - | Ω |
| $C_{OUT}$ | Capacitance of external capacitor on each 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 | - | - | |

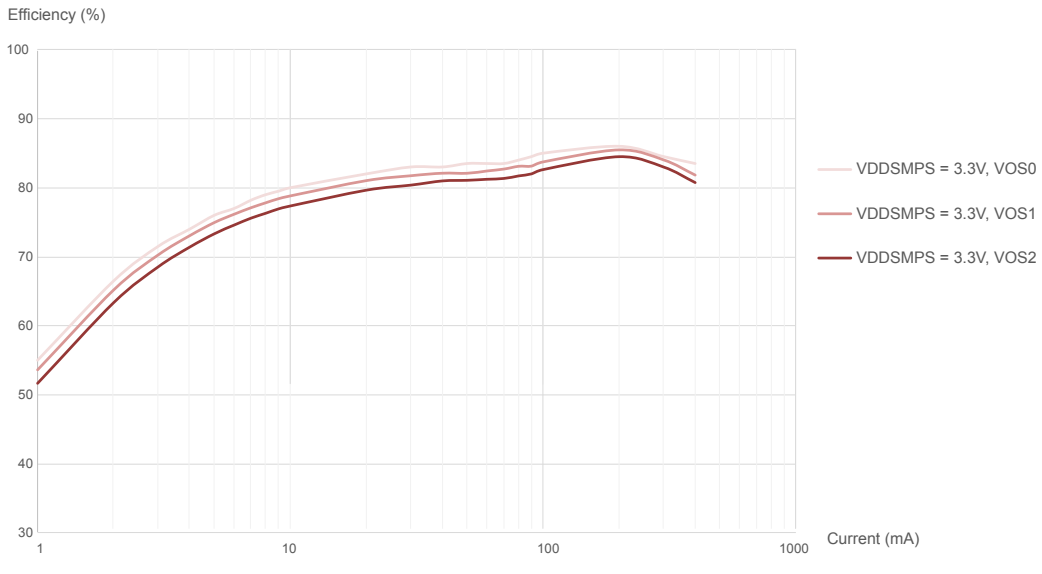
1. *Tolerance: -50% and + 30% for all conditions.*

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

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

$I_{DDLDO}$ 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 23. **SMPS efficiency versus load current in Run, Sleep, and Stop mode, $T_J$ = 30°C**




*Note: Stop mode is equivalent to VOS2 mode.*

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

Subject to general operating conditions for $T_A$.

Table 22. **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 | | |

### 5.3.5 Embedded reset and power control block characteristics

The parameters given in Table 23 are derived from tests performed under ambient temperature and $V_{DD}$ supply voltage conditions summarized in Section 5.3.1.

Table 23. **Embedded reset and power control block characteristics**

Evaluated by characterization and not tested in production, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $t_{RSTTEMPO}$(1) | Reset temporization after POR released | $V_{DD}$ rising | - | 305 | 550 | µs |
| $V_{POR/PDR}$ | Power-on/ power-down reset threshold | Rising edge | 2.57 | 2.62 | 2.69 | V |
| | | Falling edge | 2.51 | 2.57 | 2.63 | |
| $V_{PVD0}$ | Programmable voltage detector threshold 0 | Rising edge | 2.78 | 2.85 | 2.94 | |
| | | Falling edge | 2.69 | 2.75 | 2.83 | |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{PVD1}$ | Programmable voltage detector threshold 1 | Rising edge | 2.98 | 3.04 | 3.12 | V |
| | | Falling edge | 2.88 | 2.96 | 3.02 | |
| $V_{hyst_POR_PDR}$ | Hysteresis for power-on/ power-down reset | Hysteresis in Run mode | - | 55 | - | mV |
| $V_{hyst_PVD}$ | Hysteresis voltage of PVD | - | - | 95 | - | |
| $I_{DD_PVD}$ (1) | PVD consumption from VDD | - | - | - | 0.70 | µA |
| $I_{DD_POR_PDR}$ | POR and PDR consumption from VDD | - | 0.8 | - | 1.3 | |
| $V_{AVD0}$ | $V_{DDA}$ voltage detector 0 threshold | Rising edge | 2.74 | 2.81 | 2.88 | V |
| | | Falling edge | 2.67 | 2.74 | 2.79 | |
| $V_{hyst_AVD0}$ | Hysterests of $V_{DDA}$ voltage detector | - | - | 70 | - | mV |
| $V_{AVD1}$ | $V_{DDA}$ voltage detector 1 threshold | Rising edge | 2.95 | 3.00 | 3.07 | V |
| | | Falling edge | 2.89 | 2.96 | 3.01 | |
| $V_{hyst_AVD1}$ | Hysteresis of $V_{DDA}$ voltage detector | - | - | 45 | - | mV |
| $I_{DD_AVD}$ (1) | Power voltage detector consumption from $V_{DD}$ (AVD) | - | - | - | 0.3 | µA |
| $I_{DD_AVD_A}$ (1) | Analog voltage detector consumption from $V_{DDA}$ (resistor bridge) | - | - | - | 0.25 | |

1. *Specified by design. Not tested in production.*

### 5.3.6 Embedded reference voltage

The parameters given in Table 24 are derived from tests performed under the ambient temperature and supply voltage conditions summarized in Section 5.3.1.

**Table 24. Embedded reference voltage**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{REFINT}$ (1) | Internal reference voltage | -40°C < $T_J$ < +140°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 |
| $t_{start_vrefint}$ (2) | Start time of reference voltage buffer when the ADC is enabled | - | - | - | 4.4 | |
| $I_{refbuf}$ (2) | Reference buffer consumption for ADC | $V_{DD}$ = 3.3 V | 9 | 13.5 | 23 | µA |
| $\Delta V_{REFINT}$ (2) | Internal reference voltage spread over the temperature range | -40 °C < $T_J$ < +140 °C | - | 5 | 15 | mV |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $T_{coeff}$ | 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 |
| $V_{REFINT_DIV1}$ (2) | 1/4 reference voltage | - | - | 25 | - | %$V_{REFINT}$ |
| $V_{REFINT_DIV2}$ (2) | 1/2 reference voltage | | - | 50 | - | |
| $V_{REFINT_DIV3}$ (2) | 3/4 reference voltage | | - | 75 | - | |

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

**Table 25. 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 “FLASH 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 Section 5.3.1, and, unless otherwise specified, at ambient temperature.

The maximum current consumption is given for LDO regulator ON.

**Table 26. 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 | $T_J$ = 140 °C | |
| $I_{DD(Run)}$ | Supply current in Run mode | All peripherals disabled | VOS0 | 280 | 38.5 | 20.0 | 44.0 | 71.0 | 90.5 | - | mA |
| | | | | 240 | 33.0 | 17.5 | 38.5 | 65.5 | 85.5 | - | |
| | | | VOS1 | 240 | 28.5 | 14.0 | 32.0 | 51.0 | 66.5 | 115.0 | |
| | | | | 200 | 24.0 | 11.5 | 27.5 | 46.5 | 61.5 | 110.0 | |
| | | | | 170 | 20.5 | 10.0 | 24.0 | 43.0 | 58.0 | 110.0 | |
| | | | VOS2 | 170 | 18.5 | 8.5 | 21.5 | 36.5 | 49.0 | 89.0 | |
| | | | | 100 | 11.5 | 5.2 | 13.5 | 28.5 | 41.5 | 81.5 | |

| 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 | $T_J$ = 140 °C | |
| $I_{DD(Run)}$ | Supply current in Run mode | All peripherals enabled | VOS0 | 280 | 91.0 | 46.5 | 98.5 | 130.0 | 145.0 | - | mA |
| | | | | 240 | 78.0 | 40.5 | 85.0 | 115.0 | 135.0 | - | |
| | | | VOS1 | 240 | 68.5 | 32.0 | 73.0 | 92.5 | 110.0 | 160.0 | |
| | | | | 200 | 57.0 | 27.0 | 62.0 | 81.0 | 96.0 | 145.0 | |
| | | | | 170 | 49.0 | 23.0 | 54.0 | 72.0 | 87.0 | 140.0 | |
| | | | VOS2 | 170 | 44.5 | 19.5 | 47.0 | 61.0 | 73.5 | 115.0 | |
| | | | | 100 | 29.5 | 13.0 | 32.5 | 47.0 | 59.5 | 100.0 | |

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

**Table 27. 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 | $T_J$ = 140 °C | |
| $I_{DD(Run)}$ | Supply current in Run mode | All peripherals disabled | VOS0 | 280 | 34.0 | 18.0 | 39.5 | 66.5 | 86.5 | - | mA |
| | | | | 240 | 29.5 | 15.5 | 35.0 | 62.0 | 82.0 | - | |
| | | | VOS1 | 240 | 25.5 | 12.5 | 29.0 | 48.0 | 63.5 | 115.0 | |
| | | | | 200 | 21.5 | 10.5 | 25.0 | 44.0 | 59.0 | 110.0 | |
| | | | | 170 | 18.5 | 8.9 | 22.0 | 40.5 | 56.0 | 105.0 | |
| | | | VOS2 | 170 | 16.5 | 7.7 | 19.5 | 34.5 | 47.0 | 87.5 | |
| | | | | 100 | 10.0 | 4.7 | 12.5 | 27.5 | 40.5 | 80.5 | |

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

**Table 28. 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 | $T_J$ = 140 °C | |
| $I_{DD}$ (Run) | Supply current in Run mode | All peripherals disabled | VOS0 | 280 | 33.0 | 17.5 | 38.0 | 65.0 | 85.0 | - | mA |
| | | | | 240 | 28.5 | 15.0 | 33.5 | 60.5 | 80.5 | - | |
| | | | VOS1 | 240 | 24.5 | 12.0 | 28.0 | 47.0 | 62.0 | 115.0 | |
| | | | | 200 | 20.5 | 10.0 | 24.0 | 43.0 | 58.0 | 110.0 | |
| | | | | 170 | 17.5 | 8.6 | 21.0 | 40.0 | 55.0 | 105.0 | |
| | | | VOS2 | 170 | 16.0 | 7.4 | 18.5 | 33.5 | 46.5 | 86.5 | |
| | | | | 100 | 9.8 | 4.6 | 12.0 | 27.0 | 40.0 | 80.0 | |

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

**Table 29. 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 | $T_J$ = 140 °C | |
| $I_{DD(Run)}$ | Supply current in Run mode | All peripherals disabled | VOS0 | 280 | 37.0 | 19.5 | 42.0 | 69.0 | 89.0 | - | mA |
| | | | | 240 | 32.0 | 17.0 | 37.0 | 64.0 | 84.0 | - | |
| | | | VOS1 | 240 | 27.5 | 13.5 | 31.0 | 50.0 | 65.5 | 115.0 | |
| | | | | 200 | 23.0 | 11.5 | 26.5 | 45.5 | 60.5 | 110.0 | |
| | | | | 170 | 20.0 | 9.7 | 23.0 | 42.0 | 57.5 | 110.0 | |
| | | | VOS2 | 170 | 18.0 | 8.3 | 20.5 | 35.5 | 48.0 | 88.5 | |
| | | | | 100 | 11.0 | 5.1 | 13.0 | 28.5 | 41.0 | 81.0 | |

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

**Table 30. Typical consumption in Run mode with CoreMark running from flash memory and SRAM**

Evaluated by characterization. Not tested in production.

| 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 | 280 | 38.5 | 20.0 | mA | 137.0 | 72.5 | µA/MHz |
| | | | | 240 | 28.5 | 14.0 | | 119.0 | 57.5 | |
| | | | | 200 | 24.0 | 11.5 | | 120.0 | 58.0 | |
| | | | | 170 | 18.5 | 8.5 | | 110.0 | 50.0 | |
| | | | | 100 | 11.5 | 5.2 | | 113.0 | 52.0 | |
| | | All peripherals disabled, instruction cache 1-way, prefetch ON | FLASH | 280 | 34.0 | 18.0 | | 121.0 | 64.0 | |
| | | | | 240 | 25.5 | 12.5 | | 106.0 | 51.5 | |
| | | | | 170 | 21.5 | 10.5 | | 107.0 | 61.0 | |
| | | | | 100 | 10.0 | 4.7 | | 101.0 | 47.0 | |
| | | All peripherals disabled, instruction cache 2-way | SRAM | 280 | 37.0 | 19.5 | | 132.0 | 70.0 | |
| | | | | 240 | 27.5 | 13.5 | | 115.0 | 55.5 | |
| | | | | 200 | 23.0 | 11.5 | | 116.0 | 56.5 | |
| | | | | 170 | 18.0 | 8.3 | | 106.0 | 48.5 | |
| | | | | 100 | 11.0 | 5.1 | | 109.0 | 50.5 | |
| | | All peripherals disabled, instruction cache 1-way | SRAM | 280 | 33.0 | 17.5 | | 117.0 | 62.0 | |
| | | | | 240 | 24.5 | 12.0 | | 102.0 | 49.5 | |
| | | | | 170 | 16.0 | 7.4 | | 95.0 | 43.5 | |
| | | | | 100 | 9.8 | 4.6 | | 97.5 | 45.5 | |

**Table 31. Typical consumption in Run mode with SecureMark running from flash memory and SRAM**

Evaluated by characterization. Not tested in production.

| 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 | 280 | 38.5 | 20.5 | mA | 137.0 | 73.5 | µA/MHz |
| | | | | 240 | 33.5 | 18.0 | | 139.0 | 74.5 | |
| | | | | 200 | 24.5 | 12.0 | | 122.0 | 60.0 | |
| | | | | 170 | 19.0 | 8.8 | | 112.0 | 51.5 | |
| | | | | 100 | 11.5 | 5.4 | | 116.0 | 54.0 | |
| | | All peripherals disabled, instruction cache 2-way | SRAM | 280 | 36.0 | 19.5 | | 129.0 | 69.0 | |
| | | | | 240 | 27.0 | 13.0 | | 113.0 | 55.0 | |
| | | | | 200 | 23.0 | 11.0 | | 114.0 | 56.0 | |
| | | | | 170 | 18.0 | 8.2 | | 105.0 | 48.0 | |
| | | | | 100 | 11.0 | 5.0 | | 108.0 | 50.0 | |

**Table 32. 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 | $T_J$ = 140°C | |
| $I_{DD(sleep)}$ | Supply current in sleep mode | All peripherals disabled | VOS0 | 280 | 6.90 | 3.90 | 11.5 | 38 | 58.5 | - | mA |
| | | | | 240 | 6.05 | 3.40 | 11 | 37 | 58 | - | |
| | | | VOS1 | 240 | 5.20 | 2.75 | 8.1 | 27 | 42.5 | 90.5 | |
| | | | | 200 | 4.50 | 2.40 | 7.35 | 26 | 42 | 89.5 | |
| | | | | 170 | 3.90 | 2.15 | 6.75 | 25.5 | 41.5 | 89 | |
| | | | VOS2 | 170 | 3.50 | 1.85 | 5.6 | 21 | 33.5 | 73.5 | |
| | | | | 100 | 2.30 | 1.30 | 4.45 | 19.5 | 32.5 | 72 | |

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

**Table 33. 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 | $T_J$ = 140 °C | |
| $I_{DD(stop)}$ | Supply current in Stop | Flash memory in low power mode, SRAMs ON | SVOS3 | 254 | 101 | 1450 | 11500 | 20500 | 48000 | µA |
| | | Flash memory in normal mode, SRAMs ON | SVOS3 | 276 | 116 | 1500 | 11500 | 20500 | 48500 | |

| Symbol | Parameter | Conditions | | Typ LDO | Typ SMPS | Max(1)(2) | | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $T_J$ = 25 °C | $T_J$ = 85 °C | $T_J$ = 105 °C | $T_J$ = 140 °C | |
| $I_{DD(stop)}$ | Supply current in Stop | Flash memory in low power mode, SRAMs OFF except SRAM2 16 Kbytes ON | SVOS3 | 236 | 90.5 | 1350 | 10500 | 19000 | 45000 | µA |
| | | Flash memory in low power mode, SRAMs OFF except SRAM2 ON | SVOS3 | 237 | 94 | 1450 | 11000 | 19500 | 46500 | |

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

**Table 34. Typical and maximum current consumption in Standby mode**

| Symbol | Parameter | Conditions | Typ(1) | | | Max(1) | | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RTC and LSE(2) | 2.7 V | 3 V | 3.3 V | $T_J$ = 25 °C | $T_J$ = 85 °C | $T_J$ = 105 °C | $T_J$ = 140 °C | |
| $I_{DD(standby)}$ | Supply current in standby mode, IWDG OFF | OFF | 3.15 | 3.25 | 3.4 | 4.65 | 9.65 | 18.5 | 71.5 | µA |
| | | ON | 3.6 | 3.75 | 3.95 | - | - | - | - | |

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 54.

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 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
- $f_{rcc_cpu_ck}$ = 280 MHz (VOS0), $f_{rcc_cpu_ck}$ = 240 MHz (VOS1), $f_{rcc_cpu_ck}$ = 170 MHz (VOS2)
- Ambient operating temperature is 25°C and $V_{DD}$ = 3.3 V

**Table 35. Peripheral current consumption in Sleep mode**

| Peripheral Consumption Summary (LDO) | | | | | |
|---|---|---|---|---|---|
| Bus | Peripheral | IDD (TYP) | | | Unit |
| | | VOS0 | VOS1 | VOS2 | |
| AHB1 | CORDIC1 | 0.72 | 0.62 | 0.57 | µA/MHz |
| | CRC | 0.28 | 0.23 | 0.21 | |
| | DCACHE | 0.73 | 0.63 | 0.57 | |
| | FLASH | 10.5 | 9.3 | 8.5 | |
| | FMAC1 | 1.55 | 1.35 | 1.25 | |
| | GPDMA1 | 2.40 | 2.05 | 1.90 | |
| | GPDMA2 | 2.20 | 1.95 | 1.80 | |
| | ICACHE | 0.84 | 0.71 | 0.67 | |
| | RAMCFG | 0.61 | 0.54 | 0.49 | |
| | SRAM1 | 0.77 | 0.67 | 0.61 | |
| | SRAM2 | 0.95 | 0.82 | 0.77 | |
| | SRAM3 | 0.50 | 0.44 | 0.41 | |
| | TZSC1 | 1.35 | 1.15 | 1.05 | |
| AHB2 | ADC12 | 9.25 | 8.10 | 7.40 | |
| | ADC12 (independent clock) | 1.25 | 1.10 | 0.99 | |
| | ADC3 | 5.05 | 4.40 | 4.05 | |
| | ADC3 (independent clock) | 0.79 | 0.70 | 0.64 | |
| | DAC1 | 1.10 | 0.96 | 0.87 | |
| | DAC1 (independent clock) | 0.71 | 0.63 | 0.56 | |
| | DAC10 | 1.10 | 0.95 | 0.86 | |
| | DAC10 (independent clock) | 0.67 | 0.58 | 0.54 | |
| | DAC2 | 1.15 | 0.97 | 0.89 | |
| | DAC2 (independent clock) | 0.69 | 0.58 | 0.54 | |
| | DAC5 | 1.05 | 0.92 | 0.85 | |
| | DAC5 (independent clock) | 0.66 | 0.60 | 0.55 | |
| | DAC6 | 1.00 | 0.89 | 0.80 | |

| Peripheral Consumption Summary (LDO) | | | | | |
|---|---|---|---|---|---|
| Bus | Peripheral | IDD (TYP) | | | Unit |
| | | VOS0 | VOS1 | VOS2 | |
| AHB2 | DAC6 (independent clock) | 0.68 | 0.61 | 0.53 | µA/MHz |
| | DAC7 | 0.98 | 0.85 | 0.79 | |
| | DAC7 (independent clock) | 0.68 | 0.61 | 0.55 | |
| | DAC8 | 0.96 | 0.85 | 0.77 | |
| | DAC8 (independent clock) | 0.67 | 0.60 | 0.53 | |
| | DAC9 | 1.10 | 0.97 | 0.89 | |
| | DAC9 (independent clock) | 0.65 | 0.57 | 0.54 | |
| | FMAC2 | 1.75 | 1.55 | 1.40 | |
| AHB3 | DBG | 4.30 | 3.75 | 3.45 | |
| AHB4 | AES | 1.40 | 1.25 | 1.10 | |
| | CCB | 1.00 | 0.89 | 0.81 | |
| | GPIOA | 0.09 | 0.07 | 0.07 | |
| | GPIOB | 0.07 | 0.07 | 0.06 | |
| | GPIOC | 0.07 | 0.06 | 0.06 | |
| | GPIOD | 0.09 | 0.07 | 0.07 | |
| | GPIOE | 0.09 | 0.07 | 0.05 | |
| | GPIOF | 0.09 | 0.08 | 0.07 | |
| | GPIOG | 0.08 | 0.07 | 0.06 | |
| | GPIOH | 0.05 | 0.04 | 0.03 | |
| | HASH | 1.40 | 1.25 | 1.15 | |
| | OTFDEC1 | 1.05 | 0.92 | 0.82 | |
| | PKA | 5.80 | 5.10 | 4.65 | |
| | RNG | 1.75 | 1.55 | 1.40 | |
| | SAES | 7.10 | 5.80 | 5.10 | |
| | XSPI1 | 0.72 | 0.66 | 0.61 | |
| | XSPI1 (independent clock) | 1.55 | 1.35 | 1.25 | |
| APB1 | CRS | 0.55 | 0.47 | 0.46 | |
| | DTS | 2.20 | 1.87 | 1.74 | |
| | FDCAN | 9.50 | 8.40 | 7.70 | |
| | FDCAN (independent clock) | 10.10 | 8.90 | 8.10 | |
| | I2C1 | 0.98 | 0.88 | 0.85 | |
| | I2C1 (independent clock) | 1.90 | 1.67 | 1.50 | |
| | I2C2 | 0.98 | 0.88 | 0.88 | |
| | I2C2 (independent clock) | 2.00 | 1.73 | 1.58 | |
| | I3C1 | 0.73 | 0.71 | 0.70 | |
| | I3C1 (independent clock) | 2.30 | 2.00 | 1.85 | |
| | SPI2 | 1.35 | 1.20 | 1.11 | |
| | SPI2 (independent clock) | 0.48 | 0.43 | 0.41 | |
| | SPI3 | 1.42 | 1.25 | 1.17 | |

| Peripheral Consumption Summary (LDO) | | | | | |
|---|---|---|---|---|---|
| Bus | Peripheral | IDD (TYP) | | | Unit |
| | | VOS0 | VOS1 | VOS2 | |
| APB1 | SPI3 (independent clock) | 0.70 | 0.58 | 0.54 | µA/MHz |
| | TIM10 | 2.10 | 1.85 | 1.72 | |
| | TIM11 | 2.10 | 1.84 | 1.71 | |
| | TIM12 | 3.10 | 2.70 | 2.50 | |
| | TIM13 | 2.10 | 1.88 | 1.75 | |
| | TIM14 | 2.10 | 1.88 | 1.73 | |
| | TIM2 | 6.60 | 5.80 | 5.30 | |
| | TIM3 | 6.40 | 5.60 | 5.10 | |
| | TIM6 | 1.11 | 0.98 | 0.93 | |
| | TIM7 | 1.21 | 1.05 | 1.00 | |
| | TIM9 | 3.10 | 2.70 | 2.60 | |
| | UART4 | 1.40 | 1.23 | 1.16 | |
| | UART4 (independent clock) | 2.70 | 2.40 | 2.10 | |
| | UART5 | 1.42 | 1.25 | 1.17 | |
| | UART5 (independent clock) | 2.60 | 2.30 | 2.10 | |
| | UART6 | 1.42 | 1.24 | 1.17 | |
| | UART6 (independent clock) | 2.80 | 2.50 | 2.20 | |
| | UCPD1 | 1.31 | 1.16 | 1.07 | |
| | UCPD1 (independent clock) | 9.40 | 9.00 | 7.60 | |
| | USART2 | 1.55 | 1.36 | 1.27 | |
| | USART2 (independent clock) | 3.20 | 2.80 | 2.60 | |
| | USART3 | 1.49 | 1.31 | 1.23 | |
| | USART3 (independent clock) | 3.20 | 2.80 | 2.60 | |
| | WWDG1 | 0.36 | 0.33 | 0.32 | |
| APB2 | HRTIM1 | 73.00 | 64.00 | 58.00 | |
| | PLAY1 | 1.85 | 1.64 | 1.48 | |
| | PLAY1 (independent clock) | 6.80 | 6.50 | 6.00 | |
| | SPI1 | 1.52 | 1.36 | 1.22 | |
| | SPI1 (independent clock) | 0.58 | 0.50 | 0.46 | |
| | TIM1 | 10.20 | 9.00 | 8.20 | |
| | TIM15 | 5.20 | 4.60 | 4.20 | |
| | TIM16 | 4.00 | 3.60 | 3.30 | |
| | TIM17 | 4.00 | 3.50 | 3.20 | |
| | TIM4 | 6.50 | 5.70 | 5.20 | |
| | TIM5 | 6.30 | 5.50 | 5.10 | |
| | TIM8 | 10.30 | 9.00 | 8.30 | |
| | USART1 | 1.61 | 1.42 | 1.29 | |
| | USART1 (independent clock) | 2.70 | 2.40 | 2.10 | |
| | USB | 2.80 | 2.50 | 2.20 | |

| Peripheral Consumption Summary (LDO) | | | | | |
|---|---|---|---|---|---|
| Bus | Peripheral | IDD (TYP) | | | Unit |
| | | VOS0 | VOS1 | VOS2 | |
| APB2 | USB (independent clock) | 1.57 | 1.54 | 1.49 | µA/MHz |
| APB3 | COMP1 | 0.34 | 0.34 | 0.31 | |
| | COMP2 | 0.34 | 0.32 | 0.29 | |
| | COMP3 | 0.36 | 0.32 | 0.29 | |
| | COMP4 | 0.36 | 0.32 | 0.29 | |
| | COMP5 | 0.36 | 0.35 | 0.31 | |
| | COMP6 | 0.33 | 0.32 | 0.29 | |
| | COMP7 | 0.36 | 0.33 | 0.31 | |
| | COMP8 | 0.35 | 0.33 | 0.31 | |
| | I2C3 | 0.75 | 0.67 | 0.63 | |
| | I2C3 (independent clock) | 1.83 | 1.61 | 1.47 | |
| | I2C4 | 0.77 | 0.72 | 0.64 | |
| | I2C4 (independent clock) | 1.90 | 1.69 | 1.52 | |
| | LPTIM1 | 1.15 | 1.04 | 0.96 | |
| | LPTIM1 (independent clock) | 3.20 | 2.80 | 2.60 | |
| | LPUART1 | 1.10 | 0.98 | 0.91 | |
| | LPUART1 (independent clock) | 1.89 | 1.71 | 1.53 | |
| | OPAMP1 | 0.26 | 0.25 | 0.24 | |
| | OPAMP2 | 0.34 | 0.29 | 0.28 | |
| | OPAMP3 | 0.25 | 0.25 | 0.24 | |
| | POSENC1 | 1.41 | 1.23 | 1.16 | |
| | POSENC1 (independent clock) | 1.37 | 1.16 | 1.06 | |
| | POSENC2 | 1.38 | 1.23 | 1.15 | |
| | POSENC2 (independent clock) | 1.30 | 1.13 | 1.03 | |
| | RTC | 3.80 | 3.30 | 3.00 | |
| | SBS | 2.30 | 1.99 | 1.82 | |
| | TIM20 | 10.60 | 9.30 | 8.60 | |
| | TIM26 | 1.28 | 1.13 | 1.06 | |
| | TIM27 | 1.07 | 1.00 | 0.90 | |
| | VREFBUF | 0.18 | 0.17 | 0.15 | |

### Wake-up time from low-power modes

The times given in Table 36 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 $V_{DD}$ = 3.3 V.

**Table 36. Low-power mode wake-up timings**

| Symbol | Parameter | Conditions | Typ | Max | Unit |
|---|---|---|---|---|---|
| $t_{WUSLEEP}$ | Wake-up time from Sleep mode | Instruction cache enabled | 15 | 16 | CPU clock cycles |
| | | Instruction cache disabled | 15 | 16 | |
| $t_{WUSTOP}$ | Wake-up time from Stop mode | HSI 64 MHz, flash memory in normal mode | 24.5 | 26.5 | µs |
| | | HSI 64 MHz, flash memory in low-power mode | 28 | 30.5 | |
| $t_{WUSTBY}$ | Wake-up time from Standby mode | VCAP capacitors discharged | 385 | 415 | |

## 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 37. High-speed external user clock characteristics in addition to Table 54. I/O static characteristics. 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 RM0514).

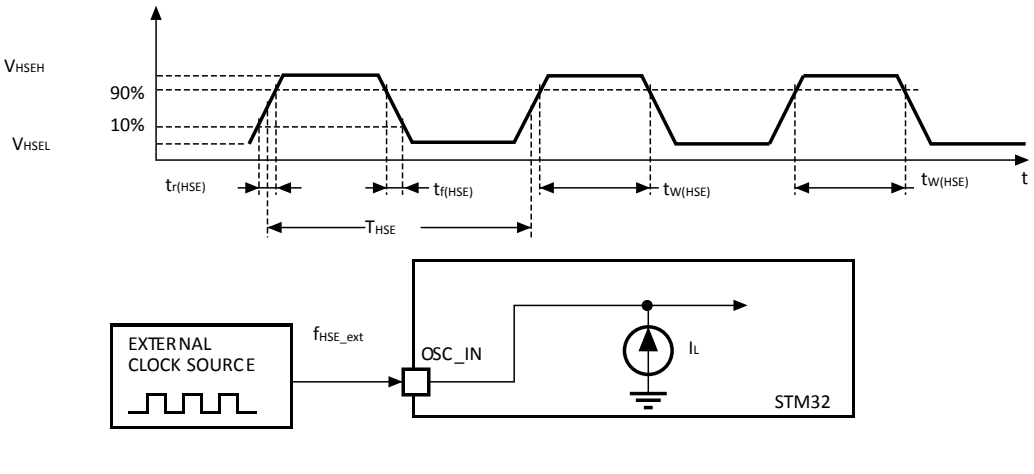
**Table 37. High-speed external user clock characteristics**

Specified by design. Not tested in production.

| 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 $V_{DD}$ | |
| $t_{w(HSEH)}$ / $t_{w(HSEL)}$ (1) | Digital OSC_IN input high or low time | External digital clock | 7 | - | - | ns |
| $V_{isw(HSEH)}$ (2) ($V_{HSEH}$ -$V_{HSEL}$) | 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. *No specified rise and fall times for a digital input signal are not specified, but the $V_{HSEH}$ and $V_{HSEL}$ conditions must be fulfilled.*
2. *The DC component of the signal must ensure that the signal peaks are located between $V_{DD}$ and $V_{SS}$.*

Figure 24. **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 38. Low-speed external user clock characteristics in addition to Table 54. I/O static characteristics. 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 the product reference manual).

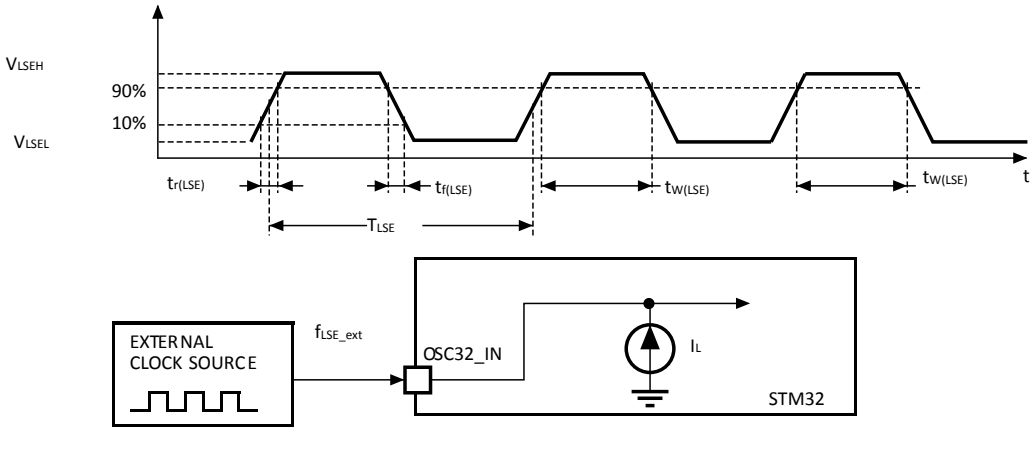
Table 38. **Low-speed external user clock characteristics**

Specified by design. Not tested in production.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{LSE_ext}$ | User external clock source frequency | External digital/analog clock | - | 32.768 | 1000 | kHz |
| $V_{LSEH}$ | 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 |

*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 25. **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 39. 4-50 MHz HSE oscillator characteristics. 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 39. **4-50 MHz HSE oscillator characteristics**

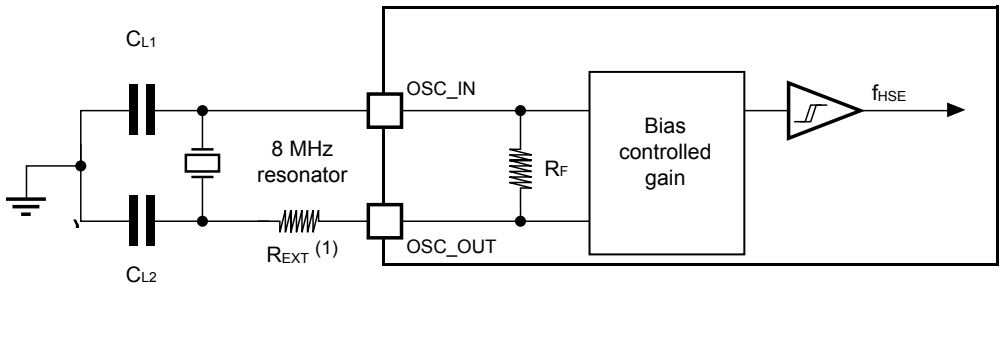
Evaluated by characterization. Not tested in production.

| Symbol | Parameter | Operating conditions (1) | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| F | Oscillator frequency | - | 4 | - | 50 | MHz |
| $R_F$ | Feedback resistor | - | - | 200 | - | kΩ |
| $I_{DD(HSE)}$ | HSE current consumption | During startup(2) | - | - | 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 |
| $t_{SU(HSE)}$(3) | Startup time | $V_{DD}$ is stabilized | - | 2 | - | ms |

1. *Resonator characteristics given by the crystal/ceramic resonator manufacturer.*
2. *This consumption level occurs during the first 2/3 of the $t_{SU(HSE)}$ startup time*
3. *$t_{SU(HSE)}$ is the startup time measured from the moment it is enabled (by software) to a stabilized 8 MHz oscillation is reached. This value is measured for a standard crystal resonator and it can vary significantly with the crystal manufacturer*

*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 26. 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 40. LSE oscillator characteristics ($f_{LSE}$ = 32.768 kHz). 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 40. LSE oscillator characteristics ($f_{LSE}$ = 32.768 kHz)**

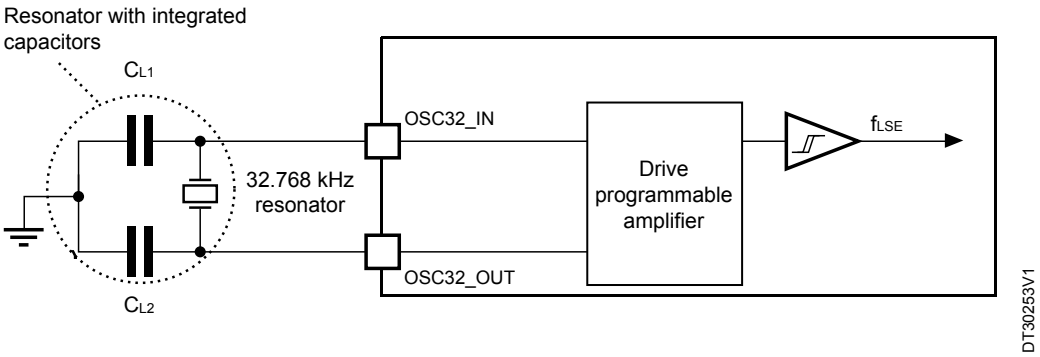
Specified by design. Not tested in production.

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

1. *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".*
2. *$t_{SU(LSE)}$ 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 and 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 27. **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 41. HSI48 oscillator characteristics to Table 43. LSI oscillator characteristics are derived from tests performed under ambient temperature and $V_{DD}$ supply voltage conditions summarized in Section 5.3.1.

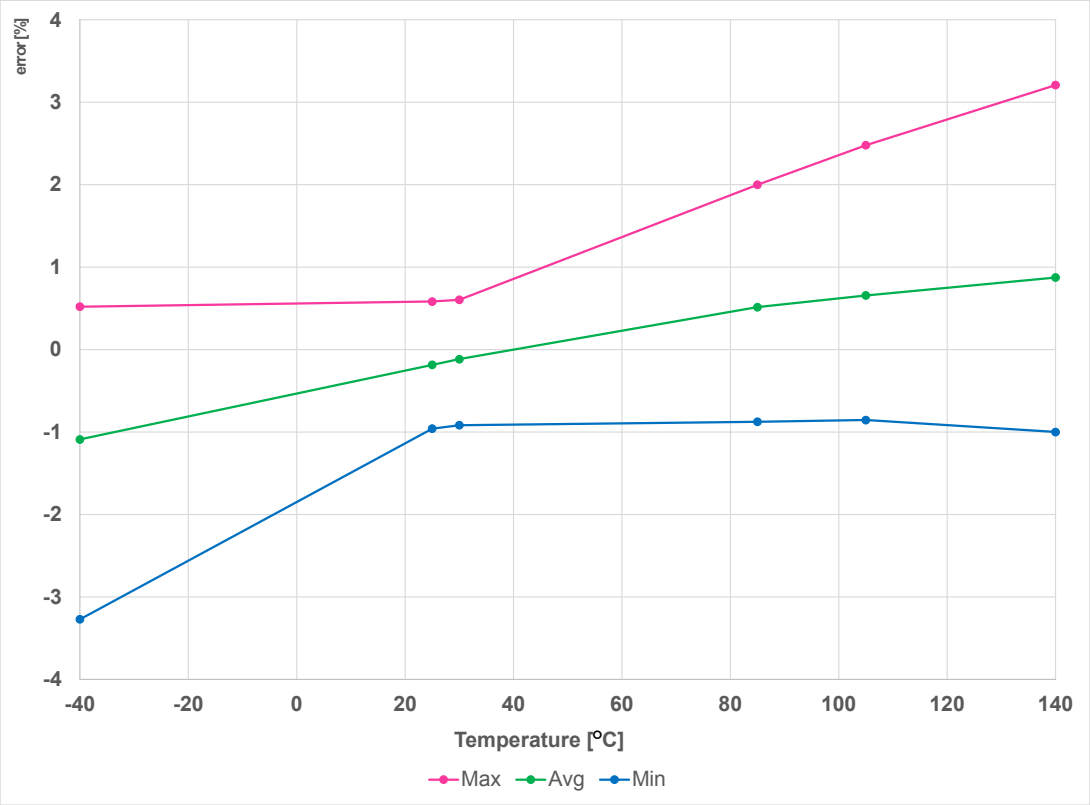
#### 48 MHz high-speed internal RC oscillator (HSI48)

Table 41. **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(2) | User trimming step | - | - | 0.175 | 0.250 | % |
| USER TRIM COVERAGE(3) | User trimming coverage | ±32 steps | ±4.70 | ±5.6 | - | |
| $DuCy_{(HSI48)}$(2) | Duty cycle | - | 45 | - | 55 | % |
| $ACC_{HSI48_REL}$(3)(4) | Accuracy of the HSI48 oscillator over temperature (reference is 30 °C) | $T_J$ = -40 to 140 °C | -4.5 | - | 4 | % |
| $\Delta_{VDD(HSI48)}$(2)(4) | HSI48 oscillator frequency drift with $V_{DD}$ (reference is 3.3 V) | $V_{DD}$ = 3.0 to 3.6 V | - | 0.025 | 0.05 | % |
| | | $V_{DD}$ = 2.7 to 3.6 V | - | 0.05 | 0.1 | |
| $t_{su(HSI48)}$(2) | HSI48 oscillator start-up time | - | - | 2.1 | 4.0 | µs |
| $I_{DD(HSI48)}$(2) | HSI48 oscillator power consumption | - | - | 350 | 400 | µA |
| $N_T$ jitter(2) | Next transition jitter accumulated jitter on 28 cycles | - | - | ±0.15 | - | ns |
| $P_T$ jitter(2) | Paired transition jitter accumulated jitter on 56 cycles(5) | - | - | ±0.25 | - | |

1. *Calibrated during manufacturing tests.*
2. *Specified by design. Not tested in production.*
3. *Evaluated by characterization. Not tested in production.*
4. *$\Delta f_{HSI} = ACC_{HSI48_REL} + \Delta V_{DD}$*
5. *Jitter measurements are performed without clock sources activated in parallel.*

Figure 28. **HSI48 frequency versus temperature**




### 64 MHz high-speed internal RC oscillator (HSI)

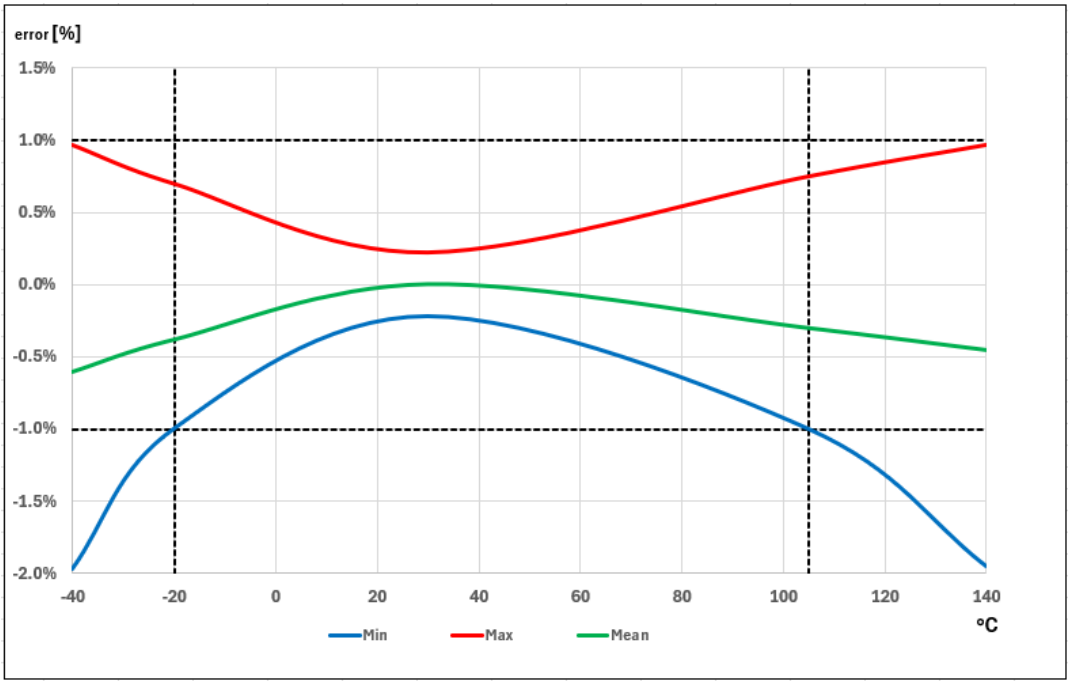
Table 42. **HSI oscillator characteristics**

Specified by design and not tested in production, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{HSI}$ | Frequency | $V_{DD}$ = 3.3 V, $T_J$ = 30 °C | 63.7(1) | 64.0 | 64.3(1) | MHz |
| TRIM | User trimming step | Trimming is not a multiple of 32 | - | 0.24 | 0.32 | % |
| | | Trimming is 128, 256, and 384 | -5.2 | -1.8 | - | |
| | | Trimming is 64, 192, 320, and 488 | -1.4 | -0.8 | - | |
| | | Other trimmings are multiples of 32 (not including multiples of 64 and 128) | -0.6 | -0.25 | - | |
| DuCy(HSI) | Duty cycle | - | 45 | - | 55 | % |
| $\Delta_{VDD}$(HSI) | Frequency drift with $V_{DD}$ (reference is 3.3 V) | $V_{DD}$= 2.7 to 3.6 V | -0.12 | - | 0.03 | % |
| $\Delta_{TEMP}$(HSI) | Frequency drift with $V_{DD}$ (reference is 64 MHz) | $T_J$= -20 to 105°C | -1(2) | - | 1(2) | |
| | | $T_J$= -40 to 140°C | -1.5(2) | - | 1(2) | |
| $t_{su}$(HSI) | Start-up time | - | - | 1.4 | 2.0 | µs |
| $t_{stab}$(HSI) | Stabilization time | At 1% of target frequency | - | 4 | 8 | µs |
| | | At 5% of target frequency | - | - | 4 | |
| $I_{DD}$(HSI) | Power consumption | - | - | 300 | 450 | µA |

1. *Specified by test in production.*
2. *Specified by characterization.*

Figure 29. **HSI frequency versus temperature**




### Low-speed internal (LSI) RC oscillator

Table 43. **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, $V_{DD}$ = 2.7 to 3.6 V | 29.4(2) | - | 33.6(2) | |
| | | $T_J$ = -40 to 140°C, $V_{DD}$ = 2.7 to 3.6 V | 28.6(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 44. PLL characteristics (wide VCO frequency range) are derived from tests performed under temperature and $V_{DD}$ supply voltage conditions summarized in Section 5.3.1.

Table 44. **PLL characteristics (wide VCO frequency range)**

Specified by design and not tested in production, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{PLL_IN}$ | PLL input clock | - | 2 | - | 16 | MHz |
| | PLL input clock duty cycle | - | 10 | - | 90 | % |

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| $f_{PLL_P_OUT}$ | PLL multiplier output clock P, Q, R | VOS0 | | 1 | - | 280(1) | MHz |
| | | VOS1 | | 1 | - | 240(1) | |
| | | VOS2 | | 1 | - | 170(1) | |
| $f_{VCO_OUT}$ | PLL VCO output | - | | 128 | - | 560(1) | |
| $t_{LOCK}$ | PLL lock time | Normal mode | | - | 45 | 100(2) | µs |
| | | Sigma-delta mode ($f_{PLL_IN}$ ≥ 8 MHz) | | - | 60 | 120(2) | |
| 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 | 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. *This value must be limited to the maximum frequency due to the product limitation.*
2. *Evaluated by characterization. Not tested in production.*

**Table 45. 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) | |
| $f_{VCO_OUT}$ | PLL VCO output | - | | 150 | - | 420 | |
| $t_{LOCK}$ | PLL lock time | Normal mode | | - | 45 | 80(3) | µs |
| | | Sigma-delta mode | | Forbidden | | | |
| 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 | 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 |

| Symbol | Parameter | Conditions | | Min(1) | Typ(1) | Max(1) | Unit |
|---|---|---|---|---|---|---|---|
| $I_{DD}$(PLL) | PLL power consumption on $V_{DD}$ | $f_{VCO_OUT}$ = 420 MHz | $V_{CORE}$ | - | 450 | - | µA |
| | | $f_{VCO_OUT}$ = 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.*

## 5.3.11 Memory characteristics

### Flash memory

The characteristics are given at $T_J$ = -40 to 140°C unless otherwise specified.
The devices are shipped to customers with the flash memory erased.

**Table 46. Flash memory characteristics**

| Symbol | Parameter | Conditions | Min | Typ | Max(1) | Unit |
|---|---|---|---|---|---|---|
| $I_{DD}$ | Supply current | Word program(2) | - | 2.5 | 3.6 | mA |
| | | Page 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 47. Flash memory programming**

Data are valid for program memory and high-cycling data memory.

| Symbol | Parameter | Conditions | Min(1) | Typ | Max(1) | Unit |
|---|---|---|---|---|---|---|
| $t_{prog}$ | Word program time | 128 bits (user area) | - | 31 | 100 | µs |
| | | 16 bits (OTP area) | - | 31 | 100 | |
| $t_{ERASE}$ | Page erase time (8 Kbytes) | | - | 2 | 10 | ms |
| $t_{ME}$ | Mass erase time | | - | 0.128 | 0.64 | s |
| $t_{BE}$ | Bank erase time | | - | 0.064 | 0.32 | |
| $V_{prog}$ | Programming voltage | | 2.7 | - | 3.6 | V |

1. *Specified by design. Not tested in production.*

**Table 48. Flash memory endurance and data retention**

| Symbol | Parameter | Conditions | Min | Unit |
|---|---|---|---|---|
| $N_{PEND}$ | Endurance program memory | $T_J$ = -40 to +140°C | 10 | kcycles |
| $N_{DEND}$ | Endurance data memory | $T_J$ = -40 to +140°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 resuming normal operation.

The test results are given in Table 49. EMS characteristics. They are based on the EMS levels and classes defined in AN1709 “EMC design guide for STM8, STM32 and legacy MCUs”.

**Table 49. 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, LQFP128, $f_{cpu}$ = 250 MHz, conform to IEC 61000-4-2 | 1B |
| $V_{FTB}$ | 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. Note that 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 50. EMI characteristics**

| Symbol | Parameter | Conditions | Monitored frequency band | Max vs. [$f_{HSE}/f_{CPU}$] | Unit |
|---|---|---|---|---|---|
| | | | | 8/250 MHz | |
| $S_{EMI}$ | Peak level(1) | $V_{DD}$ = 3.6 V, $T_A$ = 25 °C, LQFP128 SMPS conforming to IEC61967-2 | 0.1 to 30 MHz | 33 | dBµV |
| | | | 30 to 130 MHz | 40 | |
| | | | 130 MHz to 1 GHz | 28 | |
| | | | 1 GHz to 2 GHz | 21 | |
| | | | EMI level | 4 | - |

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 51. 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 pins except BOOT0 | 3A | 4000(2) | V |
| | | | BOOT0 pin | 2 | 3400 | |
| $V_{ESD(CDM)}$ | Electrostatic discharge voltage (charge device model) | $T_A$ = 25°C, conforming to ANSI/ESDA/JEDEC JS-002 | All packages except LQFP128 | C3 | 1250 | V |
| | | | LQFP128 | | 1000 | |

1. *Evaluated by characterization - Not tested in production.*
2. *The electrostatic discharge is 4000 V for all pins, except BOOT0, which passes at 3400 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 52. Electrical sensitivities**

| Symbol | Parameter | Conditions | Class |
|---|---|---|---|
| LU | Static latch-up class | $T_J$ = 140 °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 53. I/O current injection susceptibility**

Evaluated by characterization. Not tested in production.

| Symbol | Description | Functional susceptibility | | Unit |
|---|---|---|---|---|
| | | Negative injection | Positive injection | |
| $I_{INJ}$ | Injected current on pins PA4, PA5, PC14, PC15 | 0 | 0 | mA |
| | Injected current on all other pins | 5 | N/A | |

## 5.3.15 I/O port characteristics

### General input/output characteristics

Unless otherwise specified, the parameters given in Table 54. I/O static characteristics are derived from tests performed under the conditions summarized in Section 5.3.1: General operating conditions. 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 54. I/O static characteristics**

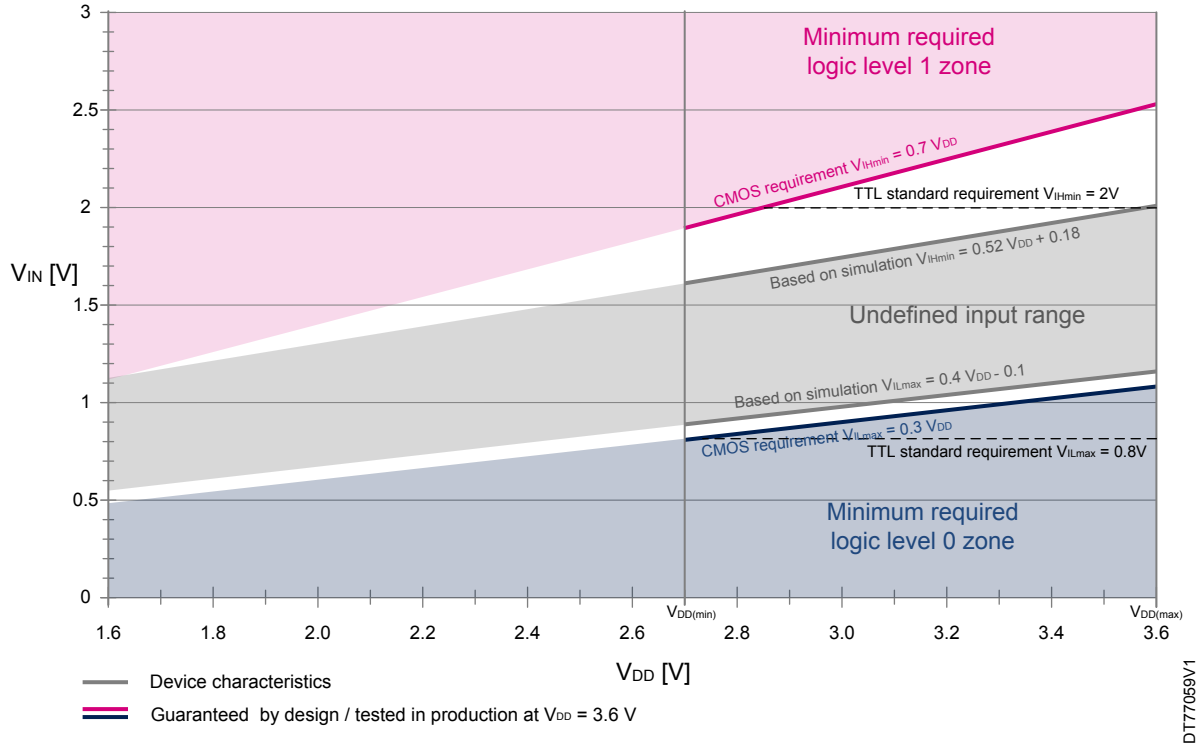
| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{IL}$ | I/O input low level voltage except BOOT0 | 2.7 V < $V_{DD}$ < 3.6 V | - | - | 0.3 $V_{DD}$(1) | V |
| | I/O input low level voltage except BOOT0 | | - | - | 0.4 $V_{DD}$ - 0.1(2) | |
| | FT_fb I/O in SMBUS 3.3 mode input low level voltage | | - | - | 0.8 | |
| | BOOT0 I/O input low level voltage | | - | - | 0.19 $V_{DD}$ + 0.1(2) | |
| $V_{IH}$ | I/O input high level voltage except BOOT0 | 2.7 V < $V_{DD}$ < 3.6 V | 0.7 $V_{DD}$(1) | - | - | V |
| | I/O input high level voltage except BOOT0 | | 0.52 $V_{DD}$ + 0.18(2) | - | - | |
| | FT_fb I/O in SMBUS 3.3 mode input high level voltage | | 1.35 | - | - | |
| | BOOT0 I/O input high level voltage | | 0.17 $V_{DD}$ + 0.6(2) | - | - | |
| $V_{HYS}$(2) | TT_xx, FT_xxx and NRST I/O input hysteresis | 2.7 V < $V_{DD}$ < 3.6 V | - | 250 | - | mV |
| | FT_fb I/O in SMBUS 3.3 mode input hysteresis | | - | 80 | - | |
| | BOOT0 I/O input hysteresis | | - | 200 | - | |
| $I_{leak}$(3) | FT_xx input leakage current(2) | 0 < $V_{IN}$ ≤ $V_{DD}$ | - | - | ±200 | nA |
| | | $V_{DD}$ < $V_{IN}$ ≤ 5.5 V (4) | - | - | 2500 | |
| | TT_xx input leakage current | 0 < $V_{IN}$ ≤ $V_{DD}$ | - | - | ±200 | |
| $R_{PU}$ | Weak pull-up(5) | $V_{IN}$ = $V_{SS}$ | 30 | 40 | 50 | kΩ |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| | equivalent resistor | | | | | kΩ |
| $R_{PD}$ | Weak pull-down equivalent resistor(5) | $V_{IN} = V_{DD}$ | 30 | 40 | 50 | |
| $C_{IO}$ | I/O pin capacitance | - | - | 5 | - | pF |

1. *Compliant with CMOS requirements.*
2. *Specified by design. Not tested in production.*
3. *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 $I_{lkg(Max)}$.*
4. *$V_{IN}$ must be lower than $V_{DD}$ + 3.6 V.*
5. *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%).*

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 30. $V_{IL}/V_{IH}$ 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: Absolute maximum ratings. 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 $\sum I_{VDD}$ (see Table 16. Current characteristics).
- 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 $\sum I_{VSS}$ (see Table 16. Current characteristics).

### Output voltage levels

Unless otherwise specified, the parameters given in Table 55. Output voltage characteristics for all I/Os except PC14 and PC15 are derived from tests performed under ambient temperature and $V_{DD}$ supply voltage conditions summarized in Section 5.3.1: General operating conditions. All I/Os are CMOS and TTL compliant.

**Table 55. Output voltage characteristics for all I/Os except PC14 and PC15**

| Symbol | Parameter | Conditions(1) | Min | Max | Unit |
|---|---|---|---|---|---|
| $V_{OL}$ | Output low level voltage | CMOS port, $I_{IO}$ = 8 mA(2)<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 0.4 | V |
| $V_{OH}$ | Output high level voltage | CMOS port(2), $I_{IO}$ = -8 mA<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | $V_{DD}$ - 0.4 | - | |
| $V_{OL}$ | Output low level voltage | TTL port(2), $I_{IO}$ = 8 mA<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 0.4 | |
| $V_{OH}$(3) | Output high level voltage | TTL port(2), $I_{IO}$ = -8 mA<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | 2.4 | - | |
| $V_{OL}$(3) | Output low level voltage | $I_{IO}$ = 20 mA<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 1.3 | |
| $V_{OH}$(3) | Output high level voltage | $I_{IO}$ = -20 mA<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | $V_{DD}$ - 1.3 | - | |
| $V_{OLFM+}$(3) | Output low level voltage for an FTf I/O pin in (FT I/O with “f” option) | $I_{IO}$ = 20 mA<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 0.4 | |
| $V_{OLSMBUS3}$(3) | Output low level voltage for an FT_fh I/O pin in (FT I/O with “b” option) | $I_{IO}$ = 20 mA<br>2.7 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 15. Voltage characteristics, 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 $\sum I_{IO}$.*
2. *TTL and CMOS outputs are compatible with JEDEC standards JESD36 and JESD52.*
3. *Specified by design. Not tested in production.*

**Table 56. Output voltage characteristics for FT_c I/Os**

| Symbol | Parameter | Conditions(1) | Min | Max | Unit |
|---|---|---|---|---|---|
| $V_{OL}$ | Output low level voltage | CMOS port, $I_{IO}$ = 2 mA(2)<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 0.4 | V |
| $V_{OH}$ | Output high level voltage | CMOS port(2), $I_{IO}$ = -2 mA<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | $V_{DD}$ - 0.4 | - | |
| $V_{OL}$ | Output low level voltage | TTL port(2), $I_{IO}$ = 2 mA<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 0.4 | |
| $V_{OH}$(3) | Output high level voltage | TTL port(2), $I_{IO}$ = -2 mA<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | 2.4 | - | |
| $V_{OL}$(3) | Output low level voltage | $I_{IO}$ = 1 mA<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 0.4 | |

| Symbol | Parameter | Conditions[1] | Min | Max | Unit |
|---|---|---|---|---|---|
| $V_{OH}$[3] | Output high level voltage | $I_{IO}$ = -1 mA<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | $V_{DD}$ - 0.4 | - | V |

1. *The $I_{IO}$ current sourced or sunk by the device must always respect the absolute maximum rating specified in Table 15. Voltage characteristics, 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 $\sum I_{IO}$.*
2. *TTL and CMOS outputs are compatible with JEDEC standards JESD36 and JESD52.*
3. *Specified by design - Not tested in production.*

### Table 57. Output voltage characteristics for PC14 and PC15

The IIO current sourced or sunk by the device must always respect the absolute maximum rating specified in Table 15, 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 $\Sigma I_{IO}$.

| Symbol | Parameter | Conditions[2] | Min | Max | Unit |
|---|---|---|---|---|---|
| $V_{OL}$ | Output low level voltage | CMOS port, $I_{IO}$ = 0.5 mA[1]<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 0.4 | V |
| $V_{OH}$ | Output high level voltage | CMOS port[1], $I_{IO}$ = -0.5 mA<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | $V_{DD}$ - 0.4 | - | |
| $V_{OL}$[2] | Output low level voltage | TTL port[1], $I_{IO}$ = 0.5 mA<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 0.4 | |
| $V_{OH}$[2] | Output high level voltage | TTL port[1], $I_{IO}$ = -0.5 mA<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V | 2.4 | - | |

1. *TTL and CMOS outputs are compatible with JEDEC standards JESD36 and JESD52.*
2. *Specified by design. Not tested in production.*

### Table 58. Output timing characteristics

Specified by design. Not tested in production.

| Speed | Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|---|
| 00 | $F_{max}$[1] | Maximum frequency | C = 50 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 8 | MHz |
| | | | C = 40 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 10 | |
| | | | C = 30 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 12 | |
| | | | C = 20 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 14 | |
| | | | C = 10 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 16 | |
| | $t_r/t_f$[2] | 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 = 40 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 17.0 | |
| | | | C = 30 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 15.5 | |
| | | | C = 20 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 14.2 | |
| | | | C = 10 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 12.2 | |
| 01 | $F_{max}$[1] | Maximum frequency | C = 50 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 40 | MHz |
| | | | C = 40 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 45 | |
| | | | C = 30 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 50 | |
| | | | C = 20 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 55 | |
| | | | C = 10 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 60 | |

| Speed | Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|---|
| 01 | $t_r/t_f$ (2) | 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 = 40 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 5.7 | |
| | | | C = 30 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 5.1 | |
| | | | C = 20 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 4.5 | |
| | | | C = 10 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 3.7 | |
| 10 | $F_{max}$ (1) | Maximum frequency | C = 50 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 80 | MHz |
| | | | C = 40 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 90 | |
| | | | C = 30 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 100 | |
| | | | C = 20 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 110 | |
| | | | C = 10 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 133 | |
| | $t_r/t_f$ (2) | 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 = 40 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 3.4 | |
| | | | C = 30 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 2.9 | |
| | | | C = 20 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 2.5 | |
| | | | C = 10 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 1.9 | |
| 11 | $F_{max}$ (1) | Maximum frequency | C = 50 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 100 | MHz |
| | | | C = 40 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 120 | |
| | | | C = 30 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 140 | |
| | | | C = 20 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 166 | |
| | | | C = 10 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 200 | |
| | $t_r/t_f$ (2) | 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 = 40 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 2.8 | |
| | | | C = 30 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 2.3 | |
| | | | C = 20 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 1.9 | |
| | | | C = 10 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 1.4 | |

1. *The maximum frequency is defined with the conditions ($t_r$ + $t_f$) ≤ 2/3 T, Skew ≤ 1/20 T, and 45% < Duty cycle < 55%.*
2. *The fall and rise times are defined between 90% and 10% and between 10% and 90% of the output waveform, respectively.*

**Table 59. Output timing characteristics for FT_c I/Os**

Specified by design. Not tested in production.

| Speed | Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|---|
| 00 | $F_{max}$ (1) | Maximum frequency | C = 50 pF, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 2 | MHz |
| | $t_r/t_f$ (2) | 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 | - | 166 | ns |
| 01 | $F_{rmax}$ (1) | Maximum frequency | C = 30 pF, 2.7 V ≤ $V_{DD}$ < 3.6 V | - | 10 | MHz |
| | $t_r/t_f$ (2) | Output high to low level fall time and output low to high level rise time | C = 30 pF, 2.7 V ≤ $V_{DD}$ < 3.6 V | - | 33 | ns |

1. *The maximum frequency is defined with the conditions (tr + tf) ≤ 2/3 T, Skew ≤ 1/20 T, and 45% < Duty cycle < 55%.*
2. *The fall and rise times are defined between 90% and 10% and between 10% and 90% of the output waveform, respectively.*

### 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 54. I/O static characteristics).

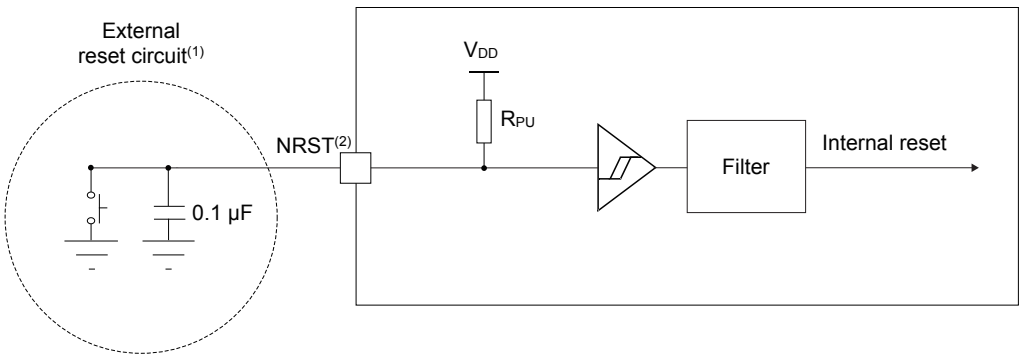
Unless otherwise specified, the parameters in Table 60. NRST pin characteristics are derived from tests performed under the ambient temperature and $V_{DD}$ supply voltage conditions summarized in Section 5.3.1.

**Table 60. 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 | 2.7 V < $V_{DD}$ < 3.6 V | - | - | 50 | ns |
| $V_{NF(NRST)}$(2) | NRST input not filtered pulse | 2.7 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 31. 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 54. I/O static characteristics, 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 61. EXTI input characteristics**

Specified by design. Not tested in production.

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

### 5.3.18 XSPI interface characteristics

Unless otherwise specified, the parameters given in Table 62 and Table 63 are derived from tests performed under the ambient temperature, $f_{HCLK}$ frequency and $V_{DD}$ supply voltage conditions summarized in Section 5.3.1: General operating conditions, 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
- 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 62. XSPI characteristics in SDR mode**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $F_{(CLK)}$ | Clock frequency | 2.7 V < $V_{DD}$ < 3.6 V, $C_L$ =15 pF | - | - | 150 | MHz |
| $t_{w(CLKH)}$ | 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 | - | 3 | - | - | |
| $t_{h(IN)}$ | Data input hold time | - | 1 | - | - | |
| $t_{v(OUT)}$ | Data output valid time | - | - | 1 | 1.5 | |
| $t_{h(OUT)}$ | Data output hold time | - | 0 | - | - | |

1. *At VOS1 these values are degraded by up to 5%.*

**Figure 32. XSPI SDR read/write timing diagram**

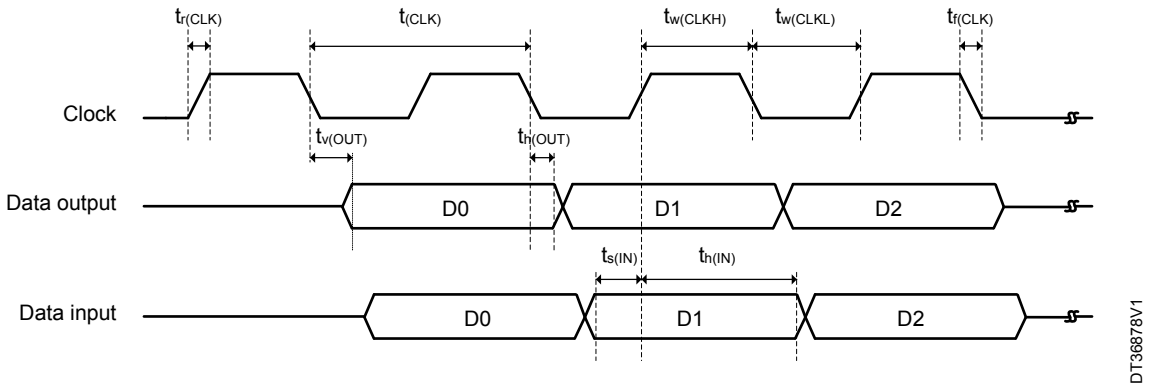



**Table 63. XSPI characteristics in DTR mode (no DQS)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $F_{CLK}$ | XSPI clock frequency | 2.7 V < $V_{DD}$ < 3.6 V, $C_L$ = 15 pF | - | - | 100(1) | MHz |
| $t_{w(CLKH)}$ | XSPI 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 | |
| $t_{w(CLKH)}$ | XSPI 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 | - | - | - | $t_{(CLK)}$ +0.5 | ns |
| $t_{sr(IN)}$, $t_{sf(IN)}$ | Data input setup time | - | 3 | - | - | ns |
| $t_{hr(IN)}$, $t_{hf(IN)}$ | Data input hold time | - | 1 | - | - | |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $t_{vr(OUT)}$ $t_{vf(OUT)}$ | Data output valid time | DHQC = 0 | - | 3.5 | 4.5 | ns |
| | | DHQC = 1, Prescaler [7:0] = 1, 2... | - | $t_{(CLK)}$ / 4 + 0.5 | $t_{(CLK)}$ / 4 + 1 | |
| $t_{hr(OUT)}$ $t_{hf(OUT)}$ | Data output hold time | DHQC = 0 | 1.5 | - | - | |
| | | DHQC = 1, Prescaler [7:0] = 1, 2... | $t_{(CLK)}$ / 4 | - | - | |

1. *The DHQC bit must be set to reach the mentioned frequency.*

**Table 64. XSPI characteristics in DTR mode (with DQS) / HyperBus**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $F_{CLK}$ | XSPI clock frequency | 2.7 V < $V_{DD}$ < 3.6 V, $C_L$ = 15 pF | - | - | 133(1)(2) | MHz |
| $t_{w(CLKH)}$ | XSPI 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 | |
| $t_{w(CLKH)}$ | XSPI 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 | - | - | |
| $t_{w(CS)}$ | Chip select high time | - | 3 * $t_{(CLK)}$ | - | - | ns |
| $t_{v(DQ)}$ | Data input valid time | - | 0 | - | - | |
| $t_{v(DS)}$ | Data strobe input valid time | - | 0 | - | - | |
| $t_{h(DS)}$ | 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 | - | -1 | - | - | ns |
| $t_{hr(DQ)}$, $t_{hf(DQ)}$ | Data input hold time | - | 3 | - | - | |
| $t_{vr(OUT)}$ $t_{vf(OUT)}$ | Data output valid time | DHQC = 0 | - | 3.5 | 4.5 | |
| | | 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. *The DHQC bit must be set to reach the mentioned frequency.*
2. *Maximum frequency value are given for a maximum RWDS to DQ skew of ± 1.0 ns.*

Figure 33. **XSPI timing diagram - DTR mode**

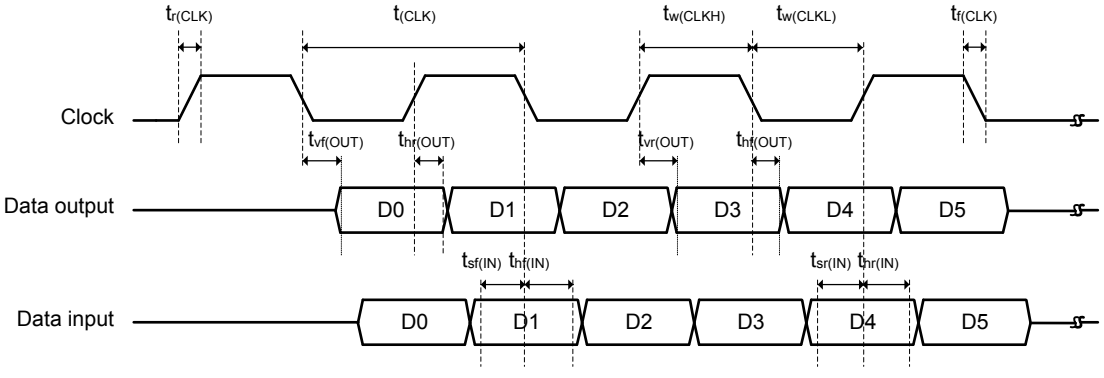



Figure 34. **XSPI HyperBus clock**

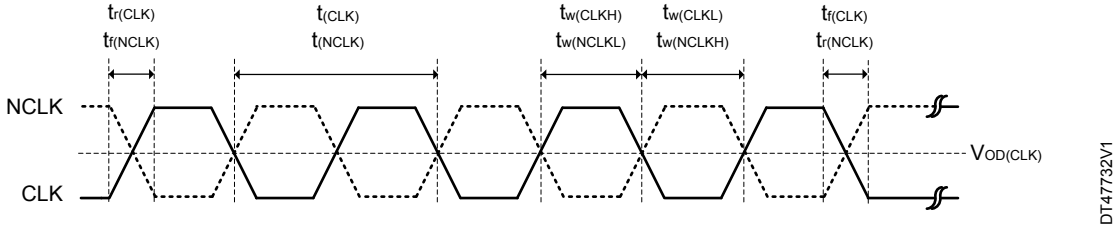



Figure 35. **XSPI HyperBus read**

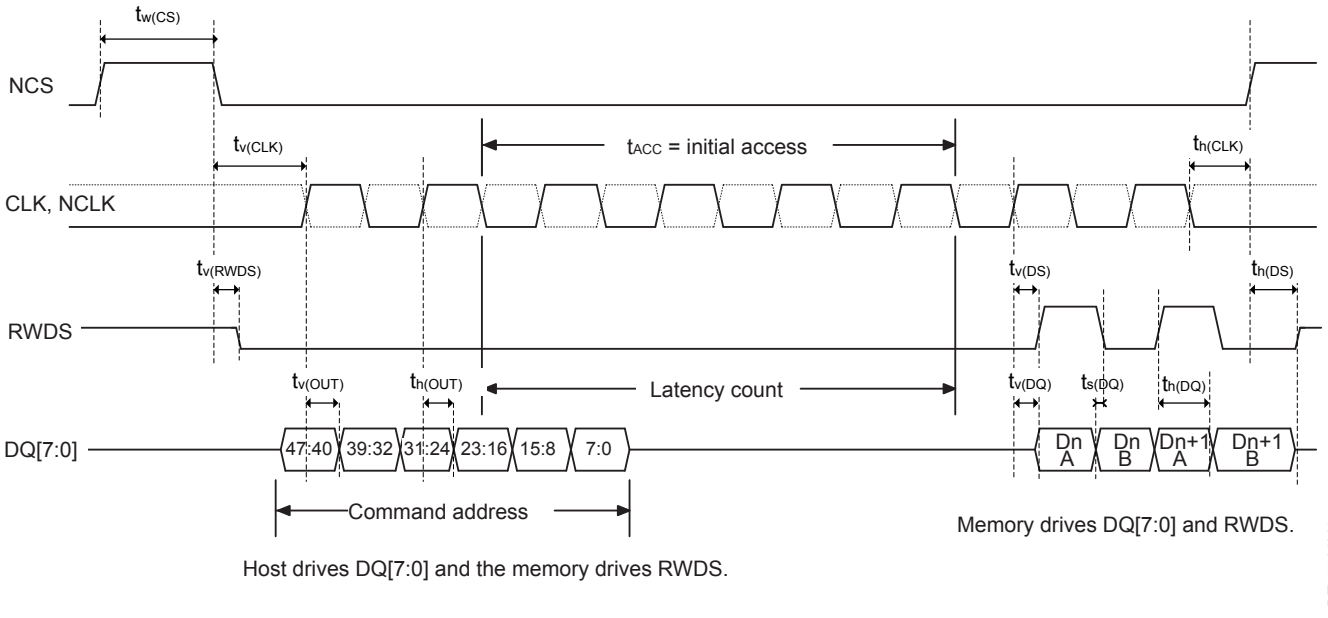
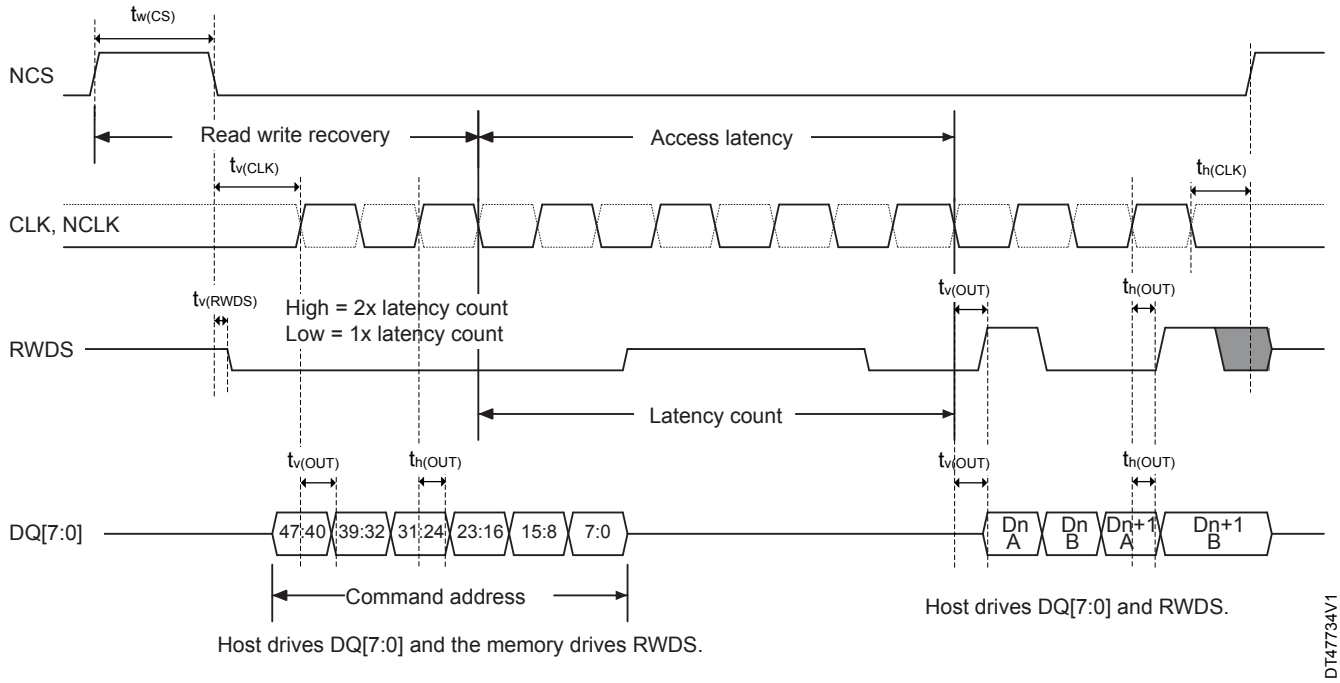


Figure 36. **XSPI HyperBus write**




### 5.3.19 Delay block (DLYB) characteristics

Unless otherwise specified, the parameters given in Table 65. Delay block characteristics are derived from tests performed under the ambient temperature, $f_{HCLK}$ frequency and $V_{DD}$ supply voltage summarized in Section 5.3.1: General operating conditions, with the following configuration:

Table 65. **Delay block characteristics**

Specified by design. Not tested in production.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $t_{init}$ | Initial delay | - | 800 | 1200 | 1500 | ps |
| $t_{\Delta}$ | Unit delay | - | 38 | 46 | 55 | ps |

### 5.3.20 Analog-to-digital converter characteristics

Unless otherwise specified, the parameters given in Table 66 are derived from tests performed under the ambient temperature, $f_{HCLK}$ frequency, and $V_{DDA}$ supply voltage conditions summarized in Section 5.3.1: General operating conditions.

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

Table 66. **12-bit ADC characteristics**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{DDA}$ | Analog supply voltage for ADC ON | - | 2.5 | - | 3.6 | V |
| $V_{REF+}$ | Positive reference voltage | - | 1.8 | - | $V_{DDA}$ | |
| $V_{REF-}$ | Negative reference voltage | - | $V_{SSA}$ | | | |
| $f_{adc_ker_ck}$ (1) | Clock frequency | 2.7 V ≤ $V_{DDA}$ ≤ 3.6 V | 1.5 | - | 80 | MHz |

| Symbol | Parameter | Conditions | | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| $f_S$ with $R_{AIN}$ = 47 Ω and $C_{PCB}$ = 22 pF | Sampling rate for fast channels (ADCx_IN[0...5]) | Resolution = 12 bits | All modes | 2.7 V ≤ $V_{DDA}$ ≤ 3.6V<br>-40°C ≤ $T_J$ ≤ 140°C<br>$f_{adc_ker_ck}$= 80 MHz<br>SMP = 2.5 | - | 5.00 | - | MSPS |
| | | Resolution = 10 bits | | | - | 5.71 | - | |
| | | Resolution = 8 bits | | | - | 6.67 | - | |
| | | Resolution = 6 bits | | | - | 8.00 | - | |
| | Sampling rate for slow channels (ADCx_IN[6...19) | Resolution = 12 bits | All modes | 2.7 V ≤ $V_{DDA}$ ≤ 3.6V<br>-40°C ≤ $T_J$ ≤ 140°C<br>$f_{adc_ker_ck}$= 80 MHz<br>SMP = shortest possible | - | 3.08 | - | |
| | | Resolution = 10 bits | | | - | 5.00 | - | |
| | | Resolution = 8 bits | | | - | 5.71 | - | |
| | | Resolution = 6 bits | | | - | 8.00 | - | |
| $t_{TRIG}$ | External trigger period | Regular conversions | $t_S$ + 6.5 + N | | 21 | - | - | $1/f_{adc_ker_ck}$ |
| | | Injected conversions | $t_S$ + 7.5 + N | | 22 | - | - | $1/f_{adc_ker_ck}$ |
| $V_{AIN}$ | Conversion voltage range | - | | | 0 | - | $V_{REF+}$ | V |
| $V_{CMIV}$ | Common mode input voltage | Differential mode | | | $V_{REF}$ / 2 − 10% | $V_{REF}$ / 2 | $V_{REF}$ / 2 + 10% | |
| | | Pseudo-differential mode | | PDIFFREF=0 (reference voltage = $V_{REF-}$) | $V_{REF-}$ | - | $V_{REF+}$ | |
| | | | | PDIFFREF=1 (reference voltage = $V_{REF}$/2) | $V_{REF}$/2 | - | $V_{REF+}$ | |
| $R_{AIN}$(2) | External input impedance | $f_{adc_ker_ck}$ = 80 MHz,<br>ts = 2.5,<br>Tolerance 4 LSBs | | Resolution = 12 bits, $T_J$ = 140°C | - | - | 321 | Ω |
| | | $f_{adc_ker_ck}$ = 80MHz,<br>ts = 2.5,<br>Tolerance 2 LSBs | | Resolution = 12 bits, $T_J$ = 125°C | - | - | 220 | |
| | | | | Resolution = 10 bits, $T_J$ = 140°C | - | - | 1039 | |
| | | | | Resolution = 10 bits, $T_J$ = 125°C | - | - | 2100 | |
| | | | | Resolution = 8 bits, $T_J$ = 140°C | - | - | 6327 | |
| | | | | esolution = 8 bits, $T_J$ = 125°C | - | - | 12000 | |
| | | | | Resolution = 6 bits, $T_J$ = 140°C | - | - | 47620 | |
| | | | | Resolution = 6 bits, $T_J$ = 125°C | - | - | 80000 | |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $C_{ADC}$ | Internal sample and hold capacitor | - | - | 3 | - | pF |
| $t_{ADCVREG_STUP}$ | ADC LDO internal voltage regulator startup time | - | - | 5 | 10 | µs |
| $t_{STAB}$ | ADC power-up time | ADC LDO internal voltage regulator 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 | - | 1 | - | 2 | |
| $t_{LATRINJ}$ | Trigger conversion latency for injected channels | - | 2 | - | 3 | |
| $t_S$ | Sampling time | - | 2.5 | - | 848.5 | |
| $t_{CONV}$ | Total conversion time (including sampling) | N-bits resolution | $t_S$ + 1.5 + N | | | |
| $I_{DDA_D(ADC)}$ | Consumption on $V_{DDA}$ and $V_{REF}$, differential mode, pseudo-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 = 2.5 MSPS | - | 500 | - | |
| | | fs = 1 MSPS | - | 150 | - | |
| | | fs = 0.1 MSPS | - | 50 | - | |
| $I_{DD(ADC)}$ | Consumption on $V_{DD}$ | $f_{adc_ker_ck}$ = 80 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. *This frequency is the analog ADC specification, it must respect the value in Table 19. Maximum allowed clock frequencies*
2. *The tolerance is two LSBs for 12-bit, 10-bit and 8-bit resolutions, otherwise specified.*

### Table 67. Minimum sampling time versus $R_{AIN}$

Specified by design. Not tested in production.
Tollerance for 2 LSB error. Data valid up to Tj = 140°C, with a 22 pF PCB capacitor, and $V_{DDA}$ = 2.7 V.
Maximum allowed $R_{AIN}$ for extra long sampling time depends from $I_{leak}$ current for given pin causing voltage drop on $R_{AIN}$ (see Table 54. I/O static characteristics)

| Resolution | $R_{AIN}$ (Ω) | Minimum sampling time (s) | |
|---|---|---|---|
| | | Fast channels (1) | Slow channels (2) |
| 12 bits | 47 | 3.11E-08 | 4.18E-08 |
| | 68 | 3.33E-08 | 4.35E-08 |
| | 100 | 3.74E-08 | 4.68E-08 |

| Resolution | $R_{AIN}$ (Ω) | Minimum sampling time (s) | |
|---|---|---|---|
| | | Fast channels (1) | Slow channels (2) |
| 12 bits | 150 | 4.51E-08 | 5.31E-08 |
| | 220 | 5.73E-08 | 6.39E-08 |
| | 330 | 7.79E-08 | 8.32E-08 |
| | 470 | 1.05E-07 | 1.09E-07 |
| | 680 | 1.46E-07 | 1.49E-07 |
| | 1000 | 2.09E-07 | 2.11E-07 |
| | 1500 | 3.08E-07 | 3.09E-07 |
| | 2200 | 4.46E-07 | 4.45E-07 |
| | 3300 | 6.62E-07 | 6.59E-07 |
| | 4700 | 9.37E-07 | 9.30E-07 |
| | 6800 | 1.35E-06 | 1.34E-06 |
| | 10000 | 2.00E-06 | 1.97E-06 |
| | 15000 | 3.00E-06 | 2.95E-06 |
| | 22000 | 4.39E-06 | 4.30E-06 |
| | 33000 | 6.48E-06 | 6.37E-06 |
| | 47000 | 8.44E-06 | 8.29E-06 |
| 10 bits | 47 | 2.50E-08 | 3.40E-08 |
| | 68 | 2.68E-08 | 3.54E-08 |
| | 100 | 3.00E-08 | 3.80E-08 |
| | 150 | 3.58E-08 | 4.29E-08 |
| | 220 | 4.52E-08 | 5.11E-08 |
| | 330 | 6.09E-08 | 6.59E-08 |
| | 470 | 8.16E-08 | 8.57E-08 |
| | 680 | 1.13E-07 | 1.16E-07 |
| | 1000 | 1.61E-07 | 1.64E-07 |
| | 1500 | 2.37E-07 | 2.38E-07 |
| | 2200 | 3.42E-07 | 3.42E-07 |
| | 3300 | 5.07E-07 | 5.05E-07 |
| | 4700 | 7.17E-07 | 7.12E-07 |
| | 6800 | 1.03E-06 | 1.02E-06 |
| | 10000 | 1.51E-06 | 1.49E-06 |
| | 15000 | 2.26E-06 | 2.23E-06 |
| | 22000 | 3.31E-06 | 3.25E-06 |
| | 33000 | 4.92E-06 | 4.82E-06 |
| | 47000 | 6.78E-06 | 6.62E-06 |
| 8 bits | 47 | 1.90E-08 | 2.62E-08 |
| | 68 | 2.02E-08 | 2.73E-08 |
| | 100 | 2.25E-08 | 2.91E-08 |
| | 150 | 2.66E-08 | 3.26E-08 |
| | 220 | 3.31E-08 | 3.83E-08 |

| Resolution | $R_{AIN}$ (Ω) | Minimum sampling time (s) | |
|---|---|---|---|
| | | Fast channels (1) | Slow channels (2) |
| 8 bits | 330 | 4.40E-08 | 4.85E-08 |
| | 470 | 5.83E-08 | 6.23E-08 |
| | 680 | 8.02E-08 | 8.36E-08 |
| | 1000 | 1.14E-07 | 1.17E-07 |
| | 1500 | 1.66E-07 | 1.68E-07 |
| | 2200 | 2.39E-07 | 2.41E-07 |
| | 3300 | 3.54E-07 | 3.54E-07 |
| | 4700 | 5.00E-07 | 4.99E-07 |
| | 6800 | 7.19E-07 | 7.15E-07 |
| | 10000 | 1.06E-06 | 1.04E-06 |
| | 15000 | 1.58E-06 | 1.56E-06 |
| | 22000 | 2.31E-06 | 2.27E-06 |
| | 33000 | 3.45E-06 | 3.37E-06 |
| | 47000 | 4.84E-06 | 4.72E-06 |
| 6 bits | 47 | 1.30E-08 | 1.85E-08 |
| | 68 | 1.37E-08 | 1.91E-08 |
| | 100 | 1.51E-08 | 2.03E-08 |
| | 150 | 1.74E-08 | 2.23E-08 |
| | 220 | 2.10E-08 | 2.56E-08 |
| | 330 | 2.71E-08 | 3.12E-08 |
| | 470 | 3.51E-08 | 3.88E-08 |
| | 680 | 4.74E-08 | 5.08E-08 |
| | 1000 | 6.63E-08 | 6.94E-08 |
| | 1500 | 9.59E-08 | 9.87E-08 |
| | 2200 | 1.37E-07 | 1.40E-07 |
| | 3300 | 2.02E-07 | 2.04E-07 |
| | 4700 | 2.85E-07 | 2.86E-07 |
| | 6800 | 4.10E-07 | 4.10E-07 |
| | 10000 | 6.05E-07 | 6.00E-07 |
| | 15000 | 9.10E-07 | 8.98E-07 |
| | 22000 | 1.34E-06 | 1.31E-06 |
| | 33000 | 2.00E-06 | 1.96E-06 |
| | 47000 | 2.83E-06 | 2.75E-06 |

1. *Fast channels correspond for ADCx_INP0 to ADCx_INP5.*
2. *Slow channels correspond to all ADC inputs except for the Fast channels.*

**Table 68. ADC accuracy (ADC1) - LDO mode**

Evaluated by characterization. Not tested in production.
ADC DC accuracy values are measured after internal calibration in continuous mode.
Characterized on LQFP128 package.

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| ET | Total unadjusted error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +/-3 | +/-7 | LSBs |
| | | | Differential | - | +/-3 | +/-6 | |
| EO | Offset error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | -2 | +0/-6 | |
| | | | Differential | - | -2 | +1/-5 | |
| EG | Gain error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +3 | +9 | |
| | | | Differential | - | +3 | +8 | |
| ED | Differential linearity error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +/-0.75 | +1.6/-1 | |
| | | | Differential | - | +/-0.75 | +1.7/-1 | |
| EL | Integral linearity error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +/-2 | +/-4 | |
| | | | Differential | - | +/-1 | +/-2.5 | |
| ENOB | Effective number of bits | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | 10 | 10.8 | - | bits |
| | | | Differential | 11 | 11.5 | - | |
| SINAD | Signal-to-noise and distortion ratio | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | 62 | 68 | - | dB |
| | | | Differential | 68 | 71 | - | |
| SNR | Signal-to-noise ratio | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | 62 | 70 | - | |
| | | | Differential | 69 | 72 | - | |
| THD | Total harmonic distortion | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | -70 | -75 | - | |
| | | | Differential | -75 | -80 | - | |

**Table 69. ADC accuracy (ADC1+ADC2+ADC3) - LDO mode**

Evaluated by characterization. Not tested in production.
ADC DC accuracy values are measured after internal calibration in continuous mode.
Characterized on LQFP128 package.

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| ET | Total unadjusted error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +/-4 | - | LSBs |

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| ET | Total unadjusted error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Differential | - | +/-4 | - | LSBs |
| EO | Offset error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | -3 | - | |
| | | | Differential | - | -3 | - | |
| EG | Gain error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +4 | - | |
| | | | Differential | - | +4 | - | |
| ED | Differential linearity error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +/-1 | - | |
| | | | Differential | - | +/-1 | - | |
| EL | Integral linearity error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +/-2 | - | |
| | | | Differential | - | +/-2 | - | |
| ENOB | Effective number of bits | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | 10.8 | - | bits |
| | | | Differential | - | 11.5 | - | - |
| SINAD | Signal-to-noise and distortion ratio | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | 68 | - | dB |
| | | | Differential | - | 71 | - | |
| SNR | Signal-to-noise ratio | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | 70 | - | |
| | | | Differential | - | 72 | - | |
| THD | Total harmonic distortion | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | -75 | - | |
| | | | Differential | - | -80 | - | |

**Table 70. ADC accuracy (ADC1) - SMPS mode**

Evaluated by characterization. Not tested in production.
ADC DC accuracy values are measured after internal calibration in continuous mode.
Characterized on LQFP128 package.
Accuracy values are valid for all ADC pins except pins PD15, PD14, PD13, PD10, PD9, PD8, PB15, PB14, PB13, PB12.

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| ET | Total unadjusted error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +/-4 | - | LSBs |
| | | | Differential | - | +/-4 | - | |
| EO | Offset error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | -3 | - | |
| | | | Differential | - | -3 | - | |
| EG | Gain error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +4 | - | |

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| EG | Gain error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Differential | - | +4 | - | LSBs |
| ED | Differential linearity error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +/-1 | - | |
| | | | Differential | - | +/-1 | - | |
| EL | Integral linearity error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +/-2 | - | |
| | | | Differential | - | +/-2 | - | |
| ENOB | Effective number of bits | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | 10.8 | - | bits |
| | | | Differential | - | 11.5 | - | - |
| SINAD | Signal-to-noise and distortion ratio | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | 68 | - | dB |
| | | | Differential | - | 71 | - | |
| SNR | Signal-to-noise ratio | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | 70 | - | |
| | | | Differential | - | 72 | - | |
| THD | Total harmonic distortion | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | -75 | - | |
| | | | Differential | - | -80 | - | |

**Table 71. ADC accuracy (ADC1+ADC2+ADC3) - SMPS mode**

Evaluated by characterization. Not tested in production.
ADC DC accuracy values are measured after internal calibration in continuous mode.
Characterized on LQFP128 package.
Accuracy values are valid for all ADC pins except pins PD15, PD14, PD13, PD10, PD9, PD8, PB15, PB14, PB13, PB12.

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| ET | Total unadjusted error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +/-5 | - | LSBs |
| | | | Differential | - | +/-5 | - | |
| EO | Offset error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | -4 | - | |
| | | | Differential | - | -4 | - | |
| EG | Gain error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +/-5 | - | |
| | | | Differential | - | +/-5 | - | |
| ED | Differential linearity error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +/-1 | - | |
| | | | Differential | - | +/-1 | - | |
| EL | Integral linearity error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | +/-2.5 | - | |

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| EL | Integral linearity error | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Differential | - | +/-2.5 | - | LSBs |
| ENOB | Effective number of bits | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | 10.8 | - | bits |
| | | | Differential | - | 11.5 | - | - |
| SINAD | Signal-to-noise and distortion ratio | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | 68 | - | dB |
| | | | Differential | - | 71 | - | |
| SNR | Signal-to-noise ratio | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | 70 | - | |
| | | | Differential | - | 72 | - | |
| THD | Total harmonic distortion | Fast and Slow channels $f_{adc_ker_ck}$ = 80MHz | Single ended | - | -70 | - | |
| | | | Differential | - | -80 | - | |

**Figure 37. ADC accuracy characteristics**

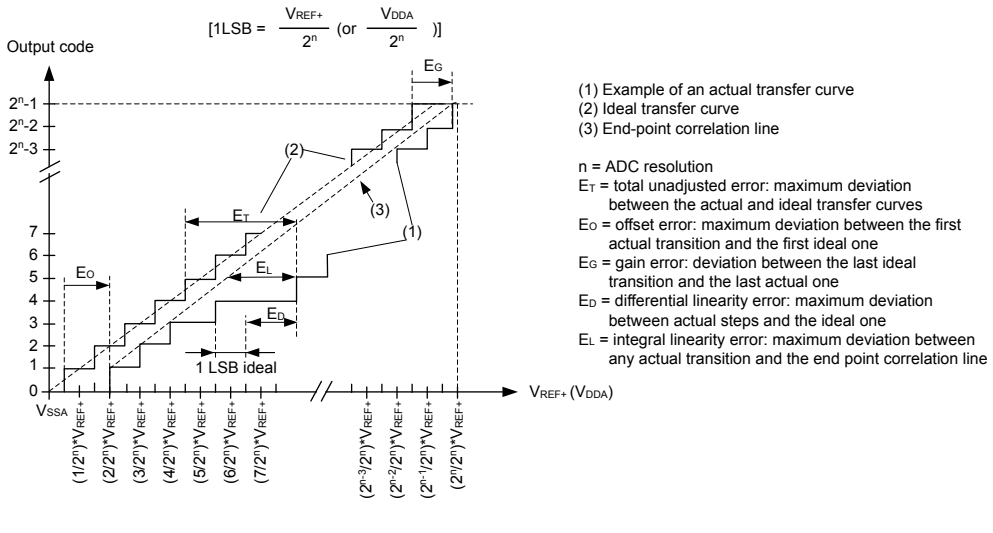
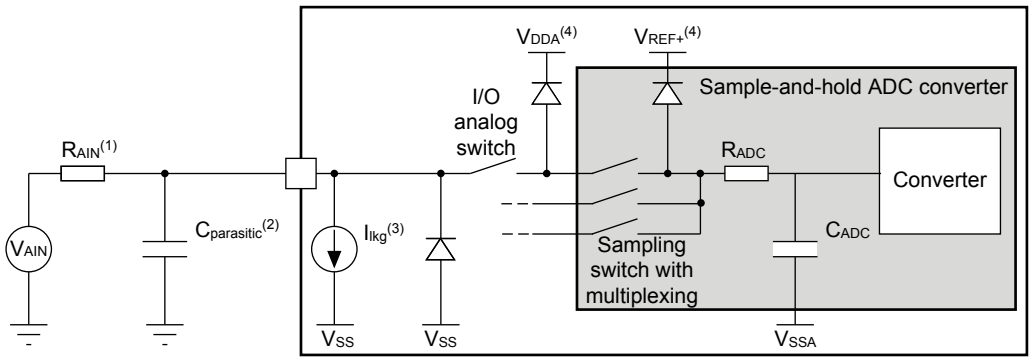


**Figure 38. Typical connection diagram when using the ADC with FT/TT pins featuring analog switch function**



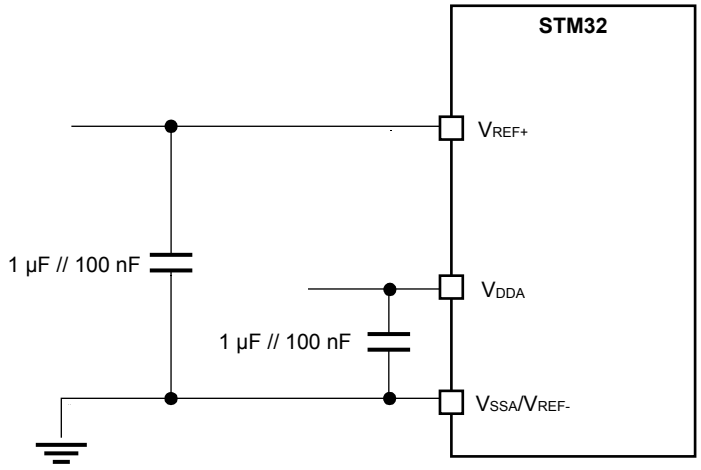

*Note:*

1. *Refer to Table 66. 12-bit ADC characteristics 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 Section 5.3.15: I/O port characteristics) for the value of the pad capacitance). A high $C_{parasitic}$ value downgrades conversion accuracy. To remedy this, $f_{adc_ker_ck}$ should be reduced.*
3. *Refer to Section 5.3.15: I/O port characteristics for the values of $I_{lkg}$.*
4. *Refer to Section 5.1.6: Power supply scheme.*

### General PCB design guidelines

It is recommended to perform power supply decoupling as shown in Figure 21 or Figure 20 and Figure 39, depending on whether $V_{REF+}$ is connected to $V_{DDA}$ or not. The 1 µF capacitors must be ceramic (good quality), and placed as close as possible to the chip.

**Figure 39. Power supply and reference decoupling ($V_{REF+}$ not connected to $V_{DDA}$)**



### 5.3.21 DAC characteristics

**Table 72. DAC 1 MSPS characteristics**

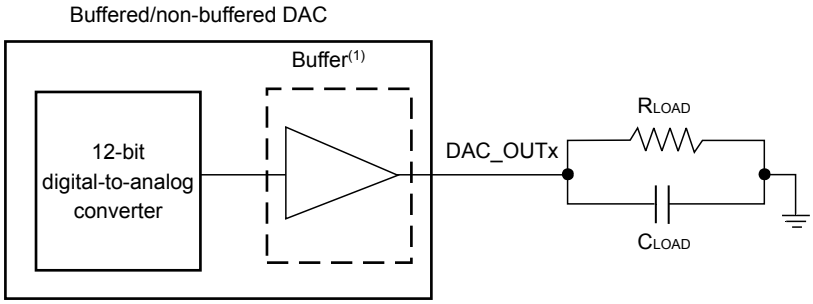
Specified by design. Not tested in production.

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| $V_{DDA}$ | Analog supply voltage for DAC ON | - | | 2.5 | 3.3 | 3.6 | V |
| $V_{REFDAC+}$ | Positive reference voltage | - | | 1.8 | - | $V_{DDA}$ | |
| $V_{REFDAC-}$ | 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 | kΩ |
| $R_{BON}$ | Output impedance sample and hold mode, output buffer ON | DAC output buffer ON | $V_{DDA}$ = 2.7 V | - | - | 1.6 | kΩ |
| $R_{BOFF}$ | Output impedance sample and hold mode, output buffer OFF | DAC output buffer OFF | $V_{DDA}$ = 2.7 V | - | - | 16.5 | kΩ |
| $C_L$ | Capacitive load | DAC output buffer ON | | - | - | 50 | pF |
| $C_{SH}$ | | Sample and hold mode | | - | 0.1 | 1 | µF |
| $V_{DAC_OUT}$ | Voltage on DAC_OUT output | DAC output buffer ON | | $V_{SSA}$ + 0.2 | - | $V_{DDA}$ – 0.2 | V |
| | | DAC output buffer OFF | | $V_{REFDAC-}$ | - | $V_{REFDAC+}$ | |
| $t_{SETTLING}$ | Settling time (full scale: for a 12-bit code transition between the lowest and the highest input codes when DAC_OUT reaches final value) | Normal mode DAC output buffer ON CL ≤ 50 pF, RL ≥ 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, CL = 10 pF | | - | 1.7 | 2 | |
| $t_{WAKEUP}$(1) | Wake-up time from off state (setting the ENx bit in the DAC Control register) until final value ±1 LSB | Normal mode DAC output buffer ON CL ≤ 50 pF, RL ≥ 5 kΩ | | - | 5 | 7.5 | µs |
| | | Normal mode DAC output buffer OFF, CL ≤ 10 pF | | - | 2 | 5.0 | |
| PSRR | $V_{DDA}$ supply rejection ratio | Normal mode DAC output buffer ON CL ≤ 50 pF, RL = 5 kΩ, DC | | 28 | 80 | - | dB |
| $T_{W_to_W}$ | Minimal time between two consecutive writes into the DAC_DORx register to guarantee a correct DAC_OUT for a small variation of the input code (1 LSB) | DAC_MCR:MODEx[2:0] = 000 or 001 CL ≤ 50 pF, RL ≥ 5 kΩ | | 1 | - | - | µs |
| | | DAC_MCR:MODEx[2:0] = 010 or 011 CL ≤ 10 pF | | 1.4 | - | - | |
| $t_{SAMP}$ | Sampling time in sample and hold mode (code transition between the lowest input code and the highest input code when DACOUT reaches final value ±1LSB) | DAC_OUT pin connected | DAC output buffer ON, $C_{SH}$ = 100 nF | - | 0.7 | 2.6 | ms |

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| $t_{SAMP}$ | Sampling time in sample and hold mode (code transition between the lowest input code and the highest input code when DACOUT reaches final value ±1LSB) | DAC_OUT pin connected | DAC output buffer OFF, $C_{SH}$ = 100 nF | - | 11.5 | 18.7 | ms |
| | | DAC_OUT pin not connected (internal connection only) | DAC output buffer OFF | - | 0.3 | 0.6 | µs |
| $I_{leak}$ | Output leakage current | Sample and hold mode, DAC_OUT pin connected | | - | - | (2) | nA |
| $CI_{int}$ | Internal sample and hold capacitor | - | | 1.8 | 2.2 | 2.6 | pF |
| $t_{TRIM}$ | Middle code offset trim time | DAC output buffer ON | | 50 | - | - | µs |
| $V_{offset}$ | Middle code offset for 1 trim code step | $V_{REFDAC+}$ = 3.6 V | | - | 850 | - | µV |
| | | $V_{REFDAC+}$ = 1.8 V | | - | 425 | - | |
| $I_{DDA(DAC)}$ | DAC consumption from $V_{DDA}$ | DAC output buffer ON | No load, middle code (0x800) | - | 590 | - | µA |
| | | | No load, worst code (0xF1C) | - | 720 | - | |
| | | DAC output buffer OFF | No load, middle code (0x800) | - | 20 | - | |
| | | Sample and hold mode, $C_{SH}$ = 100 nF | | - | 590 x Ton/ (Ton + Toff) (2) | - | |
| $I_{DDV(DAC)}$ | DAC consumption from $V_{REFDAC+}$ | DAC output buffer ON | No load, middle code (0x800) | - | 150 | - | µA |
| | | | No load, worst code (0xF1C) | - | 280 | - | |
| | | DAC output buffer OFF | No load, middle code (0x800) | - | 155 | - | |
| | | Sample and hold mode, buffer ON, $C_{SH}$ = 100 nF, worst code | | - | 150 x Ton/ (Ton+Toff) (2) | - | |
| | | Sample and hold mode, buffer OFF, $C_{SH}$ = 100 nF, worst code | | - | 155 x Ton/ (Ton+Toff) (2) | - | |

1. *In buffered mode, the output can overshoot above the final value for low input code (starting from minimum value).*
2. *Ton is the refresh phase duration. Toff is the hold phase duration. Refer to the reference manual RM0514 "STM32G56x/55x/54x/53x Arm®-based 32-bit MCUs" for more details.*

**Figure 40. 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.

DT47959V2

**Table 73. DAC 1 MSPS accuracy**

Specified by design. Not tested in production.

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| DNL | Differential non linearity (1) | DAC output buffer ON | | -2 | - | 2 | LSB |
| | | DAC output buffer OFF | | -2 | - | 2 | |
| - | monotonicity | 10 bits | | Guaranteed | | | |
| INL | Integral non linearity(2) | DAC output buffer ON<br>CL ≤ 50 pF, RL ≥ 5 kΩ | | -4 | - | 4 | |
| | | DAC output buffer OFF<br>CL ≤ 50 pF, no RL,<br>DAC_MCR:MODEx[2:0] = 011 | | -4 | - | 4 | |
| | | DAC output buffer OFF<br>CL ≤ 50 pF, no RL, Tj = -40 to 85°C,<br>DAC_MCR:MODEx[2:0] = 010 | | -4 | - | 4 | |
| | | DAC output buffer OFF<br>CL ≤ 50 pF, no RL, Tj = 85 to 140°C,<br>DAC_MCR:MODEx[2:0] = 010 | | -15 | - | 15 | |
| Offset | Offset error at code 0x800(2)) | DAC output buffer ON<br>CL ≤ 50 pF, RL ≥ 5 kΩ | $V_{REFDAC+}$ = 3.6 V | - | - | ±12 | |
| | | | $V_{REFDAC+}$ = 1.8 V | - | - | ±25 | |
| | | DAC output buffer OFF<br>CL ≤ 50 pF, no RL | | - | - | ±8 | |
| Offset1 | Offset error at code 0x001(3) | DAC output buffer OFF<br>CL ≤ 50 pF, no RL,<br>DAC_MCR:MODEx[2:0] = 011 | | - | - | ±5 | |
| | | DAC output buffer OFF<br>CL ≤ 50 pF, no RL, Tj = -40 to 85°C,<br>DAC_MCR:MODEx[2:0] = 010 | | - | - | ±5 | |
| | | DAC output buffer OFF<br>CL ≤ 50 pF, no RL, Tj = 85 to 140°C,<br>DAC_MCR:MODEx[2:0] = 010 | | - | - | ±15 | |
| OffsetCal | Offset Error at code 0x800 after calibration | DAC output buffer ON<br>CL ≤ 50 pF, RL ≥ 5 kΩ | $V_{REFDAC+}$ = 3.6 V | - | - | ±5 | |
| | | | $V_{REFDAC+}$ = 1.8 V | - | - | ±7 | |
| Gain | Gain error(4) | DAC output buffer ON<br>CL ≤ 50 pF, RL ≥ 5 kΩ | | - | - | ±1 | % |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Gain | Gain error(4) | DAC output buffer OFF<br>CL ≤ 50 pF, no RL | - | - | ±1 | % |
| TUE | Total unadjusted error | DAC output buffer ON<br>CL ≤ 50 pF, RL ≥ 5 kΩ | - | - | ±30 | LSB |
| | | DAC output buffer OFF<br>CL ≤ 50 pF, no RL | - | - | 15 | |
| TUECal | Total unadjusted error after calibration | DAC output buffer ON<br>CL ≤ 50 pF, RL ≥ 5 kΩ | - | - | ±23 | LSB |
| SNR | Signal-to-noise ratio | DAC output buffer ON<br>CL ≤ 50 pF, RL ≥ 5 kΩ<br>1 kHz, BW 500 kHz | - | 67.8 | - | dB |
| | | DAC output buffer OFF<br>CL ≤ 50 pF, no RL, 1 kHz<br>BW 500 kHz | - | 67.8 | - | |
| THD | Total harmonic distortion | DAC output buffer ON<br>CL ≤ 50 pF, RL ≥ 5 kΩ, 1 kHz | - | -78.6 | - | dB |
| | | DAC output buffer OFF<br>CL ≤ 50 pF, no RL, 1 kHz | - | -78.6 | - | |
| SINAD | Signal-to-noise and distortion ratio | DAC output buffer ON<br>CL ≤ 50 pF, RL ≥ 5 kΩ, 1 kHz | - | 67.5 | - | dB |
| | | DAC output buffer OFF<br>CL ≤ 50 pF, no RL, 1 kHz | - | 67.5 | - | |
| ENOB | Effective number of bits | DAC output buffer ON<br>CL ≤ 50 pF, RL ≥ 5 kΩ, 1 kHz | - | 10.9 | - | bits |
| | | DAC output buffer OFF<br>CL ≤ 50 pF, no RL, 1 kHz | - | 10.9 | - | |

1. *Difference between two consecutive codes - 1 LSB.*
2. *Difference between measured value at Code i and the value at Code i on a line drawn between Code 0 and last Code 4095.*
3. *Difference between the value measured at Code (0x001) and the ideal value.*
4. *Difference between ideal slope of the transfer function and measured slope computed from code 0x000 and 0xFFF when buffer is OFF, and from code giving 0.2 V and ($V_{REFDAC+}$ – 0.2) V when buffer is ON.*

**Table 74. DAC 15 MSPS characteristics**

Specified by design. Not tested in production.

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| $V_{DDA}$ | Analog supply voltage for DAC ON | - | | 2.5 | 3.3 | 3.6 | V |
| $V_{REFDAC+}$ | Positive reference voltage | - | | 2.50 | - | $V_{DDA}$ | |
| $V_{REFDAC-}$ | Negative reference voltage | - | | $V_{SSA}$ | | | |
| $V_{dac_out}$ | Voltage on dac_out output | - | | $V_{REFDAC-}$ | - | $V_{REFDAC+}$ | V |
| $t_{SETTLING}$ | Settling time (full scale: for a 12-bit code transition between the lowest and the highest input codes when DAC_OUT reaches final value) | $V_{DDA}$>2,7V<br>With one comparator on DAC output | 10%-90% | - | 16 | 22 | ns |
| | | | 5%-95% | - | 21 | 29 | |
| | | | 1%-99% | - | 33 | 46 | |
| | | | 32 lsb | - | 40 | 53 | |
| | | | 1 lsb | - | 64 | 87 | |
| | | $V_{DDA}$>2,7V | 10%-90% | - | 24 | 32 | |

| 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 final value) | With two comparators and OPAMP on DAC output | 5%-95% | - | 32 | 43 | ns |
| | | | 1%-99% | - | 49 | 67 | |
| | | | 32 lsb | - | 57 | 75 | |
| | | | 1 lsb | - | 93 | 142 | |
| $t_{WAKEUP}$(1) | Wake-up time from off state (setting the ENx bit in the DAC Control register) until final value ±1 LSB | Normal mode CL ≤ 10 pF | | - | 1.4 | 3.5 | µs |
| PSRR | $V_{DDA}$ supply rejection ratio | - | | 60 | 80 | - | dB |
| $t_{SAMP}$ | Sampling time in sample and hold mode (code transition between the lowest input code and the highest input code when DACOUT reaches final value ±1LSB) | - | | - | 0.7 | - | µs |
| $CI_{int}$ | Internal sample and hold capacitor | - | | 1.44 | 1.8 | 2.1 | pF |
| dV/dt (hold phase) | Voltage decay rate in Sample and hold mode, during hold phase | $C_{SH}$ = 4 pF<br>T = 55°C | | - | 15 | - | mV/ms |
| $I_{DDA}$(DAC) | DAC consumption from $V_{DDA}$ | No load, middle code (0x800) | | - | - | 0.6 | µA |
| $I_{DDV}$(DAC) | DAC consumption from $V_{REFDAC+}$ | No load, middle code (0x800)(2) | | - | 504 | 970 | |

1. *In buffered mode, the output can overshoot above the final value for low input code (starting from min value).*
2. *Worst case consumption is at code 0x800.*

**Table 75. DAC 15 MSPS accuracy**

Specified by design. Not tested in production.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| DNL | Differential non linearity(1) | - | -2 | - | 2 | LSB |
| | Monotonicity | 10 bits | Guaranteed | | | - |
| INL | Integral non linearity(2) | - | -5 | - | 5 | LSB |
| TUE | Total undajusted error | - | -5 | - | 5 | LSB |
| DCS_d | Dynamic code spike | Spike amplitude on DAC voltage when DAC output value is decreasing | - | 0 | 2 | LSB |
| DCS_i | Dynamic code spike | Spike amplitude on DAC voltage when DAC output value is increasing | - | 0 | 4 | LSB |

1. *Difference between two consecutive codes - 1 LSB.*
2. *Difference between measured value at code i and the value at code i on a line drawn between code 0 and last code 4095. Offset error is included.*

### 5.3.22 Analog temperature sensor characteristics

**Table 76. 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 | - | |

| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $V_{30}$(3) | Voltage at 30 °C ± 5 °C | - | 0.61 | - | 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.*
2. *Evaluated by characterization.*
3. *Measured at $V_{DDA}$ = 3.3 V ± 10 mV. The $V_{30}$ ADC conversion result is stored in the TS_CAL1 bytes.*

**Table 77. 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 140 °C, $V_{DDA}$ = 3.3 V | 0x08FF F818 - 0x08FF F819 |

### 5.3.23 Digital temperature sensor characteristics

**Table 78. Digital temperature sensor characteristics**

Specified by design, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{DTS}$(1) | Output clock frequency | - | 500 | 750 | 1150 | kHz |
| $T_{LC}$(1) | Temperature linearity coefficient | VOS2 | 1660 | 2100 | 2750 | Hz/°C |
| $T_{TOTAL_ERROR}$(1) | Temperature offset measurement, all VOS | $T_J$ = -40 to 30°C | -13 | - | 4 | °C |
| | | $T_J$ = 30°C to 140°C | -7 | - | 2 | |
| $T_{VDD_CORE}$ | Additional error due to supply variation | VOS2 | 0 | - | 0 | °C |
| | | VOS0, VOS1 | -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 characterization*

### 5.3.24 $V_{CORE}$ monitoring characteristics

**Table 79. $V_{CORE}$ monitoring characteristics**

Specified by design. Not tested in production.

| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $T_{S_VCORE}$ | ADC sampling time when reading the $V_{CORE}$ voltage | 1 | - | - | µs |

### 5.3.25 $V_{DD}$ monitoring characteristics

**Table 80. $V_{DD}$ monitoring characteristics**

Specified by design. Not tested in production.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{DDhigh}$ | High threshold $V_{DD}$ voltage monitoring | - | 3.54 | 3.58 | 3.61 | V |

### 5.3.26 Temperature monitoring

**Table 81. Temperature monitoring characteristics**

Specified by design.

| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $TEMP_{high}$ | High temperature monitoring | 130 | 135 | 140 | °C |
| $TEMP_{low}$ | Low temperature monitoring | -40 | -35 | -30 | |

### 5.3.27 $V_{REFBUF}$ characteristics

**Table 82. $V_{REFBUF}$ characteristics**

Specified by design and not tested in production, unless otherwise specified.

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| $V_{DDA}$ | Analog supply voltage | Normal mode | VRS = 000 | 3.2 | 3.3 | 3.6 | V |
| | | | VRS = 001 | 2.8 | - | 3.6 | |
| | | | VRS = 010 | 2.5 | - | 3.6 | |
| | | | VRS = 011 | 2.5 | - | 3.6 | |
| | | Degraded mode(1) | VRS = 000 | 2.5 | - | 3.2 | |
| | | | VRS = 001 | 2.5 | - | 2.8 | |
| | | | VRS = 010 | - | - | - | |
| | | | VRS = 011 | - | - | - | |
| $V_{REFBUF_OUT}$ | Voltage reference buffer output | Normal mode at 30°C, $I_{LOAD}$ = 100 µA (2) | VRS = 000 | 2.897 | 2.900 | 2.9045 | V |
| | | | VRS = 001 | 2.497(3) | 2.500 | 2.5045 | |
| | | | VRS = 010 | 2.046 | 2.048 | 2.0520 | |
| | | | VRS = 011 | 1.798 | 1.800 | 1.8030 | |
| | | Degraded mode(1) | VRS = 000 | $V_{DDA}$– 150 mV | - | $V_{DDA}$ | |
| | | | VRS = 001 | $V_{DDA}$– 150 mV | - | $V_{DDA}$ | |
| | | | VRS = 010 | - | - | - | |
| | | | VRS = 011 | - | - | - | |
| TRIM | Trim step resolution | - | - | - | ±0.05 | ±0.1 | % |
| $C_L$ | Load capacitor | - | - | 0.5 | 1 | 1.50 | µF |
| esr | Equivalent serial resistor of $C_L$ | - | - | - | - | 2 | Ω |
| $I_{load}$ | Static load current | - | - | - | - | 7 | mA |

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| $I_{load_vs}$ | Static load current during startup phase and voltage scaling | - | - | - | - | 5 | mA |
| $I_{line_reg}$ | Line regulation | 2.8 V ≤ $V_{DDA}$ ≤ 3.6 V | $I_{load}$ = 500 µA | - | 200 | - | ppm/V |
| | | | $I_{load}$ = 7 mA | - | 100 | - | |
| $I_{load_reg}$ | Load regulation | 500 µA ≤ $I_{load}$ ≤ 7 mA | Normal mode | - | 50 | - | ppm/ mA |
| $T_{coeff}$ | Temperature coefficient | -40 °C < $T_J$ < +140°C | - | - | - | $T_{coeff(VREFINT)}$ + 100 | ppm/ °C |
| PSRR | Power supply rejection | DC | - | - | 60 | - | dB |
| | | 100 kHz | - | - | 30 | - | |
| $t_{START}$ | Start-up time | $C_L$= 0.5 µF | - | - | 300 | - | µs |
| | | $C_L$= 1 µF | - | - | 500 | - | |
| | | $C_L$= 1.5 µF | - | - | 650 | 800 | |
| $I_{INRUSH}$ | Control of maximum DC current drive on $V_{REFBUF_OUT}$ during startup(3) | - | | - | 8 | 11 | mA |
| $I_{DDA(VREFBUF)}$ | Consumption from $V_{DDA}$ | $I_{LOAD}$ = 0 µA | - | - | 15 | 25 | µA |
| | | $I_{LOAD}$ = 500 µA | - | - | 16 | 30 | |
| | | $I_{LOAD}$ = 7 mA | - | - | 45 | 70 | |

1. *In degraded mode, the voltage reference buffer cannot accurately maintain the output voltage ($V_{DDA}$ - drop voltage).*
2. *Evaluated by characterization. Not tested in production.*
3. *To properly control $I_{INRUSH}$ current during the startup phase and the change of scaling, $V_{DDA}$ voltage must be set according to selected VRS range requirements.*

### 5.3.28 Comparator characteristics

**Table 83. COMP characteristics**

Specified by design and not tested in production, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{DDA}$ | Analog supply voltage | - | 2.5 | 3.3 | 3.6 | V |
| $V_{IN}$ | Comparator input voltage range | - | 0 | - | $V_{DDA}$ | |
| $V_{BG}$(1) | Scaler input voltage | - | $V_{REFINT}$ | | | |
| $V_{SC}$(2) | Scaler offset voltage | - | - | ±5 | 15 | mV |
| $I_{DDA(SCALER)}$ | Scaler static consumption from $V_{DDA}$ | BRGEN = 0 (bridge disable) | - | 200 | 360 | nA |
| | | BRGEN = 1 (bridge enable) | - | 700 | 1000 | |
| $t_{START_SCALER}$ | Scaler startup time | - | - | 75 | 125 | µs |
| $t_{START}$ | Comparator startup time to reach propagation delay specification | - | - | - | 5 | µs |
| $t_D$(3) | Propagation delay (from COMP input pin to COMP output pin) for 200 mV step with 100 mV overdrive | 50pF load on output, DGLT = 0 | - | 15 | 30 | ns |
| | | 50pF load on output, DGLT = 1 | - | 21 | 32 | |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{offset}$[2] | Comparator offset error | Full $V_{DDA}$ voltage range, full temperature range | -5 | - | 5 | mV |
| $V_{hys}$ | Comparator hysteresis | HYST[2:0] = 0 | - | 0 | - | mV |
| | | HYST[2:0] =1 | 6 | 10 | 13 | |
| | | HYST[2:0] = 2 | 13 | 20 | 25 | |
| | | HYST[2:0] = 3 | 22 | 30 | 37 | |
| | | HYST[2:0] = 4 | 30 | 40 | 50 | |
| | | HYST[2:0] = 5 | 40 | 50 | 63 | |
| | | HYST[2:0] = 6 | 58 | 73 | 90 | |
| | | HYST[2:0] = 7 | 78 | 95 | 118 | |
| $I_{DDA}$(COMP) | Comparator consumption from $V_{DDA}$ | Static | - | 500 | 850 | µA |
| | | With 50 kHz ±100 mV overdrive square signal | - | 500 | - | |

1. *Refer to Table 24.*
2. *Evaluated by characterization. Not tested in production.*
3. *Typical value is an average for all comparators propagation delay.*

### 5.3.29 Operational amplifier characteristics

**Table 84. OPAMP characteristics**

Specified by design and not tested in production, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{DDA}$ | Analog supply voltage | - | 2.5 | 3.3 | 3.6 | V |
| CMIR | Common mode input range | - | 0 | - | $V_{DDA}$ | V |
| $VI_{OFFSET}$[1] | Input offset voltage | 25 °C, no load on output | - | - | ±1.5 | mV |
| | | All voltages and temperature, no load | - | - | ±3 | |
| | | All voltages and temperature, no load, high speed mode | - | - | ±3.5 | |
| $\Delta VI_{OFFSET}$ | Input offset voltage drift | - | - | ±10 | - | µV/°C |
| TRIMOFFSETP | Offset trim step at low common input voltage (0.1 x $V_{DDA}$) | - | - | 0.8 | - | mV |
| TRIMOFFSETN | Offset trim step at high common input voltage (0.9 x $V_{DDA}$) | - | - | 0.8 | - | |
| $I_{LOAD}$ | Drive current | - | - | - | 500 | µA |
| $I_{LOAD_PGA}$ | Drive current in PGA mode | - | - | - | 270 | µA |
| $C_{LOAD}$ | Capacitive load | - | - | - | 50 | pF |
| CMRR | Common mode rejection ratio | - | - | 70 | - | dB |
| PSRR | Power supply rejection ratio | $C_{LOAD}$ ≤ 50 pf, $R_{LOAD}$ ≥ 4 kΩ[2] DC Vcom = $V_{DDA}$/2 | - | 70 | - | dB |
| GBW | Gain Bandwidth Product | 200 mV ≤ Output dynamic range ≤ $V_{DDA}$ - 200 mV | 6 | 15 | - | MHz |

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| SR[1] | Slew rate (from 10 and 90% of output voltage) | Normal mode | | 4 | 7.5 | - | V/µs |
| | | High-speed mode | | 35 | 65 | - | |
| AO | Open loop gain | 200mV ≤ Output dynamic range ≤ $V_{DDA}$ - 200 mV | | 58 | 100 | - | dB |
| $V_{OHSAT}$ | High saturation voltage | $I_{load}$ = max or $R_{load}$ = min Input at $V_{DDA}$. Follower mode[2] | | $V_{DDA}$ - 100 | - | - | mV |
| $V_{OLSAT}$ | Low saturation voltage | $I_{load}$ = max or $R_{load}$ = min Input at 0. Follower mode[2] | | - | - | $V_{SSA}$ + 100 | |
| $\varphi_m$ | Phase margin | Follower mode, Vcom=$V_{DDA}$/2 | | - | 60 | - | ° |
| GM | Gain margin | Follower mode, Vcom=$V_{DDA}$/2 | | - | 11 | - | dB |
| $t_{WAKEUP}$[1] | Wake-up time from OFF state. | Normal mode | $C_{LOAD}$ ≤ 50 pf, $R_{LOAD}$ ≥ 4 kΩ[2] follower configuration | - | 1.1 | 2.0 | µs |
| | | High-speed mode | | - | 1.1 | 2.0 | |
| $I_{bias}$ | OPAMP input bias current | See $I_{leak}$ parameter in Table 54. I/O static characteristics and Table 56. Output voltage characteristics for FT_c I/Os for a given pin. | | | | | |
| PGA gain | Noninverting gain value | PGA Gain = 2, 100 mV ≤ Output dynamic range ≤ ($V_{DDA}$ - 100 mV) | | -1 | - | 3 | % |
| | | PGA Gain = 4, 100 mV ≤ Output dynamic range ≤ ($V_{DDA}$ - 100 mV) | | -1 | - | 1 | |
| | | PGA Gain = 8 100 mV ≤ Output dynamic range ≤ ($V_{DDA}$ - 100 mV) | | -1 | - | 1 | |
| | | PGA Gain = 16, 100mV ≤ Output dynamic range ≤ $V_{DDA}$ - 100mV | | -1 | - | 1 | |
| | Inverting gain value | PGA Gain = -1 100 mV ≤ Output dynamic range ≤ ($V_{DDA}$ - 100 mV) | | -1 | - | 1.4 | % |
| | | PGA Gain = -3, 100 mV ≤ Output dynamic range ≤ ($V_{DDA}$ - 100 mV) | | -1 | - | 1 | |
| | | PGA Gain = -7 100 mV ≤ Output dynamic range ≤ ($V_{DDA}$ - 100 mV) | | -1 | - | 1 | |
| | | PGA Gain = -15, 100 mV ≤ Output dynamic range ≤ ($V_{DDA}$ - 100 mV) | | -1 | - | 1 | |
| $R_{network}$ | R2/R1 internal resistance values in noninverting PGA mode[3] | PGA Gain = 2 | | - | 10/10 | - | 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 | % |
| PGA BW | PGA bandwidth for different non inverting gain | Gain = 2 | | - | GBW/2 | - | MHz |
| | | Gain = 4 | | - | GBW/4 | - | |
| | | Gain = 8 | | - | GBW/8 | - | |

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| PGA BW | PGA bandwidth for different non inverting gain | Gain = 16 | | - | GBW/16 | - | MHz |
| | PGA bandwidth for different inverting gain | Gain = -1 | | - | GBW/2 | - | MHz |
| | | Gain = -3 | | - | GBW/4 | - | |
| | | Gain = -7 | | - | GBW/8 | - | |
| | | Gain = -15 | | - | GBW/16 | - | |
| eN | Voltage noise density | at 1 kHz, output loaded with 4 kΩ | | - | 360 | - | nV/√Hz |
| | | at 10 kHz, output loaded with 4 kΩ | | - | 160 | - | |
| $I_{DDA}$(OPAMP) | OPAMP consumption from $V_{DDA}$ | no load, follower mode, OPAINTOEN=0 | Normal mode | - | 1.6 | 2.8 | mA |
| | | | High-speed mode | - | 1.8 | 3 | |
| | | no load, follower mode, OPAINTOEN=1 | Normal mode | - | 0.8 | 1.4 | |
| | | | High-speed mode | - | 1 | 1.65 | |
| $T_{S_OPAMP_VOUT}$ | ADC sampling time when reading the OPAMP output. OPAINTOEN=1 | - | | 160 | - | - | ns |

1. *Evaluated by characterization. Not tested in production.*
2. *$R_{LOAD}$ is the resistive load connected to VSSA or to VDDA pin.*
3. *R2 is the internal resistance between OPAMP output and OPAMP inverting input. R1 is the internal resistance between OPAMP inverting input and ground. The PGA gain =1+R2/R1*

### 5.3.30 Timer characteristics

The parameters given in Table 85 are specified by design.

Refer to Section 5.3.15: I/O port characteristics for details on the input/output alternate function characteristics (output compare, input capture, external clock, PWM output).

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**Table 85. TIMx characteristics**

TIMx, is used as a general term in which x stands for 1,2,3,4,5,6,7,8,15,16, 17 or 20

| Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| $t_{res(TIM)}$ | Timer resolution time | - | 1 | - | $t_{TIMxCLK}$ |
| | | $f_{TIMxCLK}$ = 280 MHz | 3.57 | - | ns |
| $f_{EXT}$ | Timer external clock frequency on CH1 to CH4 | - | 0 | $f_{TIMxCLK}/2$ | MHz |
| | | $f_{TIMxCLK}$ = 280 MHz | 0 | 85 | MHz |
| $Res_{TIM}$ | Timer resolution | TIMx (except TIM2, TIM3, TIM4, and TIM5) | - | 16 | bit |
| | | TIM2, TIM3, TIM4, and TIM5 | - | 32 | |
| $t_{COUNTER}$ | 16-bit counter clock period | - | 1 | 65536 | $t_{TIMxCLK}$ |
| | | $f_{TIMxCLK}$ = 280 MHz | 0.00357 | 234.057 | µs |
| $t_{MAX_COUNT}$ | Maximum possible count with 32-bit counter | - | - | 65536 × 65536 | $t_{TIMxCLK}$ |
| | | $f_{TIMxCLK}$ = 280 MHz | - | 15.34 | s |

| Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| $f_{ENC}$ | Encoder frequency on TI1 and TI2 input pins | - | 0 | $f_{TIMxCLK}/4$ | MHz |
| | | $f_{TIMxCLK}$ = 280 MHz | 0 | 70 | MHz |
| $t_{W(INDEX)}$ | Index pulsewidth on ETR input | - | 2 | - | Tck |
| $t_{W(TI1, TI2)}$ | Min pulsewidth on TI1 and TI2 inputs in all encoder modes except directional clock x1 | - | 2 | - | Tck |
| | Min pulsewidth on TI1 and TI2 inputs in directional clock x1 | - | 3 | - | Tck |

**Table 86. IWDG min/max timeout period at 32 kHz (LSI)**

The exact timings still depend on the phasing of the APB interface clock versus the LSI clock so that there is always a full RC period of uncertainty.

| Prescaler divider | PR[2:0] bits | Min timeout RL[11:0]= 0x000 | Max timeout RL[11:0]= 0xFFF | Unit |
|---|---|---|---|---|
| /4 | 0 | 0.125 | 512 | ms |
| /8 | 1 | 0.250 | 1024 | |
| /16 | 2 | 0.500 | 2048 | |
| /32 | 3 | 1.0 | 4096 | |
| /64 | 4 | 2.0 | 8192 | |
| /128 | 5 | 4.0 | 16384 | |
| /256 | 6 or 7 | 8.0 | 32768 | |

**Table 87. WWDG min/max timeout value at 280 MHz (PCLK)**

| Prescaler | WDGTB | Min timeout value | Max timeout value | Unit |
|---|---|---|---|---|
| 1 | 0 | 0.014625 | 0.936 | ms |
| 2 | 1 | 0.02925 | 1.872 | |
| 4 | 2 | 0.0585 | 3.744 | |
| 8 | 3 | 0.117 | 7.488 | |

### 5.3.31 Low-power timer characteristics

**Table 88. LPTIMx characteristics**

LPTIMx is used as a general term for LPTIM1 timers.

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{res(TIM)}$ | Timer resolution time | 1 | - | $t_{lptim_ker_ck}$ |
| $f_{lptim_ker_ck}$ | Timer kernel clock | 0 | 280 | MHz |
| fEXT | Timer external clock frequency on Input1 and Input2 | 0 | $f_{lptim_ker_ck}$ / 3 | |
| ResTIM | Timer resolution | - | 16 | bit |
| $t_{MAX_COUNT}$ | Maximum possible count | - | 65535 | $t_{lptim_ker_ck}$ |

### 5.3.32 High resolution timer

The parameters given in Table 89 are derived from tests performed under ambient temperature and supply voltage conditions summarized in Section 5.3.1: General operating conditions.

**Table 89. HRTIM characteristics**

Evaluated by characterization. Not tested in production.

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $f_{HRTIM}$ | HRTIM input clock for DLL calibration | As per $T_A$ conditions | 150 | - | 280 | MHz |
| $t_{HRTIM}$ | | | 3.57 | - | - | ns |
| $t_{RES(HRTIM)}$ | high-resolution step size | $f_{HRTIM}$ = 280 MHz, $T_A$ from -40 to 105°C | - | 111 | - | ps |
| $Res_{HRTIM}$ | Timer resolution | - | - | - | 16 | bit |
| $t_{DTG}$ | Dead time generator clock period | - | 0.125 | - | 16 | $t_{HRTIM}$ |
| | | $f_{HRTIM}$ = 280 MHz | 0.446 | - | 57.14 | ns |
| $\|t_{DTR}\| / \|t_{DTF}\|$ max | Dead time range (absolute value) | - | - | - | 511 | $t_{DTG}$ |
| | | $f_{HRTIM}$ = 280 MHz | - | - | 29.2 | µs |
| $f_{CHPFRQ}$ | Chopper stage clock frequency | - | 1/256 | - | 1/16 | $f_{HRTIM}$ |
| | | $f_{HRTIM}$ = 280 MHz | 1.094 | - | 17.5 | MHz |
| $t_{1STPW}$ | Chopper first pulse length | - | 16 | - | 256 | $t_{HRTIM}$ |
| | | $f_{HRTIM}$ = 280 MHz | 0.057 | - | 0.914 | µs |

**Table 90. HRTIM output response to fault protection**

Refer to the section about faults in the chapter on High Resolution Timers in RM0514.

| Symbol | Parameter | Conditions | Min. | Typ.(1) | Max.(1) | Unit |
|---|---|---|---|---|---|---|
| $t_{LAT(DF)}$ | Digital fault response latency | Propagation delay from HRTIM1_FLTx digital input to HRTIM_CHxy output pin | - | 8.5 | 12 | ns |
| $t_{W(FLT)}$ | Minimum fault pulse width | - | 7 | - | - | |
| $t_{LAT(AF)}$ | Analog fault response latency | Propagation delay from comparator COMPx_INP input pin to HRTIM_CHxy output pin | - | 15 | 20 | |

1. *Evaluated by characterization. Not tested in production.*

**Table 91. HRTIM output response to external events 1 to 5, 11 to 13 (low-latency mode)**

EExFAST bit in HRTIM_EECR1 or HRTIM_EECR14 register is set (low latency mode). This functionality is available on external events channels 1 to 5 and 11 to 13. Refer to the section about latency to external events in the chapter on High Resolution Timers in RM0514.

| Symbol | Parameter | Conditions | Min | Typ(1) | Max(1) | Unit |
|---|---|---|---|---|---|---|
| $t_{LAT(DEEV)}$ | Digital external event response latency | Propagation delay from HRTIM1_EEVx digital input to HRTIM_CHxy output pin (30 pF load) | - | 10.5 | 14 | ns |
| $t_{W(EEV)}$ | Minimum external event pulse width | - | 7 | - | - | |
| $t_{LAT(AEEV)}$ | Analog external event response latency | Propagation delay from comparator COMPx_INP input pin to HRTIM_CHxy output pin (30 pF load) | - | 15 | 20 | |

1. *Evaluated by characterization. Not tested in production.*

### Table 92. HRTIM output response to external events 1 to 16 (synchronous mode)

EExFAST bit in HRTIM_EECR1 or HRTIM_EECR4 register is set (low latency mode). External event filtering is disabled, i.e. EExF[3:0]=0000 in HRTIM_EECR2 register. This functionality is available on external events channels 1 to 5 and 11 to 13. Refer to the section about latency to external events in the chapter on High Resolution Timers in RM0514.

| Symbol | Parameter | Conditions | Min. | Typ.(1) | Max.(1) | Unit |
|---|---|---|---|---|---|---|
| $t_{LAT(DEEV)}$ | Digital external event response latency | Propagation delay from HRTIM1_EEVx digital input to HRTIM_CHxy output pin (30pF load) (2) | - | 36 | 42 | ns |
| $t_{LAT(AEEV)}$ | Analog external event response latency | Propagation delay from COMPx_INP input pin to HRTIM_CHxy output pin (30pF load) (2) | - | 43 | 47 | ns |
| $t_{W(EEV)}$ | Minimum external event pulse width | - | 7 | - | - | ns |
| $T_{JIT(EEV)}$ | External event response jitter | Jitter of the delay from HRTIM1_EEVx digital input or COMPx_INP to HRTIM_CHxy output pin | - | - | 1 | $t_{HRTIM}$(3) |

1. *Evaluated by characterization. Not tested in production.*
2. *This parameter is given for $f_{HRTIM}$ = 280 MHz.*
3. *$_{HRTIM}$ = 1 / $f_{HRTIM}$ with $f_{HRTIM}$= 280 MHz.*

### Table 93. HRTIM synchronization input / output

Specified by design. Not tested in production.

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $t_{W(SYNCIN)}$ | Minimum pulse width on SYNCIN inputs, including HRTIM_SCIN | - | 2 | - | - | $t_{HRTIM}$ |
| $t_{RES(ESR)}$ | Response time to external synchronization request | - | - | - | 3 | $t_{HRTIM}$ |
| $t_{W(SYNCOUT)}$ | Pulse width on HRTIM_SCOUT output | - | - | 16 | - | $t_{HRTIM}$ |
| | | $f_{HRTIM}$ = 280 MHz | - | 57.14 | - | ns |

### 5.3.33 Position encoder interface (POSENC) characteristics

**Table 94. POSENC electrical characteristics**

| Symbol | Parameter | Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{posenc_ker_ck}$ | POSENC kernel clock frequency | EnDat3 12.5 Mbds | - | 100 (±100 ppm) | - | MHz |
| | | EnDat3 25 Mbds | - | 200 (±100 ppm) | - | |
| | | Hiperface DSL | - | 75 (±100 ppm) | - | |
| $t_{Strobe}$ | Minimum strobe pulse width | Off-chip source (EXTI) and PLAy (asynchronous mode) | 2x $T_{posenc_ker_ck}$ | - | - | ns |
| | | On-chip peripherals (including PLAy synchronous mode) $F_{pclk3} >= F_{source}$ | $T_{pclk3}$ | - | - | |
| | | On-chip peripherals (including PLAy synchronous mode) $F_{posenc_pclk} < F_{source}$ ($F_{source}$ / $F_{posenc_pclk}$ = k) | k x $T_{pclk3}$ | - | - | |

**Table 95. POSENC Hiperface-DSL SPI characteristics**

| Symbol | Parameter | Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{SCK}$ | POSENC SPI clock frequency | Slave receiver mode 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | - | 10 | MHz |
| | | Slave transmitter mode 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | - | 9.25(1) | |
| $t_{su(NSS)}$ | SEL setup time | Slave mode | 0 | - | - | ns |
| $t_{h(NSS)}$ | SEL hold time | Slave mode | 14 | - | - | |
| $t_{w(NSS)}$ | SEL low time | Slave mode | 16 | - | - | |
| $t_{su(SI)}$ | Data input setup time | Slave mode | 2.5 | - | - | |
| $t_{h(SI)}$ | Data input hold time | Slave mode | 14.5 | - | - | |
| $t_{dis(SO)}$ | Data output disable time | Slave mode | 32 | 51 | 55 | |
| $t_{v(SO)}$ | Data output valid time | Slave mode, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 49.5 | 53.5 | |
| $t_{h(SO)}$ | Data output hold time | Slave mode | 32 | - | - | |

1. *10 MHz achievable with an SPI controller supporting data sampling delay capability.*

### 5.3.34 Programmable logic array (PLAY) characteristics

**Table 96. PLAY electrical characteristics**

| Symbol | Parameter | Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{play_clk}$ | PLAY kernel clock frequency | - | - | - | 280 | MHz |
| $t_{PLAY_D_EXT}$ | Propagation delay from PLAY_IN to PLAY_OUT pin for combinatorial logic | Function with 1 combinatorial LE | 7 | - | 16.5 | ns |
| | | Function with 4 combinatorial LEs in series | 7 | - | 18.0 | |

| Symbol | Parameter | Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $t_{PLAY_D_COMP}$ | Propagation delay from comparator COMPx_INP input pin to PLAY output pin | - | 15 | 20 | 22 | ns |
| $t_{PLAY_D_INT}$ | Propagation delay from lein to leoutd internal signals for combinatorial logic | Function with 1 combinatorial LE | - | 5 | - | ns |

**Table 97. PLAY filter characteristics**

| Symbol | Parameter | Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $t_{PF}$ | Maximum pulse length that is guaranteed to be filtered | - | - | - | (N-1) × Tclk - 2.5 | ns |
| $t_{PP}$ | Minimum pulse length that is guaranteed to pass | - | N × Tclk + 2.5 | - | - | |

## 5.3.35 Communication interfaces

### I2C interface characteristics

The $I^2C$ interface meets the timings requirements of the $I^2C$-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
- SMBUS 2.0 specifications
- SMBUS 3.3 specifications (on FT_fh I/O)

The $I^2C$ timings requirements are specified by design, not tested in production, when the $I^2C$ 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: I/O port characteristics for the I2C I/Os characteristics.

All $I^2C$ SDA and SCL I/Os embed an analog filter, refer to Table 98. $I^2C$ analog filter characteristics for its characteristics.

**Table 98. $I^2C$ analog filter characteristics**

Evaluated by characterization. Not tested in production.
Measurement points are done at 50% $V_{DD}$.

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{AF}$ | Maximum pulse width of spikes suppressed by analog filter | 50(1) | 160(2) | ns |

1. *Spikes with widths below $t_{AF(min)}$ are filtered.*
2. *Spikes with widths above $t_{AF(max)}$ are not filtered.*

### USART interface characteristics

Unless otherwise specified, the parameters given in Table 99. USART characteristics are derived from tests performed under the ambient temperature, $f_{PCLKx}$ frequency and $V_{DD}$ supply voltage conditions summarized in Section 5.3.1, 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

Refer to Section 5.3.15: I/O port characteristics for more details on the input/output alternate function characteristics (NSS, CK, TX, RX for USART).

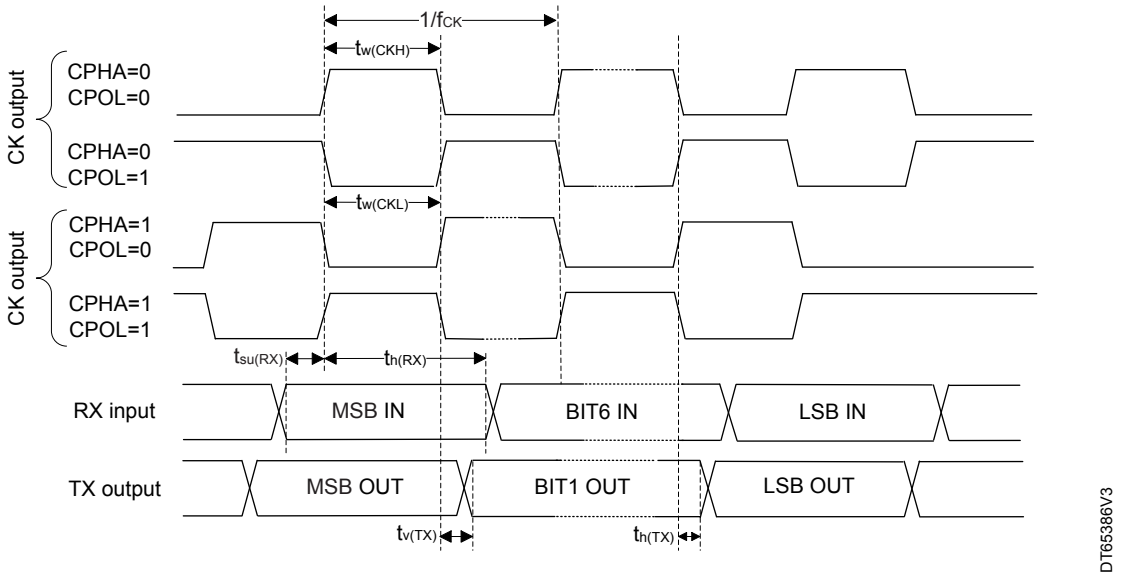
**Table 99. USART characteristics**

Evaluated by characterization. Not tested in production.
PC14, PC15 pins have limited speed max 500kHz

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{CK}$ | USART clock frequency | Master receiver | - | - | 93 | MHz |
| | | Master transmitter | | | 35/10(1) | |
| | | Slave receiver | | | 93 | |
| | | Slave transmitter Voltage range 0 | | | 35/10(1) | |
| | | Slave transmitter Voltage range 1 | | | 33/10(1) | |
| | | Slave transmitter Voltage range 2 | | | 31/10(1) | |
| $t_{su(NSS)}$ | NSS setup time | Slave mode | $T_{ker}$ + 2(2) | - | - | ns |
| $t_{h(NSS)}$ | NSS hold time | Slave mode | 2 | - | - | |
| $t_{w(SCKH)}$ $t_{w(SCKL)}$ | 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 | 14.5/36(1) | - | - | |
| | | Slave mode | 4 | - | - | |
| $t_{h(RX)}$ | Data input hold time | Master mode | 0.5 | - | - | |
| | | Slave mode | 1.5 | - | - | |
| $t_{v(TX)}$ | Data output valid time | Slave mode Voltage range 0 | - | 10 | 14/36.5(1) | |
| | | Slave mode Voltage range 1 | - | 11 | 15/38(1) | |
| | | Slave mode Voltage range 2 | - | 12 | 16/39(1) | |
| | | Master mode | - | 1 | 2/24.5(1) | |
| $t_{h(TX)}$ | Data output hold time | Slave mode | 7/16.5(1) | - | - | ns |
| | | Master mode | 0/10.5(1) | - | - | |

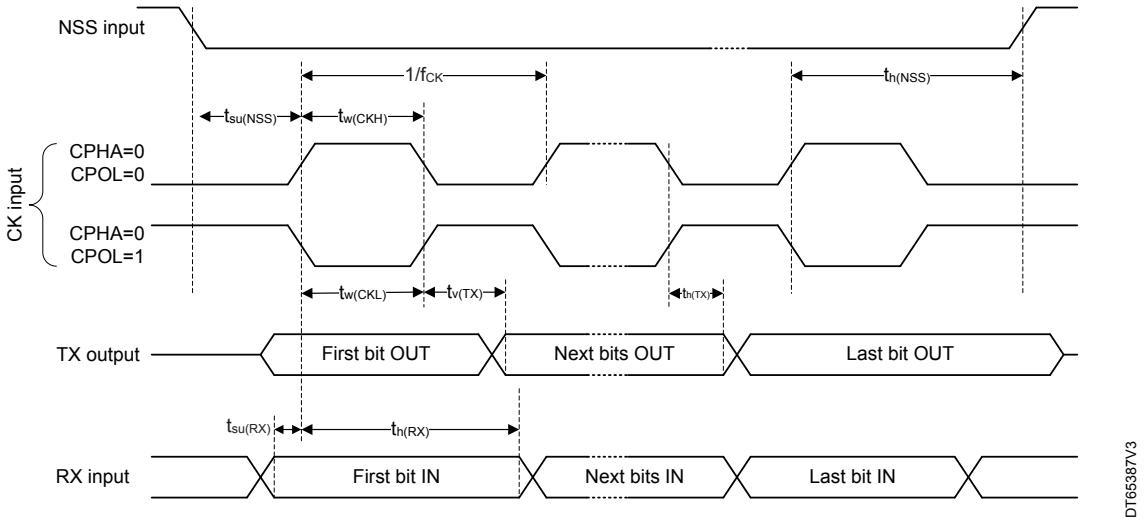
1. *While using PA8, PA9 pins*
2. *$T_{ker}$ is the usart_ker_ck_pres clock period.*

**Figure 41. USART timing diagram in Master mode**




1. *Measurement points are done at 0.5$V_{DD}$ and with external $C_L$ = 30 pF.*

**Figure 42. 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 100. I3C open-drain measured timing are obtained with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 10
- I/O compensation cell activated
- VOS level set to VOS0

The timings are in line with MIPI specification, except for the ones given in Table 100. I3C open-drain measured timing and Table 101. I3C push-pull measured timing. 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 100. I3C open-drain measured timing**

Evaluated by characterization. Not tested in production.

| Symbol | Parameter | Conditions | I3C open drain mode (specification) | | Timing measurements | | Unit |
|---|---|---|---|---|---|---|---|
| | | | Min | Max | Min | Max | |
| $t_{SU_OD}$ | SDA data setup time during open drain mode | Controller 2.7 V < $V_{DD}$ < 3.6 V | 3 | - | $T_{i3c_ker_clk}$+10 (1) | - | ns |

1. *Minimum SDA data setup time during open drain mode is 3 ns in the MIPI Alliance specification for I3C. This can be mitigated by increasing the SCL low duration in I3C_TIMINGR0 register.*

**Table 101. I3C push-pull measured timing**

Evaluated by characterization. Not tested in production.

| Symbol | Parameter | Conditions | I3C open drain mode (specification) | | Timing measurements | | Unit |
|---|---|---|---|---|---|---|---|
| | | | Min | Max | Min | Max | |
| $t_{SU_PP}$ | SDA signal data setup in push-pull mode | Controller 2.7 V < $V_{DD}$ < 3.6 V | 3 | - | 0(1) | - | ns |

1. *The timing is in line with the maximum value in the Alliance specification for I3C when compared to previous versions.*

### SPI interface characteristics

Unless otherwise specified, the parameters given in Table 102. SPI characteristics are derived from tests performed under the ambient temperature, $f_{PCLKx}$ frequency and $V_{DD}$ supply voltage conditions summarized in Section 5.3.1, 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
- 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 (NSS, SCK, MOSI, MISO for SPI).

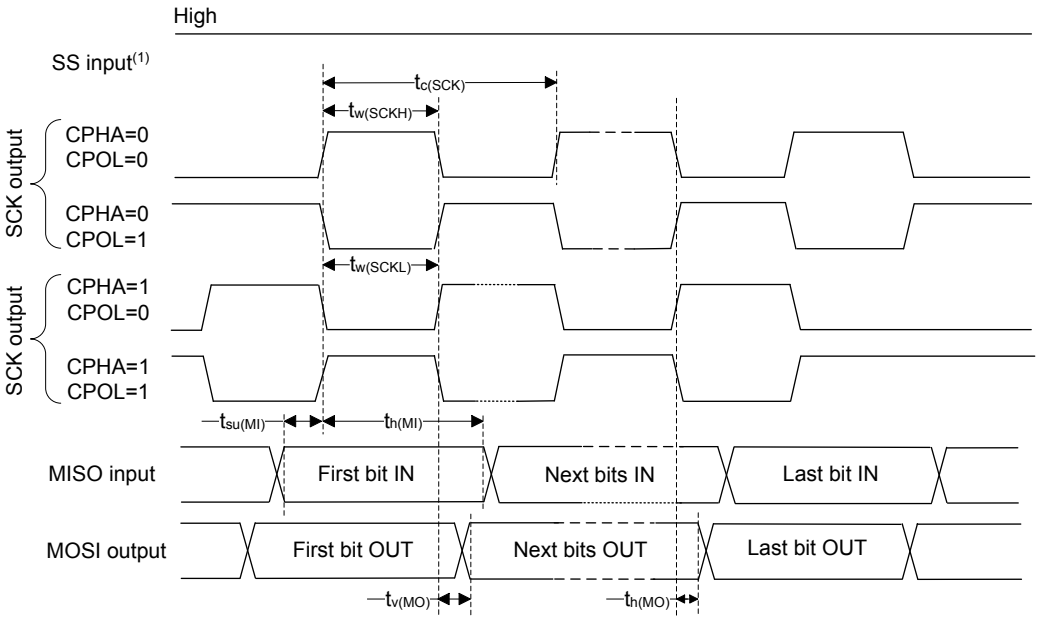
**Table 102. SPI characteristics**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{SCK}$ | SPI clock frequency | Master receiver mode 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | - | 120 | MHz |
| | | Master transmitter mode 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | - | 120 | |
| | | Slave receiver mode 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | - | 120 | |
| | | Slave transmitter mode 2.7 V ≤ $V_{DD}$ ≤ 3.6 V Voltage range 0 | - | - | 40 | |
| | | Slave transmitter mode 2.7 V ≤ $V_{DD}$ ≤ 3.6 V Voltage range 1 | - | - | 37 | |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{SCK}$ | SPI clock frequency | Slave transmitter mode<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V<br>Voltage range 2 | - | - | 34 | MHz |
| $t_{su(NSS)}$ | NSS setup time | Slave mode | 3.5 | - | - | ns |
| $t_{h(NSS)}$ | NSS hold time | Slave mode | 4.5 | - | - | ns |
| $t_{w(SCKH)}$<br>$t_{w(SCKL)}$ | SCK high and low time | Master mode | $t_{SCK}$(1) - 1 | $t_{SCK}$(1) | $t_{SCK}$(1) + 1 | ns |
| $t_{su(MI)}$ | Data input setup time | Master mode, DRDS = 0 | 3 | - | - | ns |
| | | Master mode, DRDS = 1 | 10 - $t_{SCK}/2$(1) | - | - | |
| $t_{su(SI)}$ | | Slave mode | 1.5 | - | - | |
| $t_{h(MI)}$ | Data input hold time | Master mode, DRDS = 0 | 2.5 | - | - | ns |
| | | Master mode, DRDS = 1 | $t_{SCK}/2$(1) - 5 | - | - | |
| $t_{h(SI)}$ | | Slave mode | 2.5 | - | - | |
| $t_{a(SO)}$ | Data output access time | Slave mode | 8 | 10.5 | 15 | ns |
| $t_{dis(SO)}$ | Data output disable time | Slave mode | 6 | 8 | 10.5 | ns |
| $t_{v(SO)}$ | Data output valid time | Slave mode<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V<br>Voltage range 0 | - | 9 | 12.5 | ns |
| | | Slave mode<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V<br>Voltage range 1 | - | 10 | 13.5 | |
| | | Slave mode<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V<br>Voltage range 2 | - | 11 | 14.5 | |
| $t_{v(MO)}$ | Data output valid time | Master mode | - | 0.5 | 1 | ns |
| $t_{h(SO)}$ | Data output hold time | Slave mode | 6.5 | - | - | |
| $t_{h(MO)}$ | | Master mode | 0 | - | - | |

1. *Evaluated by characterization. Not tested in production.*
2. *The maximum frequency in slave transmitter mode is determined by the sum of tv(SO) and tsu(MI) which must fit into SCK low or high phase preceding the SCK sampling edge. This value can be achieved when the SPI communicates with a master having tsu(MI) = 0 while Duty(SCK) = 50%.*
3. *$T_{SCK}$ = Tpclk × Baud rate prescaler/2*

Figure 43. **SPI timing diagram - Master mode**




1. *The SS input can be configured to active low or active high.*

Figure 44. **SPI timing diagram - Slave mode and CPHA = 0**

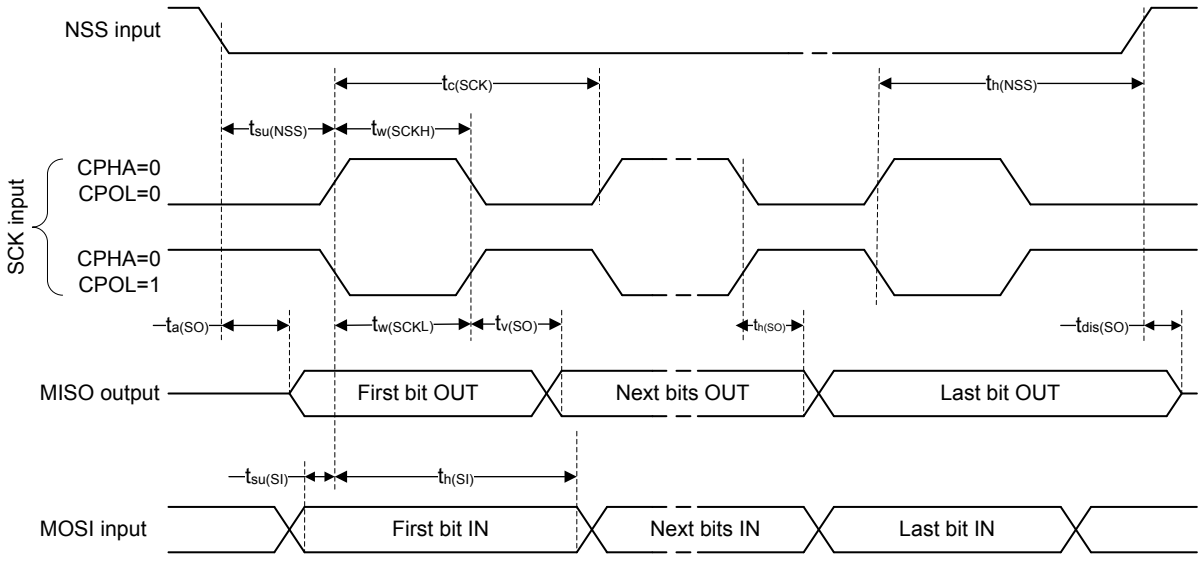
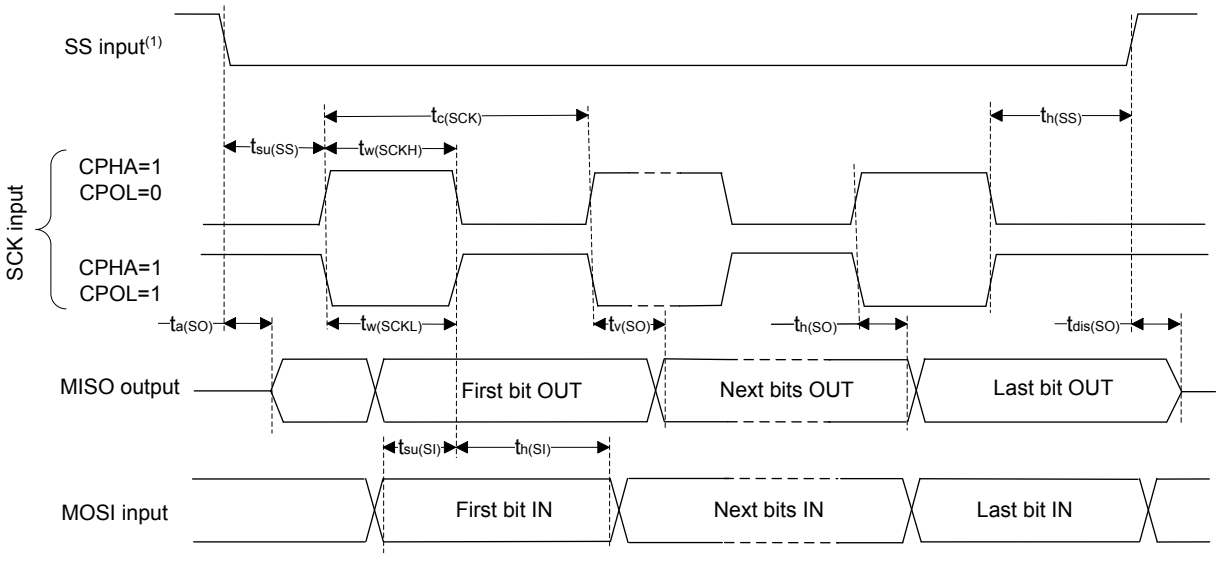


Figure 45. **SPI timing diagram - Slave mode and CPHA = 1**




1. *The SS input can be configured to active low or active high.*

### I²S interface characteristics

Unless otherwise specified, the parameters given in Table 103. I²S dynamic characteristics are derived from tests performed under the ambient temperature, $f_{PCLKx}$ frequency and $V_{DD}$ supply voltage conditions summarized in Section 5.3.1, 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
- 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 (CK,SD,WS).

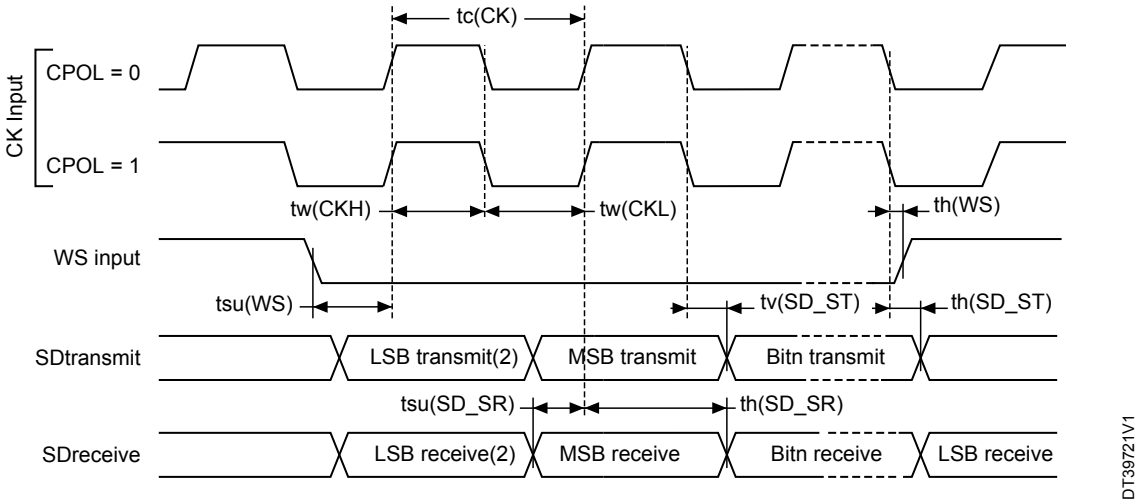
Table 103. **I²S dynamic characteristics**

Evaluated by characterization. Not tested in production.

| Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| $f_{MCK}$ | I²S main clock output | - | - | 50 | MHz |
| $f_{CK}$ | I²S clock output | Controller transmitter | - | 50 | |
| | | Target transmitter (TX) Voltage range 0 | - | 23 | |
| | | Target transmitter (TX) Voltage range 1 | - | 22 | |
| | | Target transmitter (TX) Voltage range 2 | - | 20 | |
| | | Target receiver (RX) | - | 50 | |
| $t_{v(WS)}$ | WS valid time | Controller mode | - | 1.5 | ns |
| $t_{h(WS)}$ | WS hold time | | 0.5 | - | |
| $t_{su(WS)}$ | WS setup time | Target mode | 2 | - | |

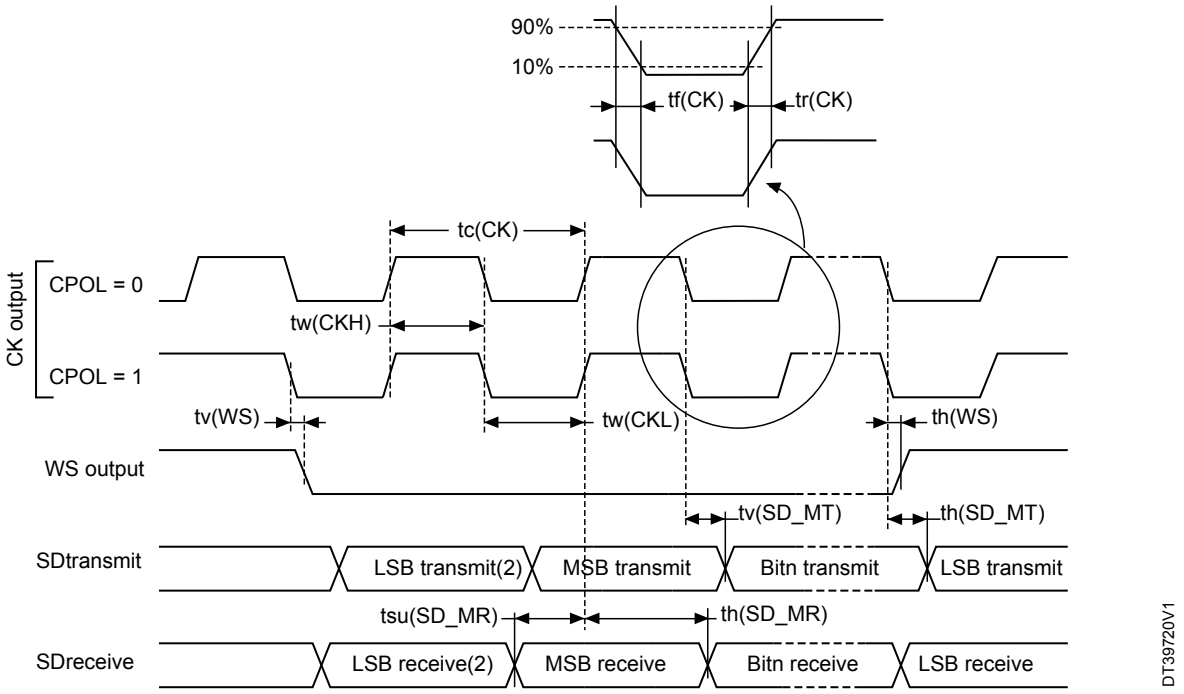
| Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| $t_{h(WS)}$ | WS hold time | Target mode | 1 | - | ns |
| $t_{su(SD_MR)}$ | Data input setup time | Controller receiver | 2.5 | - | |
| $t_{su(SD_SR)}$ | | Target receiver | 1.5 | - | |
| $t_{h(SD_MR)}$ | Data input hold time | Controller receiver | 2.5 | - | |
| $t_{h(SD_SR)}$ | | Target receiver | 2.5 | - | |
| $t_{v(SD_ST)}$ | Data output valid time | Target transmitter (after enable edge) Voltage range 0 | - | 14 | |
| | | Target transmitter (after enable edge) Voltage range 1 | - | 15 | |
| | | Target transmitter (after enable edge) Voltage range 2 | - | 16 | |
| $t_{v(SD_MT)}$ | | Controller transmitter (after enable edge) | - | 1.5 | |
| $t_{h(SD_ST)}$ | Data output hold time | Target transmitter (after enable edge) | 7 | - | |
| $t_{h(SD_MT)}$ | | Controller transmitter (after enable edge) | 0 | - | |

**Figure 46. I²S target 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 47. I²S controller timing diagram (Philips protocol)(1)




1. *LSB transmit/receive of the previously transmitted byte. No LSB transmit/receive is sent before the first byte.*
2. *Refer to Section 5.3.15: I/O port characteristics for more details on the input/output alternate function characteristics (FDCANx_TX and FDCANx_RX).*

### USB full speed (FS) characteristics

The USB interface is fully compliant with the USB specification version 2.0.

Table 104. USB DC electrical characteristics

| Symbol | Parameter | Conditions | Min(1) | Typ | Max(1) | Unit |
|---|---|---|---|---|---|---|
| $V_{DD}$ | USB full speed transceiver operating voltage | - | 3.0(2) | - | 3.6 | V |
| $V_{DI}$(3) | Differential input sensitivity | Over VCM range | 0.2 | - | - | V |
| $V_{CM}$(3) | Differential input common mode range | Includes $V_{DI}$ range | 0.8 | - | 2.5 | |
| $V_{SE}$(3) | 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 $V_{SS}$(4) | 2.8 | - | 3.6 | |
| $R_{PD}$(3) | Pull down resistor on PA11, PA12 (USB_DM, USB_DP) | $V_{IN}$ = $V_{DD}$ | 14.25 | - | 24.8 | kΩ |
| $R_{PU}$(3) | Pull-up resistor on PA12 (USB_DP) | $V_{IN}$ = $V_{SS}$, during idle | 0.9 | 1.25 | 1.575 | |
| | Pull-up resistor on PA12 (USB_DP) | $V_{IN}$ = $V_{SS}$ during reception | 1.425 | 2.25 | 3.09 | |

1. *All the voltages are measured from the local ground potential.*
2. *The USB full speed transceiver functionality is ensured down to 2.7 V but not the full USB full speed electrical characteristics, which are degraded in the 2.7-to-3.0 V $V_{DD}$ voltage range.*
3. *Specified by design. Not tested in production.*
4. *$R_L$ is the load connected on the USB full speed drivers.*

Figure 48. **USB timings - definition of data signal rise and fall time**

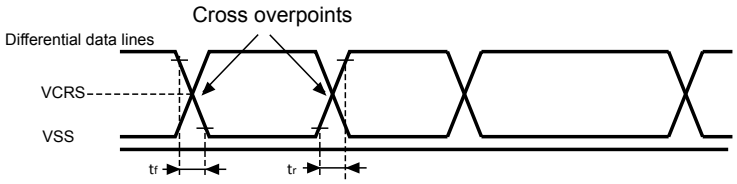



Table 105. **USB startup time**

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

1. *Specified by design. Not tested in production.*

Table 106. **USB electrical characteristics**

Specified by design. Not tested in production.

| Driver characteristics | | | | | |
|---|---|---|---|---|---|
| **Symbol** | **Parameter** | **Conditions** | **Min** | **Max** | **Unit** |
| $t_{rLS}$ | Rise time in LS(1) | $C_L$ = 200 to 600 pF | 75 | 300 | ns |
| $t_{fLS}$ | Fall time in LS(1) | $C_L$ = 200 to 600 pF | 75 | 300 | ns |
| $t_{rfmLS}$ | Rise/fall time matching in LS | $t_r/t_f$ | 80 | 125 | % |
| $t_{rFS}$ | Rise time in FS(1) | $C_L$ = 50 pF | 4 | 20 | ns |
| $t_{fFS}$ | Fall time in FS(1) | $C_L$ = 50 pF | 4 | 20 | ns |
| $t_{rfmFS}$ | Rise/fall time matching in FS | $t_r/t_f$ | 90 | 111 | % |
| $V_{CRS}$ | Output signal crossover voltage (LS/FS) | - | 1.3 | 2.0 | V |
| $Z_{DRV}$ | Output driver impedance(2) | Driving high or low | 28 | 44 | Ω |

1. *Measured from 10% to 90% of the data signal. For more detailed information, refer to USB specification - chapter 7 (version 2.0).*
2. *No external termination series resistors are required on DP (D+) and DM (D-) pins since the matching impedance is included in the embedded driver.*

Table 107. **USB BCD DC electrical characteristics**

Specified by design. Not tested in production.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $I_{DD(USBBCD)}$ | Primary detection mode consumption | - | - | - | 300 | µA |
| | Secondary detection mode consumption | - | - | - | 300 | |
| $R_{DAT_LKG}$ | Data line leakage resistance | - | 300 | - | - | kΩ |
| $V_{DAT_LKG}$ | Data line leakage voltage | - | 0.0 | - | 3.6 | V |
| $R_{DCP_DAT}$ | Dedicated charging port resistance across D+/D- | - | - | - | 200 | Ω |
| $V_{LGC_HI}$ | Logic high | - | 2.0 | - | 3.6 | V |
| $V_{LGC_LOW}$ | Logic low | - | - | - | 0.8 | |
| $V_{LGC}$ | Logic threshold | - | 0.8 | - | 2.0 | |
| $V_{DAT_REF}$ | Data detect voltage | - | 0.25 | - | 0.4 | |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{DP_SRC}$ | D+ source voltage | - | 0.5 | - | 0.7 | V |
| $V_{DM_SRC}$ | D- source voltage | - | 0.5 | - | 0.7 | |
| $I_{DP_SINK}$ | D+ sink current | - | 25 | - | 175 | µA |
| $I_{DM_SINK}$ | D- sink current | - | 25 | - | 175 | |

**Table 108. UCPD characteristics**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{DD}$ | UCPD operating supply voltage | Sink mode only | 3.0 | 3.3 | 3.6 | V |
| | | Sink and source mode | 3.135 | 3.3 | 3.465 | |

### JTAG/SWD interface characteristics

Unless otherwise specified, the parameters given in Table 109. Dynamic JTAG characteristics and Table 110. Dynamic SWD characteristics for JTAG/SWD are derived from tests performed under the ambient temperature, $f_{rcc_c_ck}$ frequency and $V_{DD}$ supply voltage summarized in Section 5.3.1: General operating conditions, 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 $V_{DD}$

Refer to Section 5.3.15: I/O port characteristics for more details on the input/output characteristics:

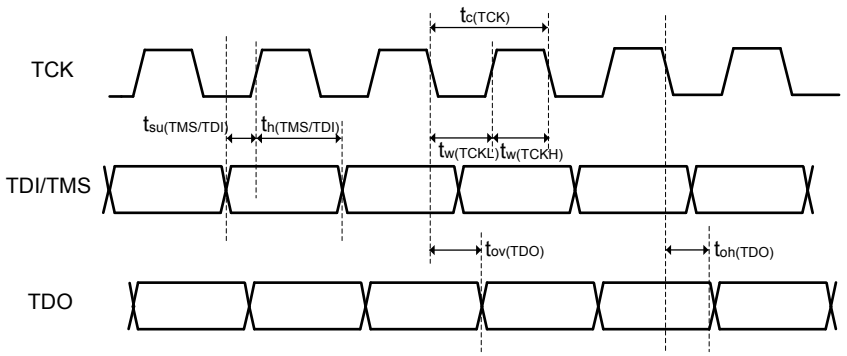
**Table 109. Dynamic JTAG characteristics**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $F_{TCK}$ | $T_{CK}$ clock frequency | - | - | - | 43 | MHz |
| $ti_{su(TMS)}$ | TMS input setup time | - | 2 | - | - | ns |
| $ti_{h(TMS)}$ | TMS input hold time | - | 0.5 | - | - | |
| $ti_{su(TDI)}$ | TDI input setup time | - | 1.5 | - | - | |
| $ti_{h(TDI)}$ | TDI input hold time | - | 0.5 | - | - | |
| $t_{ov(TDO)}$ | TDO output valid time | - | - | 8.5 | 11.5 | |
| $t_{oh(TDO)}$ | TDO output hold time | - | 6 | - | - | |

**Table 110. Dynamic SWD characteristics**

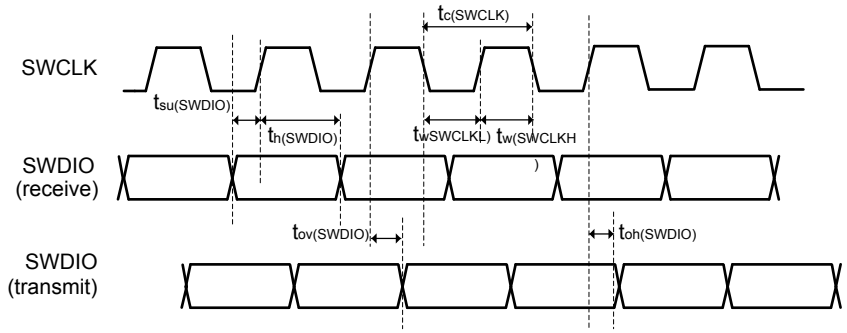
| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $F_{SWCLK}$ | SWCLK clock frequency | - | - | - | 86 | MHz |
| $ti_{su(SWDIO)}$ | SWDIO input setup time | - | 2.0 | - | - | ns |
| $ti_{h(SWDIO)}$ | SWDIO input hold time | - | 0.5 | - | - | |
| $t_{ov(SWDIO)}$ | SWDIO output valid time | - | - | 8 | 11.5 | |
| $t_{oh(SWDIO)}$ | SWDIO output hold time | - | 6 | - | - | |

Figure 49. **JTAG timing diagram**




DT40458V1

Figure 50. **SWD timing diagram**




DT40459V1

# 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 technical note "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.

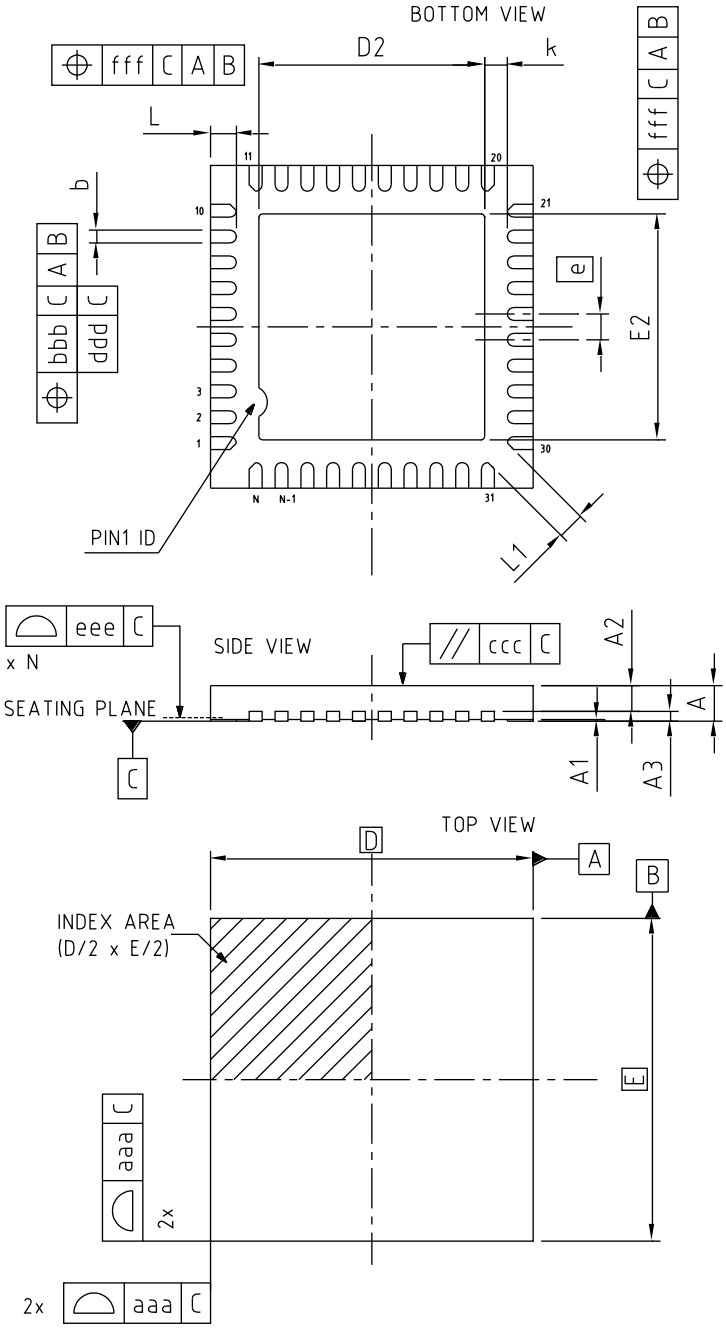
Parts marked as "ES", "E" or accompanied by an engineering sample notification letter, are not yet qualified and therefore not approved for use in production. ST is not responsible for any consequences resulting from such use. In no event will ST be liable for the customer using any of these engineering 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 UFQFPN40 package information (C036)

This UFQFPN is a 40-lead, 5 x 5 mm, 0.4 mm pitch, ultra-thin fine-pitch quad flat package.

Figure 51. **UFQFPN40 - Outline**




C036_UFQFPN40_ME_V2

**Table 111. UFQFPN40 - Mechanical data**

| Symbol | Millimeters | | | Inches[1] | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| A[2] | 0.50 | 0.55 | 0.60 | 0.0197 | 0.0217 | 0.0236 |
| A1[3] | - | 0.02 | 0.05 | - | 0.0008 | 0.0020 |
| A3 | | 0.152 REF | | | 0.0060 REF | |
| b[4] | 0.15 | 0.20 | 0.25 | 0.0059 | 0.0079 | 0.0098 |
| D[5] | | 5.00 BSC | | | 0.1969 BSC | |
| D2[6] | 3.40 | 3.50 | 3.60 | 0.1339 | 0.1378 | 0.1417 |
| E[5] | | 5.00 BSC | | | 0.1969 BSC | |
| E2[6] | 3.40 | 3.50 | 3.60 | 0.1339 | 0.1378 | 0.1417 |
| e[5] | | 0.4 BSC | | | 0.0157 BSC | |
| L | 0.30 | 0.40 | 0.50 | 0.0118 | 0.0157 | 0.0197 |
| L1 | - | 0.42 ref | - | - | 0.0165 ref | - |
| K[7] | 0.20 | - | - | 0.0079 | - | - |
| aaa[8] | | 0.10 | | | 0.0039 | |
| bbb[8] | | 0.07 | | | 0.0028 | |
| ccc[8] | | 0.10 | | | 0.0039 | |
| ddd[8] | | 0.05 | | | 0.0020 | |
| eee[8] | | 0.08 | | | 0.0031 | |
| fff[8] | | 0.10 | | | 0.0039 | |

1. *Values in inches are converted from millimeters 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 the vertical distance from the bottom surface of the plastic body to the nearest metallized package feature.*
4. *Dimension b applies to metallized terminal. If the terminal has the optional radius on the other end of the terminal, the dimension b should not be measured in that radius area.*
5. *BSC stands for basic dimensions.*
6. *Dimension D2 and E2 refer to exposed pad. If variance, see “Variations Table”. End user should verify those dimensions for each device application.*
7. *K gives the minimum separation between any two terminals or the terminals and the edges of the exposed metal heat feature.*
8. *For the tolerance of form and position*

## 6.3 LQFP48 package information (5B)

This LQFP is a 48-pins, 7 x 7 mm, low-profile quad flat package.

*Note: See list of notes in the notes section.*

**Figure 52. LQFP48- Outline(15.)**

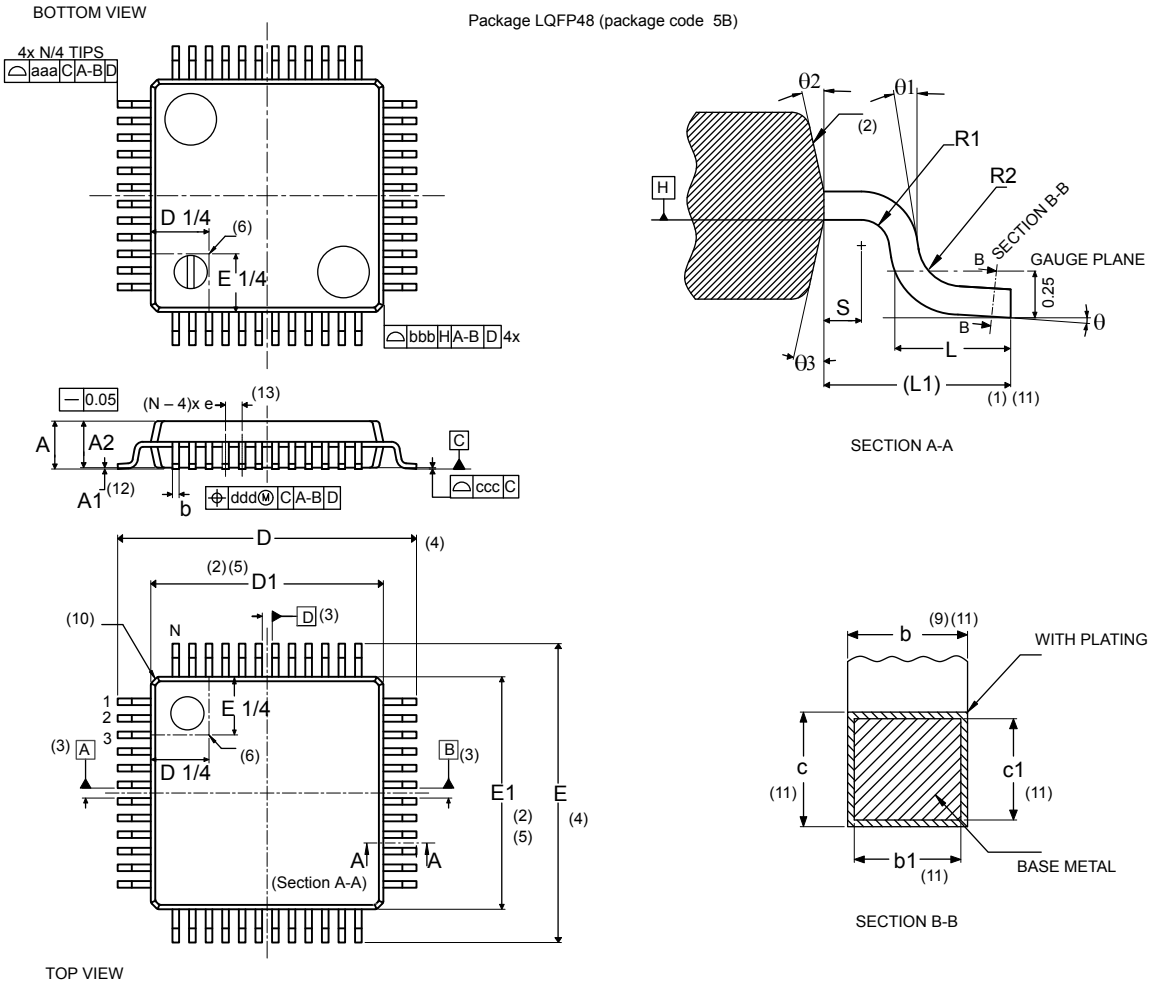


**Table 112. LQFP48 - Mechanical data**

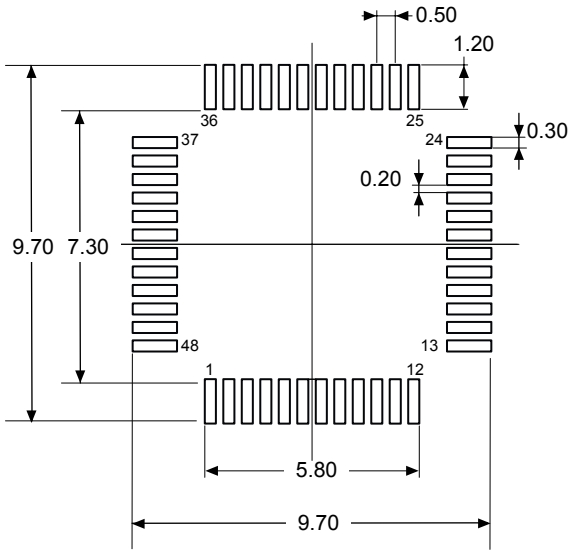
| Symbol | millimeters | | | inches[14.] | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| A | - | - | 1.60 | - | - | 0.0630 |
| A1[12.] | 0.05 | - | 0.15 | 0.0020 | - | 0.0059 |
| A2 | 1.35 | 1.40 | 1.45 | 0.0531 | 0.0551 | 0.0571 |
| b[9.][11.] | 0.17 | 0.22 | 0.27 | 0.0067 | 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.] | 9.00 BSC | | | 0.3543 BSC | | |
| D1[4.][5.] | 7.00 BSC | | | 0.2756 BSC | | |
| E[4.] | 9.00 BSC | | | 0.3543 BSC | | |
| E1[4.][5.] | 7.00 BSC | | | 0.2756 BSC | | |
| e | 0.50 BSC | | | 0.1970 BSC | | |
| L | 0.45 | 0.60 | 0.75 | 0.0177 | 0.0236 | 0.0295 |
| L1 | 1.00 REF | | | 0.0394 REF | | |
| N[13.] | 48 | | | | | |
| 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.][7.] | 0.20 | | | 0.0079 | | |
| bbb[1.][7.] | 0.20 | | | 0.0079 | | |
| ccc[1.][7.] | 0.08 | | | 0.0031 | | |
| ddd[1.][7.] | 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 4 decimal digits
15. Drawing is not to scale.

**Figure 53. LQFP48 - Footprint example**

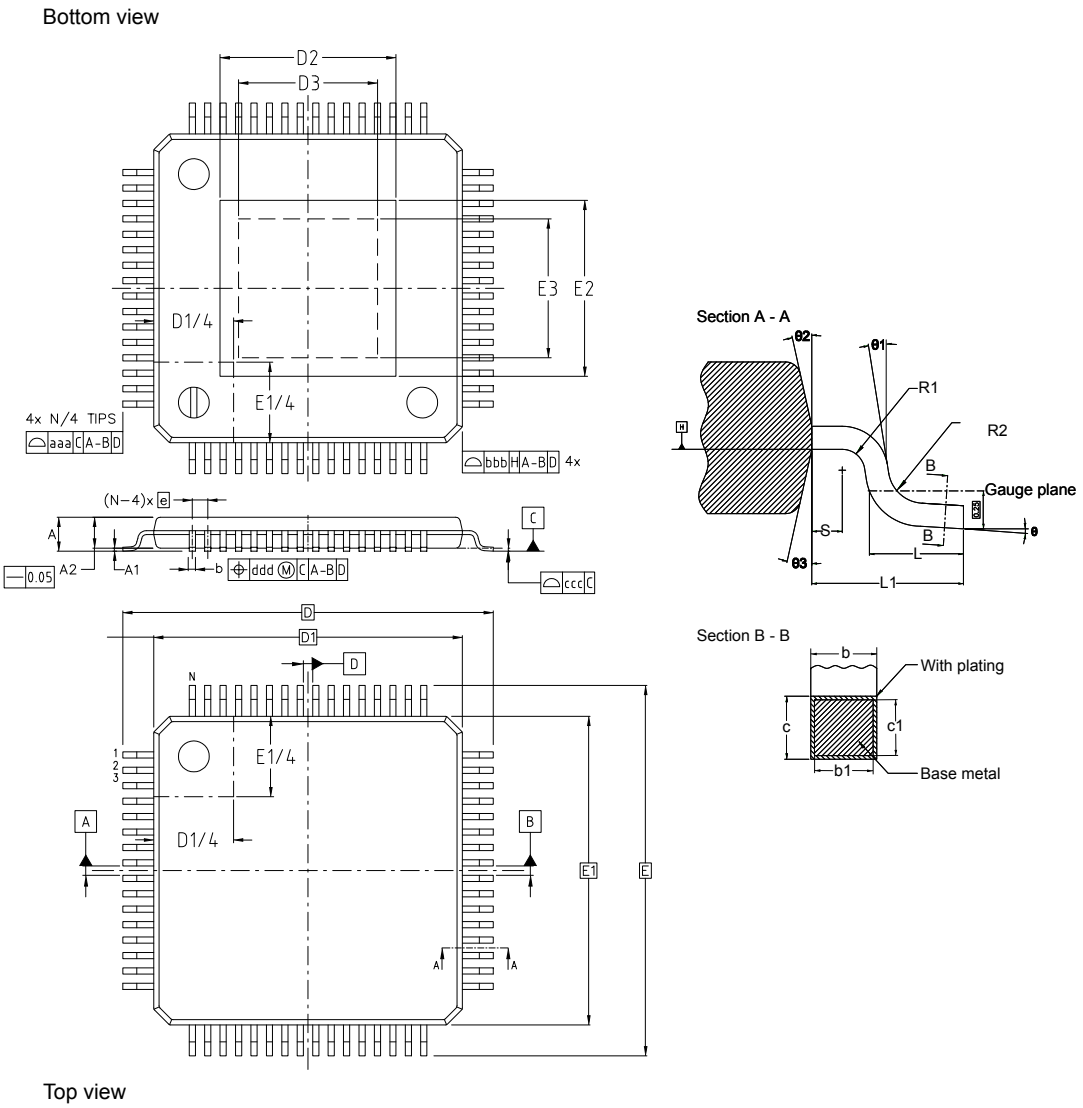



*1. Dimensions are expressed in millimeters.*

## 6.4 TQFP48-EP package information (ES_A)

This TQFP is a 48-pin, 7 x 7 mm thin quad flat package with an exposed pad (EP) measuring 3.8 x 3.8 mm.

**Figure 54. TQFP48-EP - Outline**




*Note: Drawing is not to scale.*

**Table 113. TQFP48-EP - Mechanical data**

| Symbol[1] | Millimeters | | | Inches[2] | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| 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° |
| A[3] | - | - | 1.20 | - | - | 0.0472 |
| A1[4] | 0.05 | - | 0.15 | 0.0020 | - | 0.0059 |
| A2 | 0.95 | 1.00 | 1.05 | 0.0374 | 0.0394 | 0.0413 |
| b[5][6] | 0.17 | 0.22 | 0.27 | 0.0067 | 0.0087 | 0.0106 |
| b1[6] | 0.17 | 0.20 | 0.23 | 0.0067 | 0.0079 | 0.0091 |
| c[6] | 0.09 | - | 0.20 | 0.0035 | - | 0.0079 |
| c1[6] | 0.09 | - | 0.16 | 0.0035 | - | 0.0063 |
| D[7][8] | 9.00 BSC | | | 0.3543 BSC | | |
| D1[9][10] | 7.00 BSC | | | 0.2756 BSC | | |
| D2[11] | - | - | 3.85 | - | - | 0.1516 |
| D3[12] | 2.95 | - | - | 0.1161 | - | - |
| e | 0.50 BSC | | | 0.0197 BSC | | |
| E[7][8] | 9.00 BSC | | | 0.3543 BSC | | |
| E1[9][10] | 7.00 BSC | | | 0.2756 BSC | | |
| E2[11] | - | - | 3.85 | - | - | 0.1516 |
| E3[12] | 2.95 | - | - | 0.1161 | - | - |
| L | 0.45 | 0.60 | 0.75 | 0.0177 | 0.0236 | 0.0295 |
| L1 | 1.00 REF | | | 0.0394 REF | | |
| N[13] | 48 | | | | | |
| R1 | 0.08 | - | - | 0.0031 | - | - |
| R2 | 0.08 | - | 0.20 | 0.0031 | - | 0.0079 |
| S | 0.20 | - | - | 0.0079 | - | - |

1. *Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.*
2. *Values in inches are converted from millimeters and rounded to four decimal places, except for the Θ values, which are in degrees, and N, which represents the number of pins.*
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. *The 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.*
6. *These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.*
7. *To be determined at seating datum plane C.*
8. *BSC stands for basic dimensions. It corresponds to the nominal value and has no tolerance.*
9. *The top package body size may be smaller than the bottom package size by as much as 0.15 mm.*
10. *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.*
11. *Dimensions D2 and E2 show the maximum exposed metal area on the package surface where the exposed pad is located. It includes all metal protrusions from exposed pad itself.*

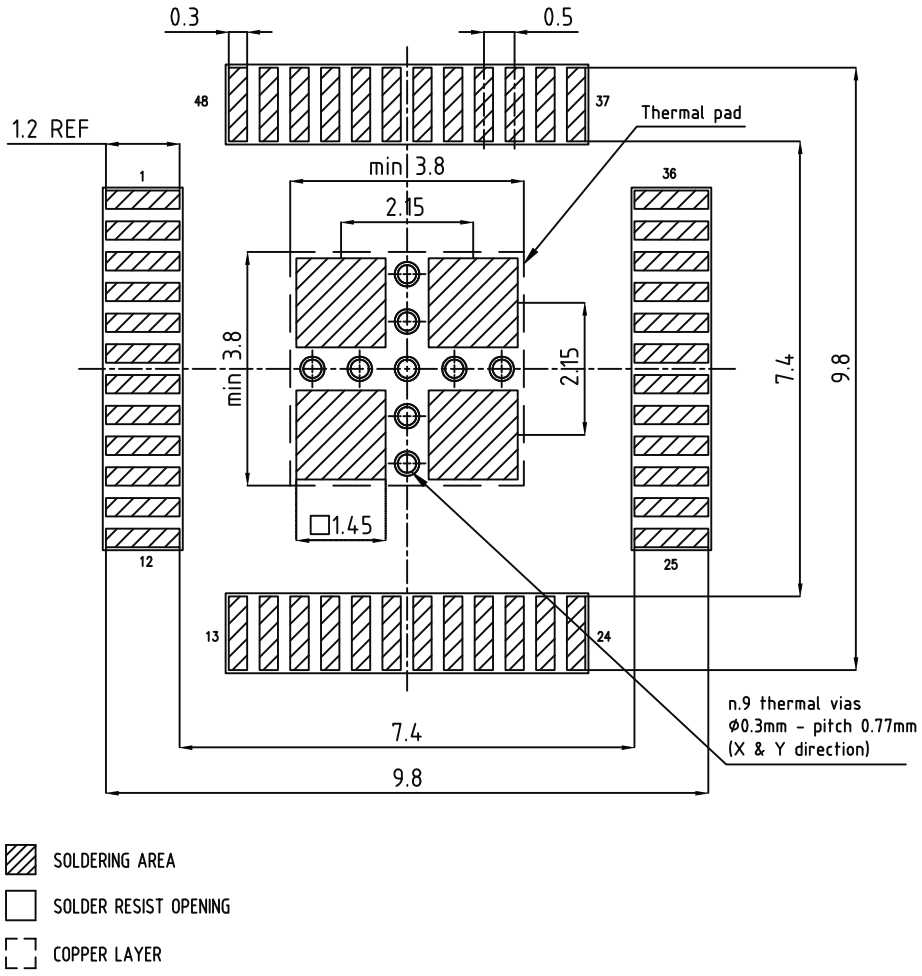
12. *Dimensions D3 and E3 show the minimum solderable area, defined as the portion of exposed pad which is guaranteed to be free from resin flashes/bleeds, bordered by internal edge of inner groove.*
13. *N represents the total number of pins.*

**Table 114. TQFP48-EP - Tolerance of form and position**

| Symbol[1] | Millimeters | | | Inches[2] | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| aaa[3] | | 0.20 | | | 0.0079 | |
| bbb[4] | | 0.20 | | | 0.0079 | |
| ccc[5] | | 0.08 | | | 0.0031 | |
| ddd[6] | | 0.08 | | | 0.0031 | |

1. *Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.*
2. *Values in inches are converted from millimeters and rounded to four decimal places.*
3. *The tolerance controls the position of the terminals with respect to datums A and B. The center of the tolerance zone for each terminal is defined by basic dimension e as related to datums A and B.*
4. *The bilateral profile tolerance controls the position of the plastic body sides. The centers of the profile zones are defined by the basic dimensions D and E.*
5. *The unilateral tolerance above the seating plane specifies the location of the bottom surface of all terminals. It is commonly known as the coplanarity of the package terminals.*
6. *The tolerance controls the position of the terminals to each other. The centers of the profile zones are defined by basic dimension e.*

Figure 55. **TQFP48-EP - Footprint example**

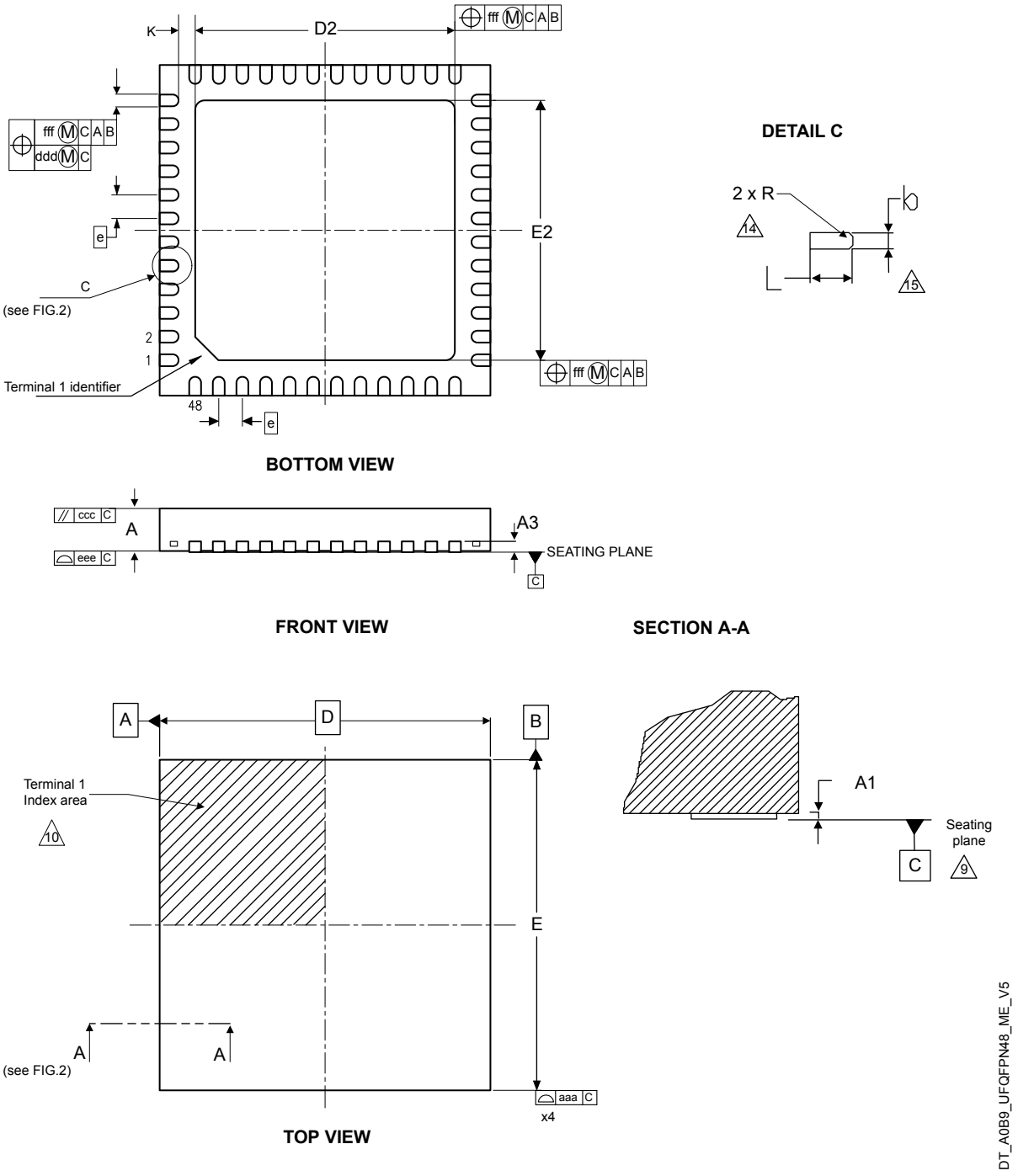



*Note: Drawing is not to scale.*

## 6.5 UFQFPN48 package information (A0B9)

This UFQFPN is a 48-lead, 7 x 7 mm, 0.5 mm pitch, ultra thin fine pitch quad flat package.

**Figure 56. UFQFPN48 - Outline**



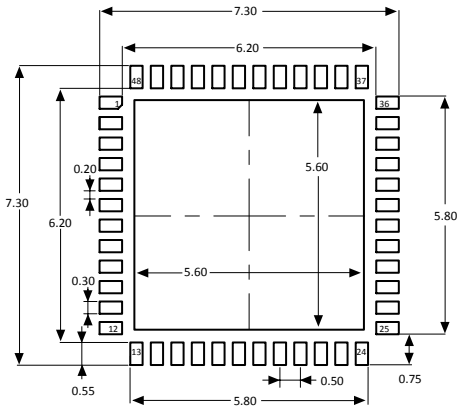

1. *Drawing is not to scale.*
2. *All leads/pads should also be soldered to the PCB to improve the lead/pad solder joint life.*
3. *There is an exposed die pad on the under side of the UFQFPN48 package. It is recommended to connect and solder this back-side pad to PCB ground.*

**Table 115. UFQFPN48 - Mechanical data**

| Symbol | Millimeters | | | Inches (1) | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| A | 0.50 | 0.55 | 0.60 | 0.0197 | 0.0217 | 0.0236 |
| A1 | 0.00 | - | 0.05 | 0.0000 | - | 0.0020 |
| b | 0.18 | 0.25 | 0.30 | 0.0071 | 0.0098 | 0.0118 |
| D(2) | | 7.00 BSC | | | 0.2756 BSC | |
| D2(3) | 5.50 | 5.60 | 5.70 | 0.2165 | 0.2205 | 0.2244 |
| E(2) | | 7.00 BSC | | | 0.2756 BSC | |
| E2(3) | 5.50 | 5.60 | 5.70 | 0.2165 | 0.2205 | 0.2244 |
| e | | 0.50 BSC | | | 0.0197 BSC | |
| N | | | 48 | | | |
| L | 0.30 | - | 0.50 | 0.0118 | - | 0.0197 |
| R | 0.10 | - | - | 0.0039 | - | - |
| aaa | | 0.15 | | | 0.0059 | |
| bbb | | 0.10 | | | 0.0039 | |
| ccc | | 0.10 | | | 0.0039 | |
| ddd | | 0.05 | | | 0.0020 | |
| eee | | 0.08 | | | 0.0031 | |
| fff | | 0.10 | | | 0.0039 | |

1. *Values in inches are converted from mm and rounded to four decimal digits.*
2. *Dimensions D and E do not include mold protrusion, not exceed 0.15 mm.*
3. *Dimensions D2 and E2 are not in accordance with JEDEC.*

**Figure 57. UFQFPN48 - Footprint example**




DT_A0B9_UFQFPN48_FP_V3

1. *Dimensions are expressed in millimeters.*

## 6.6 LQFP64 package information (5W)

This is a 64-pin, 10 x 10 mm low-profile quad flat package.

Figure 58. **LQFP64 - Outline**[15.]

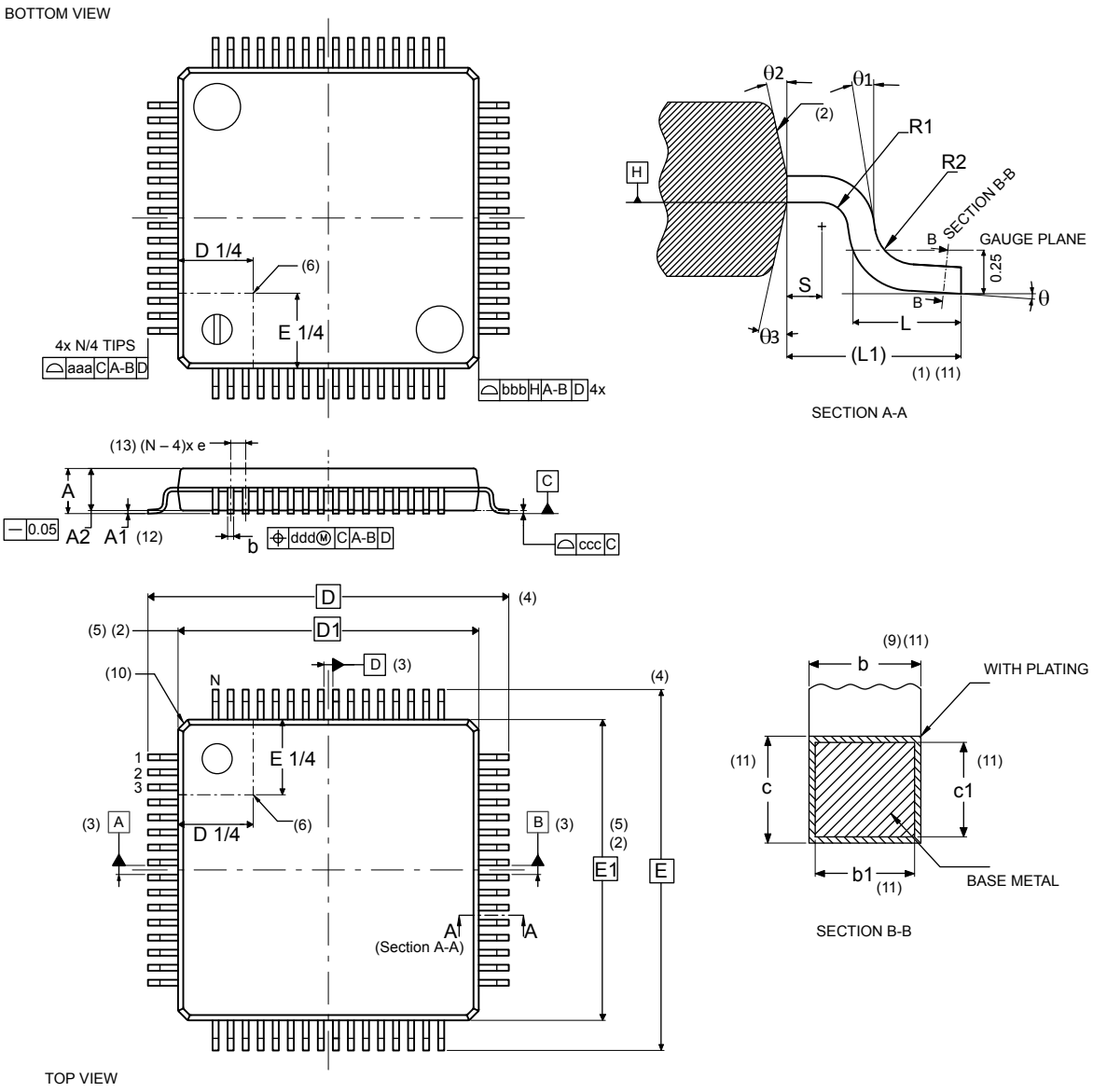


**Table 116. LQFP64 - Mechanical data**

| 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 | 00067 | 0.0079 | 0.0091 |
| c[11.] | 0.09 | - | 0.20 | 0.0035 | - | 0.0079 |
| c1[11.] | 0.09 | - | 0.16 | 0.0035 | - | 0.0063 |
| D[4.] | 12.00 BSC | | | 0.4724 BSC | | |
| D1[2.][5.] | 10.00 BSC | | | 0.3937 BSC | | |
| E[4.] | 12.00 BSC | | | 0.4724 BSC | | |
| E1[2.][5.] | 10.00 BSC | | | 0.3937 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.] | 64 | | | | | |
| 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 | | |

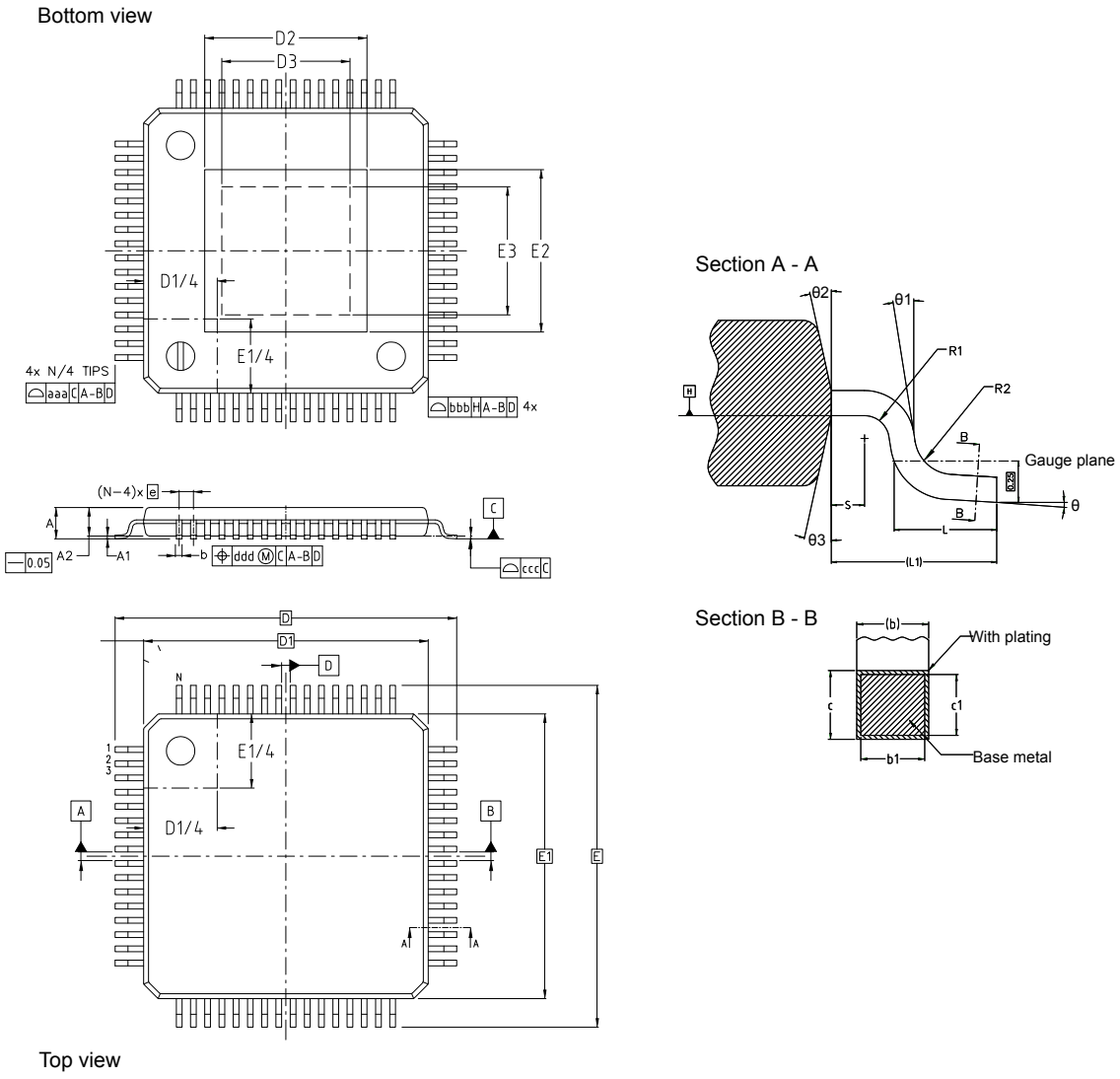
**Notes**

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 D1and 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 4 decimal digits.
15. Drawing is not to scale.

## 6.7 TQFP64-EP package information (9I_B)

This TQFP is a 64-pin, 10 x 10 mm, thin quad flat package with an exposed pad (EP) measuring 5.5 x 5.5 mm.

**Figure 59. TQFP64-EP - Outline**




*Note: The drawing is not to scale.*

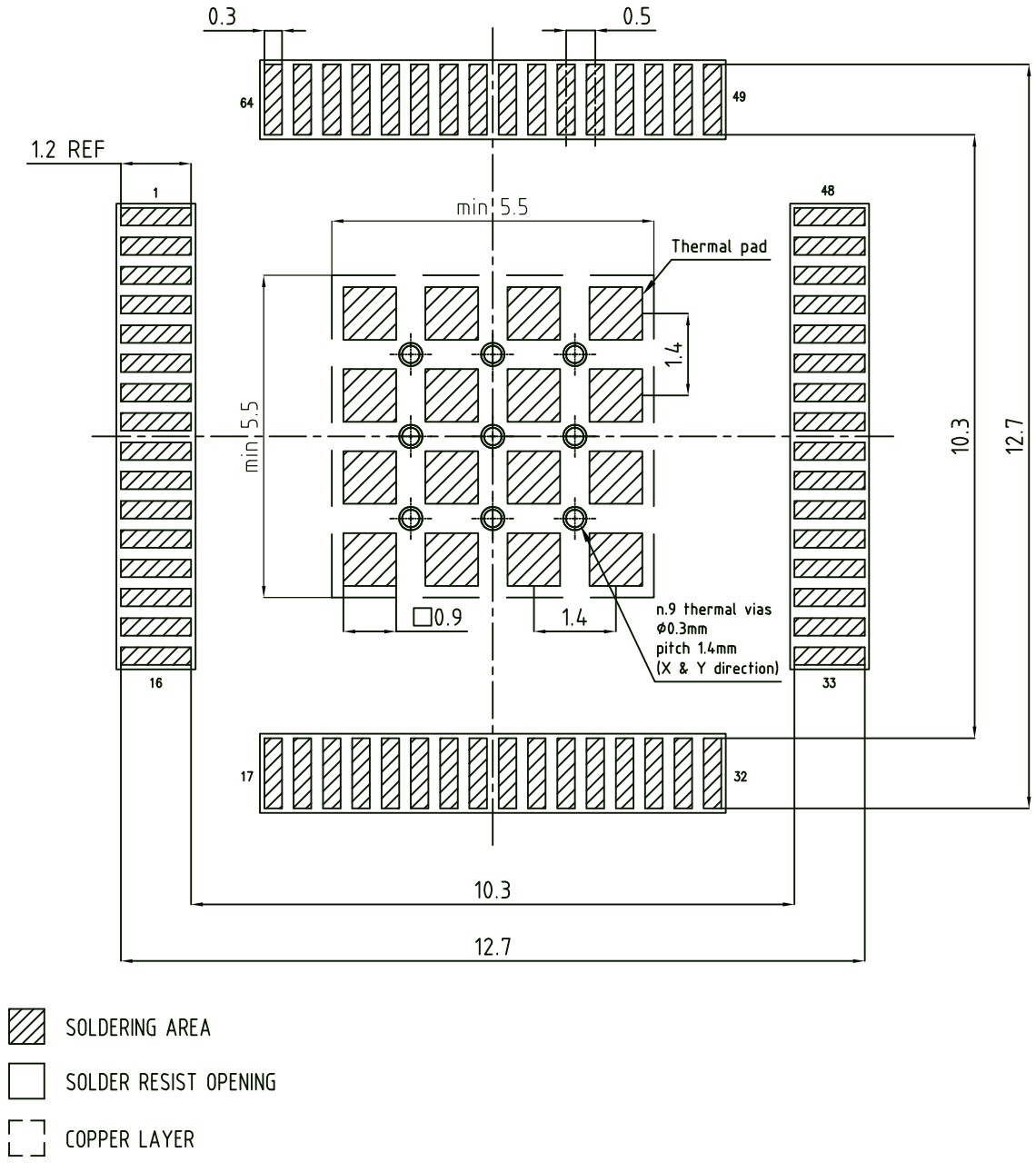
**Table 117. TQFP64-EP - Mechanical data**

| Symbol[1] | Millimeters | | | Inches[2] | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| 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° |
| A[3] | - | - | 1.20 | - | - | 0.0472 |
| A1[4] | 0.05 | - | 0.15 | 0.0020 | - | 0.0059 |
| A2 | 0.95 | 1.00 | 1.05 | 0.0374 | 0.0394 | 0.0413 |
| b[5][6] | 0.17 | 0.22 | 0.27 | 0.0067 | 0.0087 | 0.0106 |
| b1[6] | 0.17 | 0.20 | 0.23 | 0.0067 | 0.0079 | 0.0091 |
| c[6] | 0.09 | - | 0.20 | 0.0035 | - | 0.0079 |
| c1[6] | 0.09 | - | 0.16 | 0.0035 | - | 0.0063 |
| D[7] | 12.00 BSC[8] | | | 0.4724 BSC | | |
| D1[9][10] | 10.00 BSC | | | 0.3937 BSC | | |
| D2[11] | - | - | 5.55 | - | - | 0.2185 |
| D3[12] | 4.65 | - | - | 0.1831 | - | - |
| e | 0.50 BSC | | | 0.0197 BSC | | |
| E | 12.00 BSC | | | 0.4724 BSC | | |
| E1 | 10.00 BSC | | | 0.3937 BSC | | |
| E2[11] | - | - | 5.55 | - | - | 0.2185 |
| E3[12] | 4.65 | - | - | 0.1831 | - | - |
| L | 0.45 | 0.60 | 0.75 | 0.0177 | 0.0236 | 0.0295 |
| L1 | 1.00 REF | | | 0.0394 REF | | |
| N[13] | 64 | | | | | |
| R1 | 0.08 | - | - | 0.0031 | - | - |
| R2 | 0.08 | - | 0.20 | 0.0031 | - | 0.0079 |
| S | 0.20 | - | - | 0.0079 | - | - |
| aaa[14] | 0.20 | | | 0.0079 | | |
| bbb[14] | 0.20 | | | 0.0079 | | |
| ccc[14] | 0.08 | | | 0.0031 | | |
| ddd[14] | 0.08 | | | 0.0031 | | |

1. *Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.*
2. *Values in inches are converted from millimeters and rounded to four decimal places, except for the Θ values, which are provided in degrees.*
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 does not include dambar protrusion. The allowable dambar protrusion must not cause the lead width to exceed the maximum b dimension by more than 0.08 mm. The dambar must not be located on the lower radius or the foot. The minimum space between protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.*
6. *These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.*
7. *To be determined at seating datum plane C.*

8. *BSC stands for basic dimensions. It corresponds to the nominal value and has no tolerance.*
9. *The Top package body size can be smaller than the bottom package size by up to 0.15 mm.*
10. *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.*
11. *Dimensions D2 and E2 show the maximum exposed metal area on the package surface where the exposed pad is located. It includes all metal protrusions from exposed pad itself.*
12. *Dimensions D3 and E3 show the minimum solderable area, defined as the portion of exposed pad which is guaranteed to be free from resin flashes/bleeds, bordered by internal edge of inner groove.*
13. *N represents the total number of pins.*
14. *Tolerance of form and position.*

**Figure 60. TQFP64-EP - Footprint example**




*Note: The drawing is not to scale.*

## 6.8 LQFP80 package information (9X)

This is a 80-pins, 12 x 12 mm, low-profile quad flat package.

*Note: See list of notes in the notes section.*

**Figure 61. LQFP80 - Outline(15.)**

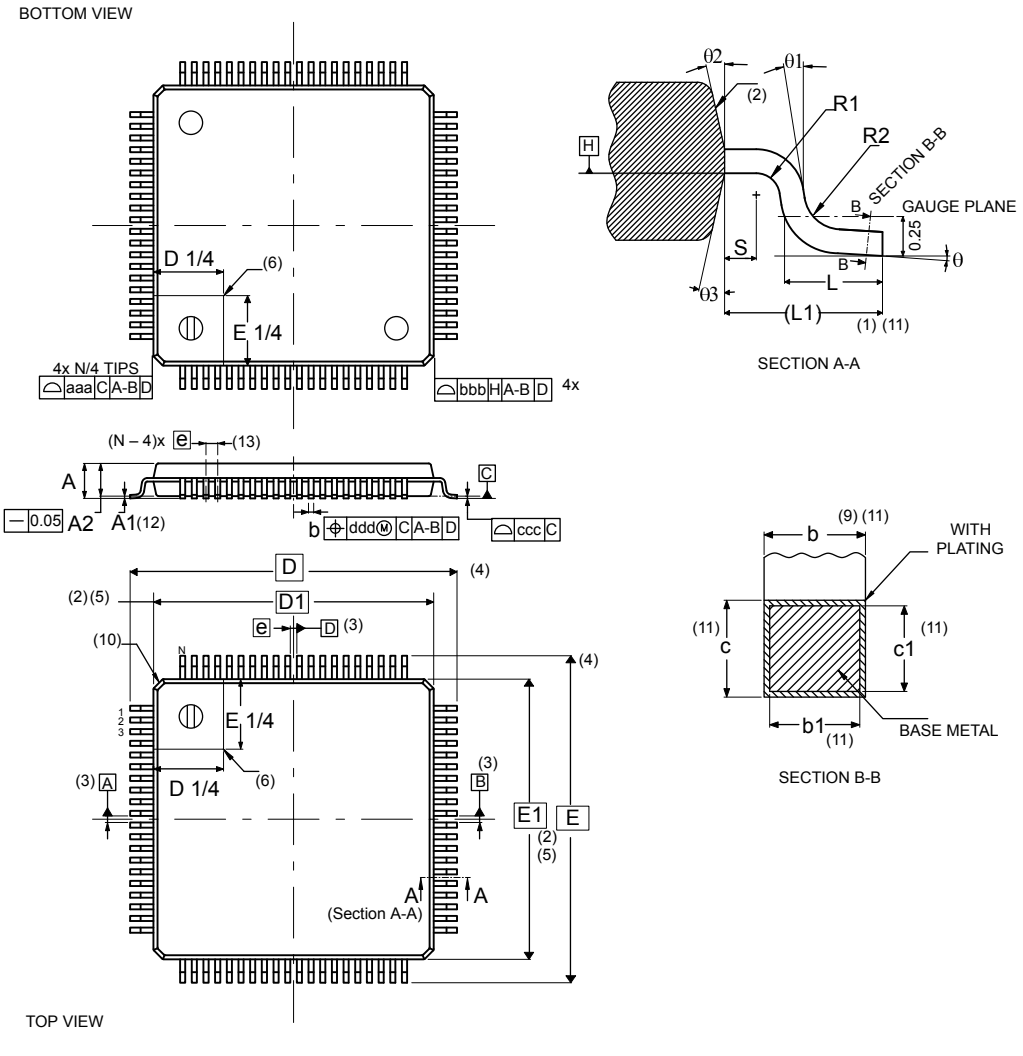


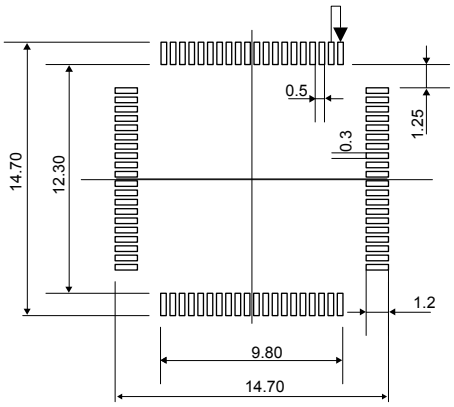
**Table 118. LQFP80 - Mechanical data**

| 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 | 00067 | 0.0079 | 0.0091 |
| c[11.] | 0.09 | - | 0.20 | 0.0035 | - | 0.0079 |
| c1[11.] | 0.09 | - | 0.16 | 0.0035 | - | 0.0063 |
| D[4.] | 14.00 BSC | | | 0.5512 BSC | | |
| D1[2.][5.] | 12.00 BSC | | | 0.4724 BSC | | |
| E[4.] | 14.00 BSC | | | 0.5512 BSC | | |
| E1[2.][5.] | 12.00 BSC | | | 0.4724 BSC | | |
| e | 0.50 BSC | | | 0.0197 BSC | | |
| L | 0.45 | 0.60 | 0.75 | 0.0177 | 0.0236 | 0.0295 |
| L1 | - | 1.00 | - | - | 0.0394 | - |
| N[13.] | 80 | | | | | |
| 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 D1and 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 4 decimal digits.
15. Drawing is not to scale.

**Figure 62. LQFP80 - Footprint example**

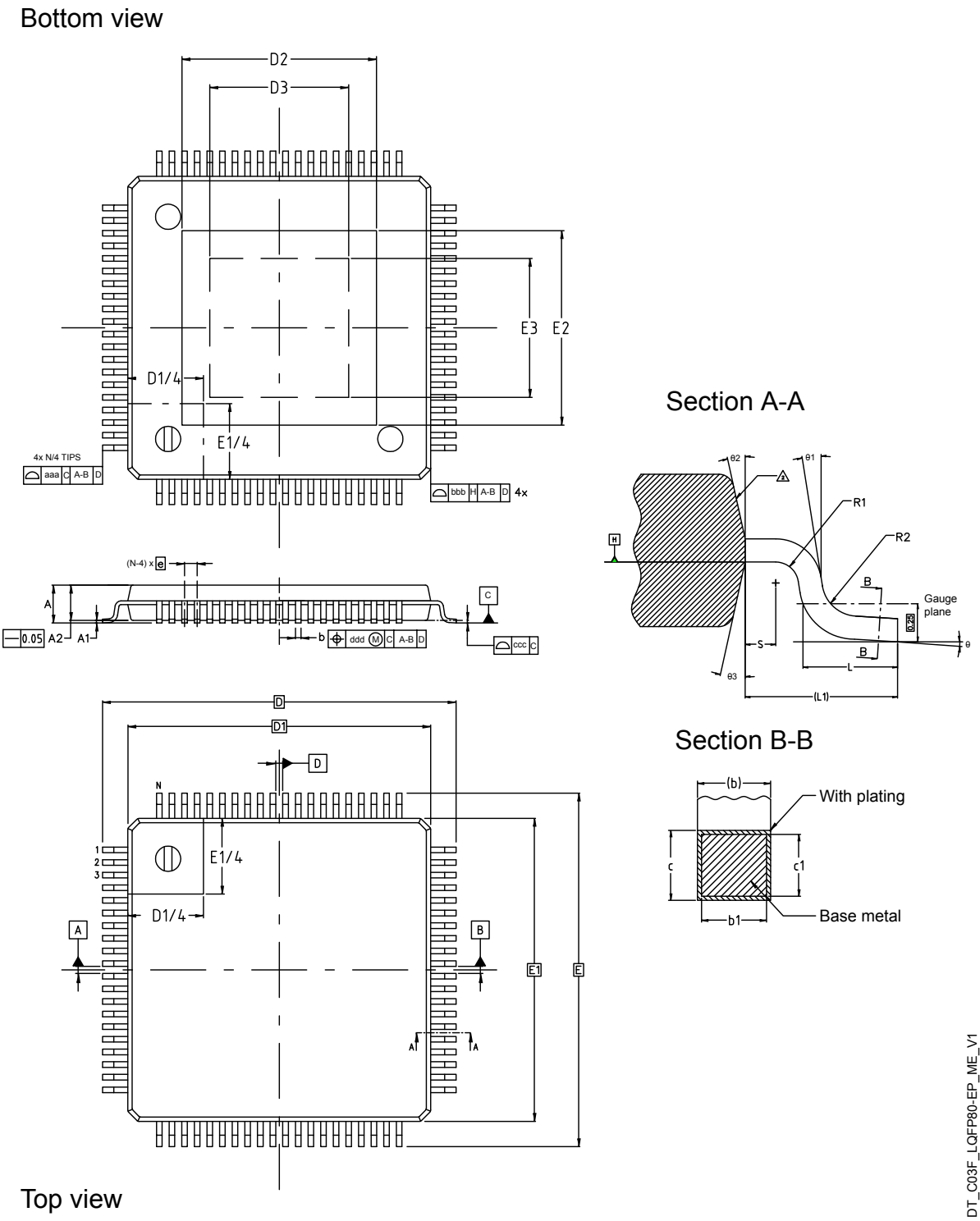



1. *Dimensions are expressed in millimeters.*

## 6.9 LQFP80-EP package information (C03F_A)

This LQFP is a 80-pin, 12 x 12 mm low-profile quad flat package with an exposed pad (EP) measuring 5.5 x 5.5 mm.

**Figure 63. LQFP80-EP - Outline**




*Note: The drawing is not to scale.*

**Table 119. LQFP80-EP - Mechanical data**

| Symbol[1] | Millimeters | | | Inches[2] | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| 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° |
| A[3] | - | - | 1.60 | - | - | 0.0630 |
| A1[4] | 0.05 | - | 0.15 | 0.0020 | - | 0.0059 |
| A2 | 1.35 | 1.40 | 1.45 | 0.0531 | 0.0551 | 0.0571 |
| b[5][6] | 0.17 | 0.22 | 0.27 | 0.0067 | 0.0087 | 0.0106 |
| b1[6] | 0.17 | 0.20 | 0.23 | 0.0067 | 0.0079 | 0.0091 |
| c[6] | 0.09 | - | 0.20 | 0.0035 | - | 0.0079 |
| c1[6] | 0.09 | - | 0.16 | 0.0035 | - | 0.0063 |
| D[7] | | 14.00 BSC[8] | | | 0.5512 BSC | |
| D1[9][10] | - | 12.00 BSC | - | - | 0.4724 BSC | - |
| D2[11] | - | - | 5.55 | - | - | 0.2185 |
| D3[12] | 4.65 | - | - | 0.1831 | - | - |
| e | | 0.50 BSC | | | 0.0197 BSC | |
| E[7] | | 14.00 BSC | | | 0.5512 BSC | |
| E1[9][10] | | 12.00 BSC | | | 0.4724 BSC | |
| E2[11] | - | - | 5.55 | - | - | 0.2185 |
| E3[12] | 4.65 | - | - | 0.1831 | - | - |
| L | 0.45 | 0.60 | 0.75 | 0.0177 | 0.0236 | 0.0295 |
| L1 | | 1.00 REF | | | 0.0394 REF | |
| R1 | 0.08 | - | - | 0.0031 | - | - |
| R2 | 0.08 | - | 0.20 | 0.0031 | - | 0.0079 |
| S | 0.20 | - | - | 0.0079 | - | - |

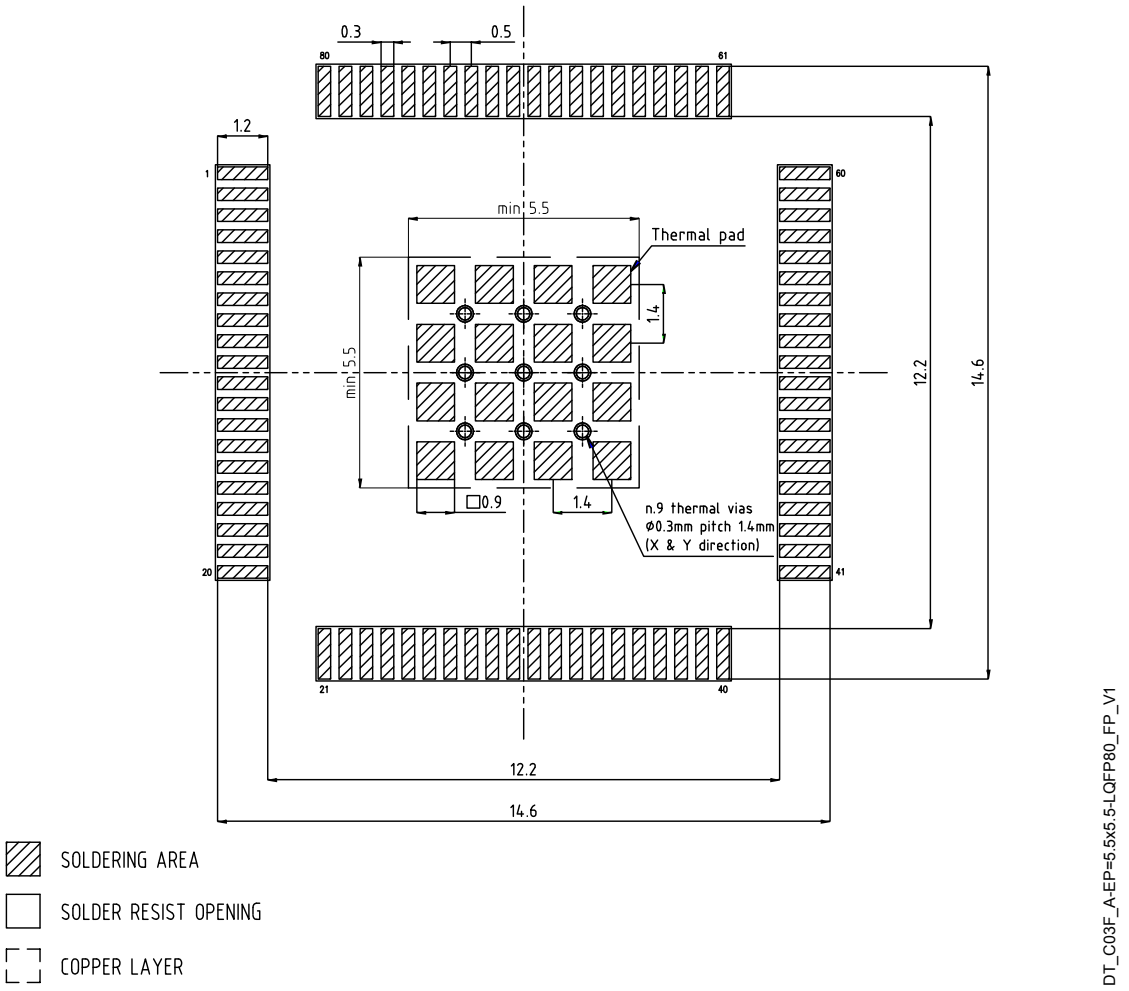
1. *Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.*
2. *Values in inches are converted from millimeters and rounded to four decimal digits, except for the Θ values, which are in degrees.*
3. *The profile height, A, is the distance from the seating plane to the highest point on the 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. *These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.*
7. *To be determined at seating datum plane C.*
8. *BSC stands for basic dimensions. It corresponds to the nominal value and has no tolerance.*
9. *The top package body size can be up to 0.15 mm smaller than the bottom package size.*
10. *Dimensions D1 and E1 do not include mold flash or protrusions. Allowable mold flash or protrusions are 0.25 mm per side. D1 and E1 are the maximum plastic body size dimensions including mold mismatch.*
11. *Dimensions D2 and E2 indicate the maximum exposed metal area on the package surface where the exposed pad is located. This area includes all metal protrusions from exposed pad.*
12. *Dimensions D3 and E3 indicate the minimum solderable area. The minimum solderable area is defined as the portion of the exposed pad that is guaranteed to be free from resin flashes or bleeds. This area is bordered by the internal edge of the inner groove.*

**Table 120. LQFP80-EP - Tolerance of form and position**

| Symbol(2) | Millimeters | | | Inches(2) | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| aaa(3) | | 0.20 | | | 0.0079 | |
| bbb(4) | | 0.20 | | | 0.0079 | |
| ccc(5) | | 0.08 | | | 0.0031 | |
| ddd(6) | | 0.08 | | | 0.0031 | |

1. *Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.*
2. *Values in inches are converted from millimeters and rounded to four decimal digits.*
3. *The tolerance controls the position of the terminals with respect to datums A and B. The center of the tolerance zone for each terminal is defined by basic dimension e as related to datums A and B.*
4. *The bilateral profile tolerance controls the position of the plastic body sides. The centers of the profile zones are defined by the basic dimensions D and E.*
5. *The unilateral tolerance above the seating plane specifies the location of the bottom surface of all terminals. It is commonly known as the coplanarity of the package terminals.*
6. *The tolerance controls the position of the terminals to each other. The centers of the profile zones are defined by basic dimension e.*

**Figure 64. LQFP80-EP - Footprint example**



## 6.10 LQFP100 package information (1L)

This LQFP is a 100-pin, 14 x 14 mm, low-profile quad flat package.

*Note: See list of notes in the notes section.*

**Figure 65. LQFP100 - Outline(15.)**

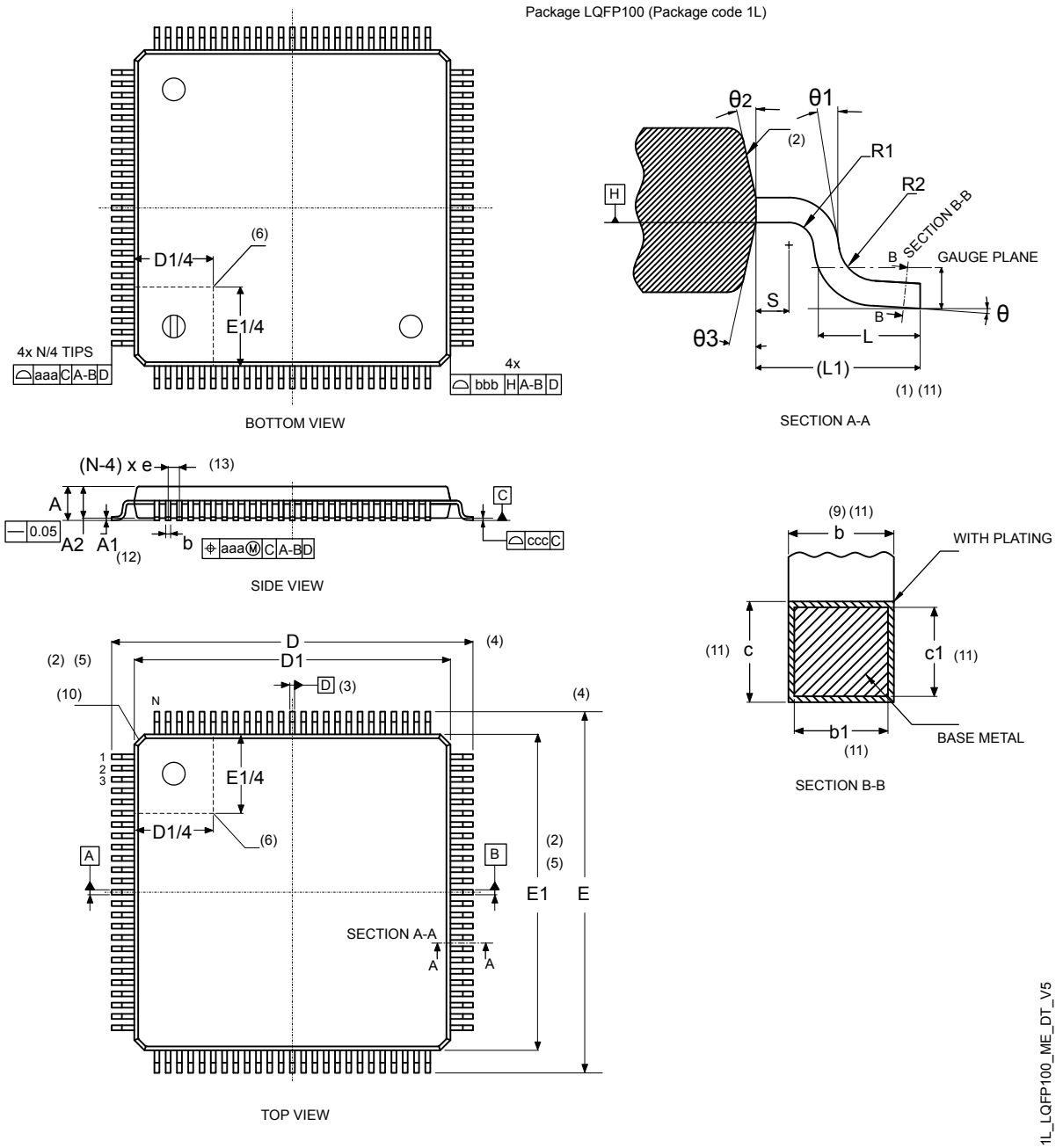


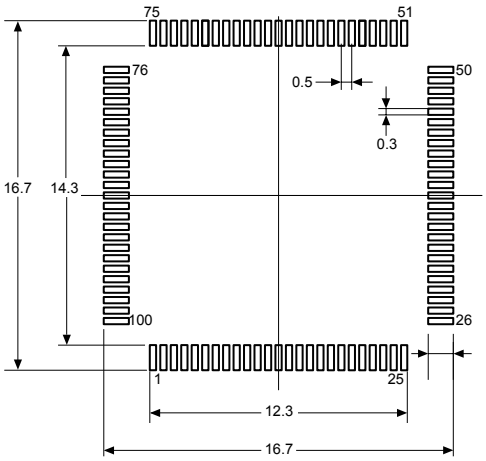
Table 121. **LQFP100 - Mechanical data**

| 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 | 0.0020 | - | 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.] | 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 | 0.0177 | 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 is allowed inwards the leads.
9. Dimension “b” does not include a 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. The minimum space between the protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.
10. The 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 4 decimal digits.
15. Drawing is not to scale.

**Figure 66. LQFP100 - Footprint example**

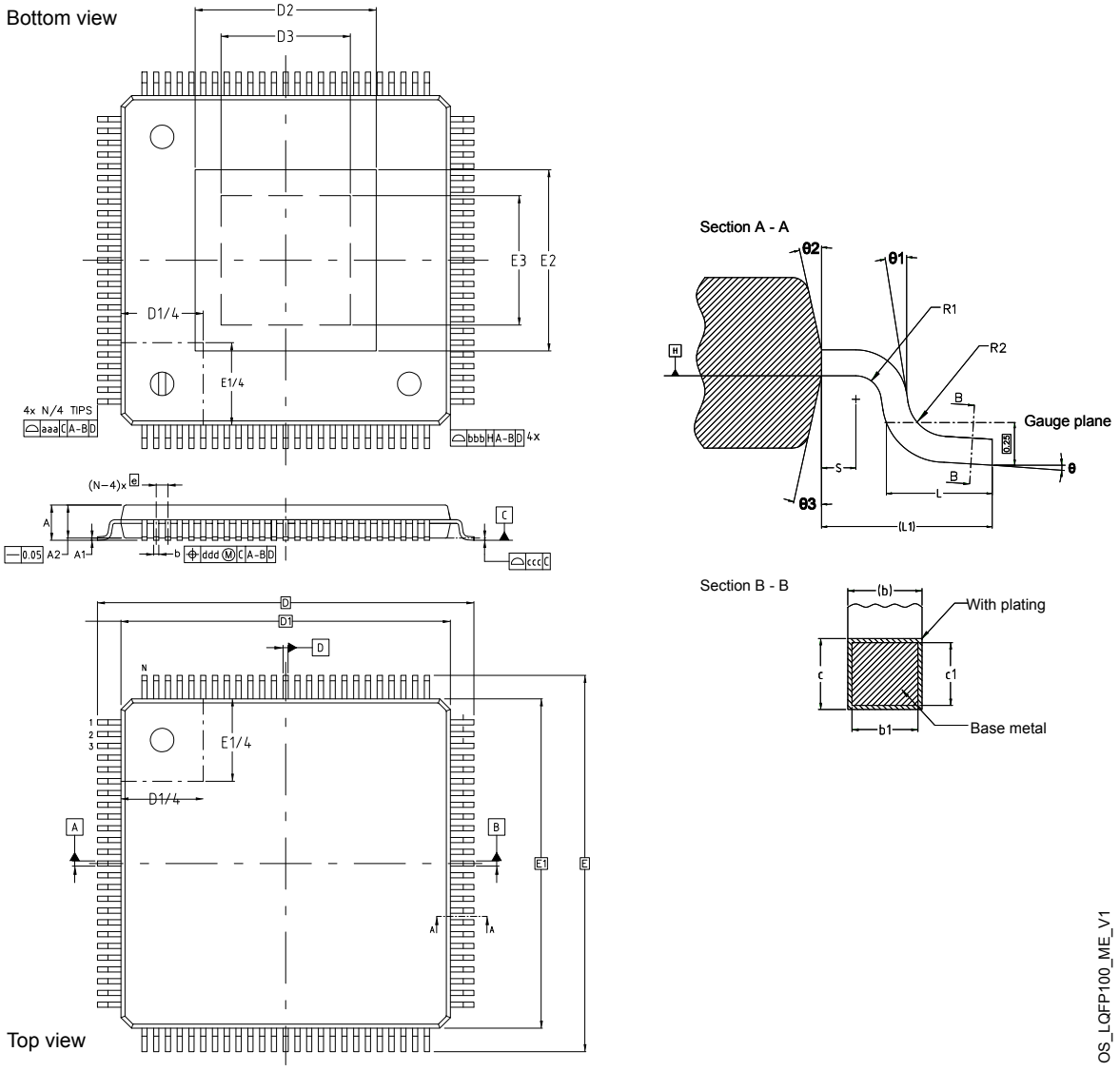



1. *Dimensions are expressed in millimeters.*

## 6.11 LQFP100-EP package information (OS_A)

This LQFP is a 100-pin, 14 x 14 mm, low-profile quad flat package with an exposed pad (EP) measuring 5.5 x 5.5 mm.

Figure 67. **LQFP100-EP - Outline**




1. *The drawing is not to scale.*

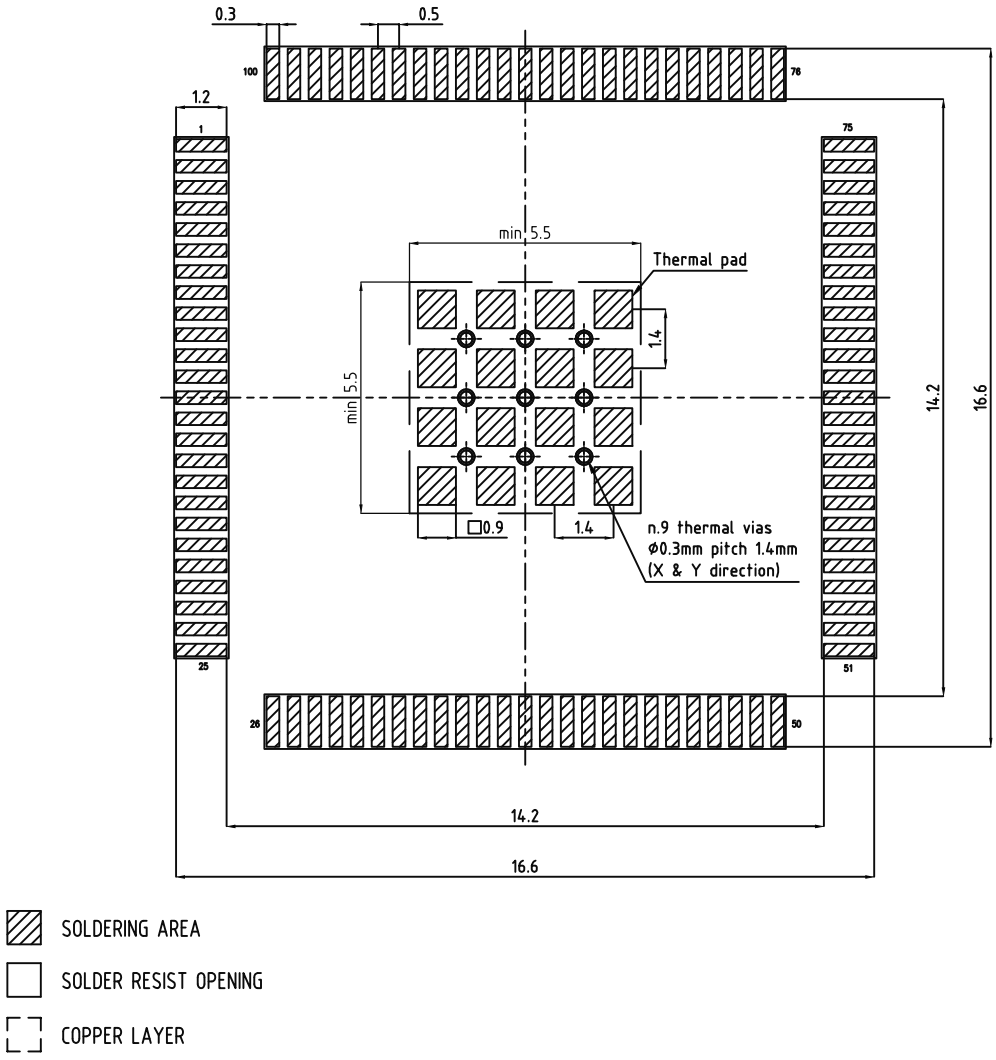
**Table 122. LQFP100-EP - Mechanical data**

| Symbol[1] | Millimeters | | | Inches[2] | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| 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° |
| A[3] | - | - | 1.60 | - | - | 0.0630 |
| A1[4] | 0.05 | - | 0.15 | 0.0020 | - | 0.0059 |
| A2 | 1.35 | 1.40 | 1.45 | 0.0531 | 0.0551 | 0.0571 |
| b[5][6] | 0.17 | 0.22 | 0.27 | 0.0067 | 0.0087 | 0.0106 |
| b1[6] | 0.17 | 0.20 | 0.23 | 0.0067 | 0.0079 | 0.0091 |
| c[6] | 0.09 | - | 0.20 | 0.0035 | - | 0.0079 |
| c1[6] | 0.09 | - | 0.16 | 0.0035 | - | 0.0063 |
| D[7][8] | 16.00 BSC | | | 0.6299 BSC | | |
| D1[8][9][10] | 14.00 BSC | | | 0.5512 BSC | | |
| D2[11] | - | - | 5.55 | - | - | 0.2185 |
| D3[12] | 4.65 | - | - | 0.1831 | - | - |
| e[8] | 0.50 BSC | | | 0.0197 BSC | | |
| E[7][8] | 16.00 BSC | | | 0.6299 BSC | | |
| E1[8][9][10] | 14.00 BSC | | | 0.5512 BSC | | |
| E2[11] | - | - | 5.55 | - | - | 0.2185 |
| E3[12] | 4.65 | - | - | 0.1831 | - | - |
| L | 0.45 | 0.60 | 0.75 | 0.0177 | 0.0236 | 0.0295 |
| L1 | 1.00 REF | | | 0.0394 REF | | |
| N[13] | 100 | | | | | |
| R1 | 0.08 | - | - | 0.0031 | - | - |
| R2 | 0.08 | - | 0.20 | 0.0031 | - | 0.0079 |
| S | 0.20 | - | - | 0.0079 | - | - |
| aaa[14] | 0.20 | | | 0.0079 | | |
| bbb[14] | 0.20 | | | 0.0079 | | |
| ccc[14] | 0.08 | | | 0.0031 | | |
| ddd[14] | 0.08 | | | 0.0031 | | |

1. *Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.*
2. *Values in inches are converted from millimeters and rounded to four decimal digits, except for the Θ values, which are provided in degrees.*
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 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.*
6. *These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.*
7. *To be determined at seating datum plane C.*

8. *BSC stands for basic dimensions. It corresponds to the nominal value and has no tolerance.*
9. *Top package body size may be smaller than the bottom package size by as much as 0.15 mm.*
10. *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.*
11. *Dimensions D2 and E2 show the maximum exposed metal area on the package surface where the exposed pad is located. It includes all metal protrusions from exposed pad itself.*
12. *Dimensions D3 and E3 show the minimum solderable area, defined as the portion of exposed pad which is guaranteed to be free from resin flashes/bleeds, bordered by internal edge of inner groove.*
13. *N represents the total number of pins on the QFP.*
14. *Tolerance of form and position.*

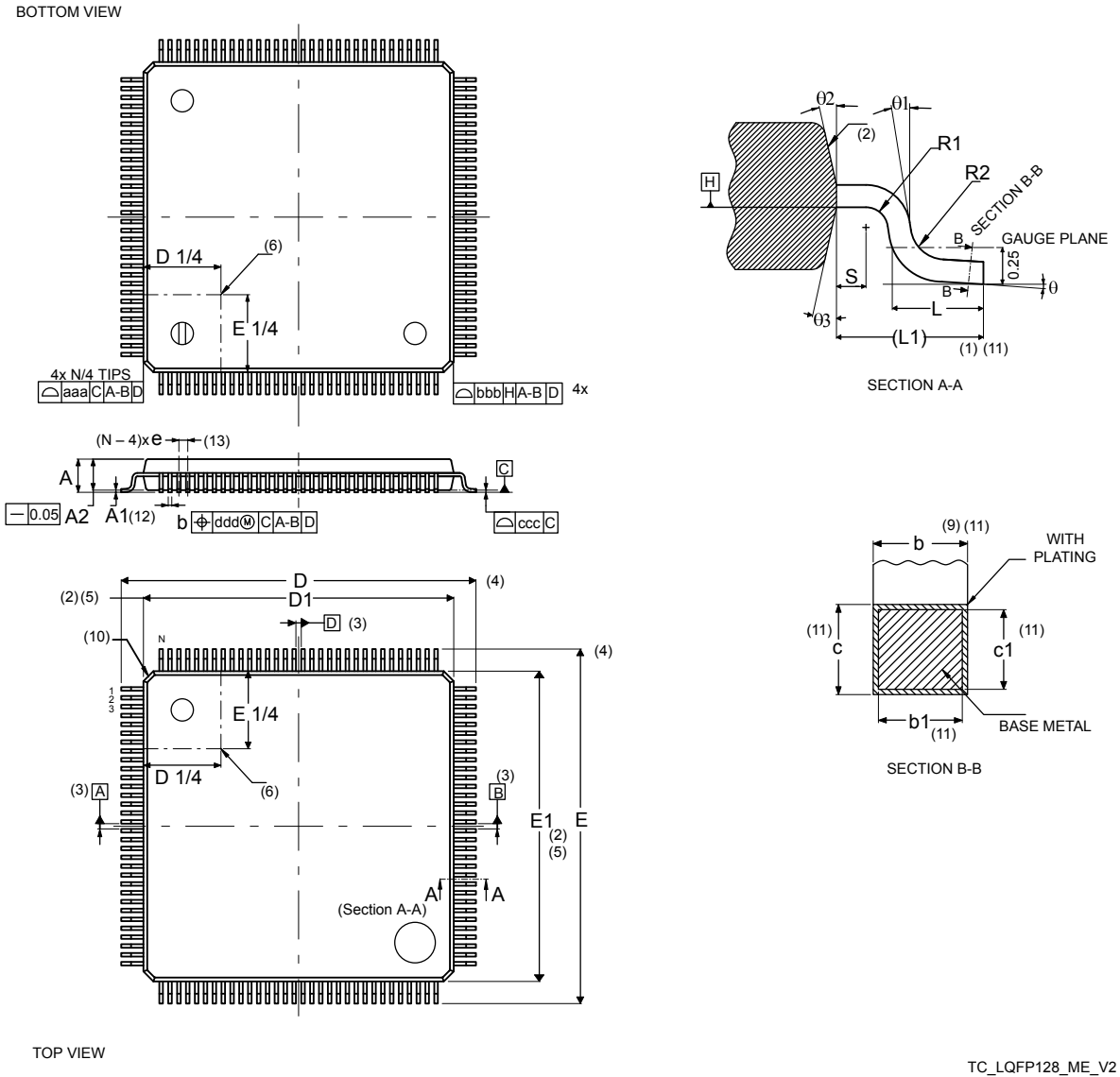
**Figure 68. LQFP100-EP - Footprint example**



## 6.12 LQFP128 package information (TC)

This LQFP128 is a 128-pin, 14 x 14 mm low-profile quad flat package.

**Figure 69. LQFP128 - Outline**




*Note:*

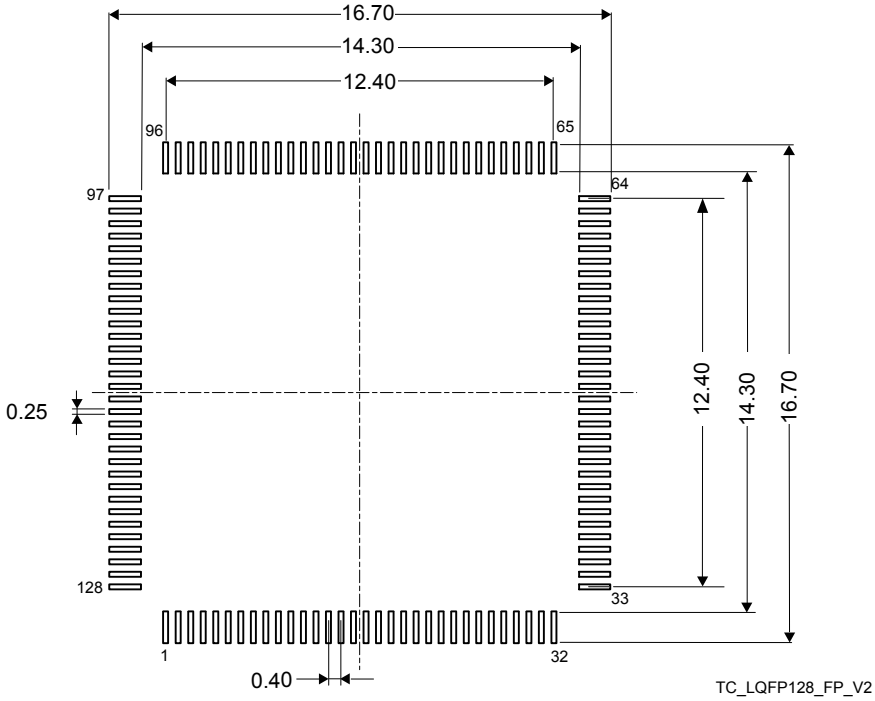
1. *Drawing is not to scale.*
2. *Datums A-B and D to be determined at datum plane H.*
3. *Details of pin 1 identifier are optional but must be located within the zone indicated.*
4. *No intrusion allowed inwards the leads.*

**Table 123. LQFP128 - Mechanical data**

| Symbol | Millimeters | | | Inches[1] | | |
|---|---|---|---|---|---|---|
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | - | - | 1.60 | - | - | 0.0630 |
| A1[2] | 0.05 | - | 0.15 | 0.0020 | - | 0.0059 |
| A2 | 1.35 | 1.40 | 1.45 | 0.0531 | 0.0551 | 0.0571 |
| b[3][4] | 0.13 | 0.18 | 0.23 | 0.0051 | 0.0071 | 0.0091 |
| b1[4] | 0.13 | 0.16 | 0.19 | 0.0051 | 0.0063 | 0.0075 |
| c[4] | 0.09 | - | 0.20 | 0.0035 | - | 0.0079 |
| c1[4] | 0.09 | - | 0.16 | 0.0035 | - | 0.0063 |
| D[5] | 16.00 BSC | | | 0.6299 BSC | | |
| D1[7] | 14.00 BSC | | | 0.5512 BSC | | |
| E[5] | 16.00 BSC | | | 0.6299 BSC | | |
| E1[6][7] | 14.00 BSC | | | 0.5512 BSC | | |
| e | 0.40 BSC | | | 0.0157 BSC | | |
| L | 0.45 | 0.60 | 0.75 | 0.0177 | 0.0236 | 0.0295 |
| L1 | 1.00 REF | | | 0.0394 REF | | |
| N[8] | 128 | | | | | |
| 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[9] | 0.20 | | | 0.0079 | | |
| bbb[9] | 0.20 | | | 0.0079 | | |
| ccc[9] | 0.08 | | | 0.0031 | | |
| ddd[9] | 0.07 | | | 0.0027 | | |

1. *Values in inches are converted from mm and rounded to 4 decimal digits.*
2. *A1 is defined as the distance from the seating plane to the lowest point on the package body.*
3. *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.*
4. *These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.*
5. *To be determined at seating datum plane C.*
6. *The Top package body size may be smaller than the bottom package size by as much as 0.15 mm.*
7. *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.*
8. *“N” is the number of terminal positions for the specified body size.*
9. *Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.*

Figure 70. **LQFP128 - Footprint example**

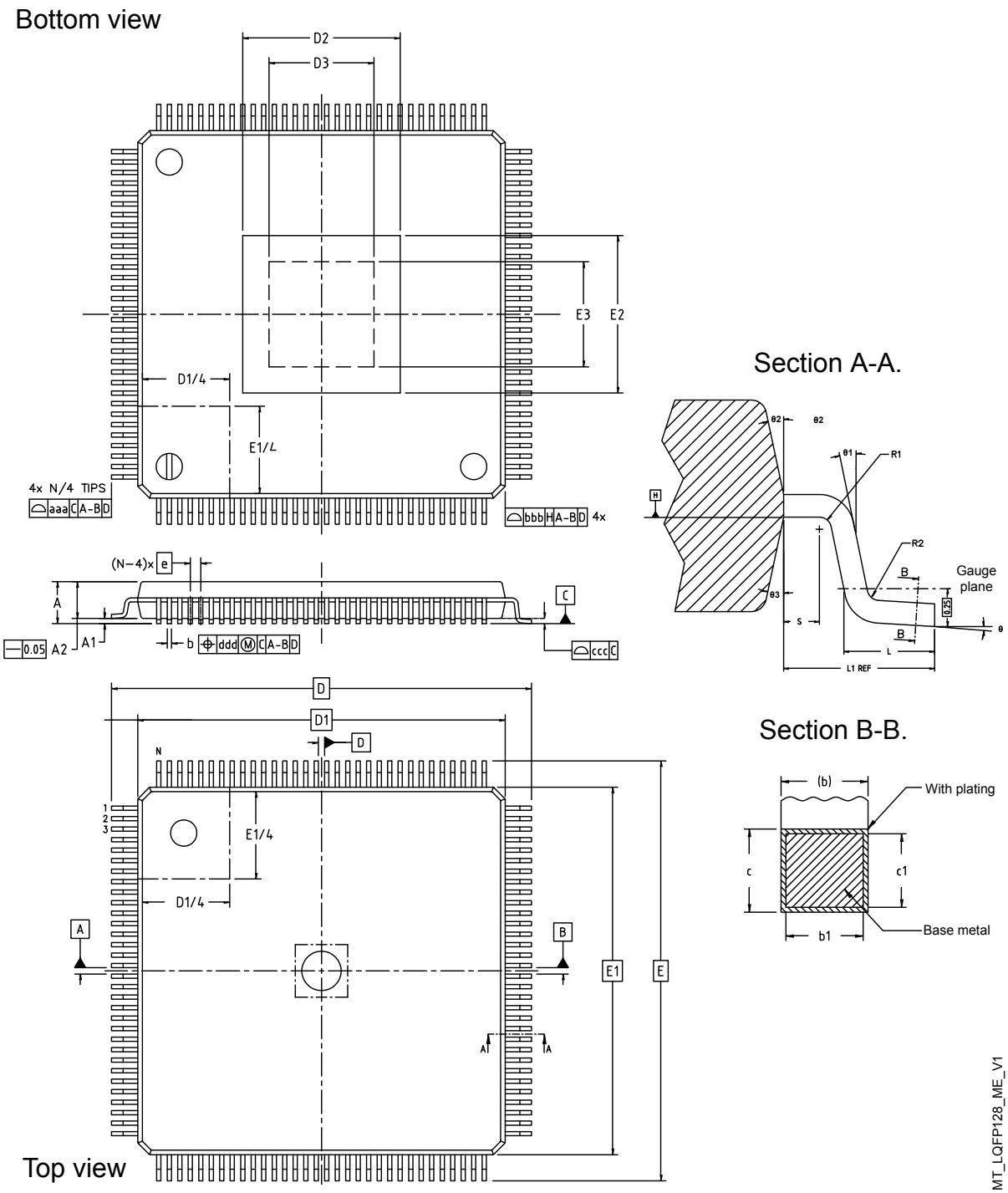



1. *Dimensions are expressed in millimeters.*

## 6.13 LQFP128-EP package information (MT_A)

This LQFP is a 128-pin, 14 x 14 mm low-profile quad flat package with an exposed pad (EP) measuring 5.715 x 5.715 mm.

**Figure 71. LQFP128-EP - Outline**




*Note: The drawing is not to scale.*

**Table 124. LQFP128-EP - Mechanical data**

| Symbol | Millimeters | | | Inches[1] | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| 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° |
| A[2] | - | - | 1.60 | - | - | 0.0630 |
| A1[3] | 0.05 | - | 0.15 | 0.0020 | - | 0.0059 |
| A2 | 1.35 | 1.40 | 1.45 | 0.0531 | 0.0551 | 0.0571 |
| b[4][5] | 0.13 | 0.18 | 0.23 | 0.0051 | 0.0071 | 0.0091 |
| b1[5] | 0.13 | 0.16 | 0.19 | 0.0051 | 0.0063 | 0.0075 |
| c[5] | 0.09 | - | 0.20 | 0.0035 | - | 0.0079 |
| c1[5] | 0.09 | - | 0.16 | 0.0035 | - | 0.0063 |
| D[6] | 16.00 BSC[7] | | | 0.6299 BSC | | |
| D1[8][9] | 14.00 BSC | | | 0.5512 BSC | | |
| D2[10] | - | - | 5.765 | - | - | 0.2270 |
| D3[11] | 4.865 | - | - | 0.1919 | - | - |
| e | 0.40 BSC | | | 0.0157 BSC | | |
| E[6] | 16.00 BSC | | | 0.6299 BSC | | |
| E1[8][9] | 14.00 BSC | | | 0.5512 BSC | | |
| E2[10] | - | - | 5.765 | - | - | 0.2270 |
| E3[11] | 4.865 | - | - | 0.1919 | - | - |
| L | 0.45 | 0.60 | 0.75 | 0.0177 | 0.0236 | 0.0295 |
| L1 | 1.00 REF | | | 0.0394 REF | | |
| N[12] | 128 | | | | | |
| R1 | 0.08 | - | - | 0.0031 | - | - |
| R2 | 0.08 | - | 0.20 | 0.0031 | - | 0.0079 |
| S | 0.20 | - | - | 0.0079 | - | - |

1. *Values in inches are converted from millimeters and rounded to four decimal places, except for the Θ values, which are in degrees, and N, which represents the number of pins.*
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. *The dimension b does not include dambar protrusion.*
5. *These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.*
6. *To be determined at seating datum plane C.*
7. *BSC stands for basic dimensions. It corresponds to the nominal value and has no tolerance.*
8. *The top package body size can be up to 0.15 mm smaller than the bottom package size.*
9. *Dimensions D1 and E1 do not include mold flash or protrusions. The allowable mold flash or protrusions is 0.25 mm per side. D1 and E1 are the maximum plastic body size dimensions including mold mismatch.*
10. *Dimensions D2 and E2 show the maximum exposed metal area on the package surface where the exposed pad is located. It includes all metal protrusions from exposed pad itself.*
11. *Dimensions D3 and E3 indicate the minimum solderable area. The minimum solderable area is defined as the portion of the exposed pad that is guaranteed to be free from resin flashes or bleeds. This area is bordered by the internal edge of the inner groove.*

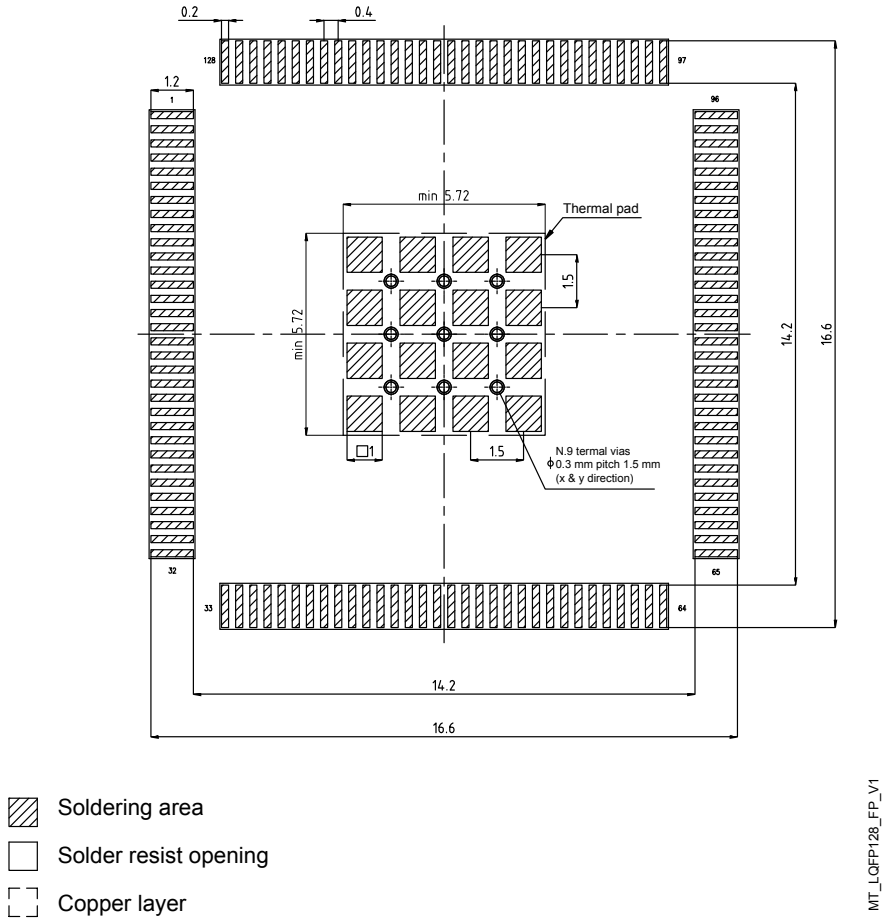
12. *N represents the total number of pins.*

**Table 125. LQFP128-EP - Tolerance of form and position**

| Symbol(2) | Millimeters | | | Inches(2) | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| aaa(3) | | 0.20 | | | 0.0079 | |
| bbb(4) | | 0.20 | | | 0.0079 | |
| ccc(5) | | 0.08 | | | 0.0031 | |
| ddd(6) | | 0.07 | | | 0.0028 | |

1. *Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.*
2. *Values in inches are converted from millimeters and rounded to four decimal digits.*
3. *The tolerance controls the position of the terminals with respect to datums A and B. The center of the tolerance zone for each terminal is defined by basic dimension e as related to datums A and B.*
4. *The bilateral profile tolerance controls the position of the plastic body sides. The centers of the profile zones are defined by the basic dimensions D and E.*
5. *The unilateral tolerance above the seating plane specifies the location of the bottom surface of all terminals. It is commonly known as the coplanarity of the package terminals.*
6. *The tolerance controls the position of the terminals to each other. The centers of the profile zones are defined by basic dimension e.*

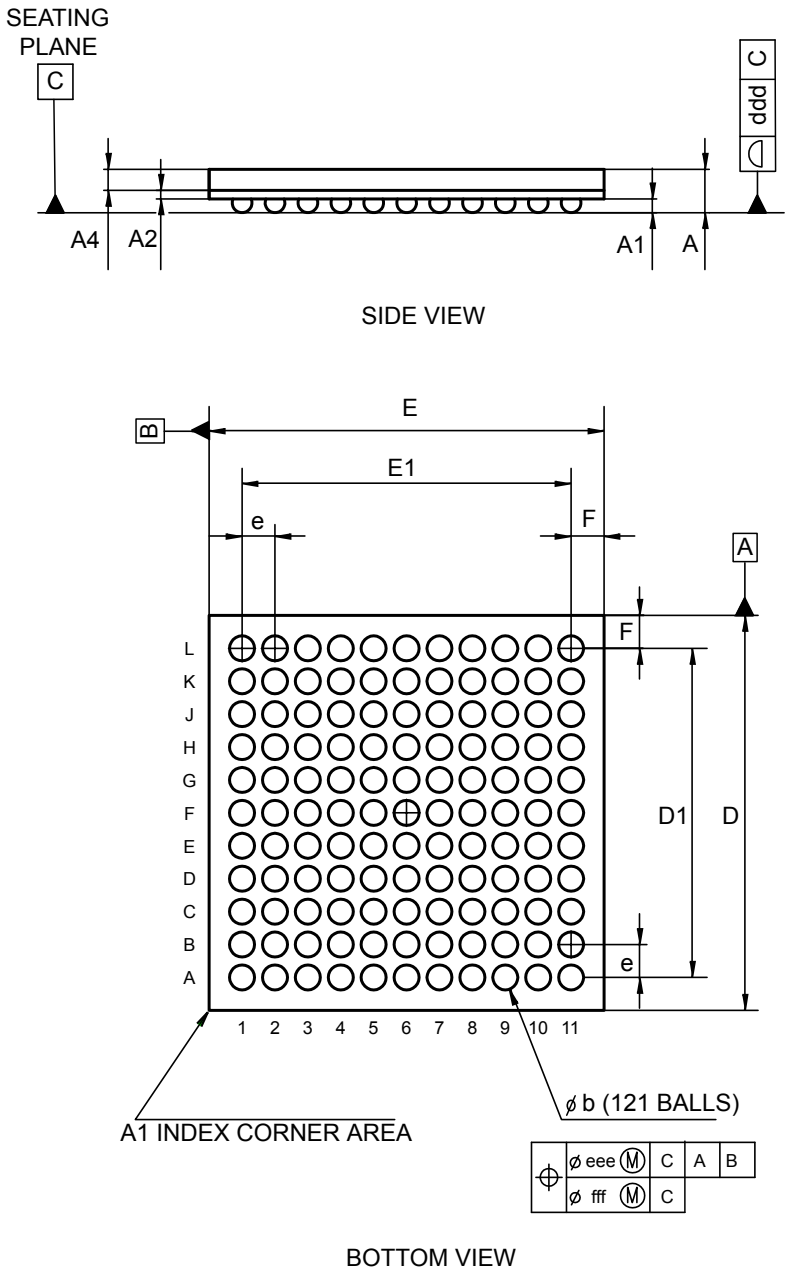
**Figure 72. LQFP128-EP - Footprint example**



## 6.14 UFBGA121 package information (B0CU)

This UFBGA is a 121-ball, 6 x 6 mm, 0.5 mm pitch, fine pitch, square ball grid array package.

**Figure 73. UFBGA121 - Outline**




B0CU_UFBGA121_ME_V1

1. *Drawing is not to scale.*
2. – *The terminal A1 corner must be identified on the top surface by using a corner chamfer, ink or metalized markings, or other feature of package body or integral heat slug.*
   – *A distinguishing feature is allowable on the bottom surface of the package to identify the terminal A1 corner. Exact shape of each corner is optional.*

**Table 126. UFBGA121 - Mechanical data**

| Symbol | millimeters | | | inches [1] | | |
|---|---|---|---|---|---|---|
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A[2] | - | - | 0.60 | - | - | 0.0236 |
| A1 | - | - | - | 0.0020 | - | - |
| A2 | - | 0.13 | - | - | 0.0051 | - |
| A4 | - | 0.32 | - | - | 0.0126 | - |
| b[3] | 0.24 | 0.29 | 0.34 | 0.0094 | 0.0114 | 0.0134 |
| D | 5.85 | 6.00 | 6.15 | 0.2303 | 0.2362 | 0.2421 |
| D1 | - | 5.00 | - | - | 0.1969 | - |
| E | 5.85 | 6.00 | 6.15 | 0.2303 | 0.2362 | 0.2421 |
| E1 | - | 5.00 | - | - | 0.1969 | - |
| e | - | 0.50 | - | - | 0.0197 | - |
| N | 121 | | | | | |
| F | - | 0.50 | - | - | 0.0197 | - |
| ddd | 0.08 | | | 0.0031 | | |
| eee [4] | 0.15 | | | 0.0059 | | |
| fff[5] | 0.05 | | | 0.0020 | | |

1. *Values in inches are converted from mm and rounded to four decimal digits.*
2. *UFBGA stands for Ultra-Thin Profile Fine Pitch Ball Grid Array. Ultra Thin profile: 0.50 < A ≤ 0.65 mm / Fine pitch: e < 1.00 mm pitch. The total profile height (Dim A) is measured from the seating plane to the top of the component. The maximum total package height is calculated by the following methodology:*

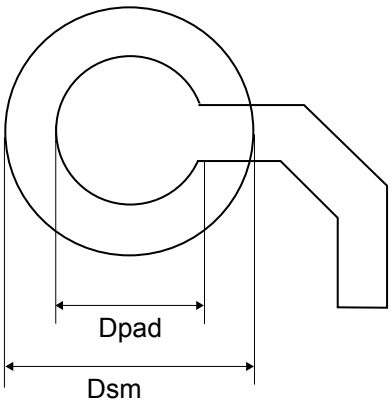
   *A Max = A1 Typ + A2 Typ + A4 Typ + √ (A1² + A2² + A4² tolerance values)*
3. *The typical balls diameter before mounting is 0.20 mm.*
4. *The tolerance of position that controls the location of the pattern of balls with respect to datum A and B.*

   *For each ball there is a cylindrical tolerance zone eee perpendicular to datum C and located on true position with respect to datum A and B as defined by e. The axis perpendicular to datum C of each ball must lie within this tolerance zone.*
5. *The tolerance of position that controls the location of the balls within the matrix with respect to each other.*

   *For each ball there is a cylindrical tolerance zone fff perpendicular to datum C and located on true position as defined by e. The axis perpendicular to datumC of each ball must lie within this tolerance zone.*

   *Each tolerance zone fff in the array is contained entirely in the respective zone eee above. The axis of each ball must lie simultaneously in both tolerance zones.*

**Figure 74. UFBGA121 - Footprint example**




DT_BGA_WLCSP_FT_V1

Table 127. **UFBGA121 - Example of PCB design rules**

| Dimension | Recommended values |
|---|---|
| Pitch | 0.5 mm |
| Dpad | 0.225 mm |
| Dsm | 0.290 mm typ. (depends on the soldermask registration tolerance) |
| Stencil opening | 0.250 mm |
| Stencil thickness | 0.100 mm |

## 6.15 Package thermal characteristics

The maximum chip-junction temperature, $T_J$ max, in degrees Celsius, can be calculated using the following equation:

$$T_J \max = T_A \max + \left(P_D \max \times \Theta_{JA}\right)$$

where:

- $T_A$ max is the maximum ambient temperature in °C.
- $\Theta_{JA}$ is the package junction-to-ambient thermal resistance in °C/W.
- $P_D$ max is the sum of $P_{INT}$ max and $P_{I/O}$ max:

$$P_D \max = P_{INT} \max + P_{I/O} \max)$$

- $P_{INT}$ max is the product of $I_{DD}$ and $V_{DD}$, expressed in Watts. This is the maximum chip internal power.

$P_{I/O}$ max represents the maximum power dissipation on output pins:

$$P_{I/O} \max = \sum\left(V_{OL} \times I_{OL}\right) + \sum\left(\left(V_{DD} - V_{OH}\right)\right) \times I_{OH}$$

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 128. **Package thermal characteristics**

| Package | Thermal resistance | | | | Unit |
|---|---|---|---|---|---|
| | junction-ambient $\Theta_{JA}$ | junction-board $\Theta_{JB}$ | junction-top case $\Theta_{JC(TOP)}$ | junction-bottom case $\Theta_{JC(BOTTOM)}$ | |
| UFQFPN40 (5 x 5 mm) | 38.2 | 20.0 | 15.6 | 3.9 | °C/W |
| LQFP48 (7 x 7 mm) | 48 | 25.5 | 12.6 | - | |
| TQFP48-EP (7 x 7 mm) | 30 | 12.2 | 17.5 | 3.1 | |
| UFQFPN48 (7 × 7 mm) | 27.7 | 11.9 | 7.8 | 2.6 | |
| LQFP64 (10 x 10 mm) | 40.9 | 23.2 | 10.7 | - | |
| TQFP64-EP (10 x 10 mm) | 25.3 | 10.9 | 13.0 | 2.8 | |
| LQFP80 (12 x 12 mm) | 39.3 | 23.6 | 10.3 | - | |
| LQFP80-EP (12 x 12 mm) | 24.7 | 11.6 | 12.6 | 2.8 | |
| LQFP100 (14 x 14 mm) | 35.9 | 21.8 | 9.0 | - | |
| LQFP100-EP (14 x 14 mm) | 24.2 | 12.2 | 16.6 | 2.8 | |
| LQFP128 (14 x 14 mm) | 38 | 23.8 | 10.0 | - | |
| LQFP128-EP (14 x 14 mm) | 24 | 12.0 | 16.2 | 2.8 | |
| UFBGA121 (6 x 6 mm) | 46.3 | 30.6 | 13.9 | - | |

# 7 Ordering information

Example: STM32 G 564 Q E T 3 Q TR

**Device family**

STM32 = Arm-based 32-bit microcontroller

**Product type**

G = General purpose

**Device subfamily**

564 = STM32G564xx (with HRTIM)

563 = STM32G563xx (without HRTIM)

**Pin count**

H = 40 pins

C = 48 pins

R = 64 pins

M = 80 pins

V = 100 pins

P = 121 balls

Q = 128 pins

**Flash memory size**

B = 128 Kbytes

C = 256 Kbytes

E = 512 Kbytes

**Package**

I = UFBGA

T = LQFP

Z = TQFP-EP/LQFP-EP (with exposed pad)

U = UFQFPN

**Temperature range** (For correct selection see Section 6.15: Package thermal characteristics. )

7 = Industrial temperature range, $T_a$ = –40 to 105°C, $T_j$ = 140°C junction

6 = Industrial temperature range, $T_a$ = –40 to 85°C, $T_j$ = 140°C junction

3 = Industrial temperature range, $T_a$ = –40 to 125°C, $T_j$ = 140°C junction

**Dedicated pinout**

Q = Dedicated pinout supporting SMPS step-down converter

**Packing**

TR = tape and reel

xxx = programmed parts

*Note: For a list of available options (such as speed and package) or for further information on any aspect of this device, contact your nearest ST sales office.*

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# Revision history

Table 129. **Document revision history**

| Date | Revision | Changes |
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