



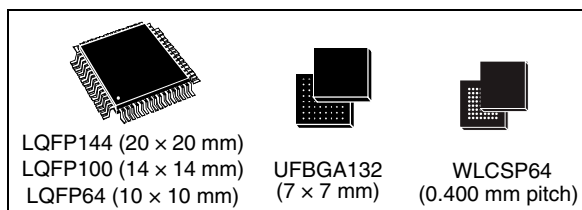
STM32L151xD STM32L152xD

Ultra-low-power 32-bit MCU ARM-based Cortex-M3, 384KB Flash, 48KB SRAM, 12KB EEPROM, LCD, USB, ADC, DAC, memory I/F

Datasheet – production data

Features

- Ultra-low-power platform
 - 1.65 V to 3.6 V power supply
 - **-40°C to 85°C/105°C** Temperature range
 - 0.35 μ A Standby mode (3 wakeup pins)
 - **1.3 μ A Standby mode + RTC**
 - 0.65 μ A Stop mode (16 wakeup lines)
 - 1.5 μ A Stop mode + RTC
 - 11 μ A Low-power Run mode
 - 238 μ A/MHz Run mode
 - 10 nA ultra-low I/O leakage
 - 8 μ s wakeup time
- Core: ARM 32-bit Cortex™-M3 CPU
 - From 32 kHz up to 32 MHz max
 - 33.3 DMIPS peak (Dhrystone 2.1)
 - Memory protection unit
- Up to 34 capacitive sensing channels
- CRC calculation unit, 96-bit unique ID
- Reset and supply management
 - Low power, ultrasafe BOR (brownout reset) with 5 selectable thresholds
 - Ultralow power POR/PDR
 - Programmable voltage detector (PVD)
- Clock sources
 - 1 to 24 MHz crystal oscillator
 - 32 kHz oscillator for RTC with calibration
 - High Speed Internal 16 MHz factory-trimmed RC (+/- 1%)
 - Internal low power 37 kHz RC
 - Internal multispeed low power 65 kHz to 4.2 MHz
 - PLL for CPU clock and USB (48 MHz)
- Pre-programmed bootloader
 - USB and USART supported
- Serial wire debug, JTAG and trace



- Up to 116 fast I/Os (102 I/Os 5V tolerant), all mappable on 16 external interrupt vectors
- Memories
 - 384 KB Flash with ECC (with 2 bank of 192 KB enabling Rww capability)
 - 48 KB RAM
 - 12 KB of true EEPROM with ECC
 - 128 Byte Backup Register
 - Memory interface controller supporting SRAM, PSRAM and NOR Flash
- LCD driver for up to 8x40 segments (contrast adjustment, blinking mode, step-up converter)
- Rich analog peripherals (down to 1.8V)
 - 3x Operational Amplifier
 - 12-bit ADC 1 Msps up to 40 channels
 - 12-bit DAC 2 ch with output buffers
 - 2x ultra-low-power-comparators (window mode and wake up capability)
- DMA controller 12x channels
- 12x peripherals communication interface
 - 1x USB 2.0 (internal 48 MHz PLL)
 - 5x USART
 - 3x SPI 16 Mbits/s (2x SPI with I2S)
 - 2x I2C (SMBus/PMBus)
 - 1x SDIO interface
- 11x timers: 1x 32-bit, 6x 16-bit with up to 4 IC/OC/PWM channels, 2x 16-bit basic timer, 2x watchdog timers (independent and window)

Table 1. Device summary

| Reference | Part number |
|-------------|--|
| STM32L151xx | STM32L151QD STM32L151RD STM32L151VD STM32L151ZD |
| STM32L152xx | STM32L152QD STM32L152RD STM32L152VD STM32L152ZD |

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1 Introduction

This datasheet provides the ordering information and mechanical device characteristics of the STM32L151xD and STM32L152xD ultra-low-power ARM Cortex™-based microcontrollers product line. STM32L15xD devices are microcontrollers with a Flash memory density of 384 Kbytes.

The ultra-low-power STM32L15xxD family includes devices in 5 different package types: from 64 pins to 144 pins. Depending on the device chosen, different sets of peripherals are included, the description below gives an overview of the complete range of peripherals proposed in this family.

These features make the ultra-low-power STM32L15xxD microcontroller family suitable for a wide range of applications:

- Medical and handheld equipment
- Application control and user interface
- PC peripherals, gaming, GPS and sport equipment
- Alarm systems, wired and wireless sensors, Video intercom
- Utility metering

This STM32L151xD and STM32L152xD datasheet should be read in conjunction with the STM32L1xxx reference manual (RM0038). The document "Getting started with STM32L1xxx hardware development" AN3216 gives a hardware implementation overview. Both documents are available from the STMicroelectronics website www.st.com.

For information on the Cortex™-M3 core please refer to the Cortex™-M3 Technical Reference Manual, available from the www.arm.com website at the following address: <http://infocenter.arm.com/help/index.jsp?topic=/com.arm.doc.ddi0337g>.

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

2 Description

The ultra-low-power STM32L15xxD incorporates the connectivity power of the universal serial bus (USB) with the high-performance ARM Cortex™-M3 32-bit RISC core operating at a 32 MHz frequency, a memory protection unit (MPU), high-speed embedded memories (Flash memory up to 384 Kbytes and RAM up to 48 Kbytes), a flexible static memory controller (FSMC) interface (for devices with packages of 100 pins and more) and an extensive range of enhanced I/Os and peripherals connected to two APB buses.

The STM32L15xxD devices offer three operational amplifiers, one 12-bit ADC, two DACs, two ultra-low-power comparators, one general-purpose 32-bit timer, six general-purpose 16-bit timers and two basic timers, which can be used as time bases.

Moreover, the STM32L15xxD devices contain standard and advanced communication interfaces: up to two I2Cs, three SPIs, two I2S, one SDIO, three USARTs, two UARTs and a USB. The STM32L15xxD devices offer up to 34 capacitive sensing channels to simply add touch sensing functionality to any application.

They also include a real-time clock and a set of backup registers that remain powered in Standby mode.

Finally, the integrated LCD controller has a built-in LCD voltage generator that allows you to drive up to 8 multiplexed LCDs with contrast independent of the supply voltage.

The ultra-low-power STM32L15xxD operates from a 1.8 to 3.6 V power supply (down to 1.65 V at power down) with BOR and from a 1.65 to 3.6 V power supply without BOR option. It is available in the -40 to +85 °C temperature range, extended to 105°C in low power dissipation state. A comprehensive set of power-saving modes allows the design of low-power applications.



2.1 Device overview

Table 2. Ultra-low-power STM32L15xxD device features and peripheral counts

| Peripheral | | STM32L15xRD | STM32L15xVD | STM32L15xQD | STM32L15xZD |
|---|------------------|---|-------------------|-------------|-------------|
| Flash (Kbytes) | | 384 | | | |
| Data EEPROM (Kbytes) | | 12 | | | |
| RAM (Kbytes) | | 48 | | | |
| FSMC | | No | multiplexed only | Yes | |
| Timers | 32 bit | 1 | | | |
| | General-purpose | 6 | | | |
| | Basic | 2 | | | |
| Communication interfaces | SPI/I2S | 3/(2) | | | |
| | I ² C | 2 | | | |
| | USART | 5 | | | |
| | USB | 1 | | | |
| | SDIO | 1 | | | |
| GPIOs | | 51 | 83 | 109 | 115 |
| Operation amplifiers | | 3 | | | |
| 12-bit synchronized ADC Number of channels | | 1 21 | 1 25 | 1 40 | 1 40 |
| 12-bit DAC Number of channels | | 2 2 | | | |
| LCD ⁽¹⁾ COM x SEG | | 1 4x32 or 8x28 | 1 4x44 or 8x40 | | |
| Comparators | | 2 | | | |
| Capacitive sensing channels | | 23 | | 33 | 34 |
| Max. CPU frequency | | 32 MHz | | | |
| Operating voltage | | 1.8 V to 3.6 V (down to 1.65 V at power-down) with BOR option 1.65 V to 3.6 V without BOR option | | | |
| Operating temperatures | | Ambient temperature: -40 to +85 °C Junction temperature: -40 to +105 °C | | | |
| Packages | | LQFP64, WLCSP64 | LQFP100 | UFBGA132 | LQFP144 |

1. STM32L152xx devices only.

2.2 Ultra-low-power device continuum

The ultra-low-power STM32L15xxD, STM32L162xD, STM32L15xxC and STM32L162xC are fully pin-to-pin and software compatible. Besides the full compatibility within the family, the devices are part of STMicroelectronics microcontrollers ultra-low-power strategy which also includes STM8L101xx and STM8L15xx devices. The STM8L and STM32L families allow a continuum of performance, peripherals, system architecture and features.

They are all based on STMicroelectronics ultralow leakage process.

Note: The ultra-low-power STM32L and general-purpose STM32Fxxxx families are pin-to-pin compatible. The STM8L15xxx devices are pin-to-pin compatible with the STM8L101xx devices. Please refer to the STM32F and STM8L documentation for more information on these devices.

2.2.1 Performance

All families incorporate highly energy-efficient cores with both Harvard architecture and pipelined execution: advanced STM8 core for STM8L families and ARM Cortex™-M3 core for STM32L family. In addition specific care for the design architecture has been taken to optimize the mA/DMIPS and mA/MHz ratios.

This allows the ultra-low-power performance to range from 5 up to 33.3 DMIPs.

2.2.2 Shared peripherals

STM8L15xxx and STM32L15xxx share identical peripherals which ensure a very easy migration from one family to another:

- Analog peripherals: ADC, DAC and comparators
- Digital peripherals: RTC and some communication interfaces

2.2.3 Common system strategy

To offer flexibility and optimize performance, the STM8L15xxx and STM32L15xxx families use a common architecture:

- Same power supply range from 1.65 V to 3.6 V
- Architecture optimized to reach ultralow consumption both in low power modes and Run mode
- Fast startup strategy from low power modes
- Flexible system clock
- Ultrasafe reset: same reset strategy including power-on reset, power-down reset, brownout reset and programmable voltage detector

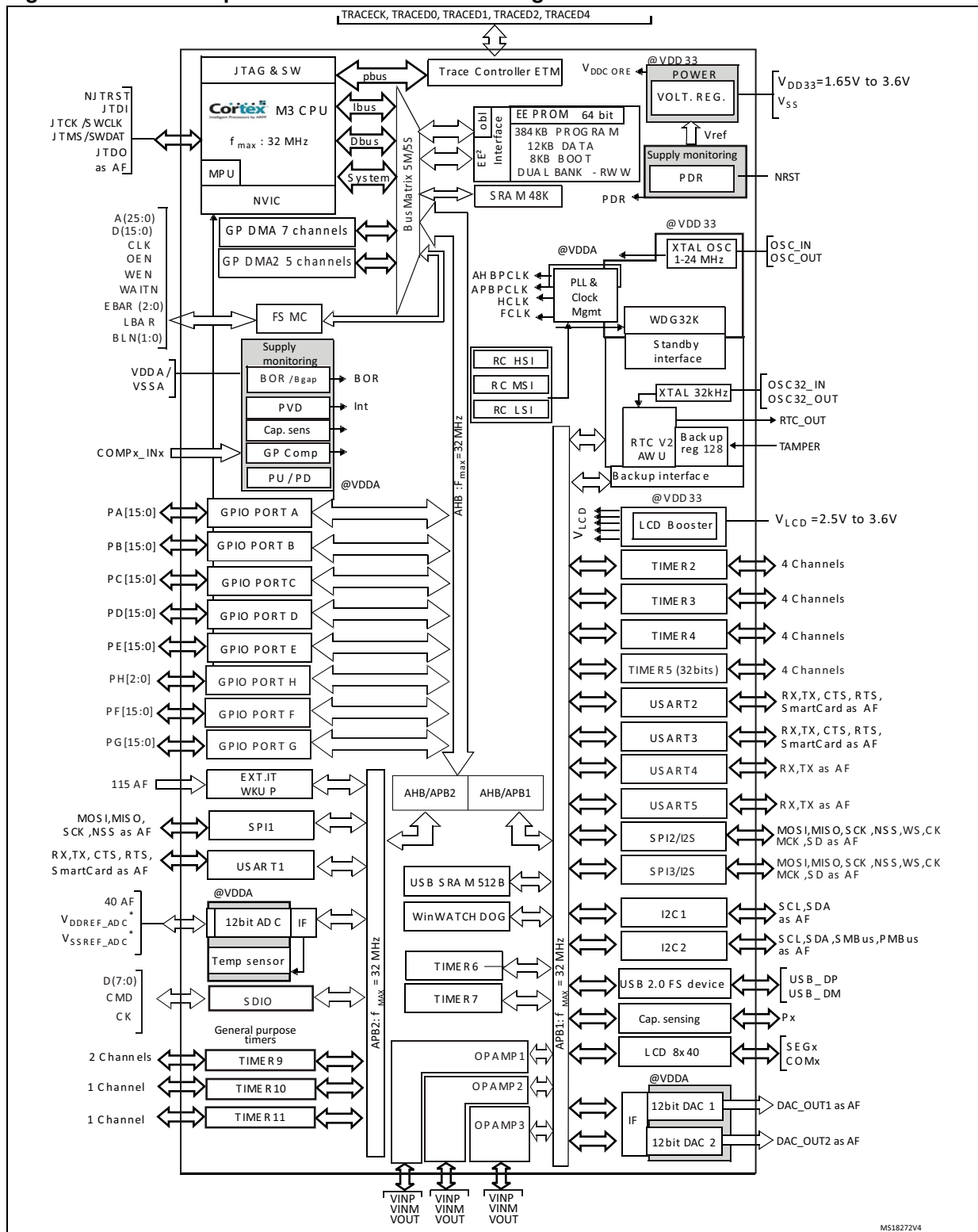
2.2.4 Features

ST ultra-low-power continuum also lies in feature compatibility:

- More than 10 packages with pin count from 20 to 144 pins and size down to 3 x 3 mm
- Memory density ranging from 4 to 384 Kbytes

3 Functional overview

Figure 1. Ultra-low-power STM32L15xxD block diagram



1. Legend:
 - AF: alternate function
 - ADC: analog-to-digital converter
 - BOR: brown out reset
 - DMA: direct memory access
 - DAC: digital-to-analog converter
 - I²C: inter-integrated circuit multimaster interface

3.1 Low power modes

The ultra-low-power STM32L15xxD supports dynamic voltage scaling to optimize its power consumption in run mode. The voltage from the internal low-drop regulator that supplies the logic can be adjusted according to the system's maximum operating frequency and the external voltage supply.

There are three power consumption ranges:

- Range 1 (V_{DD} range limited to 2.0V-3.6V), with the CPU running at up to 32 MHz
- Range 2 (full V_{DD} range), with a maximum CPU frequency of 16 MHz
- Range 3 (full V_{DD} range), with a maximum CPU frequency limited to 4 MHz (generated only with the multispeed internal RC oscillator clock source)

Seven low power modes are provided to achieve the best compromise between low power consumption, short startup time and available wakeup sources:

- **Sleep mode**

In Sleep mode, only the CPU is stopped. All peripherals continue to operate and can wake up the CPU when an interrupt/event occurs. Sleep mode power consumption at 16 MHz is about 1 mA with all peripherals off.
- **Low power run mode**

This mode is achieved with the multispeed internal (MSI) RC oscillator set to the minimum clock (131 kHz), execution from SRAM or Flash memory, and internal regulator in low power mode to minimize the regulator's operating current. In Low power run mode, the clock frequency and the number of enabled peripherals are both limited.
- **Low power sleep mode**

This mode is achieved by entering Sleep mode with the internal voltage regulator in Low power mode to minimize the regulator's operating current. In Low power sleep mode, both the clock frequency and the number of enabled peripherals are limited; a typical example would be to have a timer running at 32 kHz.

When wakeup is triggered by an event or an interrupt, the system reverts to the run mode with the regulator on.
- **Stop mode with RTC**

Stop mode achieves the lowest power consumption while retaining the RAM and register contents and real time clock. All clocks in the V_{CORE} domain are stopped, the PLL, MSI RC, HSI RC and HSE crystal oscillators are disabled. The LSE or LSI is still running. The voltage regulator is in the low power mode.

The device can be woken up from Stop mode by any of the EXTI line, in 8 μ s. The EXTI line source can be one of the 16 external lines. It can be the PVD output, the Comparator 1 event or Comparator 2 event (if internal reference voltage is on), it can be the RTC alarm(s), the USB wakeup, the RTC tamper events, the RTC timestamp event or the RTC wakeup.

- **Stop mode without RTC**

Stop mode achieves the lowest power consumption while retaining the RAM and register contents. All clocks are stopped, the PLL, MSI RC, HSI and LSI RC, LSE and HSE crystal oscillators are disabled. The voltage regulator is in the low power mode. The device can be woken up from Stop mode by any of the EXTI line, in 8 μ s. The EXTI line source can be one of the 16 external lines. It can be the PVD output, the Comparator 1 event or Comparator 2 event (if internal reference voltage is on). It can also be wakened by the USB wakeup.
- **Standby mode with RTC**

Standby mode is used to achieve the lowest power consumption and real time clock. The internal voltage regulator is switched off so that the entire V_{CORE} domain is powered off. The PLL, MSI RC, HSI RC and HSE crystal oscillators are also switched off. The LSE or LSI is still running. After entering Standby mode, the RAM and register contents are lost except for registers in the Standby circuitry (wakeup logic, IWDG, RTC, LSI, LSE Crystal 32K osc, RCC_CSR).

The device exits Standby mode in 60 μ s when an external reset (NRST pin), an IWDG reset, a rising edge on one of the three WKUP pins, RTC alarm (Alarm A or Alarm B), RTC tamper event, RTC timestamp event or RTC Wakeup event occurs.
- **Standby mode without RTC**

Standby mode is used to achieve the lowest power consumption. The internal voltage regulator is switched off so that the entire V_{CORE} domain is powered off. The PLL, MSI RC, HSI and LSI RC, HSE and LSE crystal oscillators are also switched off. After entering Standby mode, the RAM and register contents are lost except for registers in the Standby circuitry (wakeup logic, IWDG, RTC, LSI, LSE Crystal 32K osc, RCC_CSR).

The device exits Standby mode in 60 μ s when an external reset (NRST pin) or a rising edge on one of the three WKUP pin occurs.

Note: The RTC, the IWDG, and the corresponding clock sources are not stopped automatically by entering Stop or Standby mode.

Table 3. Functionalities depending on the operating power supply range

| Operating power supply range | Functionalities depending on the operating power supply range | | | |
|------------------------------|---|---------------------------|-------------------------------|----------------------------|
| | DAC and ADC operation | USB | Dynamic voltage scaling range | I/O operation |
| $V_{DD} = 1.65$ to 1.8 V | Not functional | Not functional | Range 2 or range 3 | Degraded speed performance |
| $V_{DD} = 1.8$ to 2.0 V | Conversion time up to 500 Ksps | Not functional | Range 2 or range 3 | Degraded speed performance |
| $V_{DD} = 2.0$ to 2.4 V | Conversion time up to 500 Ksps | Functional ⁽¹⁾ | Range 1, range 2 or range 3 | Full speed operation |
| $V_{DD} = 2.4$ to 3.6 V | Conversion time up to 1 Msps | Functional ⁽¹⁾ | Range 1, range 2 or range 3 | Full speed operation |

1. To be USB compliant from the IO voltage standpoint, the minimum V_{DD} is 3.0 V.

Table 4. CPU frequency range depending on dynamic voltage scaling

| CPU frequency range | Dynamic voltage scaling range |
|--|-------------------------------|
| 16 MHz to 32 MHz (1ws) 32 kHz to 16 MHz (0ws) | Range 1 |
| 8 MHz to 16 MHz (1ws) 32 kHz to 8 MHz (0ws) | Range 2 |
| 2.1MHz to 4.2 MHz (1ws) 32 kHz to 2.1 MHz (0ws) | Range 3 |

Table 5. Functionalities depending on the working mode (from Run/active down to standby)

| Ips | Run/Active | Sleep | Low-power Run | Low-power Sleep | Stop | | Standby | |
|------------------------------------|------------|-------|---------------|-----------------|-------------------|-------------------|---------|---|
| | | | | | Wakeup capability | Wakeup capability | | |
| CPU | Y | -- | Y | -- | -- | | -- | |
| Flash | Y | Y | Y | N | -- | | -- | |
| RAM | Y | Y | Y | Y | Y | | -- | |
| Backup Registers | Y | Y | Y | Y | Y | | Y | |
| EEPROM | Y | -- | Y | Y | Y | | -- | |
| Brown-out rest (BOR) | Y | Y | Y | Y | Y | Y | Y | |
| DMA | Y | Y | Y | Y | -- | | -- | |
| Programable Voltage Detector (PVD) | Y | Y | Y | Y | Y | Y | Y | |
| Power On Reset (POR) | Y | Y | Y | Y | Y | Y | Y | |
| Power Down Rest (PDR) | Y | Y | Y | Y | Y | | Y | |
| High Speed Internal (HSI) | Y | Y | -- | -- | -- | | -- | |
| High Speed External (HSE) | Y | Y | -- | -- | -- | | -- | |
| Low Speed Internal (LSI) | Y | Y | Y | Y | Y | | -- | |
| Low Speed External (LSE) | Y | Y | Y | Y | Y | | -- | |
| Multi-Speed Internal (MSI) | Y | Y | Y | Y | -- | | -- | |
| Inter-Connect Controler | Y | Y | Y | Y | -- | | -- | |
| RTC | Y | Y | Y | Y | Y | Y | Y | |
| RTC Tamper | Y | Y | Y | Y | Y | Y | Y | Y |
| Auto WakeUp (AWU) | Y | Y | Y | Y | Y | Y | Y | Y |
| LCD | Y | Y | Y | Y | Y | | -- | |
| USB | Y | Y | -- | -- | -- | Y | -- | |
| USART | Y | Y | Y | Y | Y | (1) | -- | |
| SPI | Y | Y | Y | Y | | | -- | |
| I2C | Y | Y | Y | Y | | (1) | -- | |

Table 5. Functionalities depending on the working mode (from Run/active down to standby) (continued)

| Ips | Run/Active | Sleep | Low-power Run | Low-power Sleep | Stop | | Standby | |
|---|---------------------------------------|--------------------------------------|------------------|-------------------|---|-------------------|---|-------|
| | | | | | Wakeup capability | Wakeup capability | | |
| ADC | Y | Y | -- | -- | -- | | -- | |
| DAC | Y | Y | Y | Y | Y | | -- | |
| Tempsensor | Y | Y | Y | Y | Y | | -- | |
| OP amp | Y | Y | Y | Y | Y | | -- | |
| Comparators | Y | Y | Y | Y | Y | Y | -- | |
| 16-bit and 32-bit Timers | Y | Y | Y | Y | -- | | -- | |
| IWDG | Y | Y | Y | Y | Y | Y | Y | Y |
| WWDG | Y | Y | Y | Y | -- | | -- | |
| Touch sensing | Y | Y | -- | -- | -- | | -- | |
| Systic Timer | Y | Y | Y | Y | | | -- | |
| GPIOs | Y | Y | Y | Y | Y | Y | | 3Pins |
| Wakeup time to Run mode | 0 μs | 0.36 μs | 3 μs | 32 μs | < 8 μs | | 50 μs | |
| Consumption V _{DD} =1.8V to 3.6V (Typ) | Down to 238 μA/MHz (from Flash) | Down to 55 μA/MHz (from Flash) | Down to 11 μA | Down to 4.4 μA | 0.65 μA (No RTC) V _{DD} =1.8V | | 0.35 μA (No RTC) V _{DD} =1.8V | |
| | | | | | 1.5 μA (with RTC) V _{DD} =1.8V | | 1 μA (with RTC) V _{DD} =1.8V | |
| | | | | | 0.65μA (No RTC) V _{DD} =3.0V | | 0.35 μA (No RTC) V _{DD} =3.0V | |
| | | | | | 1.7 μA (with RTC) V _{DD} =3.0V | | 1.3 μA (with RTC) V _{DD} =3.0V | |

1. The startup on communication line wakes the CPU which was made possible by an EXTI, this induces a delay before entering run mode.

3.2 ARM[®] Cortex[™]-M3 core with MPU

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

The ARM Cortex[™]-M3 32-bit RISC processor features exceptional code-efficiency, delivering the high-performance expected from an ARM core in the memory size usually associated with 8- and 16-bit devices.

The memory protection unit (MPU) improves system reliability by defining the memory attributes (such as read/write access permissions) for different memory regions. It provides up to eight different regions and an optional predefined background region.

Owing to its embedded ARM core, the STM32L15xxD is compatible with all ARM tools and software.

Nested vectored interrupt controller (NVIC)

The ultra-low-power STM32L15xxD embeds a nested vectored interrupt controller able to handle up to 56 maskable interrupt channels (not including the 16 interrupt lines of Cortex™-M3) and 16 priority levels.

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

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

3.3 Reset and supply management

3.3.1 Power supply schemes

- $V_{DD} = 1.65$ to 3.6 V: external power supply for I/Os and the internal regulator. Provided externally through V_{DD} pins.
- V_{SSA} , $V_{DDA} = 1.65$ to 3.6 V: external analog power supplies for ADC, reset blocks, RCs and PLL (minimum voltage to be applied to V_{DDA} is 1.8 V when the ADC is used). V_{DDA} and V_{SSA} must be connected to V_{DD} and V_{SS} , respectively.

3.3.2 Power supply supervisor

The device has an integrated ZEROPOWER power-on reset (POR)/power-down reset (PDR) that can be coupled with a brownout reset (BOR) circuitry.

The device exists in two versions:

- The version with BOR activated at power-on operates between 1.8 V and 3.6 V.
- The other version without BOR operates between 1.65 V and 3.6 V.

After the V_{DD} threshold is reached (1.65 V or 1.8 V depending on the BOR which is active or not at power-on), the option byte loading process starts, either to confirm or modify default thresholds, or to disable the BOR permanently: in this case, the V_{DD} min value becomes 1.65 V (whatever the version, BOR active or not, at power-on).

When BOR is active at power-on, it ensures proper operation starting from 1.8 V whatever the power ramp-up phase before it reaches 1.8 V. When BOR is not active at power-up, the power ramp-up should guarantee that 1.65 V is reached on V_{DD} at least 1 ms after it exits the POR area.

Five BOR thresholds are available through option bytes, starting from 1.8 V to 3 V. To reduce the power consumption in Stop mode, it is possible to automatically switch off the internal reference voltage (V_{REFINT}) in Stop mode. The device remains in reset mode when V_{DD} is below a specified threshold, $V_{POR/PDR}$ or V_{BOR} , without the need for any external reset circuit.

Note: The start-up time at power-on is typically 3.3 ms when BOR is active at power-up, the start-up time at power-on can be decreased down to 1 ms typically for devices with BOR inactive at power-up.

The device features an embedded programmable voltage detector (PVD) that monitors the V_{DD}/V_{DDA} power supply and compares it to the V_{PVD} threshold. This PVD offers 7 different levels between 1.85 V and 3.05 V, chosen by software, with a step around 200 mV. An interrupt can be generated when V_{DD}/V_{DDA} drops below the V_{PVD} threshold and/or when V_{DD}/V_{DDA} 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.

3.3.3 Voltage regulator

The regulator has three operation modes: main (MR), low power (LPR) and power down.

- MR is used in Run mode (nominal regulation)
- LPR is used in the Low power run, Low power sleep and Stop modes
- Power down is used in Standby mode. The regulator output is high impedance, the kernel circuitry is powered down, inducing zero consumption but the contents of the registers and RAM are lost except for the standby circuitry (wake-up logic, IWDG, RTC, LSI, LSE crystal 32K osc, RCC_CSR).

3.3.4 Boot modes

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

- Boot from Flash memory
- Boot from System memory
- Boot from embedded RAM

The boot from Flash usually boots at the beginning of the Flash (bank 1). An additional boot mechanism is available through user option byte, to allow booting from bank 2 when bank 2 contains valid code. This dual boot capability can be used to easily implement a secure field software update mechanism.

The boot loader is located in System memory. It is used to reprogram the Flash memory by using USART1, USART2 or USB. See STM32™ microcontroller system memory boot mode AN2606 for details.

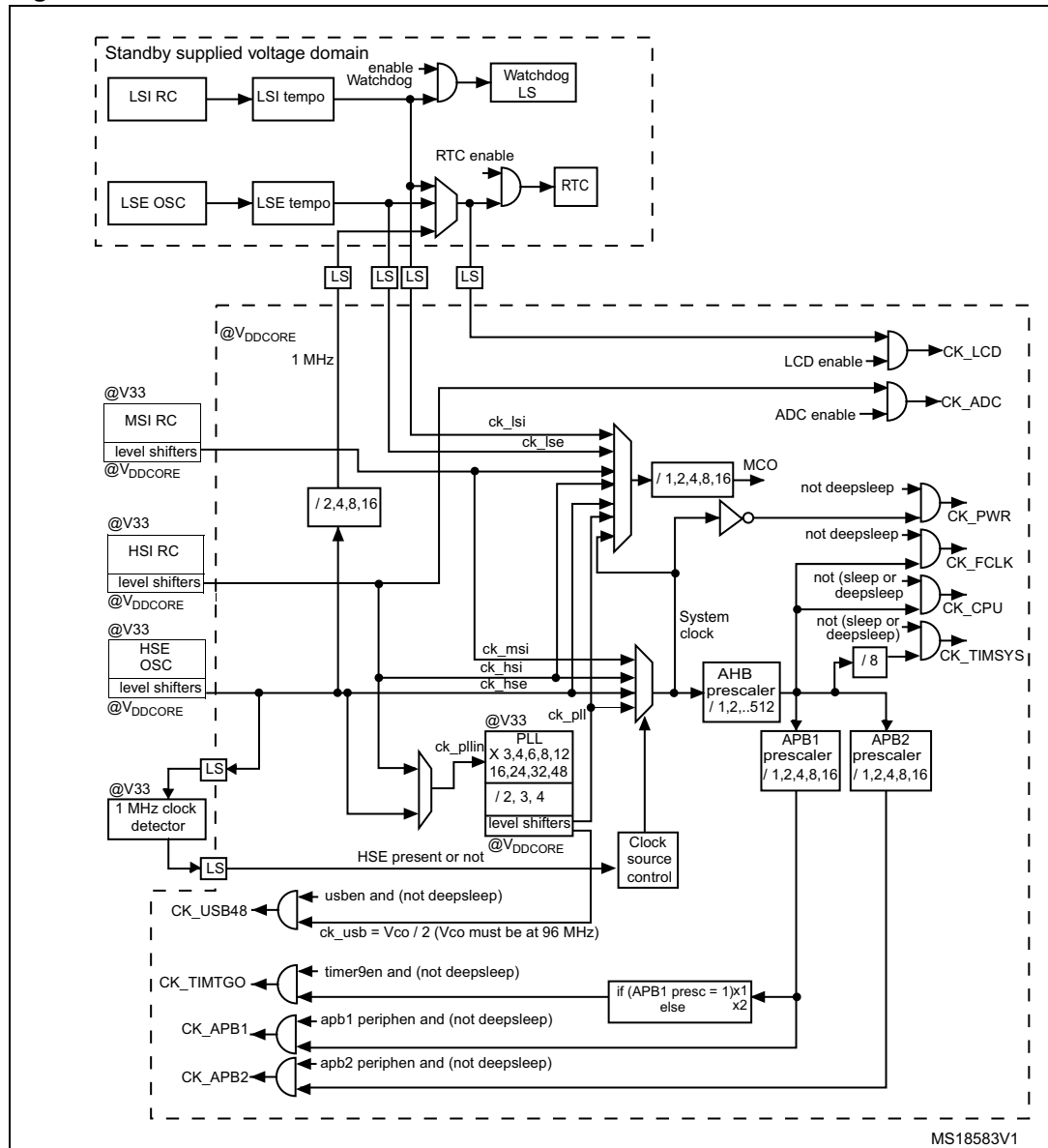
3.4 Clock management

The clock controller distributes the clocks coming from different oscillators to the core and the peripherals. It also manages clock gating for low power modes and ensures 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.
- **Safe clock switching:** clock sources can be changed safely on the fly in run mode through a configuration register.
- **Clock management:** to reduce power consumption, the clock controller can stop the clock to the core, individual peripherals or memory.
- **System clock source:** three different clock sources can be used to drive the master clock SYSCLK:
 - 1-24 MHz high-speed external crystal (HSE), that can supply a PLL
 - 16 MHz high-speed internal RC oscillator (HSI), trimmable by software, that can supply a PLL
 - Multispeed internal RC oscillator (MSI), trimmable by software, able to generate 7 frequencies (65 kHz, 131 kHz, 262 kHz, 524 kHz, 1.05 MHz, 2.1 MHz, 4.2 MHz). When a 32.768 kHz clock source is available in the system (LSE), the MSI frequency can be trimmed by software down to a $\pm 0.5\%$ accuracy.
- **Auxiliary clock source:** two ultra-low-power clock sources that can be used to drive the LCD controller and the real-time clock:
 - 32.768 kHz low-speed external crystal (LSE)
 - 37 kHz low-speed internal RC (LSI), also used to drive the independent watchdog. The LSI clock can be measured using the high-speed internal RC oscillator for greater precision.
- **RTC and LCD clock sources:** the LSI, LSE or HSE sources can be chosen to clock the RTC and the LCD, whatever the system clock.
- **USB clock source:** the embedded PLL has a dedicated 48 MHz clock output to supply the USB interface.
- **Startup clock:** after reset, the microcontroller restarts by default with an internal 2 MHz clock (MSI). The prescaler ratio and clock source can be changed by the application program as soon as the code execution starts.
- **Clock security system (CSS):** this feature can be enabled by software. If a HSE clock failure occurs, the master clock is automatically switched to HSI and a software interrupt is generated if enabled.
- **Clock-out capability (MCO: microcontroller clock output):** it outputs one of the internal clocks for external use by the application.

Several prescalers allow the configuration of the AHB frequency, each APB (APB1 and APB2) domains. The maximum frequency of the AHB and the APB domains is 32 MHz. See [Figure 2](#) for details on the clock tree.

Figure 2. Clock tree



1. For the USB function to be available, both HSE and PLL must be enabled, with the CPU running at either 24 MHz or 32 MHz.

3.5 Low power real-time clock and backup registers

The real-time clock (RTC) is an independent BCD timer/counter. Dedicated registers contain the sub-second, second, minute, hour (12/24 hour), week day, date, month, year, in BCD (binary-coded decimal) format. Correction for 28, 29 (leap year), 30, and 31 day of the month are made automatically. The RTC provides two programmable alarms and programmable periodic interrupts with wakeup from Stop and Standby modes.

The programmable wakeup time ranges from 120 μ s to 36 hours.

The RTC can be calibrated with an external 512 Hz output, and a digital compensation circuit helps reduce drift due to crystal deviation.

The RTC can also be automatically corrected with a 50/60Hz stable powerline.

The RTC calendar can be updated on the fly down to sub second precision, which enables network system synchronisation.

A time stamp can record an external event occurrence, and generates an interrupt.

There are thirty-two 32-bit backup registers provided to store 128 bytes of user application data. They are cleared in case of tamper detection.

Three pins can be used to detect tamper events. A change on one of these pins can reset backup register and generate an interrupt. To prevent false tamper event, like ESD event, these three tamper inputs can be digitally filtered.

3.6 GPIOs (general-purpose inputs/outputs)

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, and can be individually remapped using dedicated AFIO registers. All GPIOs are high current capable. The alternate function configuration of I/Os can be locked if needed following a specific sequence in order to avoid spurious writing to the I/O registers. The I/O controller is connected to the AHB with a toggling speed of up to 16 MHz.

External interrupt/event controller (EXTI)

The external interrupt/event controller consists of 24 edge detector lines used to generate interrupt/event requests. Each line can be individually configured to select the trigger event (rising edge, falling edge, both) and can be masked independently. A pending register maintains the status of the interrupt requests. The EXTI can detect an external line with a pulse width shorter than the Internal APB2 clock period. Up to 115 GPIOs can be connected to the 16 external interrupt lines. The 8 other lines are connected to RTC, PVD, USB, comparator events or capacitive sensing acquisition.

3.7 Memories

The STM32L15xxD devices have the following features:

- 48 Kbytes of embedded RAM accessed (read/write) at CPU clock speed with 0 wait states. With the enhanced bus matrix, operating the RAM does not lead to any performance penalty during accesses to the system bus (AHB and APB buses).
- The non-volatile memory is divided into three arrays:
 - 384 Kbytes of embedded Flash program memory
 - 12 Kbytes of data EEPROM
 - Options bytes

Flash program and data EEPROM are divided into two banks, this enables writing in one bank while running code or reading data in the other bank.

The options bytes are used to write-protect the memory (with 4 KB granularity) and/or readout-protect the whole memory with the following options:

- Level 0: no readout protection
- Level 1: memory readout protection, the Flash memory cannot be read from or written to if either debug features are connected or boot in RAM is selected
- Level 2: chip readout protection, debug features (Cortex-M3 JTAG and serial wire) and boot in RAM selection disabled (JTAG fuse)

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

3.8 FSMC (flexible static memory controller)

The FSMC supports the following modes: SRAM, PSRAM, NOR/OneNAND Flash.

Functionality overview:

- Up to 26 bit address bus
- Up to 16-bit data bus
- Write FIFO
- Burst mode
- Code execution from external memory
- Four chip select signals
- Up to 32 MHz external access

3.9 DMA (direct memory access)

The flexible 12-channel, general-purpose DMA is able to manage memory-to-memory, peripheral-to-memory and memory-to-peripheral transfers. The DMA controller supports circular buffer management, avoiding the generation of interrupts when the controller reaches the end of the buffer.

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

The DMA can be used with the main peripherals: SPI, I²C, USART, SDIO, general-purpose timers, DAC and ADC.

3.10 LCD (liquid crystal display)

The LCD drives up to 8 common terminals and 44 segment terminals to drive up to 320 pixels.

- Internal step-up converter to guarantee functionality and contrast control irrespective of V_{DD} . This converter can be deactivated, in which case the V_{LCD} pin is used to provide the voltage to the LCD
- Supports static, 1/2, 1/3, 1/4 and 1/8 duty
- Supports static, 1/2, 1/3 and 1/4 bias
- Phase inversion to reduce power consumption and EMI
- Up to 8 pixels can be programmed to blink
- Unneeded segments and common pins can be used as general I/O pins
- LCD RAM can be updated at any time owing to a double-buffer
- The LCD controller can operate in Stop mode

3.11 ADC (analog-to-digital converter)

A 12-bit analog-to-digital converters is embedded into STM32L15xxD devices with up to 40 external channels, performing conversions in single-shot or scan mode. In scan mode, automatic conversion is performed on a selected group of analog inputs with up to 29 external channel in a group.

The ADC can be served by the DMA controller.

An analog watchdog feature allows very precise monitoring of the converted voltage of one, some or all scanned channels. An interrupt is generated when the converted voltage is outside the programmed thresholds.

The events generated by the general-purpose timers (TIMx) can be internally connected to the ADC start triggers, to allow the application to synchronize A/D conversions and timers. An injection mode allows high priority conversions to be done by interrupting a scan mode which runs in as a background task.

The ADC includes a specific low power mode. The converter is able to operate at maximum speed even if the CPU is operating at a very low frequency and has an auto-shutdown function. The ADC's runtime and analog front-end current consumption are thus minimized whatever the MCU operating mode.

3.11.1 Temperature sensor

The temperature sensor (T_{SENSE}) generates a voltage V_{SENSE} that varies linearly with temperature.

The temperature sensor is internally connected to the ADC_IN16 input channel which is used to convert the sensor output voltage into a digital value.

The sensor provides good linearity but it has to be calibrated to obtain good overall 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 temperature changes only.

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

Table 6. Temperature sensor calibration values

| Calibration value name | Description | Memory address |
|------------------------|--|---------------------------|
| TSENSE_CAL1 | TS ADC raw data acquired at temperature of 30 °C, $V_{DDA} = 3\text{ V}$ | 0x1FF8 00FA - 0x1FF8 00FB |
| TSENSE_CAL2 | TS ADC raw data acquired at temperature of 110 °C $V_{DDA} = 3\text{ V}$ | 0x1FF8 00FE - 0x1FF8 00FF |

3.11.2 Internal voltage reference (V_{REFINT})

The internal voltage reference (V_{REFINT}) provides a stable (bandgap) voltage output for the ADC and Comparators. V_{REFINT} is internally connected to the ADC_IN17 input channel. It enables accurate monitoring of the V_{DD} value (when no external voltage, V_{REF+} , is available for ADC). The precise voltage of V_{REFINT} is individually measured for each part by ST during production test and stored in the system memory area. It is accessible in read-only mode.

Table 7. Internal voltage reference measured values

| Calibration value name | Description | Memory address |
|------------------------|--|---------------------------|
| VREFINT_CAL | Raw data acquired at temperature of 30 °C $V_{DDA} = 3\text{ V}$ | 0x1FF8 00F8 - 0x1FF8 00F9 |

3.12 DAC (digital-to-analog converter)

The two 12-bit buffered DAC channels can be used to convert two digital signals into two analog voltage signal outputs. The chosen design structure is composed of integrated resistor strings and an amplifier in non-inverting configuration.

This dual digital Interface supports the following features:

- Two DAC converters: one for each output channel
- Up to 10-bit output
- Left or right data alignment in 12-bit mode
- Synchronized update capability
- Noise-wave generation
- Triangular-wave generation
- Dual DAC channels, independent or simultaneous conversions
- DMA capability for each channel (including the underrun interrupt)
- External triggers for conversion
- Input reference voltage V_{REF+}

Eight DAC trigger inputs are used in the STM32L15xxD. The DAC channels are triggered through the timer update outputs that are also connected to different DMA channels.

3.13 Operational amplifier

The STM32L15xxD embeds three operational amplifiers with external or internal follower routing capability (or even amplifier and filter capability with external components). When one operational amplifier is selected, one external ADC channel is used to enable output measurement.

The operational amplifiers feature:

- Low input bias current
- Low offset voltage
- Low power mode
- Rail-to-rail input

3.14 Ultra-low-power comparators and reference voltage

The STM32L15xxD embeds two comparators sharing the same current bias and reference voltage. The reference voltage can be internal or external (coming from an I/O).

- One comparator with fixed threshold
- One comparator with rail-to-rail inputs, fast or slow mode. The threshold can be one of the following:
 - DAC output
 - External I/O
 - Internal reference voltage (V_{REFINT}) or a submultiple (1/4, 1/2, 3/4)

Both comparators can wake up from Stop mode, and be combined into a window comparator.

The internal reference voltage is available externally via a low power / low current output buffer (driving current capability of 1 μ A typical).

3.15 System configuration controller and routing interface

The system configuration controller provides the capability to remap some alternate functions on different I/O ports.

The highly flexible routing interface allows the application firmware to control the routing of different I/Os to the TIM2, TIM3 and TIM4 timer input captures. It also controls the routing of internal analog signals to ADC1, COMP1 and COMP2 and the internal reference voltage V_{REFINT} .

3.16 Touch sensing

The STM32L15xxD devices provide a simple solution for adding capacitive sensing functionality to any application. These devices offer up to 34 capacitive sensing channels distributed over 11 analog I/O groups. Both software and timer capacitive sensing acquisition modes are supported.

Capacitive sensing technology is able to detect the presence of a finger near a sensor which is protected from direct touch by a dielectric (glass, plastic, ...). The capacitive variation introduced by the finger (or any conductive object) is measured using a proven implementation based on a surface charge transfer acquisition principle. It consists of charging the sensor capacitance and then transferring a part of the accumulated charges into a sampling capacitor until the voltage across this capacitor has reached a specific threshold. The capacitive sensing acquisition only requires few external components to operate.

Reliable touch sensing functionality can be quickly and easily implemented using the free STM32L1xx STMTouch touch sensing firmware library.

3.17 Timers and watchdogs

The ultra-low-power STM32L15xxD devices include seven general-purpose timers, two basic timers, and two watchdog timers.

[Table 8](#) compares the features of the general-purpose and basic timers.

Table 8. Timer feature comparison

| Timer | Counter resolution | Counter type | Prescaler factor | DMA request generation | Capture/compare channels | Complementary outputs |
|------------------|--------------------|-------------------|---------------------------------|------------------------|--------------------------|-----------------------|
| TIM2, TIM3, TIM4 | 16-bit | Up, down, up/down | Any integer between 1 and 65536 | Yes | 4 | No |
| TIM5 | 32-bit | Up, down, up/down | Any integer between 1 and 65536 | Yes | 4 | No |
| TIM9 | 16-bit | Up, down, up/down | Any integer between 1 and 65536 | No | 2 | No |
| TIM10, TIM11 | 16-bit | Up | Any integer between 1 and 65536 | No | 1 | No |
| TIM6, TIM7 | 16-bit | Up | Any integer between 1 and 65536 | Yes | 0 | No |

3.17.1 General-purpose timers (TIM2, TIM3, TIM4, TIM5, TIM9, TIM10 and TIM11)

There are seven synchronizable general-purpose timers embedded in the STM32L15xxD devices (see [Table 8](#) for differences).

TIM2, TIM3, TIM4, TIM5

TIM2, TIM3, TIM4 are based on 16-bit auto-reload up/down counter. TIM5 is based on a 32-bit auto-reload up/down counter. They include a 16-bit prescaler. They feature four independent channels each for input capture/output compare, PWM or one-pulse mode output. This gives up to 16 input captures/output compares/PWMs on the largest packages.

TIM2, TIM3, TIM4, TIM5 general-purpose timers can work together or with the TIM10, TIM11 and TIM9 general-purpose timers via the Timer Link feature for synchronization or event chaining. Their counter can be frozen in debug mode. Any of the general-purpose timers can be used to generate PWM outputs.

TIM2, TIM3, TIM4, TIM5 all have independent DMA request generation.

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

TIM10, TIM11 and TIM9

TIM10 and TIM11 are based on a 16-bit auto-reload upcounter. TIM9 is based on a 16-bit auto-reload up/down counter. They include a 16-bit prescaler. TIM10 and TIM11 feature one independent channel, whereas TIM9 has two independent channels for input capture/output compare, PWM or one-pulse mode output. They can be synchronized with the TIM2, TIM3, TIM4, TIM5 full-featured general-purpose timers.

They can also be used as simple time bases and be clocked by the LSE clock source (32.768 kHz) to provide time bases independent from the main CPU clock.

3.17.2 Basic timers (TIM6 and TIM7)

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

3.17.3 SysTick timer

This timer is dedicated to the OS, but could also be used as a standard downcounter. It is based on a 24-bit downcounter with autoreload capability and a programmable clock source. It features a maskable system interrupt generation when the counter reaches 0.

3.17.4 Independent watchdog (IWDG)

The independent watchdog is based on a 12-bit downcounter and 8-bit prescaler. It is clocked from an independent 37 kHz internal RC and, as it operates independently of 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.

3.17.5 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.

3.18 Communication interfaces

3.18.1 I²C bus

Up to two I²C bus interfaces can operate in multimaster and slave modes. They can support standard and fast modes.

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

They can be served by DMA and they support SM Bus 2.0/PM Bus.

3.18.2 Universal synchronous/asynchronous receiver transmitter (USART)

The three USART and two UART interfaces are able to communicate at speeds of up to 4 Mbit/s. They support IrDA SIR ENDEC, are ISO 7816 compliant and have LIN Master/Slave capability. The three USARTs provide hardware management of the CTS and RTS signals.

All USART/UART interfaces can be served by the DMA controller.

3.18.3 Serial peripheral interface (SPI)

Up to three SPIs are able to communicate at up to 16 Mbits/s in slave and master modes in full-duplex and half-duplex communication modes. The 3-bit prescaler gives 8 master mode frequencies and the frame is configurable to 8 bits or 16 bits. The hardware CRC generation/verification supports basic SD Card/MMC modes.

The SPIs can be served by the DMA controller.

3.18.4 Inter-integrated sound (I²S)

Two standard I2S interfaces (multiplexed with SPI2 and SPI3) are available. They can operate in master or slave mode, and can be configured to operate with a 16-/32-bit resolution as input or output channels. Audio sampling frequencies from 8 kHz up to 192 kHz are supported. When either or both of the I2S interfaces is/are configured in master mode, the master clock can be output to the external DAC/CODEC at 256 times the sampling frequency.

The I2Ss can be served by the DMA controller.

3.18.5 SDIO

An SD/SDIO/MMC host interface is available, that supports MultiMediaCard System Specification Version 4.2 in three different databus modes: 1-bit (default), 4-bit and 8-bit.

The interface allows data transfer at up to 24 MHz in 8-bit mode, and is compliant with the SD Memory Card Specification Version 2.0.

The SDIO Card Specification Version 2.0 is also supported with two different databus modes: 1-bit (default) and 4-bit.

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

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

3.18.6 Universal serial bus (USB)

The STM32L15xxD embeds a USB device peripheral compatible with the USB full-speed 12 Mbit/s. The USB interface implements a full-speed (12 Mbit/s) function interface. It has software-configurable endpoint setting and supports suspend/resume. The dedicated

48 MHz clock is generated from the internal main PLL (the clock source must use a HSE crystal oscillator).

3.19 CRC (cyclic redundancy check) calculation unit

The CRC (cyclic redundancy check) calculation unit is used to get a CRC code from a 32-bit data word and a fixed generator polynomial.

Among other applications, CRC-based techniques are used to verify data transmission or storage integrity. In the scope of the EN/IEC 60335-1 standard, they offer a means of verifying the Flash memory integrity. The CRC calculation unit helps compute a signature of the software during runtime, to be compared with a reference signature generated at link-time and stored at a given memory location.

3.20 Development support

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. The JTAG JTMS and JTCK pins are shared with SWDAT and SWCLK, respectively, and a specific sequence on the JTMS pin is used to switch between JTAG-DP and SW-DP.

The JTAG port can be permanently disabled with a JTAG fuse.

Embedded Trace Macrocell™

The ARM® Embedded Trace Macrocell 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 STM32L15xxD through a small number of ETM pins to an external hardware trace port analyzer (TPA) device. The TPA is connected to a host computer using USB, Ethernet, or any other high-speed channel. Real-time instruction and data flow activity can be recorded and then formatted for display on the host computer running debugger software. TPA hardware is commercially available from common development tool vendors. It operates with third party debugger software tools.

4 Pin descriptions

Figure 3. STM32L15xZD LQFP144 pinout

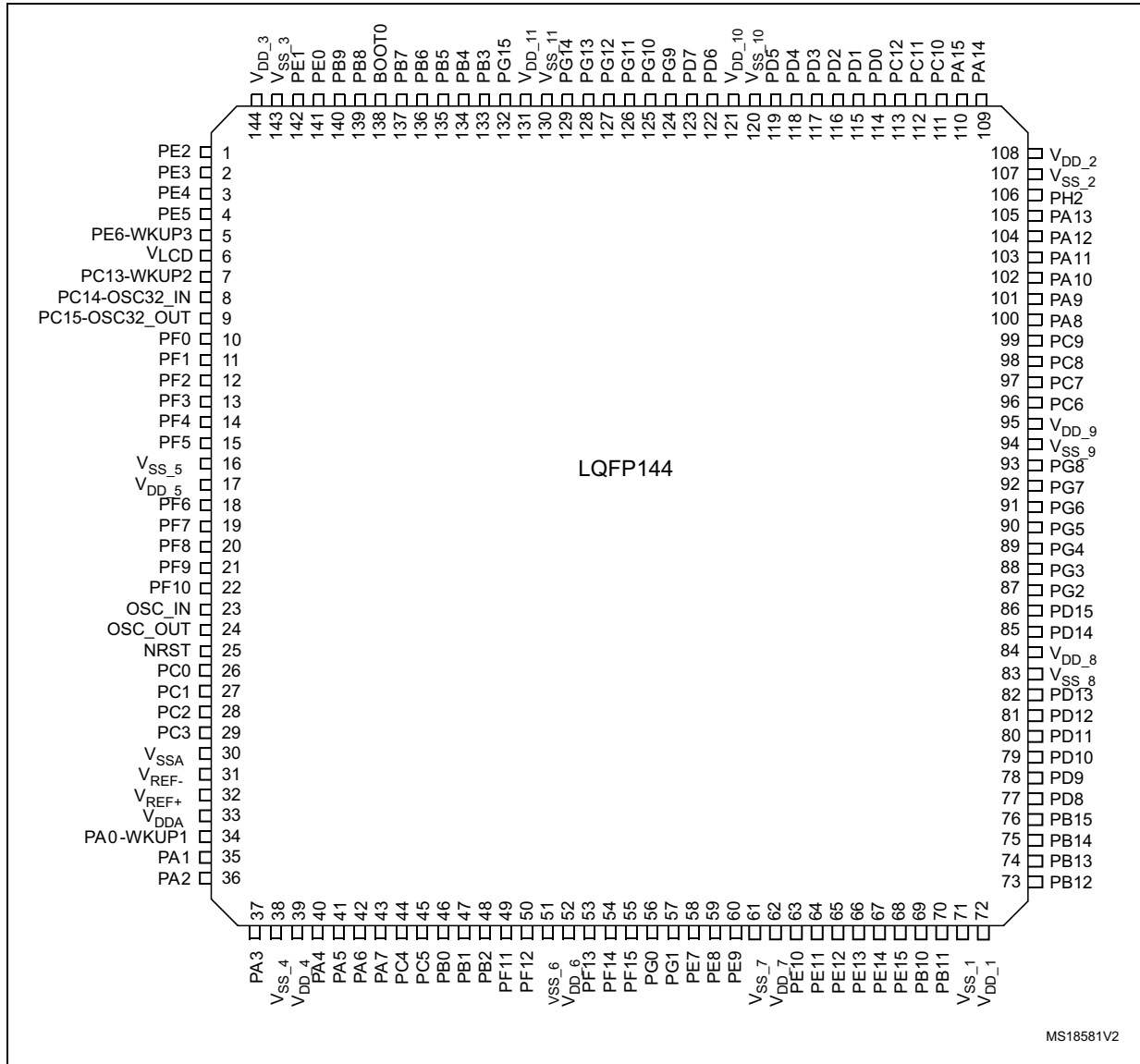
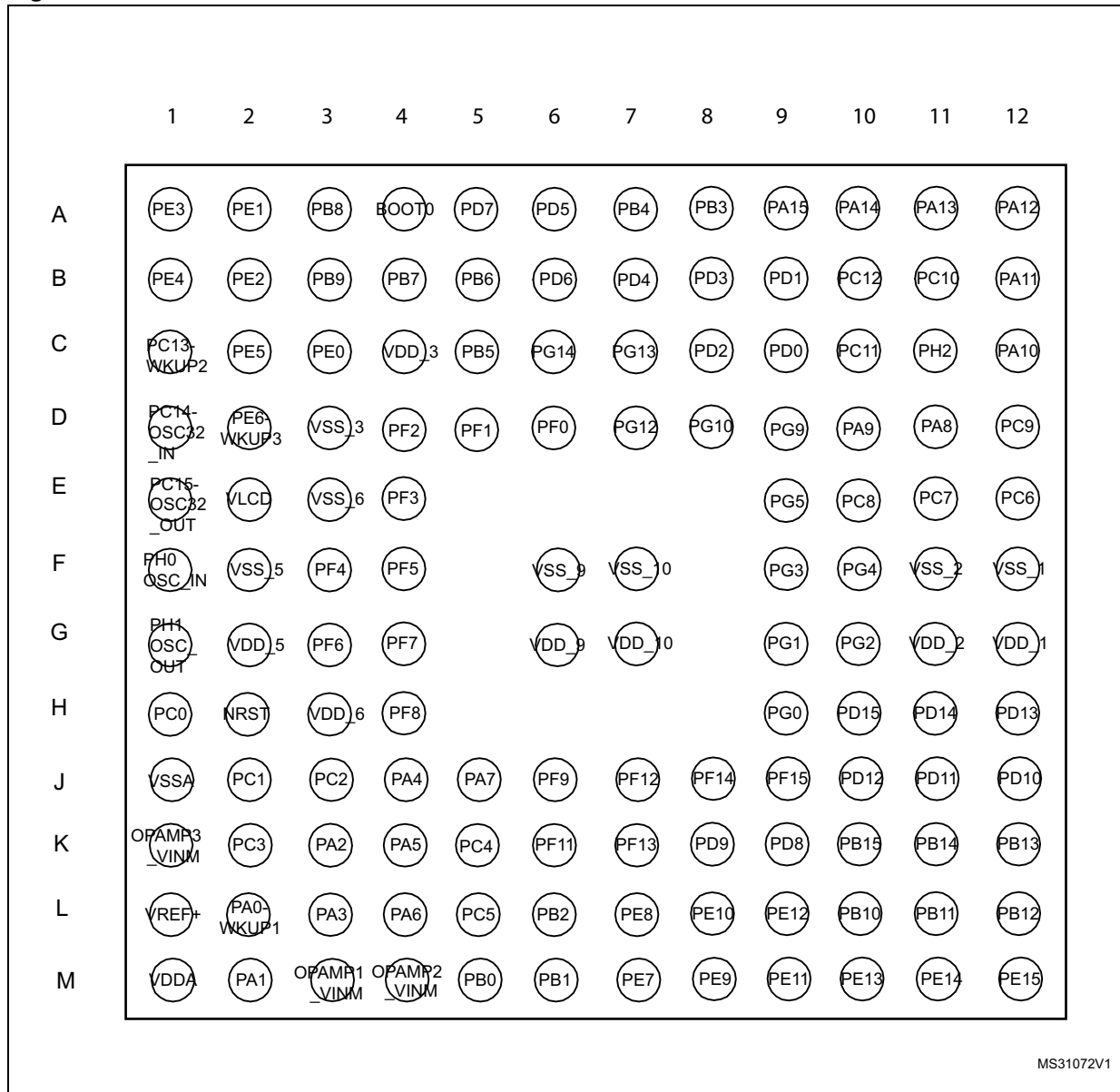


Figure 4. STM32L15xQD UFBGA132 ballout



MS31072V1

1. This figure shows the package top view.

Figure 5. STM32L15xVD LQFP100 pinout

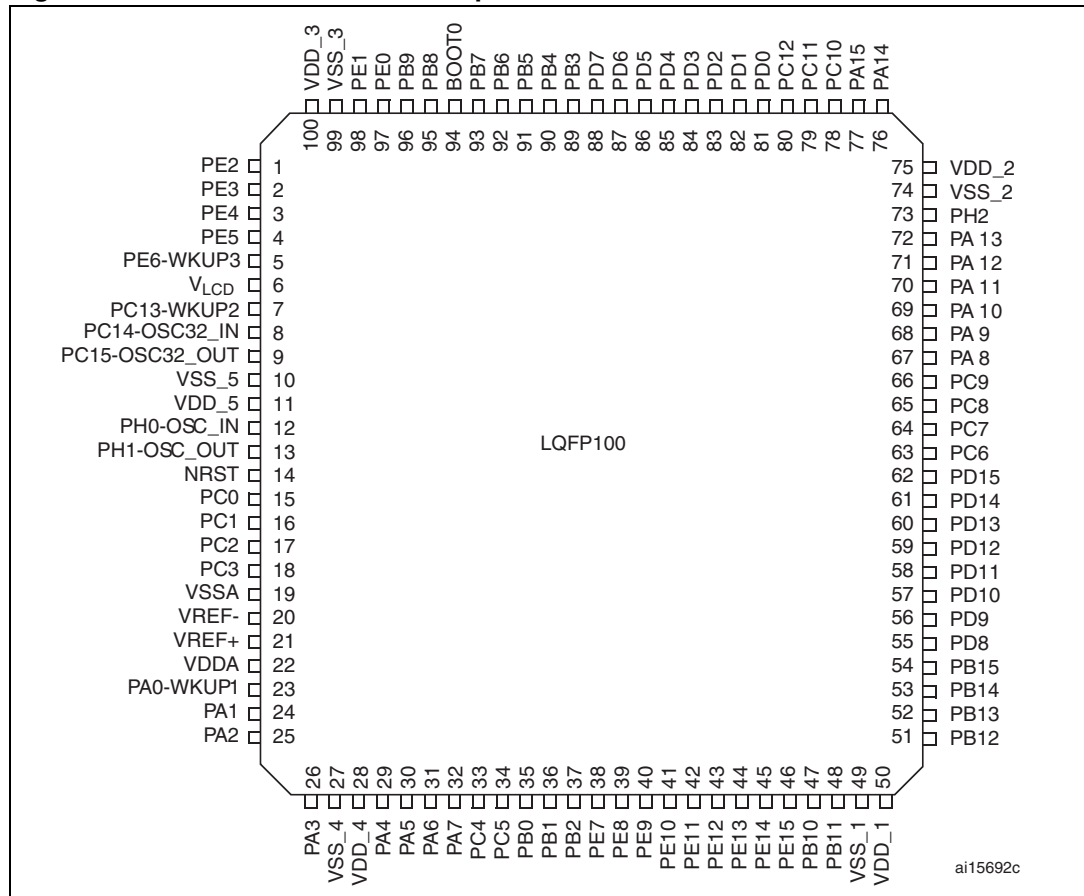


Figure 6. STM32L15xRD LQFP64 pinout

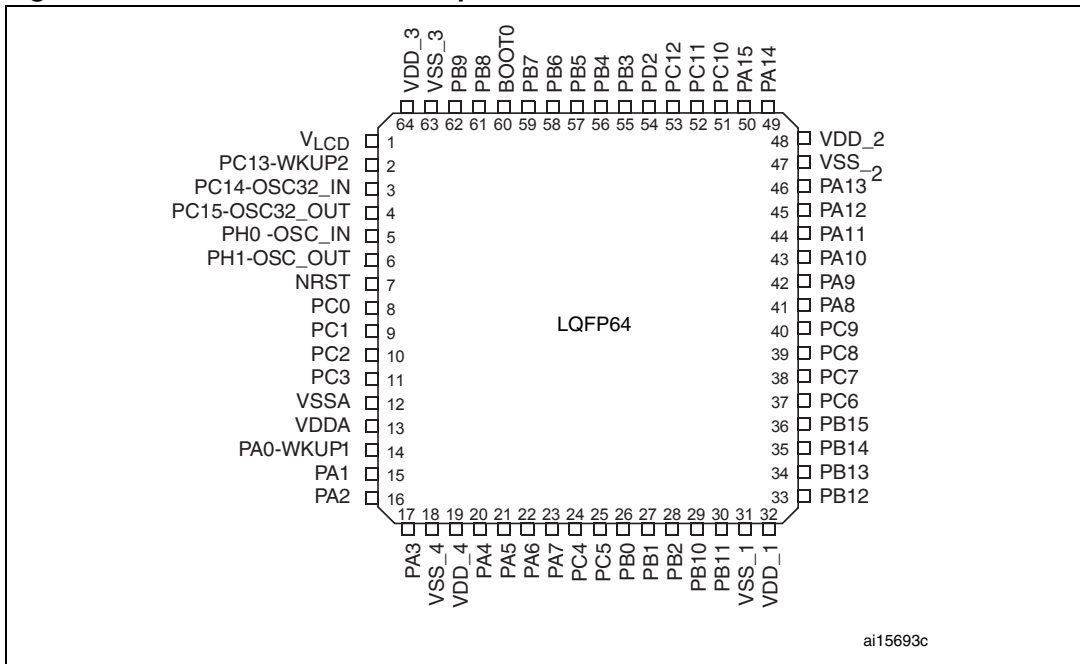
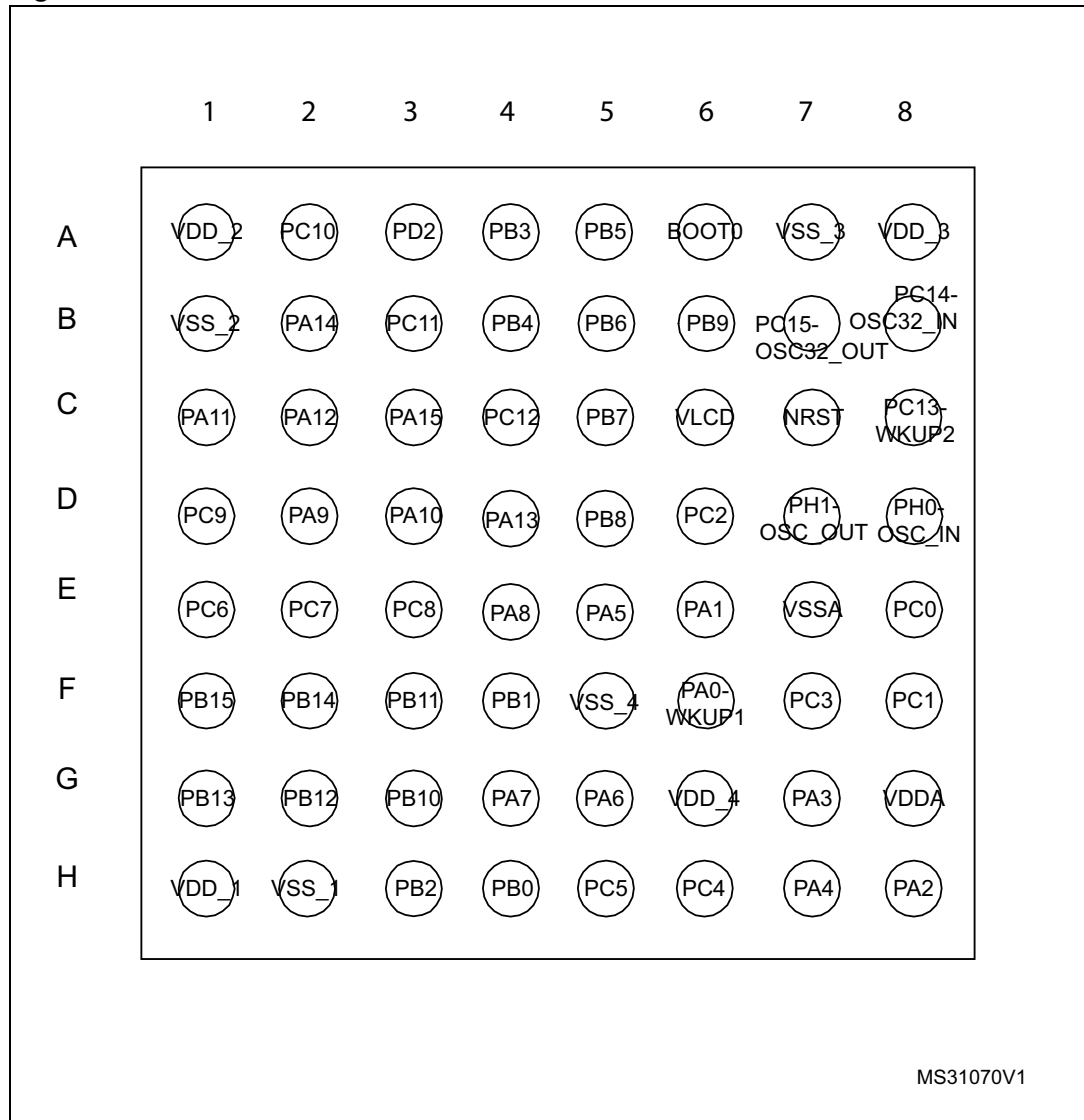


Figure 7. STM32L15xRD WLCSP64 ballout



1. This figure shows the package top view.

Table 9. STM32L15xxD pin definitions

| Pins | | | | | Pin name | Type ⁽¹⁾ | I/O Level ⁽²⁾ | Main function ⁽³⁾ (after reset) | Alternate functions |
|---------|----------|---------|--------|---------|----------------------------------|---------------------|--------------------------|---|--|
| LQFP144 | UFBGA132 | LQFP100 | LQFP64 | WLCSP64 | | | | | |
| 1 | B2 | 1 | - | - | PE2 | I/O | FT | PE2 | TIM3_ETR/LCD_SEG38/FSMC_A23/TRACECLK |
| 2 | A1 | 2 | - | - | PE3 | I/O | FT | PE3 | TIM3_CH1/LCD_SEG39/FSMC_A19/TRACED0 |
| 3 | B1 | 3 | - | - | PE4 | I/O | FT | PE4 | TIM3_CH2/FSMC_A20/TRACED1 |
| 4 | C2 | 4 | - | - | PE5 | I/O | FT | PE5 | TIM9_CH1/FSMC_A21/TRACED2 |
| 5 | D2 | 5 | - | - | PE6- WKUP3 | I/O | FT | PE6 | WKUP3/RTC_TAMP3/TIM9_CH2/TRACED3 |
| 6 | E2 | 6 | 1 | C6 | V _{LCD} ⁽⁴⁾ | S | | V _{LCD} | |
| 7 | C1 | 7 | 2 | C8 | PC13-WKUP2 | I/O | FT | PC13 | WKUP2/RTC_TAMP1/RTC_TS/RTC_OUT |
| 8 | D1 | 8 | 3 | B8 | PC14- OSC32_IN ⁽⁵⁾ | I/O | | PC14 | OSC32_IN |
| 9 | E1 | 9 | 4 | B7 | PC15- OSC32_OUT | I/O | | PC15 | OSC32_OUT |
| 10 | D6 | - | - | - | PF0 | I/O | FT | PF0 | FSMC_A0 |
| 11 | D5 | - | - | - | PF1 | I/O | FT | PF1 | FSMC_A1 |
| 12 | D4 | - | - | - | PF2 | I/O | FT | PF2 | FSMC_A2 |
| 13 | E4 | - | - | - | PF3 | I/O | FT | PF3 | FSMC_A3 |
| 14 | F3 | - | - | - | PF4 | I/O | FT | PF4 | FSMC_A4 |
| 15 | F4 | - | - | - | PF5 | I/O | FT | PF5 | FSMC_A5 |
| 16 | F2 | 10 | - | - | V _{SS_5} | S | | V _{SS_5} | |
| 17 | G2 | 11 | - | - | V _{DD_5} | S | | V _{DD_5} | |
| 18 | G3 | - | - | - | PF6 | I/O | FT | PF6 | TIM5_CH1/TIM5_ETR/ADC_IN27 |
| 19 | G4 | - | - | - | PF7 | I/O | FT | PF7 | TIM5_CH2/ADC_IN28/COMP1_INP |
| 20 | H4 | - | - | - | PF8 | I/O | FT | PF8 | TIM5_CH3/ADC_IN29/COMP1_INP |
| 21 | J6 | - | - | - | PF9 | I/O | FT | PF9 | TIM5_CH4/ADC_IN30/COMP1_INP |
| 22 | - | - | - | - | PF10 | I/O | FT | PF10 | ADC_IN30/COMP1_INP |
| 23 | F1 | 12 | 5 | D8 | PH0-OSC_IN ⁽⁶⁾ | I | | PH0 | OSC_IN |
| 24 | G1 | 13 | 6 | D7 | PH1- OSC_OUT ⁽⁶⁾ | O | | PH1 | OSC_OUT |
| 25 | H2 | 14 | 7 | C7 | NRST | I/O | | NRST | |
| 26 | H1 | 15 | 8 | E8 | PC0 | I/O | FT | PC0 | LCD_SEG18/ADC_IN10/COMP1_INP |
| 27 | J2 | 16 | 9 | F8 | PC1 | I/O | FT | PC1 | LCD_SEG19/ADC_IN11/COMP1_INP /OPAMP3_VINP |
| 28 | - | 17 | 10 | D6 | PC2 | I/O | FT | PC2 | LCD_SEG20/ADC_IN12/COMP1_INP /OPAMP3_VINM |
| - | J3 | - | - | - | PC2 | I/O | FT | PC2 | LCD_SEG20/ADC_IN12/COMP1_INP |
| - | K1 | - | - | - | OPAMP3_VINM | I | | OPAMP3_VINM | |

Table 9. STM32L15xxD pin definitions (continued)

| Pins | | | | | Pin name | Type ⁽¹⁾ | I/O Level ⁽²⁾ | Main function ⁽³⁾ (after reset) | Alternate functions |
|---------|----------|---------|--------|---------|-------------------|---------------------|--------------------------|---|--|
| LQFP144 | UFBGA132 | LQFP100 | LQFP64 | WLCSP64 | | | | | |
| 29 | K2 | 18 | 11 | F7 | PC3 | I/O | | PC3 | LCD_SEG21/ADC_IN13/COMP1_INP /OPAMP3_VOUT |
| 30 | J1 | 19 | 12 | E7 | V _{SSA} | S | | V _{SSA} | |
| 31 | - | 20 | - | - | V _{REF-} | S | | V _{REF-} | |
| 32 | L1 | 21 | - | - | V _{REF+} | S | | V _{REF+} | |
| 33 | M1 | 22 | 13 | G8 | V _{DDA} | S | | V _{DDA} | |
| 34 | L2 | 23 | 14 | F6 | PA0-WKUP1 | I/O | FT | PA0 | WKUP1/RTC_TAMP2/TIM2_CH1_ETR/TIM5_CH1/ USART2_CTS/ADC_IN0/COMP1_INP |
| 35 | M2 | 24 | 15 | E6 | PA1 | I/O | FT | PA1 | TIM2_CH2/TIM5_CH2/ USART2_RTS/LCD_SEG0/ ADC_IN1/COMP1_INP/OPAMP1_VINP |
| 36 | - | 25 | 16 | H8 | PA2 | I/O | FT | PA2 | TIM2_CH3/TIM5_CH3/TIM9_CH1/USART2_TX/ LCD_SEG1/ADC_IN2/ COMP1_INP/OPAMP1_VINM |
| - | K3 | - | - | - | PA2 | I/O | FT | PA2 | TIM2_CH3/TIM5_CH3/TIM9_CH1/USART2_TX/ LCD_SEG1/ADC_IN2/COMP1_INP |
| - | M3 | - | - | - | OPAMP1_VINM | I | | OPAMP1_VINM | |
| 37 | L3 | 26 | 17 | G7 | PA3 | I/O | | PA3 | TIM2_CH4/TIM5_CH4/TIM9_CH2/USART2_RX/ LCD_SEG2/ ADC_IN3/COMP1_INP/OPAMP1_VOUT |
| 38 | - | 27 | 18 | F5 | V _{SS_4} | S | | V _{SS_4} | |
| 39 | - | 28 | 19 | G6 | V _{DD_4} | S | | V _{DD_4} | |
| 40 | J4 | 29 | 20 | H7 | PA4 | I/O | | PA4 | SPI1_NSS/SPI3_NSS/I2S3_WS/USART2_CK/ ADC_IN4/DAC_OUT1/COMP1_INP |
| 41 | K4 | 30 | 21 | E5 | PA5 | I/O | | PA5 | TIM2_CH1_ETR/SPI1_SCK/ADC_IN5/DAC_OUT2/ COMP1_INP |
| 42 | L4 | 31 | 22 | G5 | PA6 | I/O | FT | PA6 | TIM3_CH1/TIM10_CH1/SPI1_MISO/LCD_SEG3/ ADC_IN6/COMP1_INP/OPAMP2_VINP |
| 43 | - | 32 | 23 | G4 | PA7 | I/O | FT | PA7 | TIM3_CH2/TIM11_CH1/ SPI1_MOSI/LCD_SEG4/ ADC_IN7/COMP1_INP/OPAMP2_VINM |
| - | J5 | - | - | - | PA7 | I/O | FT | PA7 | TIM3_CH2/TIM11_CH1/ SPI1_MOSI/LCD_SEG4/ ADC_IN7/COMP1_INP |
| - | M4 | - | - | - | OPAMP2_VINM | I | | OPAMP2_VINM | |
| 44 | K5 | 33 | 24 | H6 | PC4 | I/O | FT | PC4 | LCD_SEG22/ADC_IN14/COMP1_INP |
| 45 | L5 | 34 | 25 | H5 | PC5 | I/O | FT | PC5 | LCD_SEG23/ADC_IN15/COMP1_INP |
| 46 | M5 | 35 | 26 | H4 | PB0 | I/O | | PB0 | TIM3_CH3/LCD_SEG5/ADC_IN8/COMP1_INP/ VREF_OUT/ OPAMP2_VOUT |
| 47 | M6 | 36 | 27 | F4 | PB1 | I/O | FT | PB1 | TIM3_CH4/LCD_SEG6/ADC_IN9/COMP1_INP/ VREF_OUT |
| - | - | 37 | 28 | H3 | PB2 | I/O | FT | PB2/BOOT1 | COMP1_INP |
| 48 | L6 | - | - | | PB2 | I/O | FT | PB2/BOOT1 | ADC_IN0b/COMP1_INP |

Table 9. STM32L15xxD pin definitions (continued)

| Pins | | | | | Pin name | Type ⁽¹⁾ | I/O Level ⁽²⁾ | Main function ⁽³⁾ (after reset) | Alternate functions |
|---------|----------|---------|--------|---------|-------------------|---------------------|--------------------------|---|--|
| LQFP144 | UFBGA132 | LQFP100 | LQFP64 | WLCSP64 | | | | | |
| 49 | K6 | - | - | - | PF11 | I/O | FT | PF11 | ADC_IN1b/COMP1_INP |
| 50 | J7 | - | - | - | PF12 | I/O | FT | PF12 | ADC_IN2b/COMP1_INP/FSMC_A6 |
| 51 | E3 | - | - | - | V _{SS_6} | S | | V _{SS_6} | |
| 52 | H3 | - | - | - | V _{DD_6} | S | | V _{DD_6} | |
| 53 | K7 | - | - | - | PF13 | I/O | FT | PF13 | ADC_IN3b/COMP1_INP/FSMC_A7 |
| 54 | J8 | - | - | - | PF14 | I/O | FT | PF14 | ADC_IN6b/COMP1_INP/FSMC_A8 |
| 55 | J9 | - | - | - | PF15 | I/O | FT | PF15 | ADC_IN7b/COMP1_INP/FSMC_A9 |
| 56 | H9 | - | - | - | PG0 | I/O | FT | PG0 | ADC_IN8b/COMP1_INP/FSMC_A10 |
| 57 | G9 | - | - | - | PG1 | I/O | FT | PG1 | ADC_IN9b/COMP1_INP/FSMC_A11 |
| 58 | M7 | 38 | - | - | PE7 | I/O | | PE7 | FSMC_D4/ADC_IN22/COMP1_INP |
| 59 | L7 | 39 | - | - | PE8 | I/O | | PE8 | FSMC_D5/ADC_IN23/COMP1_INP |
| 60 | M8 | - | - | - | PE9 | I/O | | PE9 | TIM2_CH1_ETR/FSMC_D6/ ADC_IN24/COMP1_INP |
| 61 | - | - | - | - | V _{SS_7} | S | | V _{SS_7} | |
| 62 | - | - | - | - | V _{DD_7} | S | | V _{DD_7} | |
| 63 | L8 | 41 | - | - | PE10 | I/O | | PE10 | TIM2_CH2/ FSMC_D7/ADC_IN25/COMP1_INP |
| 64 | M9 | 42 | - | - | PE11 | I/O | FT | PE11 | TIM2_CH3/FSMC_D8 |
| 65 | L9 | 43 | - | - | PE12 | I/O | FT | PE12 | TIM2_CH4/SPI1_NSS/FSMC_D9 |
| 66 | M10 | 44 | - | - | PE13 | I/O | FT | PE13 | SPI1_SCK/FSMC_D10 |
| 67 | M11 | 45 | - | - | PE14 | I/O | FT | PE14 | SPI1_MISO/FSMC_D11 |
| 68 | M12 | 46 | - | - | PE15 | I/O | FT | PE15 | SPI1_MOSI/FSMC_D12 |
| 69 | L10 | 47 | 29 | G3 | PB10 | I/O | FT | PB10 | TIM2_CH3/I2C2_SCL/USART3_TX/LCD_SEG10 |
| 70 | L11 | 48 | 30 | F3 | PB11 | I/O | FT | PB11 | TIM2_CH4/I2C2_SDA/ USART3_RX/LCD_SEG11 |
| 71 | F12 | 49 | 31 | H2 | V _{SS_1} | S | | V _{SS_1} | |
| 72 | G12 | 50 | 32 | H1 | V _{DD_1} | S | | V _{DD_1} | |
| 73 | L12 | 51 | 33 | G2 | PB12 | I/O | FT | PB12 | TIM10_CH1/I2C2_SMBA/SPI2_NSS/I2S2_WS/ USART3_CK/ LCD_SEG12/ADC_IN18/COMP1_INP |
| 74 | K12 | 52 | 34 | G1 | PB13 | I/O | FT | PB13 | TIM9_CH1/SPI2_SCK/ I2S2_CK/ USART3_CTS/ LCD_SEG13/ADC_IN19/COMP1_INP |
| 75 | K11 | 53 | 35 | F2 | PB14 | I/O | FT | PB14 | TIM9_CH2/SPI2_MISO/ USART3_RTS/LCD_SEG14/ ADC_IN20/COMP1_INP |
| 76 | K10 | 54 | 36 | F1 | PB15 | I/O | FT | PB15 | TIM11_CH1/SPI2_MOSI/I2S2_SD/LCD_SEG15/ ADC_IN21/COMP1_INP/RTC_REFIN |
| 77 | K9 | 55 | - | - | PD8 | I/O | FT | PD8 | USART3_TX/LCD_SEG28/FSMC_D13 |
| 78 | K8 | 56 | - | - | PD9 | I/O | FT | PD9 | USART3_RX/LCD_SEG29/FSMC_D14 |
| 79 | J12 | 57 | - | - | PD10 | I/O | FT | PD10 | USART3_CK/LCD_SEG30/FSMC_D15 |
| 80 | J11 | 58 | - | - | PD11 | I/O | FT | PD11 | USART3_CTS/LCD_SEG31/FSMC_A16 |
| 81 | J10 | 59 | - | - | PD12 | I/O | FT | PD12 | TIM4_CH1 / USART3_RTS/LCD_SEG32/FSMC_A17 |

Table 9. STM32L15xxD pin definitions (continued)

| Pins | | | | | Pin name | Type ⁽¹⁾ | I/O Level ⁽²⁾ | Main function ⁽³⁾ (after reset) | Alternate functions |
|---------|----------|---------|--------|---------|-------------------|---------------------|--------------------------|---|---|
| LQFP144 | UFPGA132 | LQFP100 | LQFP64 | WLCSP64 | | | | | |
| 82 | H12 | 60 | - | - | PD13 | I/O | FT | PD13 | TIM4_CH2/LCD_SEG33/FSMC_A18 |
| 83 | - | - | - | - | V _{SS_8} | S | | V _{SS_8} | |
| 84 | - | - | - | - | V _{DD_8} | S | | V _{DD_8} | |
| 85 | H11 | 61 | - | - | PD14 | I/O | FT | PD14 | TIM4_CH3/LCD_SEG34/FSMC_D0 |
| 86 | H10 | 62 | - | - | PD15 | I/O | FT | PD15 | TIM4_CH4/LCD_SEG35/FSMC_D1 |
| 87 | G10 | - | - | - | PG2 | I/O | FT | PG2 | FSMC_A12/ADC_IN10b/COMP1_INP |
| 88 | F9 | - | - | - | PG3 | I/O | FT | PG3 | FSMC_A13/ADC_IN11b/COMP1_INP |
| 89 | F10 | - | - | - | PG4 | I/O | FT | PG4 | FSMC_A14/ADC_IN12b/COMP1_INP |
| 90 | E9 | - | - | - | PG5 | I/O | FT | PG5 | FSMC_A15 |
| 91 | - | - | - | - | PG6 | I/O | FT | PG6 | |
| 92 | - | - | - | - | PG7 | I/O | FT | PG7 | |
| 93 | - | - | - | - | PG8 | I/O | FT | PG8 | |
| 94 | F6 | - | - | - | V _{SS_9} | S | | V _{SS_9} | |
| 95 | G6 | - | - | - | V _{DD_9} | S | | V _{DD_9} | |
| 96 | E12 | 63 | 37 | E1 | PC6 | I/O | FT | PC6 | TIM3_CH1/I2S2_MCK/LCD_SEG24/SDIO_D6 |
| 97 | E11 | 64 | 38 | E2 | PC7 | I/O | FT | PC7 | TIM3_CH2/I2S3_MCK/LCD_SEG25/SDIO_D7 |
| 98 | E10 | 65 | 39 | E3 | PC8 | I/O | FT | PC8 | TIM3_CH3/LCD_SEG26/SDIO_D0 |
| 99 | D12 | 66 | 40 | D1 | PC9 | I/O | FT | PC9 | TIM3_CH4/LCD_SEG27/SDIO_D1 |
| 100 | D11 | 67 | 41 | E4 | PA8 | I/O | FT | PA8 | USART1_CK/MCO/LCD_COM0 |
| 101 | D10 | 68 | 42 | D2 | PA9 | I/O | FT | PA9 | USART1_TX / LCD_COM1 |
| 102 | C12 | 69 | 43 | D3 | PA10 | I/O | FT | PA10 | USART1_RX / LCD_COM2 |
| 103 | B12 | 70 | 44 | C1 | PA11 | I/O | FT | PA11 | USART1_CTS/ USB_DM/SPI1_MISO |
| 104 | A12 | 71 | 45 | C2 | PA12 | I/O | FT | PA12 | USART1_RTS/USB_DP/SPI1_MOSI |
| 105 | A11 | 72 | 46 | D4 | PA13 | I/O | FT | JTMS-SWDAT | |
| 106 | C11 | 73 | - | - | PH2 | I/O | FT | PH2 | FSMC_A22 |
| 107 | F11 | 74 | 47 | B1 | V _{SS_2} | S | | V _{SS_2} | |
| 108 | G11 | 75 | 48 | A1 | V _{DD_2} | S | | V _{DD_2} | |
| 109 | A10 | 76 | 49 | B2 | PA14 | I/O | FT | JTCK-SWCLK | |
| 110 | A9 | 77 | 50 | C3 | PA15 | I/O | FT | JTDI | TIM2_CH1_ETR/ SPI1_NSS/SPI3_NSS/ I2S3_WS/LCD_SEG17 |
| 111 | B11 | 78 | 51 | A2 | PC10 | I/O | FT | PC10 | SPI3_SCK/I2S3_CK/USART3_TX/ UART4_TX/ LCD_SEG28/LCD_SEG40/LCD_COM4/SDIO_D2 |
| 112 | C10 | 79 | 52 | B3 | PC11 | I/O | FT | PC11 | SPI3_MISO/USART3_RX/UART4_RX/ LCD_SEG29/LCD_SEG41/LCD_COM5/SDIO_D3 |
| 113 | B10 | 80 | 53 | C4 | PC12 | I/O | FT | PC12 | SPI3_MOSI/I2S3_SD/USART3_CK/ UART5_TX/ LCD_SEG30/ LCD_SEG42/LCD_COM6/SDIO_CK |

Table 9. STM32L15xxD pin definitions (continued)

| Pins | | | | | Pin name | Type ⁽¹⁾ | I/O Level ⁽²⁾ | Main function ⁽³⁾ (after reset) | Alternate functions |
|---------|----------|---------|--------|---------|--------------------|---------------------|--------------------------|---|--|
| LQFP144 | UFPGA132 | LQFP100 | LQFP64 | WLCSP64 | | | | | |
| 114 | C9 | 81 | - | - | PD0 | I/O | FT | PD0 | TIM9_CH1/SPI2_NSS/I2S2_WS/ FSMC_D2 |
| 115 | B9 | 82 | - | - | PD1 | I/O | FT | PD1 | SPI2_SCK/I2S2_CK/FSMC_D3 |
| 116 | C8 | 83 | 54 | A3 | PD2 | I/O | FT | PD2 | TIM3_ETR/UART5_RX/LCD_SEG31/LCD_SEG43/ LCD_COM7/SDIO_CMD |
| 117 | B8 | 84 | - | - | PD3 | I/O | FT | PD3 | SPI2_MISO/USART2_CTS/FSMC_CLK |
| 118 | B7 | 85 | - | - | PD4 | I/O | FT | PD4 | SPI2_MOSI/I2S2_SD/USART2_RTS/FSMC_NOE |
| 119 | A6 | 86 | - | - | PD5 | I/O | FT | PD5 | USART2_TX/FSMC_NWE |
| 120 | F7 | - | - | - | V _{SS_10} | S | | V _{SS_10} | |
| 121 | G7 | - | - | - | V _{DD_10} | S | | V _{DD_10} | |
| 122 | B6 | 87 | - | - | PD6 | I/O | FT | PD6 | USART2_RX/FSMC_NWAIT |
| 123 | A5 | 88 | - | - | PD7 | I/O | FT | PD7 | TIM9_CH2/USART2_CK/FSMC_NE1 |
| 124 | D9 | - | - | - | PG9 | I/O | FT | PG9 | FSMC_NE2 |
| 125 | D8 | - | - | - | PG10 | I/O | FT | PG10 | FSMC_NE3 |
| 126 | - | - | - | - | PG11 | I/O | FT | PG11 | |
| 127 | D7 | - | - | - | PG12 | I/O | FT | PG12 | FSMC_NE4 |
| 128 | C7 | - | - | - | PG13 | I/O | FT | PG13 | FSMC_A24 |
| 129 | C6 | - | - | - | PG14 | I/O | FT | PG14 | FSMC_A25 |
| 130 | - | - | - | - | V _{SS_11} | S | | V _{SS_11} | |
| 131 | - | - | - | - | V _{DD_11} | S | | V _{DD_11} | |
| 132 | - | - | - | - | PG15 | I/O | FT | PG15 | |
| 133 | A8 | 89 | 55 | A4 | PB3 | I/O | FT | JTDO | TIM2_CH2/SPI1_SCK/SPI3_SCK/ I2S3_CK/ LCD_SEG7/COMP2_INM |
| 134 | A7 | 90 | 56 | B4 | PB4 | I/O | FT | NJTRST | TIM3_CH1/ SPI1_MISO/SPI3_MISO/LCD_SEG8/ COMP2_INP |
| 135 | C5 | 91 | 57 | A5 | PB5 | I/O | FT | PB5 | TIM3_CH2 /I2C1_SMBA/SPI1_MOSI/SPI3_MOSI/ I2S3_SD/LCD_SEG9/COMP2_INP |
| 136 | B5 | 92 | 58 | B5 | PB6 | I/O | FT | PB6 | TIM4_CH1/I2C1_SCL/USART1_TX/COMP2_INP |
| 137 | B4 | 93 | 59 | C5 | PB7 | I/O | FT | PB7 | TIM4_CH2/I2C1_SDA/USART1_RX/PVD_IN/ FSMC_NADV/ COMP2_INP |
| 138 | A4 | 94 | 60 | A6 | BOOT0 | I | | BOOT0 | |
| 139 | A3 | 95 | 61 | D5 | PB8 | I/O | FT | PB8 | TIM4_CH3/TIM10_CH1/I2C1_SCL/LCD_SEG16/ SDIO_D4 |
| 140 | B3 | 96 | 62 | B6 | PB9 | I/O | FT | PB9 | TIM4_CH4/ TIM11_CH1/I2C1_SDA/LCD_COM3/ SDIO_D5 |
| 141 | C3 | 97 | - | - | PE0 | I/O | FT | PE0 | TIM4_ETR/TIM10_CH1/LCD_SEG36 /FSMC_NBL0 |
| 142 | A2 | 98 | - | - | PE1 | I/O | FT | PE1 | TIM11_CH1/LCD_SEG37/FSMC_NBL1 |
| 143 | D3 | 99 | 63 | A7 | V _{SS_3} | S | | V _{SS_3} | |
| 144 | C4 | 100 | 64 | A8 | V _{DD_3} | S | | V _{DD_3} | |

1. I = input, O = output, S = supply.
2. FT = 5 V tolerant.
3. Function availability depends on the chosen device.
4. Applicable to STM32L152xD devices only. In STM32L151xD devices, this pin should be connected to V_{DD} .
5. The PC14 and PC15 I/Os are only configured as OSC32_IN/OSC32_OUT when the LSE oscillator is ON (by setting the LSEON bit in the RCC_CSR register). The LSE oscillator pins OSC32_IN/OSC32_OUT can be used as general-purpose PH0/PH1 I/Os, respectively, when the LSE oscillator is off (after reset, the LSE oscillator is off). The LSE has priority over the GPIO function. For more details, refer to Using the OSC32_IN/OSC32_OUT pins as GPIO PC14/PC15 port pins section in the STM32L151xx, STM32L152xx and STM32L162xx reference manual (RM0038).
6. The PH0 and PH1 I/Os are only configured as OSC_IN/OSC_OUT when the HSE oscillator is ON (by setting the HSEON bit in the RCC_CR register). The HSE oscillator pins OSC_IN/OSC_OUT can be used as general-purpose PH0/PH1 I/Os, respectively, when the HSE oscillator is off (after reset, the HSE oscillator is off). The HSE has priority over the GPIO function.



Table 10. Alternate function input/output

| Port name | Digital alternate function number | | | | | | | | | | | | | | | |
|-----------|-----------------------------------|--------------|----------|------------|--------|--------|-----------|------------------|-----------|-----|--------|-----------|--------|--------|----------------------------|-----------|
| | AFIO0 | AFIO1 | AFIO2 | AFIO3 | AFIO4 | AFIO5 | AFIO6 | AFIO7 | AFIO8 | .. | AFIO10 | AFIO11 | AFIO12 | .. | AFIO14 | AFIO15 |
| | Alternate function | | | | | | | | | | | | | | | |
| | SYSTEM | TIM2 | TIM3/4/5 | TIM9/10/11 | I2C1/2 | SPI1/2 | SPI3 | USART1/2/3 | UART4/5 | USB | LCD | FSMC/SDIO | CPRI | SYSTEM | | |
| BOOT0 | BOOT0 | | | | | | | | | | | | | | | EVENT OUT |
| NRST | NRST | | | | | | | | | | | | | | | |
| PA0-WKUP1 | WKUP1/TAMPER2 | TIM2_CH1_ETR | TIM5_CH1 | | | | | USART2_CTS | | | | | | | COMP1_INP/TIMx_IC1_0/G1IO1 | EVENT OUT |
| PA1 | | TIM2_CH2 | TIM5_CH2 | | | | | USART2_RTS | | | | SEG0 | | | COMP1_INP/TIMx_IC2_0/G1IO2 | EVENT OUT |
| PA2 | | TIM2_CH3 | TIM5_CH3 | TIM9_CH1 | | | | USART2_TX | | | | SEG1 | | | COMP1_INP/TIMx_IC3_0/G1IO3 | EVENT OUT |
| PA3 | | TIM2_CH4 | TIM5_CH4 | TIM9_CH2 | | | | USART2_RX | | | | SEG2 | | | COMP1_INP/TIMx_IC4_0/G1IO4 | EVENT OUT |
| PA4 | | | | | | | SPI1_NSS | SPI3_NSS I2S3_WS | USART2_CK | | | | | | COMP1_INP/TIMx_IC1_1 | EVENT OUT |
| PA5 | | TIM2_CH1_ETR | | | | | SPI1_SCK | | | | | | | | COMP1_INP/TIMx_IC2_1 | EVENT OUT |
| PA6 | | | TIM3_CH1 | TIM10_CH1 | | | SPI1_MISO | | | | | SEG3 | | | COMP1_INP/TIMx_IC3_1/G2IO1 | EVENT OUT |
| PA7 | | | TIM3_CH2 | TIM11_CH1 | | | SPI1_MOSI | | | | | SEG4 | | | COMP1_INP/TIMx_IC4_1/G2IO2 | EVENT OUT |
| PA8 | MCO | | | | | | | USART1_CK | | | | COM0 | | | TIMx_IC1_2/G4IO1 | EVENT OUT |
| PA9 | | | | | | | | USART1_TX | | | | COM1 | | | TIMx_IC2_2/G4IO2 | EVENT OUT |
| PA10 | | | | | | | | USART1_RX | | | | COM2 | | | TIMx_IC3_2/G4IO3 | EVENT OUT |



Table 10. Alternate function input/output (continued)

| Port name | Digital alternate function number | | | | | | | | | | | | | | | |
|-----------|-----------------------------------|--------------|----------|------------|------------|-----------|----------------------|------------|---------|-------|--------|-----------|---------|----------------------|---------------|--------------|
| | AFIO0 | AFIO1 | AFIO2 | AFIO3 | AFIO4 | AFIO5 | AFIO6 | AFIO7 | AFIO8 | .. | AFIO10 | AFIO11 | AFIO12 | .. | AFIO14 | AFIO15 |
| | Alternate function | | | | | | | | | | | | | | | |
| | SYSTEM | TIM2 | TIM3/4/5 | TIM9/10/11 | I2C1/2 | SPI1/2 | SPI3 | USART1/2/3 | UART4/5 | USB | LCD | FSMC/SDIO | | CPRI | SYSTEM | |
| PA11 | | | | | | SPI1_MISO | | USART1_CTS | | USBDM | | | | TIMx_IC4_2/ G4IO4 | EVENT OUT | |
| PA12 | | | | | | SPI1_MOSI | | USART1_RTS | | USBDP | | | | TIMx_IC1_3/ | EVENT OUT | |
| PA13 | JTMS-SWDIO | | | | | | | | | | | | | TIMx_IC2_3/ G5IO1 | EVENT OUT | |
| PA14 | JTCK-SWCLK | | | | | | | | | | | | | TIMx_IC3_3/ G5IO2 | EVENT TOUT | |
| PA15 | JTDI | TIM2_CH1_ETR | | | | SPI1_NSS | SPI3_NSS I2S3_WS | | | | | SEG17 | | TIMx_IC4_3/ G5IO3 | EVENT TOUT | |
| PB0 | | | TIM3_CH3 | | | | | | | | | SEG5 | | COMP1_INP/ G3IO1 | EVENT TOUT | |
| PB1 | | | TIM3_CH4 | | | | | | | | | SEG6 | | COMP1_INP/ G3IO2 | EVENT OUT | |
| PB2 | BOOT1 | | | | | | | | | | | | | COMP1_INP/ G3IO3 | EVENT OUT | |
| PB3 | JTDO | TIM2_CH2 | | | | SPI1_SCK | SPI3_SCK I2S3_CK | | | | | SEG7 | | | | EVENT OUT |
| PB4 | JTRST | | TIM3_CH1 | | | SPI1_MISO | SPI3_MISO | | | | | SEG8 | | G6IO1 | EVENT OUT | |
| PB5 | | | TIM3_CH2 | | I2C1_ SMBA | SPI1_MOSI | SPI3_MOSI I2S3_SD | | | | | SEG9 | | G6IO2 | EVENT OUT | |
| PB6 | | | TIM4_CH1 | | I2C1_SCL | | | USART1_TX | | | | | | G6IO3 | EVENT OUT | |
| PB7 | | | TIM4_CH2 | | I2C1_SDA | | | USART1_RX | | | | NADV | | G6IO4 | EVENT OUT | |
| PB8 | | | TIM4_CH3 | TIM10_ CH1 | I2C1_SCL | | | | | | | SEG16 | SDIO_D4 | | EVENT OUT | |
| PB9 | | | TIM4_CH4 | TIM11_ CH1 | I2C1_SDA | | | | | | | COM3 | SDIO_D5 | | EVENT OUT | |



Table 10. Alternate function input/output (continued)

| Port name | Digital alternate function number | | | | | | | | | | | | | | | |
|-----------|-----------------------------------|----------|----------|------------|-----------|----------------------|-------|------------|---------|-----|--------|-----------|---------|------------------------------------|--------|-----------|
| | AFIO0 | AFIO1 | AFIO2 | AFIO3 | AFIO4 | AFIO5 | AFIO6 | AFIO7 | AFIO8 | .. | AFIO10 | AFIO11 | AFIO12 | .. | AFIO14 | AFIO15 |
| | Alternate function | | | | | | | | | | | | | | | |
| | SYSTEM | TIM2 | TIM3/4/5 | TIM9/10/11 | I2C1/2 | SPI1/2 | SPI3 | USART1/2/3 | UART4/5 | USB | LCD | FSMC/SDIO | | CPRI | SYSTEM | |
| PB10 | | TIM2_CH3 | | | I2C2_SCL | | | USART3_TX | | | | SEG10 | | | | EVENT OUT |
| PB11 | | TIM2_CH4 | | | I2C2_SDA | | | USART3_RX | | | | SEG11 | | | | EVENT OUT |
| PB12 | | | | TIM10_CH1 | I2C2_SMBA | SPI2_NSS I2S2_WS | | USART3_CK | | | | SEG12 | | COMP1_INP/ G7IO1 | | EVENT OUT |
| PB13 | | | | TIM9_CH1 | | SPI2_SCK I2S2_CK | | USART3_CTS | | | | SEG13 | | COMP1_INP/ G7IO2 | | EVENT OUT |
| PB14 | | | | TIM9_CH2 | | SPI2_MISO | | USART3_RTS | | | | SEG14 | | COMP1_INP/ G7IO3 | | EVENT OUT |
| PB15 | RTC_REFIN | | | TIM11_CH1 | | SPI2_MOSI I2S2_SD | | | | | | SEG15 | | COMP1_INP/ G7IO4 | | EVENT OUT |
| PC0 | | | | | | | | | | | | SEG18 | | COMP1_INP/ TIMx_IC1_4/ G8IO1 | | EVENT OUT |
| PC1 | | | | | | | | | | | | SEG19 | | COMP1_INP/ TIMx_IC2_4/ G8IO2 | | EVENT OUT |
| PC2 | | | | | | | | | | | | SEG20 | | COMP1_INP/ TIMx_IC3_4/ G8IO3 | | EVENT OUT |
| PC3 | | | | | | | | | | | | SEG21 | | COMP1_INP/ TIMx_IC4_4/ G8IO4 | | EVENT OUT |
| PC4 | | | | | | | | | | | | SEG22 | | COMP1_INP/ TIMx_IC1_5/ G9IO1 | | EVENT OUT |
| PC5 | | | | | | | | | | | | SEG23 | | COMP1_INP/ TIMx_IC2_5/ G9IO2 | | EVENT OUT |
| PC6 | | | TIM3_CH1 | | | I2S2_MCK | | | | | | SEG24 | SDIO_D6 | TIMx_IC3_5/ G10IO1 | | EVENT OUT |



Table 10. Alternate function input/output (continued)

| Port name | Digital alternate function number | | | | | | | | | | | | | | | |
|-----------------------|---|-------|----------|----------------|--------|---------------------|----------------------|------------|----------|-----|--------------------------|---------------|--------|-----------------------|--------------|--------|
| | AFIO0 | AFIO1 | AFIO2 | AFIO3 | AFIO4 | AFIO5 | AFIO6 | AFIO7 | AFIO8 | .. | AFIO10 | AFIO11 | AFIO12 | .. | AFIO14 | AFIO15 |
| | Alternate function | | | | | | | | | | | | | | | |
| | SYSTEM | TIM2 | TIM3/4/5 | TIM9/ 10/11 | I2C1/2 | SPI1/2 | SPI3 | USART1/2/3 | UART4/5 | USB | LCD | FSMC/ SDIO | | CPRI | SYSTEM | |
| PC7 | | | TIM3_CH2 | | | | I2S3_MCK | | | | SEG25 | SDIO_D7 | | TIMx_IC4_5/ G10IO2 | EVENT OUT | |
| PC8 | | | TIM3_CH3 | | | | | | | | SEG26 | SDIO_D0 | | TIMx_IC1_6/ G10IO3 | EVENT OUT | |
| PC9 | | | TIM3_CH4 | | | | | | | | SEG27 | SDIO_D1 | | TIMx_IC2_6/ G10IO4 | EVENT OUT | |
| PC10 | | | | | | | SPI3_SCK I2S3_CK | USART3_TX | UART4_TX | | COM4/ SEG28/ SEG40 | SDIO_D2 | | TIMx_IC3_6/ G5IO4 | EVENT OUT | |
| PC11 | | | | | | | SPI3_MISO | USART3_RX | UART4_RX | | COM5/ SEG29 /SEG41 | SDIO_D3 | | TIMx_IC4_6 | EVENT OUT | |
| PC12 | | | | | | | SPI3_MOSI I2S3_SD | USART3_CK | UART5_TX | | COM6/ SEG30/ SEG42 | SDIO_CK | | TIMx_IC1_7 | EVENT OUT | |
| PC13- WKUP2 | WKUP2/ TAMPER1/ TIMESTAMP/ ALARM_OUT/ 512Hz | | | | | | | | | | | | | TIMx_IC2_7 | EVENT OUT | |
| PC14 OSC32_ IN | OSC32_IN | | | | | | | | | | | | | TIMx_IC3_7 | EVENT OUT | |
| PC15 OSC32_ OUT | OSC32_OUT | | | | | | | | | | | | | TIMx_IC4_7 | EVENT OUT | |
| PD0 | | | | TIM9_CH1 | | SPI2_NSS I2S2_WS | | | | | | D2 /DA2 | | TIMx_IC1_8 | EVENT OUT | |
| PD1 | | | | | | SPI2_SCK I2S2_CK | | | | | | D3 /DA3 | | TIMx_IC2_8 | EVENT OUT | |
| PD2 | | | TIM3_ETR | | | | | | UART5_RX | | COM7/ SEG31/ SEG43 | SDIO_ CMD | | TIMx_IC3_8 | EVENT OUT | |



Table 10. Alternate function input/output (continued)

| Port name | Digital alternate function number | | | | | | | | | | | | | | | |
|-----------|-----------------------------------|-------|----------|------------|--------|----------------------|-------|------------|---------|-----|--------|-----------|--------|-------------|-----------|--------|
| | AFIO0 | AFIO1 | AFIO2 | AFIO3 | AFIO4 | AFIO5 | AFIO6 | AFIO7 | AFIO8 | .. | AFIO10 | AFIO11 | AFIO12 | .. | AFIO14 | AFIO15 |
| | Alternate function | | | | | | | | | | | | | | | |
| | SYSTEM | TIM2 | TIM3/4/5 | TIM9/10/11 | I2C1/2 | SPI1/2 | SPI3 | USART1/2/3 | UART4/5 | USB | LCD | FSMC/SDIO | | CPRI | SYSTEM | |
| PD3 | | | | | | SPI2_MISO | | USART2_CTS | | | | CLK | | TIMx_IC4_8 | EVENT OUT | |
| PD4 | | | | | | SPI2_MOSI I2S2_SD | | USART2_RTS | | | | NOE | | TIMx_IC1_9 | EVENT OUT | |
| PD5 | | | | | | | | USART2_TX | | | | NWE | | TIMx_IC2_9 | EVENT OUT | |
| PD6 | | | | | | | | USART2_RX | | | | NWAIT | | TIMx_IC3_9 | EVENT OUT | |
| PD7 | | | | TIM9_CH2 | | | | USART2_CK | | | | NE1 | | TIMx_IC4_9 | EVENT OUT | |
| PD8 | | | | | | | | USART3_TX | | | SEG28 | D13/DA13 | | TIMx_IC1_10 | EVENT OUT | |
| PD9 | | | | | | | | USART3_RX | | | SEG29 | D14/DA14 | | TIMx_IC2_10 | EVENT OUT | |
| PD10 | | | | | | | | USART3_CK | | | SEG30 | D15/DA15 | | TIMx_IC3_10 | EVENT OUT | |
| PD11 | | | | | | | | USART3_CTS | | | SEG31 | A16 | | TIMx_IC4_10 | EVENT OUT | |
| PD12 | | | TIM4_CH1 | | | | | USART3_RTS | | | SEG32 | A17 | | TIMx_IC1_11 | EVENT OUT | |
| PD13 | | | TIM4_CH2 | | | | | | | | SEG33 | A18 | | TIMx_IC2_11 | EVENT OUT | |
| PD14 | | | TIM4_CH3 | | | | | | | | SEG34 | D0/DA0 | | TIMx_IC3_11 | EVENT OUT | |
| PD15 | | | TIM4_CH4 | | | | | | | | SEG35 | D1/DA1 | | TIMx_IC4_11 | EVENT OUT | |
| PE0 | | | TIM4_ETR | TIM10_CH1 | | | | | | | SEG36 | NBL0 | | TIMx_IC1_12 | EVENT OUT | |
| PE1 | | | | TIM11_CH1 | | | | | | | SEG37 | NBL1 | | TIMx_IC2_12 | EVENT OUT | |



Table 10. Alternate function input/output (continued)

| Port name | Digital alternate function number | | | | | | | | | | | | | | | |
|-----------|-----------------------------------|--------------|----------|------------|--------|-----------|-------|------------|---------|-----|--------|-----------|--------|---------------------------|-----------|--------|
| | AFIO0 | AFIO1 | AFIO2 | AFIO3 | AFIO4 | AFIO5 | AFIO6 | AFIO7 | AFIO8 | .. | AFIO10 | AFIO11 | AFIO12 | .. | AFIO14 | AFIO15 |
| | Alternate function | | | | | | | | | | | | | | | |
| | SYSTEM | TIM2 | TIM3/4/5 | TIM9/10/11 | I2C1/2 | SPI1/2 | SPI3 | USART1/2/3 | UART4/5 | USB | LCD | FSMC/SDIO | | CPRI | SYSTEM | |
| PE2 | TRACECK | | TIM3_ETR | | | | | | | | SEG 38 | A23 | | TIMx_IC3_12 | EVENT OUT | |
| PE3 | TRACED0 | | TIM3_CH1 | | | | | | | | SEG 39 | A19 | | TIMx_IC4_12 | EVENT OUT | |
| PE4 | TRACED1 | | TIM3_CH2 | | | | | | | | | A20 | | TIMx_IC1_13 | EVENT OUT | |
| PE5 | TRACED2 | | | TIM9_CH1 | | | | | | | | A21 | | TIMx_IC2_13 | EVENT OUT | |
| PE6-WKUP3 | WKUP3/ TAMPER3 / TRACED3 | | | TIM9_CH2 | | | | | | | | | | TIMx_IC3_13 | EVENT OUT | |
| PE7 | | | | | | | | | | | | D4/DA4 | | COMP1_INP/ TIMx_IC4_13 | EVENT OUT | |
| PE8 | | | | | | | | | | | | D5/DA5 | | COMP1_INP/ TIMx_IC1_14 | EVENT OUT | |
| PE9 | | TIM2_CH1_ETR | | | | | | | | | | D6/DA6 | | COMP1_INP/ TIMx_IC2_14 | EVENT OUT | |
| PE10 | | TIM2_CH2 | | | | | | | | | | D7/DA7 | | COMP1_INP/ TIMx_IC3_14 | EVENT OUT | |
| PE11 | | TIM2_CH3 | | | | | | | | | | D8/DA8 | | TIMx_IC4_14 | EVENT OUT | |
| PE12 | | TIM2_CH4 | | | | SPI1_NSS | | | | | | D9/DA9 | | TIMx_IC1_15 | EVENT OUT | |
| PE13 | | | | | | SPI1_SCK | | | | | | D10/DA10 | | TIMx_IC2_15 | EVENT OUT | |
| PE14 | | | | | | SPI1_MISO | | | | | | D11/DA11 | | TIMx_IC3_15 | EVENT OUT | |
| PE15 | | | | | | SPI1_MOSI | | | | | | D12/DA12 | | TIMx_IC4_15 | EVENT OUT | |
| PF0 | | | | | | | | | | | | A0 | | | EVENT OUT | |



Table 10. Alternate function input/output (continued)

| Port name | Digital alternate function number | | | | | | | | | | | | | | | |
|-----------|-----------------------------------|-------|----------|------------|--------|--------|-------|------------|---------|-----|--------|-----------|--------|------------------|-----------|--------|
| | AFIO0 | AFIO1 | AFIO2 | AFIO3 | AFIO4 | AFIO5 | AFIO6 | AFIO7 | AFIO8 | .. | AFIO10 | AFIO11 | AFIO12 | .. | AFIO14 | AFIO15 |
| | Alternate function | | | | | | | | | | | | | | | |
| | SYSTEM | TIM2 | TIM3/4/5 | TIM9/10/11 | I2C1/2 | SPI1/2 | SPI3 | USART1/2/3 | UART4/5 | USB | LCD | FSMC/SDIO | | CPRI | SYSTEM | |
| PF1 | | | | | | | | | | | | A1 | | | EVENT OUT | |
| PF2 | | | | | | | | | | | | A2 | | | EVENT OUT | |
| PF3 | | | | | | | | | | | | A3 | | | EVENT OUT | |
| PF4 | | | | | | | | | | | | A4 | | | EVENT OUT | |
| PF5 | | | | | | | | | | | | A5 | | | EVENT OUT | |
| PF6 | | | TIM5_ETR | | | | | | | | | | | COMP1_INP G11IO1 | EVENT OUT | |
| PF7 | | | TIM5_CH2 | | | | | | | | | | | COMP1_INP G11IO2 | EVENT OUT | |
| PF8 | | | TIM5_CH3 | | | | | | | | | | | COMP1_INP G11IO3 | EVENT OUT | |
| PF9 | | | TIM5_CH4 | | | | | | | | | | | COMP1_INP G11IO4 | EVENT OUT | |
| PF10 | | | | | | | | | | | | | | COMP1_INP G11IO5 | EVENT OUT | |
| PF11 | | | | | | | | | | | | | | COMP1_INP G3IO4 | EVENT OUT | |
| PF12 | | | | | | | | | | | | A6 | G3IO5 | | EVENT OUT | |
| PF13 | | | | | | | | | | | | A7 | G9IO3 | | EVENT OUT | |
| PF14 | | | | | | | | | | | | A8 | G9IO4 | | EVENT OUT | |
| PF15 | | | | | | | | | | | | A9 | G2IO3 | | EVENT OUT | |



Table 10. Alternate function input/output (continued)

| Port name | Digital alternate function number | | | | | | | | | | | | | | | |
|-----------|-----------------------------------|-------|----------|------------|--------|--------|-------|------------|---------|-----|--------|-----------|--------|-------|-----------|--------|
| | AFIO0 | AFIO1 | AFIO2 | AFIO3 | AFIO4 | AFIO5 | AFIO6 | AFIO7 | AFIO8 | .. | AFIO10 | AFIO11 | AFIO12 | .. | AFIO14 | AFIO15 |
| | Alternate function | | | | | | | | | | | | | | | |
| | SYSTEM | TIM2 | TIM3/4/5 | TIM9/10/11 | I2C1/2 | SPI1/2 | SPI3 | USART1/2/3 | UART4/5 | USB | LCD | FSMC/SDIO | | CPRI | SYSTEM | |
| PG0 | | | | | | | | | | | | A10 | | G2IO4 | EVENT OUT | |
| PG1 | | | | | | | | | | | | A11 | | G2IO5 | EVENT OUT | |
| PG2 | | | | | | | | | | | | A12 | | G7IO5 | EVENT OUT | |
| PG3 | | | | | | | | | | | | A13 | | G7IO6 | EVENT OUT | |
| PG4 | | | | | | | | | | | | A14 | | G7IO7 | EVENT OUT | |
| PG5 | | | | | | | | | | | | A15 | | | EVENT OUT | |
| PG6 | | | | | | | | | | | | | | | EVENT OUT | |
| PG7 | | | | | | | | | | | | | | | EVENT OUT | |
| PG8 | | | | | | | | | | | | | | | EVENT OUT | |
| PG9 | | | | | | | | | | | | NE2 | | | EVENT OUT | |
| PG10 | | | | | | | | | | | | NE3 | | | EVENT OUT | |
| PG11 | | | | | | | | | | | | | | | EVENT OUT | |
| PG12 | | | | | | | | | | | | NE4 | | | EVENT OUT | |
| PG13 | | | | | | | | | | | | A24 | | | EVENT OUT | |
| PG14 | | | | | | | | | | | | A25 | | | EVENT OUT | |

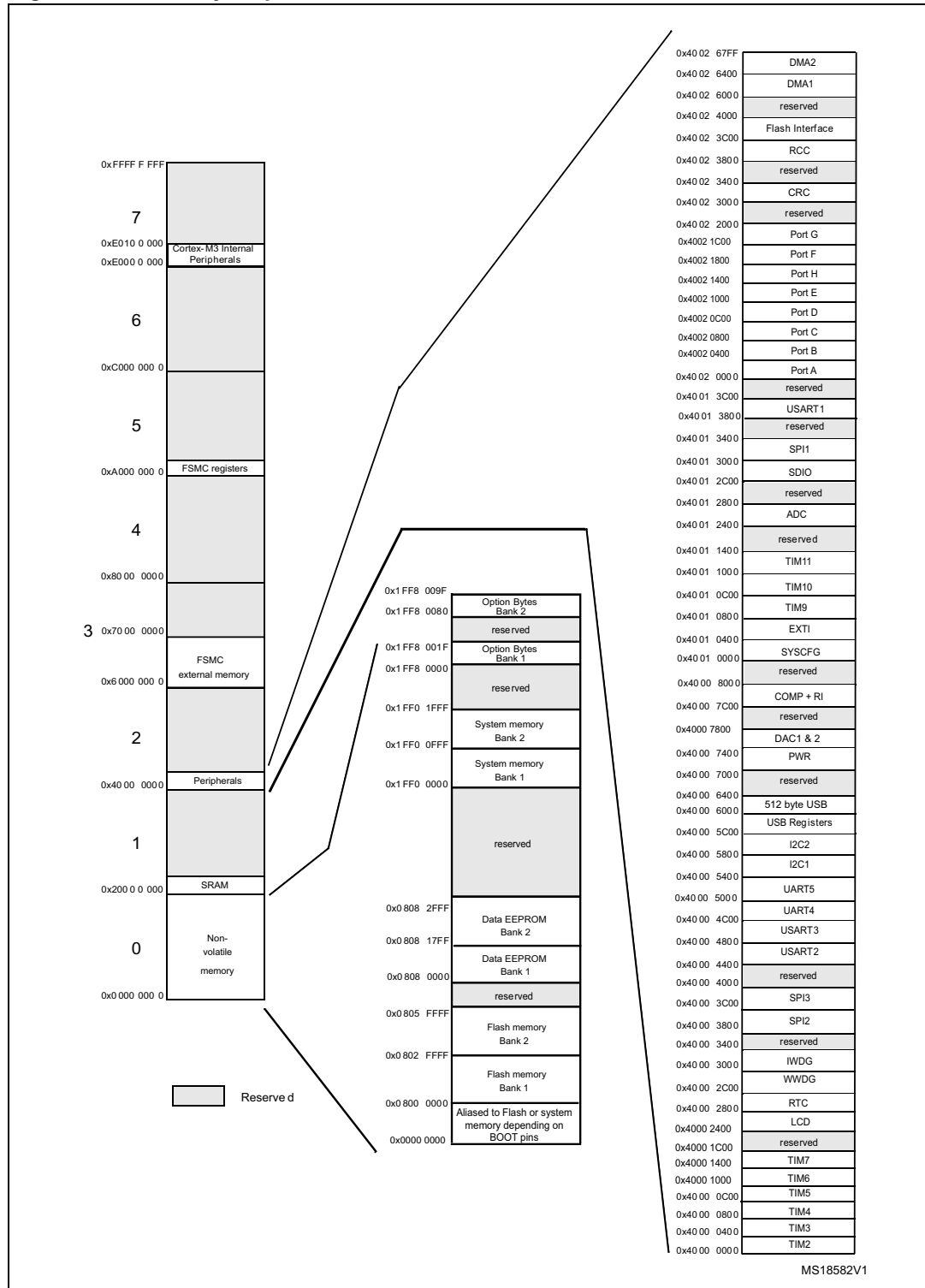


Table 10. Alternate function input/output (continued)

| Port name | Digital alternate function number | | | | | | | | | | | | | | | |
|------------|-----------------------------------|-------|----------|------------|--------|--------|-------|------------|---------|-----|--------|-----------|--------|------|--------|-----------|
| | AFIO0 | AFIO1 | AFIO2 | AFIO3 | AFIO4 | AFIO5 | AFIO6 | AFIO7 | AFIO8 | .. | AFIO10 | AFIO11 | AFIO12 | .. | AFIO14 | AFIO15 |
| | Alternate function | | | | | | | | | | | | | | | |
| | SYSTEM | TIM2 | TIM3/4/5 | TIM9/10/11 | I2C1/2 | SPI1/2 | SPI3 | USART1/2/3 | UART4/5 | USB | LCD | FSMC/SDIO | | CPRI | SYSTEM | |
| PG15 | | | | | | | | | | | | | | | | EVENT OUT |
| PH0OSC_IN | OSC_IN | | | | | | | | | | | | | | | |
| PH1OSC_OUT | OSC_OUT | | | | | | | | | | | | | | | |
| PH2 | | | | | | | | | | | | A22 | | | | |

5 Memory mapping

Figure 8. Memory map



6 Electrical characteristics

6.1 Parameter conditions

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

6.1.1 Minimum and maximum values

Unless otherwise specified the minimum and maximum values are guaranteed in the worst conditions of ambient temperature, supply voltage and frequencies by tests in production on 100% of the devices with an ambient temperature at $T_A = 25\text{ }^\circ\text{C}$ and $T_A = T_{A\text{max}}$ (given by the selected temperature range).

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

6.1.2 Typical values

Unless otherwise specified, typical data are based on $T_A = 25\text{ }^\circ\text{C}$, $V_{DD} = 3.6\text{ V}$ (for the $1.65\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ voltage range). They are given only as design guidelines and are not tested.

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

6.1.3 Typical curves

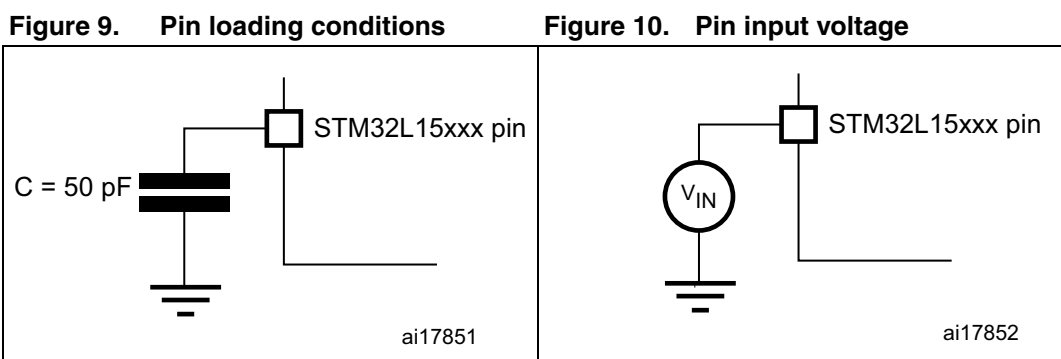
Unless otherwise specified, all typical curves are given only as design guidelines and are not tested.

6.1.4 Loading capacitor

The loading conditions used for pin parameter measurement are shown in [Figure 9](#).

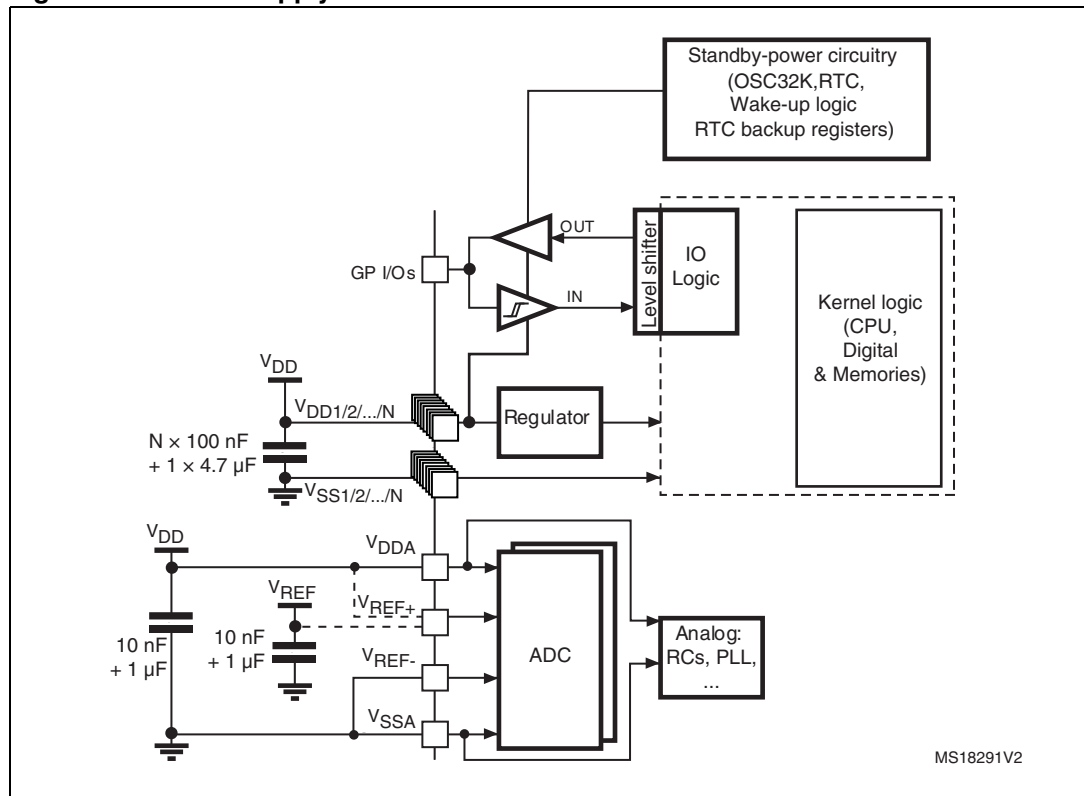
6.1.5 Pin input voltage

The input voltage measurement on a pin of the device is described in [Figure 10](#).



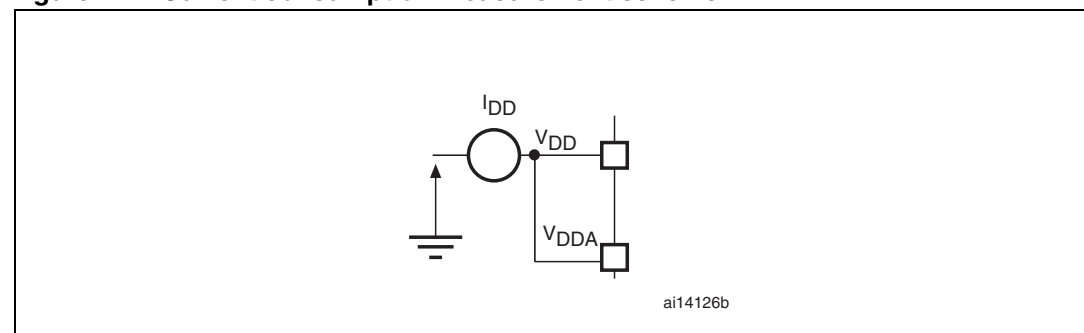
6.1.6 Power supply scheme

Figure 11. Power supply scheme



6.1.7 Current consumption measurement

Figure 12. Current consumption measurement scheme



6.2 Absolute maximum ratings

Stresses above the absolute maximum ratings listed in [Table 11: Voltage characteristics](#), [Table 12: Current characteristics](#), and [Table 13: Thermal characteristics](#) may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these conditions is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

Table 11. Voltage characteristics

| Symbol | Ratings | Min | Max | Unit |
|-------------------------|---|------------------------------------|--------------|------|
| $V_{DD}-V_{SS}$ | External main supply voltage (including V_{DDA} and V_{DD}) ⁽¹⁾ | -0.3 | 4.0 | V |
| V_{IN} ⁽²⁾ | Input voltage on five-volt tolerant pin | $V_{SS} - 0.3$ | $V_{DD}+4.0$ | |
| | Input voltage on any other pin | $V_{SS} - 0.3$ | 4.0 | |
| $ \Delta V_{DDX} $ | Variations between different V_{DD} power pins | | 50 | mV |
| $ V_{SSX} - V_{SS} $ | Variations between all different ground pins | | 50 | |
| $V_{ESD(HBM)}$ | Electrostatic discharge voltage (human body model) | see Section 6.3.11 | | |

1. All main power (V_{DD} , V_{DDA}) and ground (V_{SS} , V_{SSA}) pins must always be connected to the external power supply, in the permitted range.
2. V_{IN} maximum must always be respected. Refer to [Table 12](#) for maximum allowed injected current values.

Table 12. Current characteristics

| Symbol | Ratings | Max. | Unit |
|-------------------------------|---|--------|------|
| I_{VDD} | Total current into V_{DD}/V_{DDA} power lines (source) ⁽¹⁾ | 80 | mA |
| I_{VSS} | Total current out of V_{SS} ground lines (sink) ⁽¹⁾ | 80 | |
| I_{IO} | Output current sunk by any I/O and control pin | 25 | |
| | Output current sourced by any I/O and control pin | - 25 | |
| $I_{INJ(PIN)}$ ⁽²⁾ | Injected current on five-volt tolerant I/O ⁽³⁾ | +0 /-5 | |
| | Injected current on any other pin ⁽⁴⁾ | ± 5 | |
| $\Sigma I_{INJ(PIN)}$ | Total injected current (sum of all I/O and control pins) ⁽⁵⁾ | ± 25 | |

1. All main power (V_{DD} , V_{DDA}) and ground (V_{SS} , V_{SSA}) pins must always be connected to the external power supply, in the permitted range.
2. Negative injection disturbs the analog performance of the device. See note in [Section 6.3.19](#).
3. Positive current injection is not possible on these I/Os. A negative injection is induced by $V_{IN} < V_{SS}$. $I_{INJ(PIN)}$ must never be exceeded. Refer to [Table 11](#) for maximum allowed input voltage values.
4. A positive injection is induced by $V_{IN} > V_{DD}$ while a negative injection is induced by $V_{IN} < V_{SS}$. $I_{INJ(PIN)}$ must never be exceeded. Refer to [Table 11: Voltage characteristics](#) for the maximum allowed input voltage values.
5. When several inputs are submitted to a current injection, the maximum $\Sigma I_{INJ(PIN)}$ is the absolute sum of the positive and negative injected currents (instantaneous values).

Table 13. Thermal characteristics

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

6.3 Operating conditions

6.3.1 General operating conditions

Table 14. General operating conditions

| Symbol | Parameter | Conditions | Min | Max | Unit |
|-----------------|---|---|------|-----|------|
| f_{HCLK} | Internal AHB clock frequency | | 0 | 32 | MHz |
| f_{PCLK1} | Internal APB1 clock frequency | | 0 | 32 | |
| f_{PCLK2} | Internal APB2 clock frequency | | 0 | 32 | |
| V_{DD} | Standard operating voltage | BOR detector disabled | 1.65 | 3.6 | V |
| | | BOR detector enabled, at power on | 1.8 | 3.6 | |
| | | BOR detector disabled, after power on | 1.65 | 3.6 | |
| $V_{DDA}^{(1)}$ | Analog operating voltage (ADC and DAC not used) | Must be the same voltage as $V_{DD}^{(2)}$ | 1.65 | 3.6 | V |
| | Analog operating voltage (ADC or DAC used) | | 1.8 | 3.6 | |
| P_D | Power dissipation at $T_A = 85\text{ °C}^{(3)}$ | UFPGA132 package | | 333 | mW |
| T_A | Temperature range | Maximum power dissipation | -40 | 85 | °C |
| | | Low power dissipation ⁽⁴⁾ | -40 | 105 | |
| T_J | Junction temperature range | $-40\text{ °C} \leq T_A \leq 105\text{ °C}$ | -40 | 105 | °C |

- When the ADC is used, refer to [Table 64: ADC characteristics](#).
- It is recommended to power V_{DD} and V_{DDA} from the same source. A maximum difference of 300 mV between V_{DD} and V_{DDA} can be tolerated during power-up and operation.
- If T_A is lower, higher P_D values are allowed as long as T_J does not exceed T_J max (see [Table 78: Thermal characteristics on page 134](#)).
- In low power dissipation state, T_A can be extended to this range as long as T_J does not exceed T_J max (see [Table 78: Thermal characteristics on page 134](#)).

6.3.2 Embedded reset and power control block characteristics

The parameters given in the following table are derived from the tests performed under the ambient temperature condition summarized in [Table 14](#).

Table 15. Embedded reset and power control block characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|----------------------|---|--|------|------|----------|-----------|
| $t_{VDD}^{(1)}$ | V_{DD} rise time rate | BOR detector enabled | 0 | | ∞ | $\mu s/V$ |
| | | BOR detector disabled | 0 | | 1000 | |
| | V_{DD} fall time rate | BOR detector enabled | 20 | | ∞ | |
| | | BOR detector disabled | 0 | | 1000 | |
| $T_{RSTTEMPO}^{(1)}$ | Reset temporization | V_{DD} rising, BOR enabled | | 2 | 3.3 | ms |
| | | V_{DD} rising, BOR disabled ⁽²⁾ | 0.4 | 0.7 | 1.6 | |
| $V_{POR/PDR}$ | Power on/power down reset threshold | Falling edge | 1 | 1.5 | 1.65 | V |
| | | Rising edge | 1.3 | 1.5 | 1.65 | |
| V_{BOR0} | Brown-out reset threshold 0 | Falling edge | 1.67 | 1.7 | 1.74 | |
| | | Rising edge | 1.69 | 1.76 | 1.8 | |
| V_{BOR1} | Brown-out reset threshold 1 | Falling edge | 1.87 | 1.93 | 1.97 | |
| | | Rising edge | 1.96 | 2.03 | 2.07 | |
| V_{BOR2} | Brown-out reset threshold 2 | Falling edge | 2.22 | 2.30 | 2.35 | |
| | | Rising edge | 2.31 | 2.41 | 2.44 | |
| V_{BOR3} | Brown-out reset threshold 3 | Falling edge | 2.45 | 2.55 | 2.60 | |
| | | Rising edge | 2.54 | 2.66 | 2.7 | |
| V_{BOR4} | Brown-out reset threshold 4 | Falling edge | 2.68 | 2.8 | 2.85 | |
| | | Rising edge | 2.78 | 2.9 | 2.95 | |
| V_{PVD0} | Programmable voltage detector threshold 0 | Falling edge | 1.8 | 1.85 | 1.88 | |
| | | Rising edge | 1.88 | 1.94 | 1.99 | |
| V_{PVD1} | PVD threshold 1 | Falling edge | 1.98 | 2.04 | 2.09 | |
| | | Rising edge | 2.08 | 2.14 | 2.18 | |
| V_{PVD2} | PVD threshold 2 | Falling edge | 2.20 | 2.24 | 2.28 | |
| | | Rising edge | 2.28 | 2.34 | 2.38 | |
| V_{PVD3} | PVD threshold 3 | Falling edge | 2.39 | 2.44 | 2.48 | |
| | | Rising edge | 2.47 | 2.54 | 2.58 | |
| V_{PVD4} | PVD threshold 4 | Falling edge | 2.57 | 2.64 | 2.69 | |
| | | Rising edge | 2.68 | 2.74 | 2.79 | |
| V_{PVD5} | PVD threshold 5 | Falling edge | 2.77 | 2.83 | 2.88 | |
| | | Rising edge | 2.87 | 2.94 | 2.99 | |
| V_{PVD6} | PVD threshold 6 | Falling edge | 2.97 | 3.05 | 3.09 | |
| | | Rising edge | 3.08 | 3.15 | 3.20 | |

Table 15. Embedded reset and power control block characteristics (continued)

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|-------------------|--------------------|---|-----|-----|-----|------|
| V_{hyst} | Hysteresis voltage | BOR0 threshold | - | 40 | - | mV |
| | | All BOR and PVD thresholds excepting BOR0 | - | 100 | - | |

1. Guaranteed by characterisation, not tested in production.
2. Valid for device version without BOR at power up. Please see option "D" in Ordering information scheme for more details.

6.3.3 Embedded internal reference voltage

The parameters given in [Table 16](#) are based on characterization results, unless otherwise specified.

Table 16. Embedded internal reference voltage

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---------------------------|--|--|-------|-------|---------|-------------------|
| $V_{REFINT_out}^{(1)}$ | Internal reference voltage | $-40\text{ °C} < T_J < +105\text{ °C}$ | 1.202 | 1.224 | 1.242 | V |
| I_{REFINT} | Internal reference current consumption | | - | 1.4 | 2.3 | μA |
| $T_{VREFINT}$ | Internal reference startup time | | - | 2 | 3 | ms |
| V_{VREF_MEAS} | V_{DDA} and V_{REF+} voltage during V_{REFINT} factory measure | | 2.99 | 3 | 3.01 | V |
| A_{VREF_MEAS} | Accuracy of factory-measured V_{REF} value ⁽²⁾ | Including uncertainties due to ADC and V_{DDA}/V_{REF+} values | - | - | ± 5 | mV |
| $T_{Coeff}^{(3)}$ | Temperature coefficient | $-40\text{ °C} < T_J < +105\text{ °C}$ | - | 20 | 50 | ppm/°C |
| | | $0\text{ °C} < T_J < +50\text{ °C}$ | - | - | 20 | |
| $A_{Coeff}^{(3)}$ | Long-term stability | 1000 hours, $T = 25\text{ °C}$ | - | - | 1000 | ppm |
| $VDDCoeff^{(3)}$ | Voltage coefficient | $3.0\text{ V} < V_{DDA} < 3.6\text{ V}$ | - | - | 2000 | ppm/V |
| $T_{S_vrefint}^{(3)(4)}$ | ADC sampling time when reading the internal reference voltage | | - | 5 | 10 | μs |
| $T_{ADC_BUF}^{(3)}$ | Startup time of reference voltage buffer for ADC | | - | - | 10 | μs |
| $I_{BUF_ADC}^{(3)}$ | Consumption of reference voltage buffer for ADC | | - | 13.5 | 25 | μA |
| $I_{VREF_OUT}^{(3)}$ | $VREF_OUT$ output current ⁽⁵⁾ | | - | - | 1 | μA |
| $C_{VREF_OUT}^{(3)}$ | $VREF_OUT$ output load | | - | - | 50 | pF |
| $I_{LPBUF}^{(3)}$ | Consumption of reference voltage buffer for $VREF_OUT$ and COMP | | - | 730 | 1200 | nA |
| $V_{REFINT_DIV1}^{(3)}$ | 1/4 reference voltage | | 24 | 25 | 26 | % V_{REFINT} |
| $V_{REFINT_DIV2}^{(3)}$ | 1/2 reference voltage | | 49 | 50 | 51 | |
| $V_{REFINT_DIV3}^{(3)}$ | 3/4 reference voltage | | 74 | 75 | 76 | |

1. Tested in production.
2. The internal V_{REF} value is individually measured in production and stored in dedicated EEPROM bytes.
3. Guaranteed by design, not tested in production.
4. Shortest sampling time can be determined in the application by multiple iterations.
5. To guarantee less than 1% $VREF_OUT$ deviation.

6.3.4 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. The current consumption is measured as described in [Figure 12: Current consumption measurement scheme](#).

All Run-mode current consumption measurements given in this section are performed with a reduced code that gives a consumption equivalent to Dhrystone 2.1 code.

Maximum current consumption

The MCU is placed under the following conditions:

- $V_{DD} = 3.6\text{ V}$
- All I/O pins are in input mode with a static value at V_{DD} or V_{SS} (no load)
- All peripherals are disabled except when explicitly mentioned
- The Flash memory access time is adjusted depending on f_{HCLK} frequency and voltage range
- Prefetch and 64-bit access are enabled in configurations with 1 wait state

The parameters given in [Table 17](#), [Table 14](#) and [Table 15](#) are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in [Table 14](#).

Table 17. Current consumption in Run mode, code with data processing running from Flash

| Symbol | Parameter | Conditions | f_{HCLK} | Typ | Max ⁽¹⁾ | | | Unit | | |
|------------------------------|--|---|--|--|--------------------|-------|--------|-------|---------------|-------------|
| | | | | | 55 °C | 85 °C | 105 °C | | | |
| I_{DD} (Run from Flash) | Supply current in Run mode, code executed from Flash | $f_{HSE} = f_{HCLK}$ up to 16 MHz included, $f_{HSE} = f_{HCLK}/2$ above 16 MHz (PLL ON) ⁽²⁾ | Range 3, $V_{CORE}=1.2\text{ V}$, $VOS[1:0] = 11$ | 1 MHz | 360 | 500 | 500 | 500 | μA | |
| | | | | 2 MHz | 620 | 750 | 750 | 750 | | |
| | | | | 4 MHz | 1070 | 1200 | 1200 | 1200 | | |
| | | | | Range 2, $V_{CORE}=1.5\text{ V}$, $VOS[1:0] = 10$ | 4 MHz | 1.30 | 1.6 | 1.6 | 1.6 | mA |
| | | | | 8 MHz | 2.4 | 2.9 | 2.9 | 2.9 | | |
| | | | | 16 MHz | 4.6 | 5.2 | 5.2 | 5.2 | | |
| | | | Range 1, $V_{CORE}=1.8\text{ V}$, $VOS[1:0] = 01$ | 8 MHz | 2.9 | 3.5 | 3.5 | 3.5 | | |
| | | | 16 MHz | 5.7 | 6.5 | 6.5 | 6.5 | | | |
| | | | 32 MHz | 10.4 | 12 | 12 | 12 | | | |
| | | | HSI clock source (16 MHz) | Range 2, $V_{CORE}=1.5\text{ V}$, $VOS[1:0] = 10$ | 16 MHz | 4.5 | 5.2 | 5.2 | 5.2 | |
| | | | | Range 1, $V_{CORE}=1.8\text{ V}$, $VOS[1:0] = 01$ | 32 MHz | 10.9 | 12.3 | 12.3 | 12.3 | |
| | | | MSI clock, 65 kHz | Range 3, $V_{CORE}=1.2\text{ V}$, $VOS[1:0] = 11$ | 65 kHz | 0.05 | 0.079 | 0.092 | 0.13 | |
| | | | MSI clock, 524 kHz | | 524 kHz | 0.17 | 0.2 | 0.21 | 0.25 | |
| | | | MSI clock, 4.2 MHz | | 4.2 MHz | 1.0 | 1.1 | 1.1 | 1.2 | |

1. Based on characterization, not tested in production, unless otherwise specified.

2. Oscillator bypassed (HSEBYP = 1 in RCC_CR register).

Table 18. Current consumption in Run mode, code with data processing running from RAM

| Symbol | Parameter | Conditions | | f _{HCLK} | Typ | Max ⁽¹⁾ | | | Unit | |
|-----------------------------------|--|--|---|---|---------|--------------------|-------|---------------------|------|----|
| | | | | | | 55 °C | 85 °C | 105 °C | | |
| I _{DD} (Run from RAM) | Supply current in Run mode, code executed from RAM, Flash switched off | f _{HSE} = f _{HCLK} up to 16 MHz included, f _{HSE} = f _{HCLK} /2 above 16 MHz (PLL ON) ⁽²⁾ | Range 3, V _{CORE} =1.2 V VOS[1:0] = 11 | 1 MHz | 310 | 470 | 470 | 470 | μA | |
| | | | | 2 MHz | 590 | 780 | 780 | 780 | | |
| | | | | 4 MHz | 1030 | 1200 | 1200 | 1200 ⁽³⁾ | | |
| | | | | Range 2, V _{CORE} =1.5 V VOS[1:0] = 10 | 4 MHz | 1.2 | 1.5 | 1.5 | 1.5 | mA |
| | | | | 8 MHz | 2.3 | 3 | 3 | 3 | | |
| | | | | 16 MHz | 4.3 | 5 | 5 | 5 | | |
| | | | | Range 1, V _{CORE} =1.8 V VOS[1:0] = 01 | 8 MHz | 2.7 | 3.5 | 3.5 | 3.5 | |
| | | | | | 16 MHz | 5.0 | 5.55 | 5.55 | 5.55 | |
| | | | | | 32 MHz | 9.8 | 10.9 | 10.9 | 10.9 | |
| | | | HSI clock source (16 MHz) | Range 2, V _{CORE} =1.5 V VOS[1:0] = 10 | 16 MHz | 4.3 | 4.8 | 4.8 | 4.8 | |
| | | | | Range 1, V _{CORE} =1.8 V VOS[1:0] = 01 | 32 MHz | 10.1 | 11.7 | 11.7 | 11.7 | |
| | | | MSI clock, 65 kHz | Range 3, V _{CORE} =1.2 V VOS[1:0] = 11 | 65 kHz | 40 | 48.5 | 63 | 100 | μA |
| | | | MSI clock, 524 kHz | | 524 kHz | 148 | 175 | 183 | 215 | |
| | | | MSI clock, 4.2 MHz | | 4.2 MHz | 990 | 1032 | 1034 | 1100 | |

1. Based on characterization, not tested in production, unless otherwise specified.
2. Oscillator bypassed (HSEBYP = 1 in RCC_CR register).
3. Tested in production.

Table 19. Current consumption in Sleep mode

| Symbol | Parameter | Conditions | | f _{HCLK} | Typ | Max ⁽¹⁾ | | | Unit |
|---|--|--|---|---|--------|--------------------|-------|--------------------|------|
| | | | | | | 55 °C | 85 °C | 105 °C | |
| I _{DD} (Sleep) | Supply current in Sleep mode, code executed from RAM, Flash switched OFF | f _{HSE} = f _{HCLK} up to 16 MHz included, f _{HSE} = f _{HCLK} /2 above 16 MHz (PLL ON) ⁽²⁾ | Range 3, V _{CORE} =1.2 V VOS[1:0] = 11 | 1 MHz | 180 | 220 | 220 | 220 | μA |
| | | | | 2 MHz | 225 | 300 | 300 | 300 | |
| | | | | 4 MHz | 300 | 380 | 380 | 380 ⁽³⁾ | |
| | | | Range 2, V _{CORE} =1.5 V VOS[1:0] = 10 | 4 MHz | 360 | 500 | 500 | 500 | |
| | | | | 8 MHz | 570 | 700 | 700 | 700 | |
| | | | | 16 MHz | 990 | 1100 | 1100 | 1100 | |
| | | | Range 1, V _{CORE} =1.8 V VOS[1:0] = 01 | 8 MHz | 675 | 800 | 800 | 800 | |
| | | | | 16 MHz | 1150 | 1250 | 1250 | 1250 | |
| | | | | 32 MHz | 2300 | 2700 | 2700 | 2700 | |
| | | HSI clock source (16 MHz) | Range 2, V _{CORE} =1.5 V VOS[1:0] = 10 | 16 MHz | 1025 | 1100 | 1100 | 1100 | |
| | | | | Range 1, V _{CORE} =1.8 V VOS[1:0] = 01 | 32 MHz | 2460 | 2700 | 2700 | |
| | | MSI clock, 65 kHz | Range 3, V _{CORE} =1.2 V VOS[1:0] = 11 | 65 kHz | 30 | 36 | 46 | 72 | |
| | | MSI clock, 524 kHz | | 524 kHz | 50 | 58 | 67 | 92 | |
| | | MSI clock, 4.2 MHz | | 4.2 MHz | 210 | 245 | 251 | 273 | |
| I _{DD} (Sleep) | Supply current in Sleep mode, code executed from Flash | f _{HSE} = f _{HCLK} up to 16 MHz included, f _{HSE} = f _{HCLK} /2 above 16 MHz (PLL ON) ⁽²⁾ | Range 3, V _{CORE} =1.2 V VOS[1:0] = 11 | 1 MHz | 190 | 250 | 250 | 250 | μA |
| | | | | 2 MHz | 235 | 300 | 300 | 300 | |
| | | | | 4 MHz | 315 | 380 | 380 | 380 | |
| | | | Range 2, V _{CORE} =1.5 V VOS[1:0] = 10 | 4 MHz | 390 | 500 | 500 | 500 | |
| | | | | 8 MHz | 600 | 700 | 700 | 700 | |
| | | | | 16 MHz | 1000 | 1120 | 1120 | 1120 | |
| | | | Range 1, V _{CORE} =1.8 V VOS[1:0] = 01 | 8 MHz | 690 | 800 | 800 | 800 | |
| | | | | 16 MHz | 1160 | 1300 | 1300 | 1300 | |
| | | | | 32 MHz | 2310 | 2700 | 2700 | 2700 | |
| | | HSI clock source (16 MHz) | Range 2, V _{CORE} =1.5 V VOS[1:0] = 10 | 16 MHz | 1040 | 1160 | 1160 | 1160 | |
| Range 1, V _{CORE} =1.8 V VOS[1:0] = 01 | 32 MHz | | | 2500 | 2800 | 2800 | 2800 | | |
| I _{DD} (Sleep) | Supply current in Sleep mode, code executed from Flash | MSI clock, 65 kHz | Range 3, V _{CORE} =1.2V VOS[1:0] = 11 | 65 kHz | 42 | 50 | 60 | 90 | μA |
| | | MSI clock, 524 kHz | | 524 kHz | 63 | 72 | 82 | 110 | |
| | | MSI clock, 4.2 MHz | | 4.2 MHz | 230 | 263 | 265 | 290 | |

1. Based on characterization, not tested in production, unless otherwise specified.
2. Oscillator bypassed (HSEBYP = 1 in RCC_CR register)
3. Tested in production.

Table 20. Current consumption in Low power run mode

| Symbol | Parameter | Conditions | | | Typ | Max (1) | Unit |
|---------------------------|---|--|--|---------------------------|-----|---------|---------|
| I_{DD} (LP Run) | Supply current in Low power run mode | All peripherals OFF, code executed from RAM, Flash switched OFF, V_{DD} from 1.65 V to 3.6 V | MSI clock, 65 kHz $f_{HCLK} = 32$ kHz | $T_A = -40$ °C to 25 °C | 11 | 14 | μA |
| | | | | $T_A = 85$ °C | 26 | 32 | |
| | | | | $T_A = 105$ °C | 53 | 72 | |
| | | | MSI clock, 65 kHz $f_{HCLK} = 65$ kHz | $T_A = -40$ °C to 25 °C | 18 | 21 | |
| | | | | $T_A = 85$ °C | 33 | 40 | |
| | | | | $T_A = 105$ °C | 60 | 78 | |
| | | | MSI clock, 131 kHz $f_{HCLK} = 131$ kHz | $T_A = -40$ °C to 25 °C | 36 | 41 | |
| | | | | $T_A = 55$ °C | 39 | 44 | |
| | | | | $T_A = 85$ °C | 50 | 58 | |
| | | All peripherals OFF, code executed from Flash, V_{DD} from 1.65 V to 3.6 V | MSI clock, 65 kHz $f_{HCLK} = 32$ kHz | $T_A = -40$ °C to 25 °C | 36 | 40.5 | |
| | | | | $T_A = 85$ °C | 53 | 60 | |
| | | | | $T_A = 105$ °C | 81 | 100 | |
| | | | MSI clock, 65 kHz $f_{HCLK} = 65$ kHz | $T_A = -40$ °C to 25 °C | 44 | 49 | |
| | | | | $T_A = 85$ °C | 61 | 67 | |
| | | | | $T_A = 105$ °C | 89 | 107 | |
| | | | MSI clock, 131 kHz $f_{HCLK} = 131$ kHz | $T_A = -40$ °C to 25 °C | 64 | 71 | |
| | | | | $T_A = 55$ °C | 68 | 73 | |
| | | | | $T_A = 85$ °C | 80 | 88 | |
| | | | $T_A = 105$ °C | 101 | 110 | | |
| $I_{DD\ max}$ (LP Run) | Max allowed current in Low power run mode | V_{DD} from 1.65 V to 3.6 V | | | - | 200 | |

1. Based on characterization, not tested in production, unless otherwise specified.

Table 21. Current consumption in Low power sleep mode

| Symbol | Parameter | Conditions | | Typ | Max (1) | Unit | |
|--|---|--|---|---------------------------|---------|------|---------|
| I_{DD} (LP Sleep) | Supply current in Low power sleep mode | All peripherals OFF, V_{DD} from 1.65 V to 3.6 V | MSI clock, 65 kHz $f_{HCLK} = 32$ kHz Flash OFF | $T_A = -40$ °C to 25 °C | 4.4 | - | μA |
| | | | MSI clock, 65 kHz $f_{HCLK} = 32$ kHz Flash ON | $T_A = -40$ °C to 25 °C | 18 | 21 | |
| | | | | $T_A = 85$ °C | 24 | 27 | |
| | | | | $T_A = 105$ °C | 35 | 43 | |
| | | | MSI clock, 65 kHz $f_{HCLK} = 65$ kHz, Flash ON | $T_A = -40$ °C to 25 °C | 18.6 | 21 | |
| | | | | $T_A = 85$ °C | 24.5 | 28 | |
| | | | | $T_A = 105$ °C | 35 | 42 | |
| | | | MSI clock, 131 kHz $f_{HCLK} = 131$ kHz, Flash ON | $T_A = -40$ °C to 25 °C | 22 | 25 | |
| | | $T_A = 55$ °C | | 23.5 | 26 | | |
| | | $T_A = 85$ °C | | 28.5 | 31 | | |
| | | TIM9 and USART1 enabled, Flash ON, V_{DD} from 1.65 V to 3.6 V | MSI clock, 65 kHz $f_{HCLK} = 32$ kHz | $T_A = -40$ °C to 25 °C | 18 | 20.5 | |
| | | | | $T_A = 85$ °C | 24 | 27 | |
| | | | | $T_A = 105$ °C | 35 | 43 | |
| | | | MSI clock, 65 kHz $f_{HCLK} = 65$ kHz | $T_A = -40$ °C to 25 °C | 18.6 | 21 | |
| | | | | $T_A = 85$ °C | 24.5 | 28 | |
| | | | | $T_A = 105$ °C | 35 | 42 | |
| MSI clock, 131 kHz $f_{HCLK} = 131$ kHz | $T_A = -40$ °C to 25 °C | | 22 | 25 | | | |
| | $T_A = 55$ °C | | 23.5 | 26 | | | |
| | $T_A = 85$ °C | | 28.5 | 31 | | | |
| | $T_A = 105$ °C | | 39 | 45 | | | |
| | | | | | | | |
| | | | | | | | |
| I_{DD} max (LP Sleep) | Max allowed current in Low power Sleep mode | V_{DD} from 1.65 V to 3.6 V | | | - | 200 | |

1. Based on characterization, not tested in production, unless otherwise specified.

Table 22. Typical and maximum current consumptions in Stop mode

| Symbol | Parameter | Conditions | | Typ | Max ⁽¹⁾ | Unit | |
|--|--|---|-------------------------------------|---|--------------------|------|----|
| I _{DD} (Stop with RTC) | Supply current in Stop mode with RTC enabled | RTC clocked by LSI or LSE external clock (32.768kHz), regulator in LP mode, HSI and HSE OFF (no independent watchdog) | LCD OFF | T _A = -40°C to 25°C V _{DD} = 1.8 V | 1.5 | | μA |
| | | | | T _A = -40°C to 25°C | 1.7 | 4 | |
| | | | | T _A = 55°C | 2.4 | 6 | |
| | | | | T _A = 85°C | 5.4 | 10 | |
| | | | | T _A = 105°C | 11.0 | 23 | |
| | | | LCD ON (static duty) ⁽²⁾ | T _A = -40°C to 25°C | 3.8 | 6 | |
| | | | | T _A = 55°C | 4.4 | 7 | |
| | | | | T _A = 85°C | 7.4 | 12 | |
| | | | LCD ON (1/8 duty) ⁽³⁾ | T _A = -40°C to 25°C | 7.8 | 10 | |
| | | | | T _A = 55°C | 8.3 | 11 | |
| | | | | T _A = 85°C | 11.4 | 16 | |
| | | | | T _A = 105°C | 20.5 | 44 | |
| | Supply current in Stop mode with RTC enabled | RTC clocked by LSE external quartz (32.768kHz), regulator in LP mode, HSI and HSE OFF (no independent watchdog ⁽⁴⁾) | LCD OFF | T _A = -40°C to 25°C | 2.1 | - | |
| | | | | T _A = 55°C | 2.8 | - | |
| | | | | T _A = 85°C | 3.8 | - | |
| | | | | T _A = 105°C | 11.1 | - | |
| | | | LCD ON (static duty) ⁽²⁾ | T _A = -40°C to 25°C | 4.2 | - | |
| | | | | T _A = 55°C | 4.8 | - | |
| | | | | T _A = 85°C | 7.9 | - | |
| | | | LCD ON (1/8 duty) ⁽³⁾ | T _A = -40°C to 25°C | 8.2 | - | |
| | | | | T _A = 55°C | 8.7 | - | |
| | | | | T _A = 85°C | 11.9 | - | |
| | | | LCD OFF | T _A = -40°C to 25°C V _{DD} = 1.8V | 1.6 | - | |
| | | | | T _A = -40°C to 25°C V _{DD} = 3.0V | 1.9 | - | |
| T _A = -40°C to 25°C V _{DD} = 3.6V | 2.1 | - | | | | | |

Table 22. Typical and maximum current consumptions in Stop mode (continued)

| Symbol | Parameter | Conditions | Typ | Max ⁽¹⁾ | Unit | |
|--------------------------------|---|---|--------------------------------|--------------------|-------------------|----|
| I _{DD} (Stop) | Supply current in Stop mode (RTC disabled) | Regulator in LP mode, HSI and HSE OFF, independent watchdog and LSI enabled | T _A = -40°C to 25°C | 1.6 | 2.2 | μA |
| | | Regulator in LP mode, LSI, HSI and HSE OFF (no independent watchdog) | T _A = -40°C to 25°C | 0.65 | 1 | |
| | | | T _A = 55°C | 1.3 | 3 | |
| | | | T _A = 85°C | 4.4 | 9 | |
| | | | T _A = 105°C | 10.0 | 22 ⁽⁵⁾ | |
| I _{DD} (WU from Stop) | Supply current during wakeup from Stop mode | MSI = 4.2 MHz | T _A = -40°C to 25°C | 2 | - | mA |
| | | MSI = 1.05 MHz | | 1.45 | - | |
| | | MSI = 65 kHz ⁽⁶⁾ | | 1.45 | - | |

1. Based on characterization, not tested in production, unless otherwise specified.
2. LCD enabled with external VLCD, static duty, division ratio = 256, all pixels active, no LCD connected.
3. LCD enabled with external VLCD, 1/8 duty, 1/3 bias, division ratio = 64, all pixels active, no LCD connected.
4. Based on characterization done with a 32.768 kHz crystal (MC306-G-06Q-32.768, manufacturer JFVNY) with two 6.8 pF loading capacitors.
5. Tested in production.
6. When MSI = 64 kHz, the RMS current is measured over the first 15 μs following the wakeup event. For the remaining part of the wakeup period, the current corresponds the Run mode current.

Table 23. Typical and maximum current consumptions in Standby mode

| Symbol | Parameter | Conditions | Typ | Max ⁽¹⁾ | Unit | |
|------------------------------------|---|--|----------------------------------|--------------------|--------------------|----|
| I _{DD} (Standby with RTC) | Supply current in Standby mode with RTC enabled | RTC clocked by LSI (no independent watchdog) | T _A = -40 °C to 25 °C | 1.3 | 1.9 | μA |
| | | | T _A = 55 °C | 1.44 | 2.2 | |
| | | | T _A = 85 °C | 1.90 | 4 | |
| | | | T _A = 105 °C | 3.05 | 8.3 ⁽²⁾ | |
| | | RTC clocked by LSE external quartz(no independent watchdog) ⁽³⁾ | T _A = -40 °C to 25 °C | 1.7 | - | |
| | | | T _A = 55 °C | 1.84 | - | |
| | | | T _A = 85 °C | 2.33 | - | |
| | | | T _A = 105 °C | 3.59 | - | |
| I _{DD} (Standby) | Supply current in Standby mode (RTC disabled) | Independent watchdog and LSI enabled | T _A = -40 °C to 25 °C | 1 | 1.7 | |
| | | Independent watchdog and LSI OFF | T _A = -40 °C to 25 °C | 0.35 | 0.6 | |
| | | | T _A = 55 °C | 0.47 | 0.9 | |
| | | | T _A = 85 °C | 1.2 | 2.75 | |
| | | | T _A = 105 °C | 2.9 | 7 ⁽²⁾ | |
| I _{DD} (WU from Standby) | Supply current during wakeup time from Standby mode | T _A = -40 °C to 25 °C | 1 | - | | |

1. Based on characterization, not tested in production, unless otherwise specified

2. Tested in production.
3. Based on characterization done with a 32.768 kHz crystal (MC306-G-06Q-32.768, manufacturer JFVNY) with two 6.8pF loading capacitors.

Wakeup time from low-power mode

The wakeup times given in the following table are measured with the MSI RC oscillator. The clock source used to wake up the device depends on the current operating mode:

- Sleep mode: the clock source is the clock that was set before entering Sleep mode
- Stop mode: the clock source is the MSI oscillator in the range configured before entering Stop mode
- Standby mode: the clock source is the MSI oscillator running at 2.1 MHz

All timings are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in [Table 14](#).

Table 24. Typical and maximum timings in Low power modes

| Symbol | Parameter | Conditions | Typ | Max ⁽¹⁾ | Unit |
|----------------------------------|---|---|------|--------------------|------|
| t _{WUSLEEP} | Wakeup from Sleep mode | f _{HCLK} = 32 MHz | 0.4 | - | μs |
| t _{WUSLEEP_LP} | Wakeup from Low power sleep mode f _{HCLK} = 262 kHz | f _{HCLK} = 262 kHz Flash enabled | 46 | - | |
| | | f _{HCLK} = 262 kHz Flash switched OFF | 46 | - | |
| t _{WUSTOP} | Wakeup from Stop mode, regulator in Run mode | f _{HCLK} = f _{MSI} = 4.2 MHz | 8.2 | - | |
| | | f _{HCLK} = f _{MSI} = 4.2 MHz Voltage range 1 and 2 | 7.7 | 8.9 | |
| | Wakeup from Stop mode, regulator in low power mode | f _{HCLK} = f _{MSI} = 4.2 MHz Voltage range 3 | 8.2 | 13.1 | |
| | | f _{HCLK} = f _{MSI} = 2.1 MHz | 10.2 | 13.4 | |
| | | f _{HCLK} = f _{MSI} = 1.05 MHz | 16 | 20 | |
| | | f _{HCLK} = f _{MSI} = 524 kHz | 31 | 37 | |
| | | f _{HCLK} = f _{MSI} = 262 kHz | 57 | 66 | |
| | | f _{HCLK} = f _{MSI} = 131 kHz | 112 | 123 | |
| f _{HCLK} = MSI = 65 kHz | 221 | 236 | | | |
| t _{WUSTDBY} | Wakeup from Standby mode FWU bit = 1 | f _{HCLK} = MSI = 2.1 MHz | 58 | 104 | |
| | Wakeup from Standby mode FWU bit = 0 | f _{HCLK} = MSI = 2.1 MHz | 2.6 | 3.25 | ms |

1. Based on characterization, not tested in production, unless otherwise specified

On-chip peripheral current consumption

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

- all I/O pins are in input mode with a static value at V_{DD} or V_{SS} (no load)
- all peripherals are disabled unless otherwise mentioned
- the given value is calculated by measuring the current consumption
 - with all peripherals clocked off
 - with only one peripheral clocked on

Table 25. Peripheral current consumption⁽¹⁾

| Peripheral | | Typical consumption, $V_{DD} = 3.0\text{ V}$, $T_A = 25\text{ °C}$ | | | | Unit |
|------------|--------|---|--|--|-------------------------|--|
| | | Range 1, $V_{CORE} = 1.8\text{ V}$ $VOS[1:0] = 01$ | Range 2, $V_{CORE} = 1.5\text{ V}$ $VOS[1:0] = 10$ | Range 3, $V_{CORE} = 1.2\text{ V}$ $VOS[1:0] = 11$ | Low power sleep and run | |
| APB1 | TIM2 | 13 | 11 | 9 | 11 | $\mu\text{A}/\text{MHz}$ (f_{HCLK}) |
| | TIM3 | 12 | 10 | 9 | 11 | |
| | TIM4 | 12 | 10 | 9 | 11 | |
| | TIM5 | 16 | 13 | 11 | 14 | |
| | TIM6 | 4 | 4 | 4 | 4 | |
| | TIM7 | 4 | 4 | 4 | 4 | |
| | LCD | 4 | 3 | 3 | 4 | |
| | WWDG | 3 | 2.5 | 2.5 | 3 | |
| | SPI2 | 8 | 7 | 9 | 7.5 | |
| | SPI3 | 7 | 6 | 7 | 6 | |
| | USART2 | 8 | 7 | 7 | 7 | |
| | USART3 | 8 | 7 | 7 | 7 | |
| | USART4 | 8 | 7 | 7 | 7 | |
| | USART5 | 8 | 7 | 7 | 7 | |
| | I2C1 | 8 | 7 | 6 | 7 | |
| | I2C2 | 7 | 6 | 5 | 6 | |
| | USB | 15 | 7 | 7 | 7 | |
| | PWR | 3 | 3 | 3 | 3 | |
| | DAC | 6 | 5 | 4.5 | 5 | |
| COMP | 4 | 3.5 | 3.5 | 4 | | |

Table 25. Peripheral current consumption⁽¹⁾ (continued)

| Peripheral | | Typical consumption, V _{DD} = 3.0 V, T _A = 25 °C | | | | Unit |
|-------------|--------------------|--|--|--|-------------------------------|--------------------------------|
| | | Range 1, V _{CORE} = 1.8 V VOS[1:0] = 01 | Range 2, V _{CORE} = 1.5 V VOS[1:0] = 10 | Range 3, V _{CORE} = 1.2 V VOS[1:0] = 11 | Low power sleep and run | |
| APB2 | SYSCFG & RI | 3 | 2 | 2 | 3 | μA/MHz (f _{HCLK}) |
| | TIM9 | 8 | 7 | 6 | 7 | |
| | TIM10 | 6 | 5 | 5 | 5 | |
| | TIM11 | 6 | 5 | 5 | 5 | |
| | ADC ⁽²⁾ | 10 | 8 | 7 | 8 | |
| | SDIO | 20 | 6 | 5 | 6 | |
| | SPI1 | 4 | 4 | 4 | 4 | |
| | USART1 | 8 | 7 | 6 | 7 | |
| AHB | GPIOA | 7 | 6 | 5 | 6 | |
| | GPIOB | 7 | 6 | 5 | 6 | |
| | GPIOC | 7 | 6 | 5 | 6 | |
| | GPIOD | 7 | 6 | 5 | 6 | |
| | GPIOE | 7 | 6 | 5 | 6 | |
| | GPIOF | 7 | 6 | 5 | 6 | |
| | GPIOG | 7 | 6 | 5 | 6 | |
| | GPIOH | 2 | 2 | 1 | 2 | |
| | CRC | 0.5 | 0.5 | 0.5 | 1 | |
| | FLASH | 26 | 26 | 29 | .. ⁽³⁾ | |
| | DMA1 | 18 | 15 | 13 | 18 | |
| | DMA2 | 16 | 14 | 12 | 16 | |
| FSMC | 15 | 12 | 10 | 12 | | |
| All enabled | | 279 | 221 | 219 | 215 | |

Table 25. Peripheral current consumption⁽¹⁾ (continued)

| Peripheral | Typical consumption, V _{DD} = 3.0 V, T _A = 25 °C | | | | Unit |
|--|--|--|--|-------------------------------|------|
| | Range 1, V _{CORE} = 1.8 V VOS[1:0] = 01 | Range 2, V _{CORE} = 1.5 V VOS[1:0] = 10 | Range 3, V _{CORE} = 1.2 V VOS[1:0] = 11 | Low power sleep and run | |
| I _{DD} (RTC) | 0.4 | | | | μA |
| I _{DD} (LCD) | 3.1 | | | | |
| I _{DD} (ADC) ⁽⁴⁾ | 1450 | | | | |
| I _{DD} (DAC) ⁽⁵⁾ | 340 | | | | |
| I _{DD} (COMP1) | 0.16 | | | | |
| I _{DD} (COMP2) | Slow mode | 2 | | | |
| | Fast mode | 5 | | | |
| I _{DD} (PVD / BOR) ⁽⁶⁾ | 2.6 | | | | |
| I _{DD} (IWDG) | 0.25 | | | | |

1. Data based on differential I_{DD} measurement between all peripherals OFF or one peripheral with clock enabled, in the following conditions: f_{HCLK} = 32 MHz (range 1), f_{HCLK} = 16 MHz (range 2), f_{HCLK} = 4 MHz (range 3), f_{HCLK} = 64kHz (Low power run/sleep), f_{APB1} = f_{HCLK}, f_{APB2} = f_{HCLK}; default prescaler value for each peripheral. The CPU is in Sleep mode in both cases. No I/O pins toggling. Not tested in production.
2. HSI oscillator is OFF for this measure.
3. In low power sleep and run mode, the Flash memory must always be in power-down mode.
4. Data based on a differential I_{DD} measurement between ADC in reset configuration and continuous ADC conversion (HSI consumption not included).
5. Data based on a differential I_{DD} measurement between DAC in reset configuration and continuous DAC conversion of V_{DD}/2. DAC is in buffered mode, output is left floating.
6. Including supply current of internal reference voltage.

6.3.5 External clock source characteristics

High-speed external user clock generated from an external source

Table 26. High-speed external user clock characteristics⁽¹⁾

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|--|--------------------------------------|------------|--------------------|-----|--------------------|------|
| f _{HSE_ext} | User external clock source frequency | | 1 | 8 | 32 | MHz |
| V _{HSEH} | OSC_IN input pin high level voltage | | 0.7V _{DD} | - | V _{DD} | V |
| V _{HSEL} | OSC_IN input pin low level voltage | | V _{SS} | - | 0.3V _{DD} | |
| t _{w(HSE)} t _{w(HSE)} | OSC_IN high or low time | | 12 | - | - | ns |
| t _{r(HSE)} t _{f(HSE)} | OSC_IN rise or fall time | | - | - | 20 | |
| C _{in(HSE)} | OSC_IN input capacitance | | - | 2.6 | - | pF |

Table 26. High-speed external user clock characteristics⁽¹⁾

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|-----------------------|------------------------------|----------------------------------|-----|-----|-----|------|
| DuCy _(HSE) | Duty cycle | | 45 | - | 55 | % |
| I _L | OSC_IN Input leakage current | $V_{SS} \leq V_{IN} \leq V_{DD}$ | - | - | ±1 | μA |

1. Guaranteed by design, not tested in production.

Low-speed external user clock generated from an external source

The characteristics given in the following table result from tests performed using a low-speed external clock source, and under ambient temperature and supply voltage conditions summarized in [Table 14](#).

Table 27. Low-speed external user clock characteristics⁽¹⁾

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|------------------------------|---------------------------------------|----------------------------------|-------------|--------|-------------|---------|
| f_{LSE_ext} | User external clock source frequency | | 1 | 32.768 | 1000 | kHz |
| V_{LSEH} | OSC32_IN input pin high level voltage | | $0.7V_{DD}$ | - | V_{DD} | V |
| V_{LSEL} | OSC32_IN input pin low level voltage | | V_{SS} | - | $0.3V_{DD}$ | |
| $t_{w(LSE)}$ $t_{w(LSE)}$ | OSC32_IN high or low time | | 465 | - | - | ns |
| $t_{r(LSE)}$ $t_{f(LSE)}$ | OSC32_IN rise or fall time | | - | - | 10 | |
| $C_{IN(LSE)}$ | OSC32_IN input capacitance | | - | 0.6 | - | pF |
| $DuCy_{(LSE)}$ | Duty cycle | | 45 | - | 55 | % |
| I_L | OSC32_IN Input leakage current | $V_{SS} \leq V_{IN} \leq V_{DD}$ | - | - | ± 1 | μA |

1. Guaranteed by design, not tested in production

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

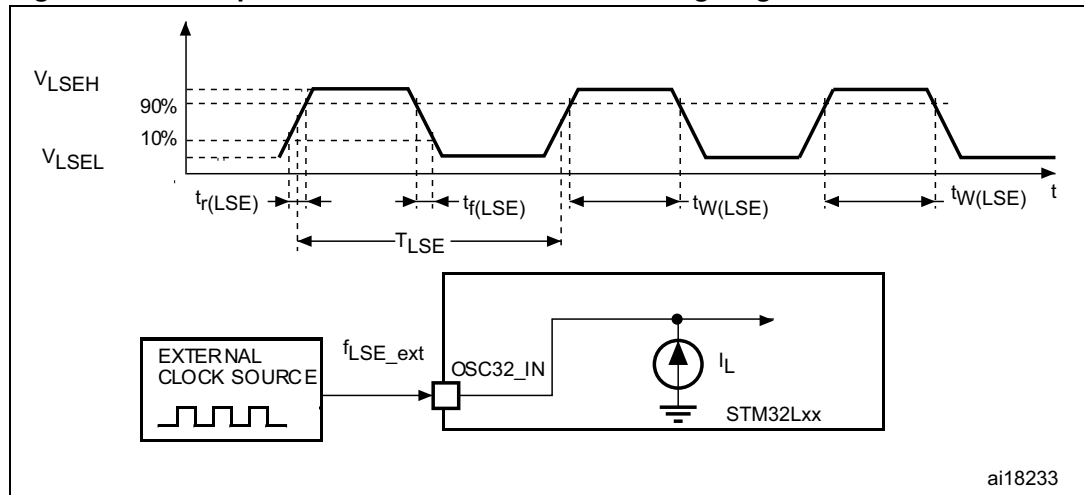
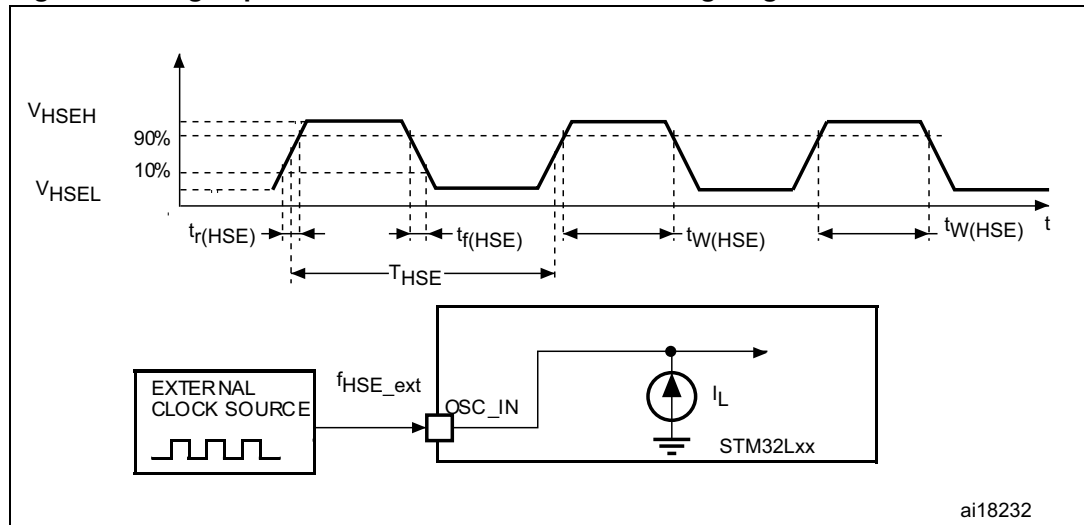


Figure 14. High-speed external clock source AC timing diagram



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

The high-speed external (HSE) clock can be supplied with a 1 to 24 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 28](#). In the application, the resonator and the load capacitors have to be placed as close as possible to the oscillator pins in order to minimize output distortion and startup stabilization time. Refer to the crystal resonator manufacturer for more details on the resonator characteristics (frequency, package, accuracy).

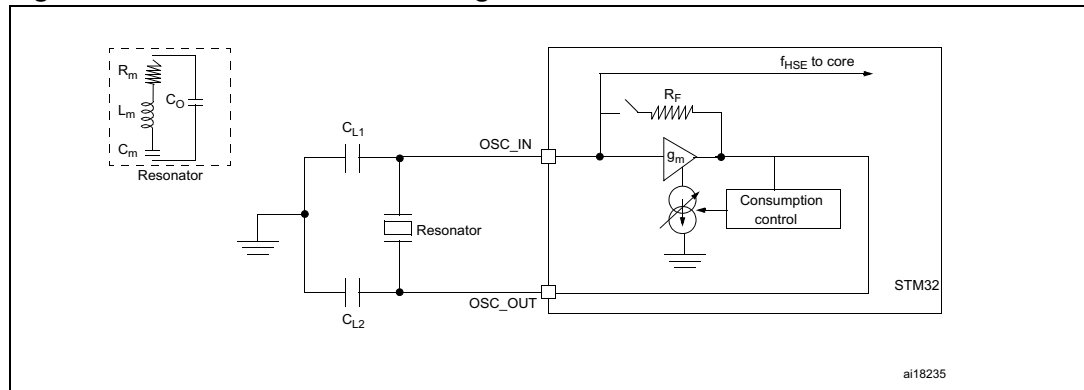
Table 28. HSE 1-24 MHz oscillator characteristics⁽¹⁾⁽²⁾

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|-------------------------------------|--|--|-----|-----|------------------------------------|-------|
| f _{OSC_IN} | Oscillator frequency | | 1 | | 24 | MHz |
| R _F | Feedback resistor | | - | 200 | - | kΩ |
| C | Recommended load capacitance versus equivalent serial resistance of the crystal (R _S) ⁽³⁾ | R _S = 30 Ω | - | 20 | - | pF |
| I _{HSE} | HSE driving current | V _{DD} = 3.3 V, V _{IN} = V _{SS} with 30 pF load | - | - | 3 | mA |
| I _{DD(HSE)} | HSE oscillator power consumption | C = 20 pF f _{OSC} = 16 MHz | - | - | 2.5 (startup) 0.7 (stabilized) | mA |
| | | C = 10 pF f _{OSC} = 16 MHz | - | - | 2.5 (startup) 0.46 (stabilized) | |
| g _m | Oscillator transconductance | Startup | 3.5 | - | - | mA /V |
| t _{SU(HSE)} ⁽⁴⁾ | Startup time | V _{DD} is stabilized | - | 1 | - | ms |

1. Resonator characteristics given by the crystal/ceramic resonator manufacturer.
2. Based on characterization results, not tested in production.
3. The relatively low value of the RF resistor offers a good protection against issues resulting from use in a humid environment, due to the induced leakage and the bias condition change. However, it is recommended to take this point into account if the MCU is used in tough humidity conditions.
4. t_{SU(HSE)} is the startup time measured from the moment it is enabled (by software) to a stabilized 8 MHz oscillation is reached. This value is measured for a standard crystal resonator and it can vary significantly with the crystal manufacturer.

For C_{L1} and C_{L2}, it is recommended to use high-quality external ceramic capacitors in the 5 pF to 25 pF range (typ.), designed for high-frequency applications, and selected to match the requirements of the crystal or resonator (see [Figure 15](#)). C_{L1} and C_{L2} are usually the same size. The crystal manufacturer typically specifies a load capacitance which is the series combination of C_{L1} and C_{L2}. PCB and MCU pin capacitance must be included (10 pF can be used as a rough estimate of the combined pin and board capacitance) when sizing C_{L1} and C_{L2}. Refer to the application note AN2867 “Oscillator design guide for ST microcontrollers” available from the ST website www.st.com.

Figure 15. HSE oscillator circuit diagram



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

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

The low-speed external (LSE) clock can be supplied with a 32.768 kHz crystal/ceramic resonator oscillator. All the information given in this paragraph are based on characterization results obtained with typical external components specified in [Table 29](#). In the application, the resonator and the load capacitors have to be placed as close as possible to the oscillator pins in order to minimize output distortion and startup stabilization time. Refer to the crystal resonator manufacturer for more details on the resonator characteristics (frequency, package, accuracy).

Table 29. LSE oscillator characteristics ($f_{LSE} = 32.768 \text{ kHz}$)⁽¹⁾

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|------------------------|--|---|-----|--------|-----|------|
| f_{LSE} | Low speed external oscillator frequency | | - | 32.768 | - | kHz |
| R_F | Feedback resistor | | - | 1.2 | - | MΩ |
| $C^{(2)}$ | Recommended load capacitance versus equivalent serial resistance of the crystal (R_S) ⁽³⁾ | $R_S = 30 \text{ k}\Omega$ | - | 8 | - | pF |
| I_{LSE} | LSE driving current | $V_{DD} = 3.3 \text{ V}, V_{IN} = V_{SS}$ | - | - | 1.1 | μA |
| $I_{DD} \text{ (LSE)}$ | LSE oscillator current consumption | $V_{DD} = 1.8 \text{ V}$ | - | 450 | - | nA |
| | | $V_{DD} = 3.0 \text{ V}$ | - | 600 | - | |
| | | $V_{DD} = 3.6 \text{ V}$ | - | 750 | - | |
| g_m | Oscillator transconductance | | 3 | | - | μA/V |
| $t_{SU(LSE)}^{(4)}$ | Startup time | V_{DD} is stabilized | - | 1 | - | s |

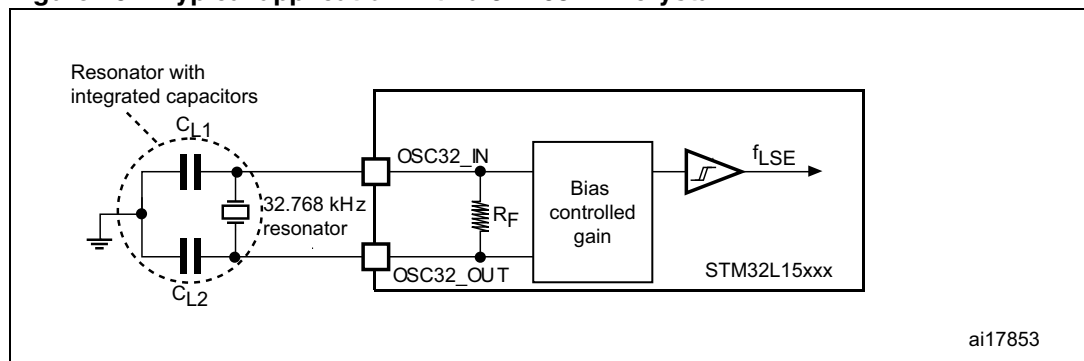
1. Based on characterization, not tested in production.
2. Refer to the note and caution paragraphs below the table, and to the application note AN2867 “Oscillator design guide for ST microcontrollers”.
3. The oscillator selection can be optimized in terms of supply current using an high quality resonator with small R_S value for example MSIV-TIN32.768kHz. Refer to crystal manufacturer for more details.
4. $t_{SU(LSE)}$ is the startup time measured from the moment it is enabled (by software) to a stabilized 32.768 kHz oscillation is reached. This value is measured for a standard crystal resonator and it can vary significantly with the crystal manufacturer.

Note: For C_{L1} and C_{L2} , it is recommended to use high-quality ceramic capacitors in the 5 pF to 15 pF range selected to match the requirements of the crystal or resonator (see [Figure 16](#)). C_{L1} and C_{L2} are usually the same size. The crystal manufacturer typically specifies a load capacitance which is the series combination of C_{L1} and C_{L2} . Load capacitance C_L has the following formula: $C_L = C_{L1} \times C_{L2} / (C_{L1} + C_{L2}) + C_{stray}$ where C_{stray} is the pin capacitance and board or trace PCB-related capacitance. Typically, it is between 2 pF and 7 pF.

Caution: To avoid exceeding the maximum value of C_{L1} and C_{L2} (15 pF) it is strongly recommended to use a resonator with a load capacitance $C_L \leq 7$ pF. Never use a resonator with a load capacitance of 12.5 pF.

Example: if you choose a resonator with a load capacitance of $C_L = 6$ pF and $C_{stray} = 2$ pF, then $C_{L1} = C_{L2} = 8$ pF.

Figure 16. Typical application with a 32.768 kHz crystal



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6.3.6 Internal clock source characteristics

The parameters given in [Table 30](#) are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in [Table 14](#).

High-speed internal (HSI) RC oscillator

Table 30. HSI oscillator characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---------------------|---|--|-------------------|-----------|------------------|---------------|
| f_{HSI} | Frequency | $V_{DD} = 3.0\text{ V}$ | - | 16 | - | MHz |
| $TRIM^{(1)(2)}$ | HSI user-trimmed resolution | Trimming code is not a multiple of 16 | - | ± 0.4 | 0.7 | % |
| | | Trimming code is a multiple of 16 | - | - | ± 1.5 | % |
| $ACC_{HSI}^{(2)}$ | Accuracy of the factory-calibrated HSI oscillator | $V_{DDA} = 3.0\text{ V}, T_A = 25\text{ }^\circ\text{C}$ | -1 ⁽³⁾ | - | 1 ⁽³⁾ | % |
| | | $V_{DDA} = 3.0\text{ V}, T_A = 0\text{ to }55\text{ }^\circ\text{C}$ | -1.5 | - | 1.5 | % |
| | | $V_{DDA} = 3.0\text{ V}, T_A = -10\text{ to }70\text{ }^\circ\text{C}$ | -2 | - | 2 | % |
| | | $V_{DDA} = 3.0\text{ V}, T_A = -10\text{ to }85\text{ }^\circ\text{C}$ | -2.5 | - | 2 | % |
| | | $V_{DDA} = 3.0\text{ V}, T_A = -10\text{ to }105\text{ }^\circ\text{C}$ | -4 | - | 2 | % |
| | | $V_{DDA} = 1.65\text{ V to }3.6\text{ V}$ $T_A = -40\text{ to }105\text{ }^\circ\text{C}$ | -4 | - | 3 | % |
| $t_{SU(HSI)}^{(2)}$ | HSI oscillator startup time | | - | 3.7 | 6 | μs |
| $I_{DD(HSI)}^{(2)}$ | HSI oscillator power consumption | | - | 100 | 140 | μA |

1. The trimming step differs depending on the trimming code. It is usually negative on the codes which are multiples of 16 (0x00, 0x10, 0x20, 0x30...0xE0).
2. Based on characterization, not tested in production.
3. Tested in production.

Low-speed internal (LSI) RC oscillator

Table 31. LSI oscillator characteristics

| Symbol | Parameter | Min | Typ | Max | Unit |
|---------------------|--|-----|-----|-----|---------------|
| $f_{LSI}^{(1)}$ | LSI frequency | 26 | 38 | 56 | kHz |
| $D_{LSI}^{(2)}$ | LSI oscillator frequency drift $0^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$ | -10 | - | 4 | % |
| $t_{su(LSI)}^{(3)}$ | LSI oscillator startup time | - | - | 200 | μs |
| $I_{DD(LSI)}^{(3)}$ | LSI oscillator power consumption | - | 400 | 510 | nA |

1. Tested in production.
2. This is a deviation for an individual part, once the initial frequency has been measured.
3. Guaranteed by design, not tested in production.

Multi-speed internal (MSI) RC oscillator

Table 32. MSI oscillator characteristics

| Symbol | Parameter | Condition | Typ | Max | Unit |
|-------------------------------------|---|-------------|-----------|-----|---------------|
| f_{MSI} | Frequency after factory calibration, done at $V_{\text{DD}} = 3.3 \text{ V}$ and $T_{\text{A}} = 25 \text{ }^{\circ}\text{C}$ | MSI range 0 | 65.5 | - | kHz |
| | | MSI range 1 | 131 | - | |
| | | MSI range 2 | 262 | - | |
| | | MSI range 3 | 524 | - | MHz |
| | | MSI range 4 | 1.05 | - | |
| | | MSI range 5 | 2.1 | - | |
| | | MSI range 6 | 4.2 | - | |
| ACC_{MSI} | Frequency error after factory calibration | | ± 0.5 | - | % |
| $D_{\text{TEMP}(\text{MSI})}^{(1)}$ | MSI oscillator frequency drift $0 \text{ }^{\circ}\text{C} \leq T_{\text{A}} \leq 85 \text{ }^{\circ}\text{C}$ | | ± 3 | - | % |
| $D_{\text{VOLT}(\text{MSI})}^{(1)}$ | MSI oscillator frequency drift $1.65 \text{ V} \leq V_{\text{DD}} \leq 3.6 \text{ V}$, $T_{\text{A}} = 25 \text{ }^{\circ}\text{C}$ | | - | 2.5 | %/V |
| $I_{\text{DD}(\text{MSI})}^{(2)}$ | MSI oscillator power consumption | MSI range 0 | 0.75 | - | μA |
| | | MSI range 1 | 1 | - | |
| | | MSI range 2 | 1.5 | - | |
| | | MSI range 3 | 2.5 | - | |
| | | MSI range 4 | 4.5 | - | |
| | | MSI range 5 | 8 | - | |
| | | MSI range 6 | 15 | - | |

Table 32. MSI oscillator characteristics (continued)

| Symbol | Parameter | Condition | Typ | Max | Unit |
|-----------------------|------------------------------------|------------------------------------|-----|-----|---------|
| $t_{SU(MSI)}$ | MSI oscillator startup time | MSI range 0 | 30 | - | μs |
| | | MSI range 1 | 20 | - | |
| | | MSI range 2 | 15 | - | |
| | | MSI range 3 | 10 | - | |
| | | MSI range 4 | 6 | - | |
| | | MSI range 5 | 5 | - | |
| | | MSI range 6, Voltage range 1 and 2 | 3.5 | - | |
| | | MSI range 6, Voltage range 3 | 5 | - | |
| $t_{STAB(MSI)}^{(2)}$ | MSI oscillator stabilization time | MSI range 0 | - | 40 | μs |
| | | MSI range 1 | - | 20 | |
| | | MSI range 2 | - | 10 | |
| | | MSI range 3 | - | 4 | |
| | | MSI range 4 | - | 2.5 | |
| | | MSI range 5 | - | 2 | |
| | | MSI range 6, Voltage range 1 and 2 | - | 2 | |
| | | MSI range 3, Voltage range 3 | - | 3 | |
| $f_{OVER(MSI)}$ | MSI oscillator frequency overshoot | Any range to range 5 | - | 4 | MHz |
| | | Any range to range 6 | - | 6 | |

1. This is a deviation for an individual part, once the initial frequency has been measured.
2. Based on characterization, not tested in production.

6.3.7 PLL characteristics

The parameters given in [Table 33](#) are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in [Table 14](#).

Table 33. PLL characteristics

| Symbol | Parameter | Value | | | Unit |
|------------------------|---|-------|-----|--------------------|------|
| | | Min | Typ | Max ⁽¹⁾ | |
| f _{PLL_IN} | PLL input clock ⁽²⁾ | 2 | - | 24 | MHz |
| | PLL input clock duty cycle | 45 | - | 55 | % |
| f _{PLL_OUT} | PLL output clock | 2 | - | 32 | MHz |
| t _{LOCK} | Worst case PLL lock time PLL input = 2 MHz PLL VCO = 96 MHz | - | 100 | 130 | μs |
| Jitter | Cycle-to-cycle jitter | - | | ± 600 | ps |
| I _{DDA} (PLL) | Current consumption on V _{DDA} | - | 220 | 450 | μA |
| I _{DD} (PLL) | Current consumption on V _{DD} | - | 120 | 150 | |

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

6.3.8 Memory characteristics

The characteristics are given at T_A = -40 to 105 °C unless otherwise specified.

RAM memory

Table 34. RAM and hardware registers

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|--------|------------------------------------|----------------------|------|-----|-----|------|
| VRM | Data retention mode ⁽¹⁾ | STOP mode (or RESET) | 1.65 | - | - | V |

1. Minimum supply voltage without losing data stored in RAM (in Stop mode or under Reset) or in hardware registers (only in Stop mode).

Flash memory and data EEPROM

Table 35. Flash memory and data EEPROM characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max ⁽¹⁾ | Unit |
|-------------------|--|---|------|------|--------------------|------|
| V _{DD} | Operating voltage Read / Write / Erase | | 1.65 | - | 3.6 | V |
| t _{prog} | Programming time for word or half-page | Erasing | - | 3.28 | 3.94 | ms |
| | | Programming | - | 3.28 | 3.94 | |
| I _{DD} | Average current during the whole programming / erase operation | T _A = 25 °C, V _{DD} = 3.6 V | - | 600 | 900 | μA |
| | Maximum current (peak) during the whole programming / erase operation | | - | 1.5 | 2.5 | mA |

1. Guaranteed by design, not tested in production.

Table 36. Flash memory and data EEPROM endurance and retention

| Symbol | Parameter | Conditions | Value | | | Unit |
|---------------------------------|---|-------------------------------------|--------------------|-----|-----|---------|
| | | | Min ⁽¹⁾ | Typ | Max | |
| N _{CYC} ⁽²⁾ | Cycling (erase / write) Program memory | T _A = -40°C to 105 °C | 10 | - | - | kcycles |
| | Cycling (erase / write) EEPROM data memory | | 300 | - | - | |
| t _{RET} ⁽²⁾ | Data retention (program memory) after 10 kcycles at T _A = 85 °C | T _{RET} = +85 °C | 30 | - | - | years |
| | Data retention (EEPROM data memory) after 300 kcycles at T _A = 85 °C | | 30 | - | - | |
| | Data retention (program memory) after 10 kcycles at T _A = 105 °C | T _{RET} = +105 °C | 10 | - | - | |
| | Data retention (EEPROM data memory) after 300 kcycles at T _A = 105 °C | | 10 | - | - | |

1. Based on characterization not tested in production.

2. Characterization is done according to JEDEC JESD22-A117.

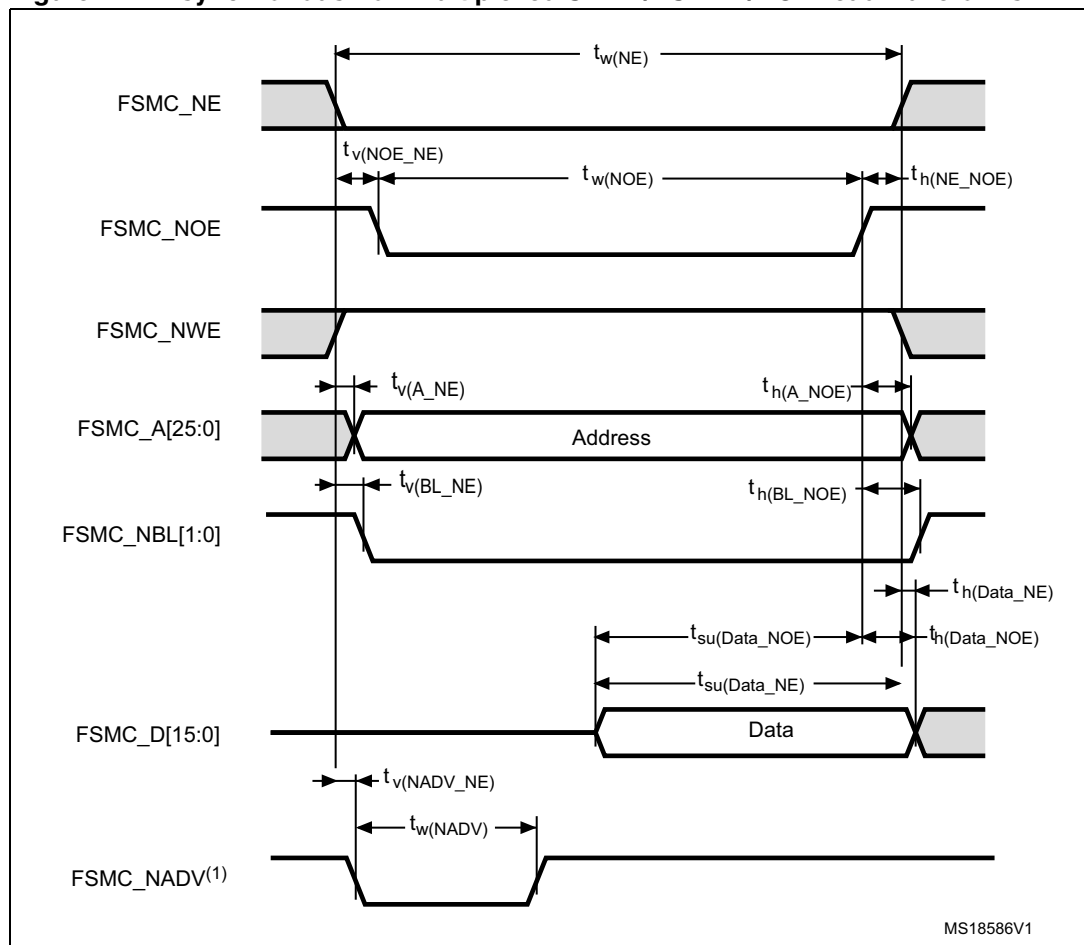
6.3.9 FSMC characteristics

Asynchronous waveforms and timings

Figure 17 through Figure 20 represent asynchronous waveforms and Table 37 through Table 40 provide the corresponding timings. The results shown in these tables are obtained with the following FSMC configuration:

- AddressSetupTime = 0 (AddressSetupTime = 1, for asynchronous multiplexed modes)
- AddressHoldTime = 1
- DataSetupTime = 1

Figure 17. Asynchronous non-multiplexed SRAM/PSRAM/NOR read waveforms



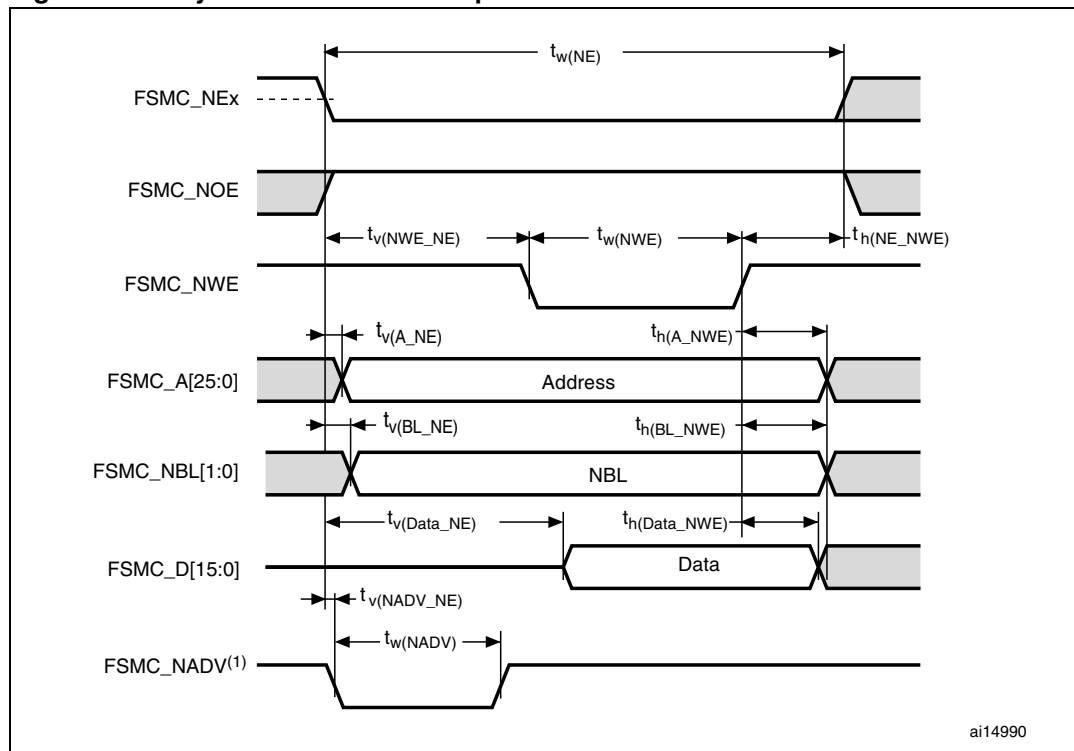
1. Mode 2/B, C and D only. In Mode 1, FSMC_NADV is not used.

Table 37. Asynchronous non-multiplexed SRAM/PSRAM/NOR read timings⁽¹⁾

| Symbol | Parameter | Min | Max | Unit |
|---------------------|---|----------------------|----------------|------|
| $t_{w(NE)}$ | FSMC_NE low time | $T_{HCLK} - 2$ | T_{HCLK} | ns |
| $t_{v(NO_NE)}$ | FSMC_NEx low to FSMC_NOE low | 0 | 2 | ns |
| $t_{w(NO_E)}$ | FSMC_NOE low time | T_{HCLK} | $T_{HCLK} - 1$ | ns |
| $t_{h(NE_NOE)}$ | FSMC_NOE high to FSMC_NE high hold time | 0 | - | ns |
| $t_{v(A_NE)}$ | FSMC_NEx low to FSMC_A valid | - | 4 | ns |
| $t_{h(A_NOE)}$ | Address hold time after FSMC_NOE high | $T_{HCLK} + 1.5$ | - | ns |
| $t_{v(BL_NE)}$ | FSMC_NEx low to FSMC_BL valid | - | 0.5 | ns |
| $t_{h(BL_NOE)}$ | FSMC_BL hold time after FSMC_NOE high | $2 * T_{HCLK} - 0.5$ | - | ns |
| $t_{su(Data_NE)}$ | Data to FSMC_NEx high setup time | T_{HCLK} | - | ns |
| $t_{su(Data_NOE)}$ | Data to FSMC_NOEx high setup time | T_{HCLK} | - | ns |
| $t_{h(Data_NOE)}$ | Data hold time after FSMC_NOE high | 0 | - | ns |
| $t_{h(Data_NE)}$ | Data hold time after FSMC_NEx high | 0 | - | ns |
| $t_{v(NADV_NE)}$ | FSMC_NEx low to FSMC_NADV low | - | 2 | ns |
| $t_{w(NADV)}$ | FSMC_NADV low time | - | T_{HCLK} | ns |

1. $C_L = 30$ pF.

Figure 18. Asynchronous non-multiplexed SRAM/PSRAM/NOR write waveforms



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

Table 38. Asynchronous non-multiplexed SRAM/PSRAM/NOR write timings⁽¹⁾

| Symbol | Parameter | Min | Max | Unit |
|--------------------|---|------------------------|------------------------|------|
| $t_{w(NE)}$ | FSMC_NE low time | $2 \cdot T_{HCLK} - 3$ | $2 \cdot T_{HCLK} + 2$ | ns |
| $t_{v(NWE_NE)}$ | FSMC_NEx low to FSMC_NWE low | 0.5 | 1 | ns |
| $t_{w(NWE)}$ | FSMC_NWE low time | $T_{HCLK} - 2$ | $T_{HCLK} + 3$ | ns |
| $t_{h(NE_NWE)}$ | FSMC_NWE high to FSMC_NE high hold time | $T_{HCLK} - 2.5$ | - | ns |
| $t_{v(A_NE)}$ | FSMC_NEx low to FSMC_A valid | - | 0 | ns |
| $t_{h(A_NWE)}$ | Address hold time after FSMC_NWE high | $T_{HCLK} - 2.5$ | - | ns |
| $t_{v(BL_NE)}$ | FSMC_NEx low to FSMC_BL valid | - | 0 | ns |
| $t_{h(BL_NWE)}$ | FSMC_BL hold time after FSMC_NWE high | $T_{HCLK} - 4$ | - | ns |
| $t_{v(Data_NE)}$ | FSMC_NEx low to Data valid | - | T_{HCLK} | ns |
| $t_{h(Data_NWE)}$ | Data hold time after FSMC_NWE high | $T_{HCLK} - 2.5$ | - | ns |

1. $C_L = 30$ pF.

Figure 19. Asynchronous multiplexed PSRAM/NOR read waveforms

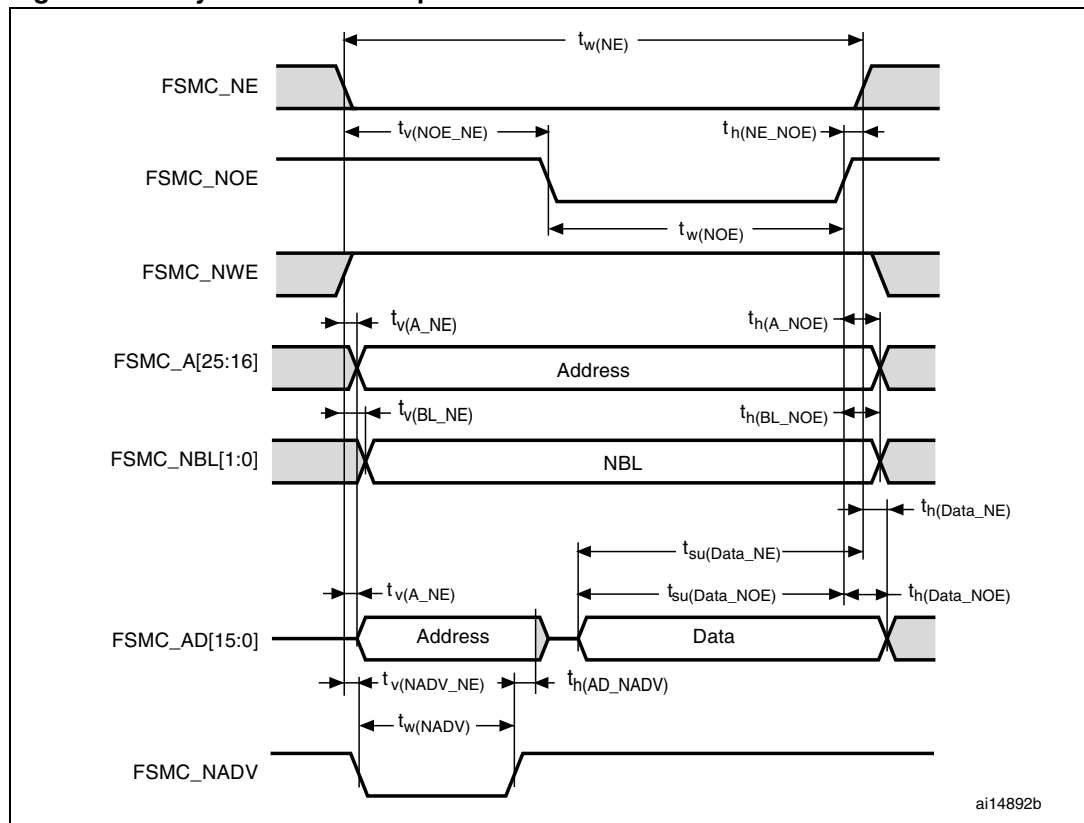


Table 39. Asynchronous multiplexed PSRAM/NOR read timings⁽¹⁾

| Symbol | Parameter | Min | Max | Unit |
|--------------------|---|--------------------------|------------------------|------|
| $t_{w(NE)}$ | FSMC_NE low time | $3 \cdot T_{HCLK} - 1.5$ | $3 \cdot T_{HCLK} + 1$ | ns |
| $t_{v(NO_NE)}$ | FSMC_NEx low to FSMC_NOE low | $2 \cdot T_{HCLK} - 1$ | $2 \cdot T_{HCLK}$ | ns |
| $t_{w(NO)}$ | FSMC_NOE low time | $T_{HCLK} - 0.5$ | $T_{HCLK} + 0.5$ | ns |
| $t_{h(NE_NO)}$ | FSMC_NOE high to FSMC_NE high hold time | 0 | - | ns |
| $t_{v(A_NE)}$ | FSMC_NEx low to FSMC_A valid | - | 5 | ns |
| $t_{v(NADV_NE)}$ | FSMC_NEx low to FSMC_NADV low | 1.5 | 2 | ns |
| $t_{w(NADV)}$ | FSMC_NADV low time | $T_{HCLK} - 0.5$ | T_{HCLK} | ns |
| $t_{h(AD_NADV)}$ | FSMC_AD(address) valid hold time after FSMC_NADV high | $T_{HCLK} - 6$ | - | ns |
| $t_{h(A_NO)}$ | Address hold time after FSMC_NOE high | $2 \cdot T_{HCLK} - 1$ | - | ns |
| $t_{h(BL_NO)}$ | FSMC_BL time after FSMC_NOE high | 1.5 | - | ns |
| $t_{v(BL_NE)}$ | FSMC_NEx low to FSMC_BL valid | - | 0 | ns |
| $t_{su(Data_NE)}$ | Data to FSMC_NEx high setup time | T_{HCLK} | - | ns |
| $t_{su(Data_NO)}$ | Data to FSMC_NOE high setup time | T_{HCLK} | - | ns |
| $t_{h(Data_NE)}$ | Data hold time after FSMC_NEx high | 0 | - | ns |
| $t_{h(Data_NO)}$ | Data hold time after FSMC_NOE high | 0 | - | ns |

1. $C_L = 30$ pF.

Figure 20. Asynchronous multiplexed PSRAM/NOR write waveforms

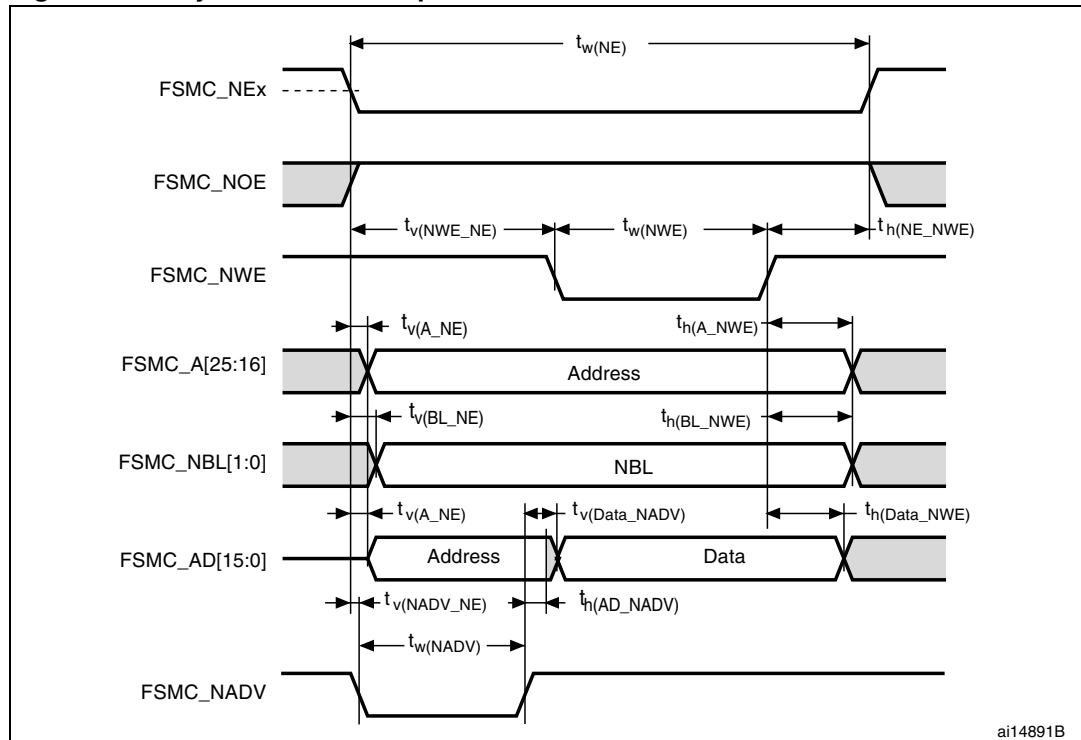


Table 40. Asynchronous multiplexed PSRAM/NOR write timings⁽¹⁾

| Symbol | Parameter | Min | Max | Unit |
|---------------------|--|------------------------|------------------------|------|
| $t_{w(NE)}$ | FSMC_NE low time | $4 \cdot T_{HCLK} - 3$ | $4 \cdot T_{HCLK} + 2$ | ns |
| $t_{v(NWE_NE)}$ | FSMC_NEx low to FSMC_NWE low | T_{HCLK} | $T_{HCLK} + 1$ | ns |
| $t_{w(NWE)}$ | FSMC_NWE low time | $2 \cdot T_{HCLK} - 2$ | $2 \cdot T_{HCLK} + 4$ | ns |
| $t_{h(NE_NWE)}$ | FSMC_NWE high to FSMC_NE high hold time | $T_{HCLK} - 2.5$ | - | ns |
| $t_{v(A_NE)}$ | FSMC_NEx low to FSMC_A valid | - | 6 | ns |
| $t_{v(NADV_NE)}$ | FSMC_NEx low to FSMC_NADV low | 1.5 | 2 | ns |
| $t_{w(NADV)}$ | FSMC_NADV low time | $T_{HCLK} - 4$ | $T_{HCLK} + 4$ | ns |
| $t_{h(AD_NADV)}$ | FSMC_AD (address) valid hold time after FSMC_NADV high | $T_{HCLK} - 5$ | - | ns |
| $t_{h(A_NWE)}$ | Address hold time after FSMC_NWE high | $T_{HCLK} - 2.5$ | - | ns |
| $t_{h(BL_NWE)}$ | FSMC_BL hold time after FSMC_NWE high | $T_{HCLK} - 3$ | - | ns |
| $t_{v(BL_NE)}$ | FSMC_NEx low to FSMC_BL valid | - | 0.5 | ns |
| $t_{v(Data_NADV)}$ | FSMC_NADV high to Data valid | - | $T_{HCLK} + 6$ | ns |
| $t_{h(Data_NWE)}$ | Data hold time after FSMC_NWE high | $T_{HCLK} - 2.5$ | - | ns |

1. $C_L = 30$ pF.

Synchronous waveforms and timings

Figure 21 through Figure 24 represent synchronous waveforms and Table 42 through Table 44 provide the corresponding timings. The results shown in these tables are obtained with the following FSMC configuration:

- BurstAccessMode = FSMC_BurstAccessMode_Enable;
- MemoryType = FSMC_MemoryType_CRAM;
- WriteBurst = FSMC_WriteBurst_Enable;
- CLKDivision = 1;
- DataLatency = 1 for NOR Flash; DataLatency = 0 for PSRAM

Figure 21. Synchronous multiplexed NOR/PSRAM read timings

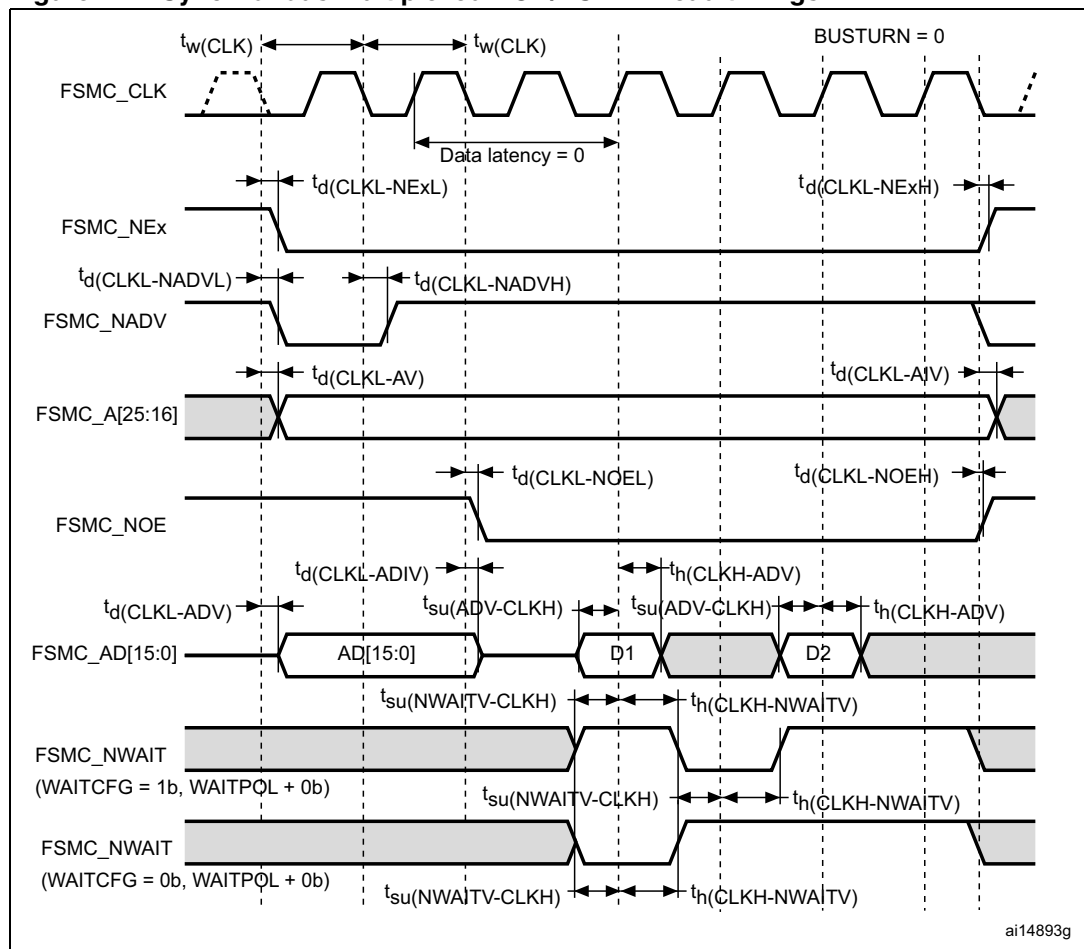


Table 41. Synchronous multiplexed NOR/PSRAM read timings⁽¹⁾

| Symbol | Parameter | Min | Max | Unit |
|------------------------------|---|---------------------------------|-----------------------|------|
| $t_{w(\text{CLK})}$ | FSMC_CLK period | $2 \cdot T_{\text{HCLK}} - 0.5$ | - | ns |
| $t_{d(\text{CLKL-NExL})}$ | FSMC_CLK low to FSMC_NEx low ($x = 0...2$) | - | 0 | ns |
| $t_{d(\text{CLKL-NExH})}$ | FSMC_CLK low to FSMC_NEx high ($x = 0...2$) | $T_{\text{HCLK}} + 1.5$ | - | ns |
| $t_{d(\text{CLKL-NADV})}$ | FSMC_CLK low to FSMC_NADV low | - | 3 | ns |
| $t_{d(\text{CLKL-NADVH})}$ | FSMC_CLK low to FSMC_NADV high | 3.5 | - | ns |
| $t_{d(\text{CLKL-AV})}$ | FSMC_CLK low to FSMC_Ax valid ($x = 16...25$) | - | 0 | ns |
| $t_{d(\text{CLKL-AIV})}$ | FSMC_CLK low to FSMC_Ax invalid ($x = 16...25$) | 0 | - | ns |
| $t_{d(\text{CLKL-NOEL})}$ | FSMC_CLK low to FSMC_NOE low | - | $T_{\text{HCLK}} - 1$ | ns |
| $t_{d(\text{CLKL-NOEH})}$ | FSMC_CLK low to FSMC_NOE high | 2.5 | - | ns |
| $t_{d(\text{CLKL-ADV})}$ | FSMC_CLK low to FSMC_AD[15:0] valid | - | 4 | ns |
| $t_{d(\text{CLKL-ADIV})}$ | FSMC_CLK low to FSMC_AD[15:0] invalid | 0 | - | ns |
| $t_{su(\text{ADV-CLKH})}$ | FSMC_A/D[15:0] valid data before FSMC_CLK high | 6 | - | ns |
| $t_h(\text{CLKH-ADV})$ | FSMC_A/D[15:0] valid data after FSMC_CLK high | 4 | - | ns |
| $t_{su(\text{NWAITV-CLKH})}$ | FSMC_NWAIT valid before FSMC_CLK high | TBD | - | ns |
| $t_h(\text{CLKH-NWAITV})$ | FSMC_NWAIT valid after FSMC_CLK high | TBD | - | ns |

1. $C_L = 30$ pF.

Figure 22. Synchronous multiplexed PSRAM write timings

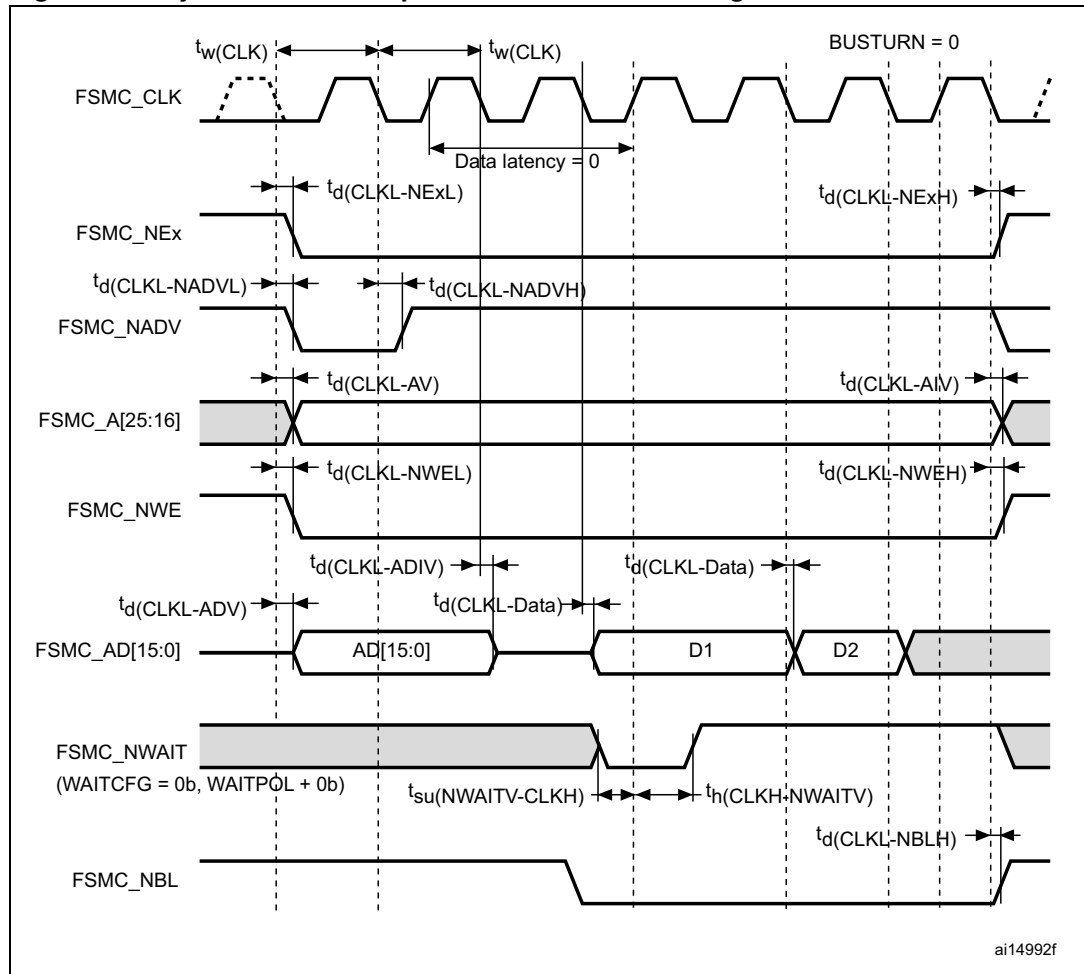


Table 42. Synchronous multiplexed PSRAM write timings⁽¹⁾

| Symbol | Parameter | Min | Max | Unit |
|------------------------------|---|---------------------------|-----|------|
| $t_{w(\text{CLK})}$ | FSMC_CLK period | $2 \cdot T_{\text{HCLK}}$ | - | ns |
| $t_{d(\text{CLKL-NExL})}$ | FSMC_CLK low to FSMC_NEx low (x = 0...2) | - | 0 | ns |
| $t_{d(\text{CLKL-NExH})}$ | FSMC_CLK low to FSMC_NEx high (x = 0...2) | 0 | - | ns |
| $t_{d(\text{CLKL-NADV})}$ | FSMC_CLK low to FSMC_NADV low | - | 0 | ns |
| $t_{d(\text{CLKL-NADVH})}$ | FSMC_CLK low to FSMC_NADV high | 0 | - | ns |
| $t_{d(\text{CLKL-AV})}$ | FSMC_CLK low to FSMC_Ax valid (x = 16...25) | - | 0 | ns |
| $t_{d(\text{CLKL-AIV})}$ | FSMC_CLK low to FSMC_Ax invalid (x = 16...25) | $T_{\text{HCLK}} + 4$ | - | ns |
| $t_{d(\text{CLKL-NWEL})}$ | FSMC_CLK low to FSMC_NWE low | - | 0 | ns |
| $t_{d(\text{CLKL-NWEH})}$ | FSMC_CLK low to FSMC_NWE high | 1 | - | ns |
| $t_{d(\text{CLKL-ADIV})}$ | FSMC_CLK low to FSMC_AD[15:0] invalid | 5 | - | ns |
| $t_{d(\text{CLKL-DATA})}$ | FSMC_A/D[15:0] valid after FSMC_CLK low | - | 6 | ns |
| $t_{su(\text{NWAITV-CLKH})}$ | FSMC_NWAIT valid before FSMC_CLK high | TBD | - | ns |
| $t_h(\text{CLKH-NWAITV})$ | FSMC_NWAIT valid after FSMC_CLK high | TBD | - | ns |
| $t_{d(\text{CLKL-NBLH})}$ | FSMC_CLK low to FSMC_NBL high | 1 | - | ns |

1. $C_L = 30$ pF.

Figure 23. Synchronous non-multiplexed NOR/PSRAM read timings

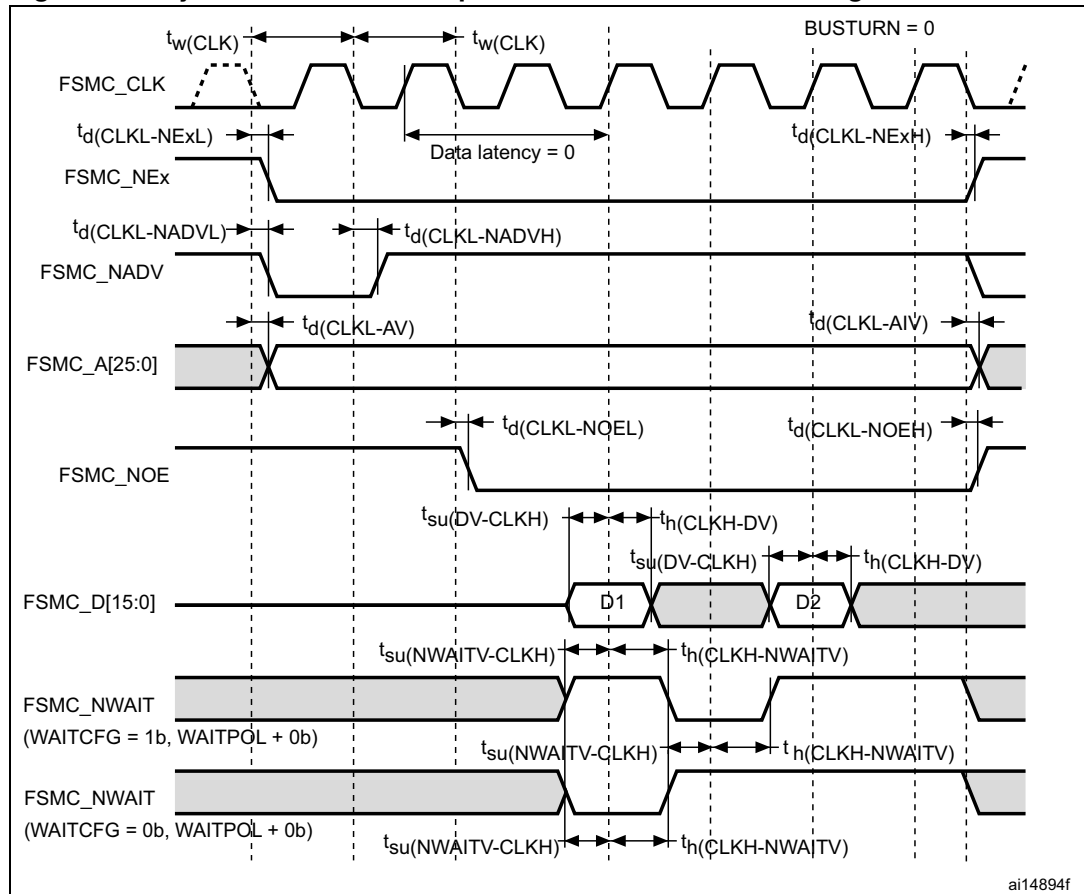


Table 43. Synchronous non-multiplexed NOR/PSRAM read timings⁽¹⁾

| Symbol | Parameter | Min | Max | Unit |
|------------------------------|---|---------------------------------|-----------------------|------|
| $t_w(\text{CLK})$ | FSMC_CLK period | $2 \cdot T_{\text{HCLK}} - 0.5$ | - | ns |
| $t_d(\text{CLKL-NExL})$ | FSMC_CLK low to FSMC_NEx low (x = 0...2) | - | 0 | ns |
| $t_d(\text{CLKL-NExH})$ | FSMC_CLK low to FSMC_NEx high (x = 0...2) | 0 | - | ns |
| $t_d(\text{CLKL-NADVl})$ | FSMC_CLK low to FSMC_NADV low | - | 3 | ns |
| $t_d(\text{CLKL-NADVh})$ | FSMC_CLK low to FSMC_NADV high | 3.5 | - | ns |
| $t_d(\text{CLKL-AV})$ | FSMC_CLK low to FSMC_Ax valid (x = 16...25) | - | 0 | ns |
| $t_d(\text{CLKL-AIV})$ | FSMC_CLK low to FSMC_Ax invalid (x = 16...25) | 0 | - | ns |
| $t_d(\text{CLKL-NOEL})$ | FSMC_CLK low to FSMC_NOE low | - | $T_{\text{HCLK}} + 1$ | ns |
| $t_d(\text{CLKL-NOEH})$ | FSMC_CLK low to FSMC_NOE high | 2.5 | - | ns |
| $t_{su}(\text{DV-CLKH})$ | FSMC_D[15:0] valid data before FSMC_CLK high | 4 | - | ns |
| $t_h(\text{CLKH-DV})$ | FSMC_D[15:0] valid data after FSMC_CLK high | 4 | - | ns |
| $t_{su}(\text{NWAITV-CLKH})$ | FSMC_NWAIT valid before FSMC_CLK high | TBD | - | ns |
| $t_h(\text{CLKH-NWAITV})$ | FSMC_NWAIT valid after FSMC_CLK high | TBD | - | ns |

1. $C_L = 30$ pF.

Figure 24. Synchronous non-multiplexed PSRAM write timings

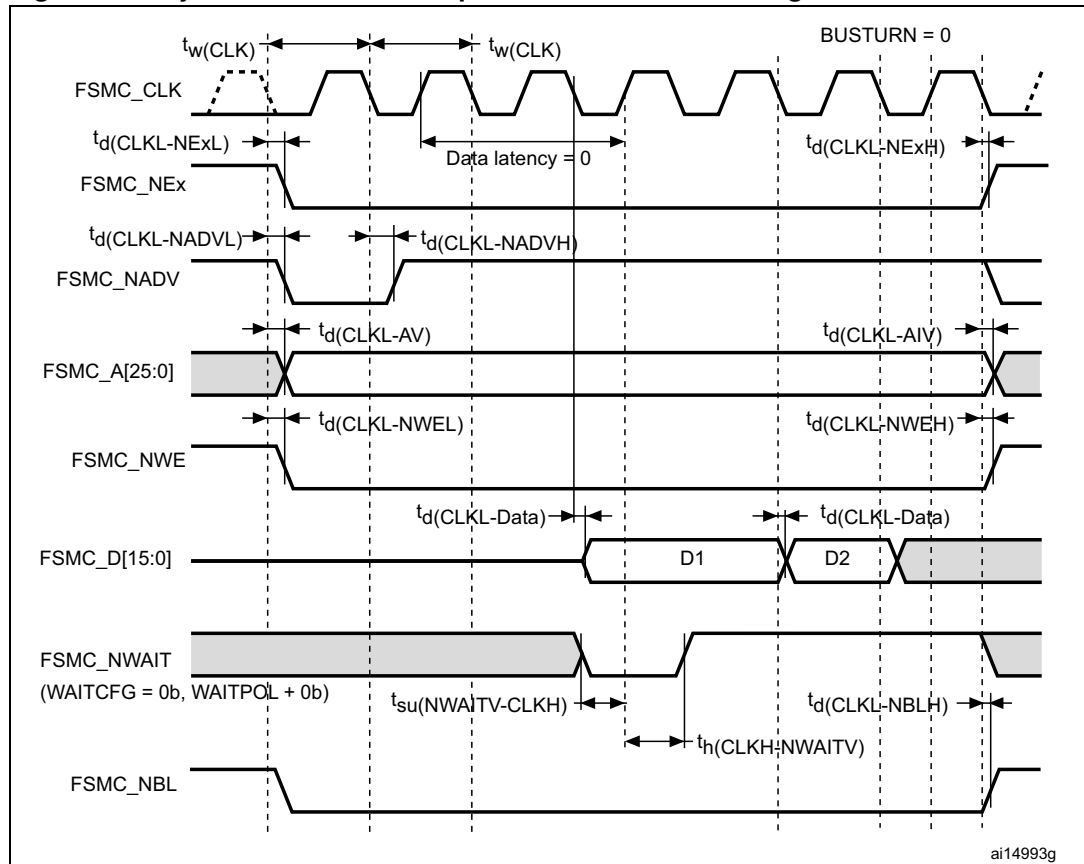


Table 44. Synchronous non-multiplexed PSRAM write timings⁽¹⁾

| Symbol | Parameter | Min | Max | Unit |
|-----------------------|---|------------------------|-----|------|
| $t_{w(CLK)}$ | FSMC_CLK period | $2 \cdot T_{HCLK} - 3$ | - | ns |
| $t_{d(CLKL-NExL)}$ | FSMC_CLK low to FSMC_NEx low (x = 0...2) | - | 0 | ns |
| $t_{d(CLKL-NExH)}$ | FSMC_CLK low to FSMC_NEx high (x = 0...2) | 1 | - | ns |
| $t_{d(CLKL-NADVl)}$ | FSMC_CLK low to FSMC_NADV low | - | 5 | ns |
| $t_{d(CLKL-NADVh)}$ | FSMC_CLK low to FSMC_NADV high | 7 | - | ns |
| $t_{d(CLKL-AV)}$ | FSMC_CLK low to FSMC_Ax valid (x = 16...25) | - | 0 | ns |
| $t_{d(CLKL-AIV)}$ | FSMC_CLK low to FSMC_Ax invalid (x = 16...25) | $T_{HCLK} + 4$ | - | ns |
| $t_{d(CLKL-NWEL)}$ | FSMC_CLK low to FSMC_NWE low | - | 2 | ns |
| $t_{d(CLKL-NWEH)}$ | FSMC_CLK low to FSMC_NWE high | 5 | - | ns |
| $t_{d(CLKL-DATA)}$ | FSMC_D[15:0] valid data after FSMC_CLK low | - | 7 | ns |
| $t_{d(CLKL-NBLH)}$ | FSMC_CLK low to FSMC_NBL high | 3 | - | ns |
| $t_{su(NWAITV-CLKH)}$ | FSMC_NWAIT valid before FSMC_CLK high | TBD | - | ns |
| $t_{h(CLKH-NWAITV)}$ | FSMC_NWAIT valid after FSMC_CLK high | TBD | - | ns |

1. $C_L = 30$ pF.

6.3.10 EMC characteristics

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

Functional EMS (electromagnetic susceptibility)

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

- **Electrostatic discharge (ESD)** (positive and negative) is applied to all device pins until a functional disturbance occurs. This test is compliant with the IEC 61000-4-2 standard.
- **FTB: A Burst of Fast Transient voltage** (positive and negative) is applied to 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 normal operations to be resumed.

The test results are given in [Table 45](#). They are based on the EMS levels and classes defined in application note AN1709.

Table 45. EMS characteristics

| Symbol | Parameter | Conditions | Level/Class |
|------------|---|---|-------------|
| V_{FESD} | Voltage limits to be applied on any I/O pin to induce a functional disturbance | $V_{DD} = 3.3\text{ V}$, LQFP100, $T_A = +25\text{ °C}$, $f_{HCLK} = 32\text{ MHz}$ conforms to IEC 61000-4-2 | 2B |
| V_{EFTB} | Fast transient voltage burst limits to be applied through 100 pF on V_{DD} and V_{SS} pins to induce a functional disturbance | $V_{DD} = 3.3\text{ V}$, LQFP100, $T_A = +25\text{ °C}$, $f_{HCLK} = 32\text{ MHz}$ conforms to IEC 61000-4-4 | 4A |

Designing hardened software to avoid noise problems

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

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

Software recommendations

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

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

Prequalification trials

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

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

Electromagnetic Interference (EMI)

The electromagnetic field emitted by the device are monitored while a simple application is executed (toggling 2 LEDs through the I/O ports). This emission test is compliant with IEC 61967-2 standard which specifies the test board and the pin loading.

Table 46. EMI characteristics

| Symbol | Parameter | Conditions | Monitored frequency band | Max vs. frequency range | | | Unit |
|------------------|------------|---|--------------------------|-------------------------|------------------------|------------------------|------|
| | | | | 4 MHz voltage range 3 | 16 MHz voltage range 2 | 32 MHz voltage range 1 | |
| S _{EMI} | Peak level | V _{DD} = 3.3 V, T _A = 25 °C, LQFP100 package compliant with IEC 61967-2 | 0.1 to 30 MHz | 3 | -6 | -5 | dBµV |
| | | | 30 to 130 MHz | 18 | 4 | -7 | |
| | | | 130 MHz to 1GHz | 15 | 5 | -7 | |
| | | | SAE EMI Level | 2.5 | 2 | 1 | - |

6.3.11 Absolute maximum ratings (electrical sensitivity)

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

Electrostatic discharge (ESD)

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

Table 47. ESD absolute maximum ratings

| Symbol | Ratings | Conditions | Class | Maximum value ⁽¹⁾ | Unit |
|-----------------------|---|--|-------|------------------------------|------|
| V _{ESD(HBM)} | Electrostatic discharge voltage (human body model) | T _A = +25 °C, conforming to JESD22-A114 | 2 | 2000 | V |
| V _{ESD(CDM)} | Electrostatic discharge voltage (charge device model) | T _A = +25 °C, conforming to JESD22-C101 | II | 500 | |

1. Based on characterization results, not tested in production.

Static latch-up

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

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

These tests are compliant with EIA/JESD 78A IC latch-up standard.

Table 48. Electrical sensitivities

| Symbol | Parameter | Conditions | Class |
|--------|-----------------------|--|------------|
| LU | Static latch-up class | T _A = +105 °C conforming to JESD78A | II level A |

6.3.12 I/O current injection characteristics

As a general rule, current injection to the I/O pins, due to external voltage below V_{SS} or above V_{DD} (for standard pins) should be avoided during normal product operation. However, in order to give an indication of the robustness of the microcontroller in cases when abnormal injection accidentally happens, susceptibility tests are performed on a sample basis during device characterization.

Functional susceptibility to I/O current injection

While a simple application is executed on the device, the device is stressed by injecting current into the I/O pins programmed in floating input mode. While current is injected into the I/O pin, one at a time, the device is checked for functional failures.

The failure is indicated by an out of range parameter: ADC error, out of spec current injection on adjacent pins or other functional failure (for example reset, oscillator frequency deviation, LCD levels, etc.).

The test results are given in the following table.

Table 49. I/O current injection susceptibility

| Symbol | Description | Functional susceptibility | | Unit |
|------------------|--|---------------------------|--------------------|------|
| | | Negative injection | Positive injection | |
| I _{INJ} | Injected current on true open-drain pins | -5 | +0 | mA |
| | Injected current on all 5 V tolerant (FT) pins | -5 | +0 | |
| | Injected current on any other pin | -5 | +5 | |

6.3.13 I/O port characteristics

General input/output characteristics

Unless otherwise specified, the parameters given in [Table 50](#) are derived from tests performed under the conditions summarized in [Table 14](#). All I/Os are CMOS and TTL compliant.

Table 50. I/O static characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|-----------|--|---|-----------------------|------|-------------------|------------|
| V_{IL} | Input low level voltage | TTL ports $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | $V_{SS} - 0.3$ | - | 0.8 | V |
| V_{IH} | Standard I/O input high level voltage | | $2^{(1)}$ | - | $V_{DD} + 0.3$ | |
| | FT ⁽²⁾ I/O input high level voltage | - | - | 5.5V | | |
| V_{IL} | Input low level voltage | CMOS ports $1.65\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | -0.3 | - | $0.3V_{DD}^{(3)}$ | V |
| V_{IH} | Standard I/O Input high level voltage | CMOS ports $1.65\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | $0.7 V_{DD}^{(3)(4)}$ | - | $V_{DD} + 0.3$ | |
| | FT ⁽⁵⁾ I/O input high level voltage | CMOS ports $1.65\text{ V} \leq V_{DD} \leq 2.0\text{ V}$ | | - | 5.25 | |
| | | CMOS ports $2.0\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | - | 5.5 | |
| V_{hys} | Standard I/O Schmitt trigger voltage hysteresis ⁽⁶⁾ | | $10\% V_{DD}^{(7)}$ | - | - | |
| I_{lkg} | Input leakage current ⁽⁸⁾⁽³⁾ | $V_{SS} \leq V_{IN} \leq V_{DD}$ I/Os with LCD | - | - | ± 50 | nA |
| | | $V_{SS} \leq V_{IN} \leq V_{DD}$ I/Os with analog switches | - | - | ± 50 | |
| | | $V_{SS} \leq V_{IN} \leq V_{DD}$ I/Os with analog switches and LCD | - | - | ± 50 | |
| | | $V_{SS} \leq V_{IN} \leq V_{DD}$ I/Os with USB | - | - | TBD | |
| | | $V_{SS} \leq V_{IN} \leq V_{DD}$ Standard I/Os | - | - | ± 50 | |
| R_{PU} | Weak pull-up equivalent resistor ⁽⁹⁾⁽³⁾ | $V_{IN} = V_{SS}$ | 30 | 45 | 60 | k Ω |
| R_{PD} | Weak pull-down equivalent resistor ⁽⁹⁾⁽³⁾ | $V_{IN} = V_{DD}$ | 30 | 45 | 60 | k Ω |
| C_{IO} | I/O pin capacitance | | - | 5 | - | pF |

1. Guaranteed by design.
2. FT = 5V tolerant. To sustain a voltage higher than $V_{DD} + 0.5$ the internal pull-up/pull-down resistors must be disabled.
3. Tested in production
4. $0.7V_{DD}$ for 5V-tolerant receiver
5. FT = Five-volt tolerant.
6. Hysteresis voltage between Schmitt trigger switching levels. Based on characterization, not tested in production.
7. With a minimum of 200 mV. Based on characterization, not tested in production.

- 8. The max. value may be exceeded if negative current is injected on adjacent pins.
- 9. Pull-up and pull-down resistors are designed with a true resistance in series with a switchable PMOS/NMOS. This MOS/NMOS contribution to the series resistance is minimum (~10% order).

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 the non-standard V_{OL}/V_{OH} specifications given in [Table 51](#).

in the user application, the number of I/O pins which can drive current must be limited to respect the absolute maximum rating specified in [Section 6.2](#):

- 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 I_{VDD} (see [Table 12](#)).
- 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 I_{VSS} (see [Table 12](#)).

Output voltage levels

Unless otherwise specified, the parameters given in [Table 51](#) are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in [Table 14](#). All I/Os are CMOS and TTL compliant.

Table 51. Output voltage characteristics

| Symbol | Parameter | Conditions | Min | Max | Unit |
|-------------------|---|---|---------------|------|------|
| $V_{OL}^{(1)(2)}$ | Output low level voltage for an I/O pin when 8 pins are sunk at same time | $I_{IO} = +8 \text{ mA}$ $2.7 \text{ V} < V_{DD} < 3.6 \text{ V}$ | - | 0.4 | V |
| $V_{OH}^{(3)(2)}$ | Output high level voltage for an I/O pin when 8 pins are sourced at same time | | 2.4 | - | |
| $V_{OL}^{(1)(4)}$ | Output low level voltage for an I/O pin when 8 pins are sunk at same time | $I_{IO} = +4 \text{ mA}$ $1.65 \text{ V} < V_{DD} < 2.7 \text{ V}$ | - | 0.45 | |
| $V_{OH}^{(3)(4)}$ | Output high level voltage for an I/O pin when 8 pins are sourced at same time | | $V_{DD}-0.45$ | - | |
| $V_{OL}^{(1)(4)}$ | Output low level voltage for an I/O pin when 4 pins are sunk at same time | $I_{IO} = +20 \text{ mA}$ $2.7 \text{ V} < V_{DD} < 3.6 \text{ V}$ | - | 1.3 | |
| $V_{OH}^{(3)(4)}$ | Output high level voltage for an I/O pin when 4 pins are sourced at same time | | $V_{DD}-1.3$ | - | |

1. The I_{IO} current sunk by the device must always respect the absolute maximum rating specified in [Table 12](#) and the sum of I_{IO} (I/O ports and control pins) must not exceed I_{VSS} .
2. Tested in production.
3. The I_{IO} current sourced by the device must always respect the absolute maximum rating specified in [Table 12](#) and the sum of I_{IO} (I/O ports and control pins) must not exceed I_{VDD} .
4. Based on characterization data, not tested in production.

Input/output AC characteristics

The definition and values of input/output AC characteristics are given in [Figure 25](#) and [Table 52](#), respectively.

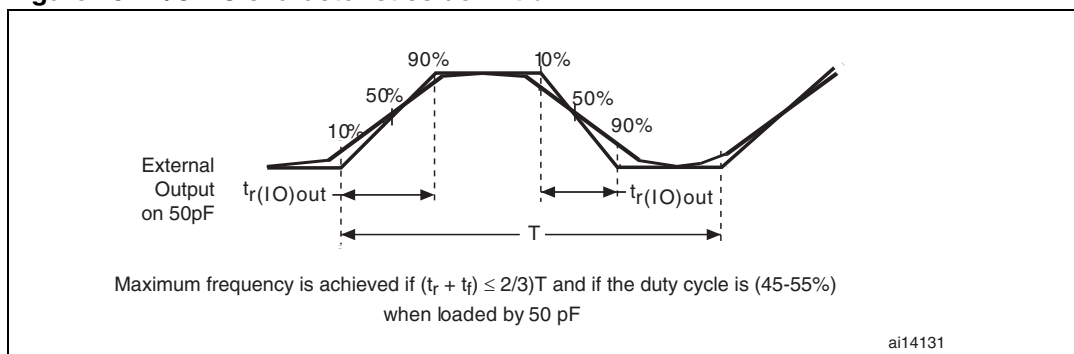
Unless otherwise specified, the parameters given in [Table 52](#) are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in [Table 14](#).

Table 52. I/O AC characteristics⁽¹⁾

| OSPEEDRx [1:0] bit value ⁽¹⁾ | Symbol | Parameter | Conditions | Min | Max ⁽²⁾ | Unit |
|---|--|---|--|-----|--------------------|------|
| 00 | $f_{\max(\text{IO})\text{out}}$ | Maximum frequency ⁽³⁾ | $C_L = 50 \text{ pF}, V_{DD} = 2.7 \text{ V to } 3.6 \text{ V}$ | - | 400 | kHz |
| | | | $C_L = 50 \text{ pF}, V_{DD} = 1.65 \text{ V to } 2.7 \text{ V}$ | - | 400 | |
| | $t_{f(\text{IO})\text{out}}$ $t_{r(\text{IO})\text{out}}$ | Output rise and fall time | $C_L = 50 \text{ pF}, V_{DD} = 2.7 \text{ V to } 3.6 \text{ V}$ | - | 625 | ns |
| | | | $C_L = 50 \text{ pF}, V_{DD} = 1.65 \text{ V to } 2.7 \text{ V}$ | - | 625 | |
| 01 | $f_{\max(\text{IO})\text{out}}$ | Maximum frequency ⁽³⁾ | $C_L = 50 \text{ pF}, V_{DD} = 2.7 \text{ V to } 3.6 \text{ V}$ | - | 2 | MHz |
| | | | $C_L = 50 \text{ pF}, V_{DD} = 1.65 \text{ V to } 2.7 \text{ V}$ | - | 1 | |
| | $t_{f(\text{IO})\text{out}}$ $t_{r(\text{IO})\text{out}}$ | Output rise and fall time | $C_L = 50 \text{ pF}, V_{DD} = 2.7 \text{ V to } 3.6 \text{ V}$ | - | 125 | ns |
| | | | $C_L = 50 \text{ pF}, V_{DD} = 1.65 \text{ V to } 2.7 \text{ V}$ | - | 250 | |
| 10 | $F_{\max(\text{IO})\text{out}}$ | Maximum frequency ⁽³⁾ | $C_L = 50 \text{ pF}, V_{DD} = 2.7 \text{ V to } 3.6 \text{ V}$ | - | 10 | MHz |
| | | | $C_L = 50 \text{ pF}, V_{DD} = 1.65 \text{ V to } 2.7 \text{ V}$ | - | 2 | |
| | $t_{f(\text{IO})\text{out}}$ $t_{r(\text{IO})\text{out}}$ | Output rise and fall time | $C_L = 50 \text{ pF}, V_{DD} = 2.7 \text{ V to } 3.6 \text{ V}$ | - | 25 | ns |
| | | | $C_L = 50 \text{ pF}, V_{DD} = 1.65 \text{ V to } 2.7 \text{ V}$ | - | 125 | |
| 11 | $F_{\max(\text{IO})\text{out}}$ | Maximum frequency ⁽³⁾ | $C_L = 30 \text{ pF}, V_{DD} = 2.7 \text{ V to } 3.6 \text{ V}$ | - | 50 | MHz |
| | | | $C_L = 50 \text{ pF}, V_{DD} = 1.65 \text{ V to } 2.7 \text{ V}$ | - | 8 | |
| | $t_{f(\text{IO})\text{out}}$ $t_{r(\text{IO})\text{out}}$ | Output rise and fall time | $C_L = 30 \text{ pF}, V_{DD} = 2.7 \text{ V to } 3.6 \text{ V}$ | - | 5 | ns |
| | | | $C_L = 50 \text{ pF}, V_{DD} = 1.65 \text{ V to } 2.7 \text{ V}$ | - | 30 | |
| - | $t_{\text{EXTI}pw}$ | Pulse width of external signals detected by the EXTI controller | | 8 | - | ns |

1. The I/O speed is configured using the OSPEEDRx[1:0] bits. Refer to the STM32L151xx, STM32L152xx and STM32L162xx reference manual for a description of GPIO Port configuration register.
2. Guaranteed by design. Not tested in production.
3. The maximum frequency is defined in [Figure 25](#).

Figure 25. I/O AC characteristics definition



6.3.14 NRST pin characteristics

The NRST pin input driver uses CMOS technology.

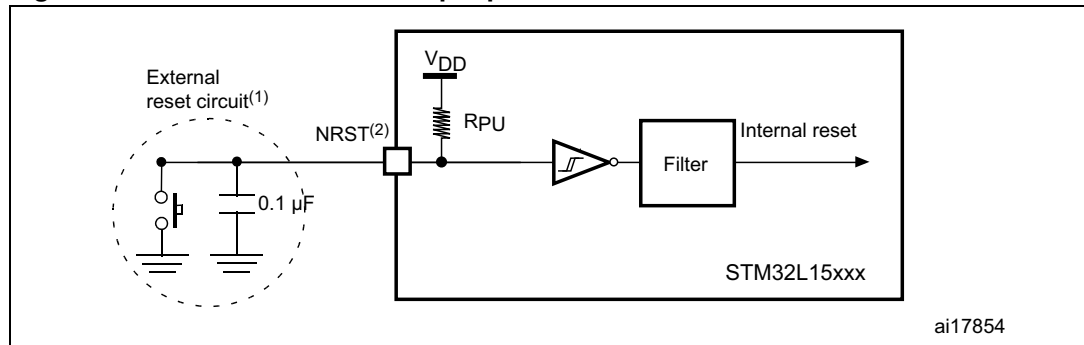
Unless otherwise specified, the parameters given in [Table 53](#) are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in [Table 14](#).

Table 53. NRST pin characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|-----------------------|---|--|--------------------|-----|----------|------------|
| $V_{IL(NRST)}^{(1)}$ | NRST input low level voltage | | V_{SS} | - | 0.8 | V |
| $V_{IH(NRST)}^{(1)}$ | NRST input high level voltage | | 1.4 | - | V_{DD} | |
| $V_{OL(NRST)}^{(1)}$ | NRST output low level voltage | $I_{OL} = 2 \text{ mA}$ $2.7 \text{ V} < V_{DD} < 3.6 \text{ V}$ | - | - | 0.4 | |
| | | $I_{OL} = 1.5 \text{ mA}$ $1.65 \text{ V} < V_{DD} < 2.7 \text{ V}$ | - | - | | |
| $V_{hys(NRST)}^{(1)}$ | NRST Schmitt trigger voltage hysteresis | | $10\%V_{DD}^{(2)}$ | - | - | mV |
| R_{PU} | Weak pull-up equivalent resistor ⁽³⁾ | $V_{IN} = V_{SS}$ | 30 | 45 | 60 | k Ω |
| $V_{F(NRST)}^{(1)}$ | NRST input filtered pulse | | - | - | 50 | ns |
| $V_{NF(NRST)}^{(1)}$ | NRST input not filtered pulse | | 350 | - | - | ns |

1. Guaranteed by design, not tested in production.
2. 200 mV minimum value
3. The pull-up is designed with a true resistance in series with a switchable PMOS. This PMOS contribution to the series resistance is around 10%.

Figure 26. 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 53](#). Otherwise the reset will not be taken into account by the device.

6.3.15 TIM timer characteristics

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

Refer to [Section 6.3.12: I/O current injection characteristics](#) for details on the input/output alternate function characteristics (output compare, input capture, external clock, PWM output).

Table 54. TIMx⁽¹⁾ characteristics

| Symbol | Parameter | Conditions | Min | Max | Unit |
|------------------|--|--------------------------------|--------|----------------------|---------------|
| $t_{res(TIM)}$ | Timer resolution time | | 1 | - | $t_{TIMxCLK}$ |
| | | $f_{TIMxCLK} = 32 \text{ MHz}$ | 31.25 | - | ns |
| f_{EXT} | Timer external clock frequency on CH1 to CH4 | | 0 | $f_{TIMxCLK}/2$ | MHz |
| | | $f_{TIMxCLK} = 32 \text{ MHz}$ | 0 | 16 | MHz |
| Res_{TIM} | Timer resolution | | | 16 | bit |
| $t_{COUNTER}$ | 16-bit counter clock period when internal clock is selected (timer's prescaler disabled) | | 1 | 65536 | $t_{TIMxCLK}$ |
| | | $f_{TIMxCLK} = 32 \text{ MHz}$ | 0.0312 | 2048 | μs |
| t_{MAX_COUNT} | Maximum possible count | | - | 65536×65536 | $t_{TIMxCLK}$ |
| | | $f_{TIMxCLK} = 32 \text{ MHz}$ | - | 134.2 | s |

1. TIMx is used as a general term to refer to the TIM2, TIM3 and TIM4 timers.

6.3.16 Communications interfaces

I²C interface characteristics

Unless otherwise specified, the parameters given in [Table 55](#) are derived from tests performed under ambient temperature, f_{PCLK1} frequency and V_{DD} supply voltage conditions summarized in [Table 14](#).

The STM32L151xD and STM32L152xD product line I²C interface meets the requirements of the standard I²C communication protocol with the following restrictions: SDA and SCL are not “true” open-drain I/O pins. When configured as open-drain, the PMOS connected between the I/O pin and V_{DD} is disabled, but is still present.

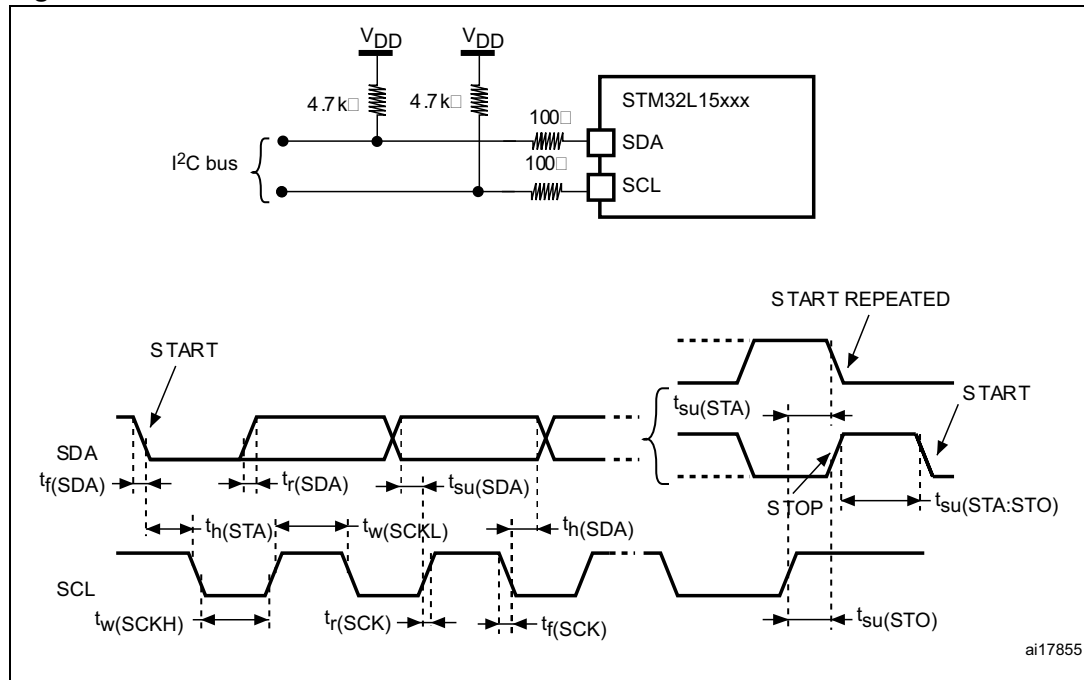
The I²C characteristics are described in [Table 55](#). Refer also to [Section 6.3.12: I/O current injection characteristics](#) for more details on the input/output alternate function characteristics (SDA and SCL).

Table 55. I²C characteristics

| Symbol | Parameter | Standard mode I ² C ⁽¹⁾ | | Fast mode I ² C ⁽¹⁾⁽²⁾ | | Unit |
|--------------------------|---|---|------|--|--------------------|------|
| | | Min | Max | Min | Max | |
| $t_{w(SCLL)}$ | SCL clock low time | 4.7 | - | 1.3 | - | μs |
| $t_{w(SCLH)}$ | SCL clock high time | 4.0 | - | 0.6 | - | |
| $t_{su(SDA)}$ | SDA setup time | 250 | - | 100 | - | ns |
| $t_h(SDA)$ | SDA data hold time | 0 | - | 0 | 900 ⁽³⁾ | |
| $t_r(SDA)$ $t_r(SCL)$ | SDA and SCL rise time | - | 1000 | $20 + 0.1C_b$ | 300 | |
| $t_f(SDA)$ $t_f(SCL)$ | SDA and SCL fall time | - | 300 | - | 300 | |
| $t_h(STA)$ | Start condition hold time | 4.0 | - | 0.6 | - | |
| $t_{su(STA)}$ | Repeated Start condition setup time | 4.7 | - | 0.6 | - | μs |
| $t_{su(STO)}$ | Stop condition setup time | 4.0 | - | 0.6 | - | μs |
| $t_{w(STO:STA)}$ | Stop to Start condition time (bus free) | 4.7 | - | 1.3 | - | μs |
| C_b | Capacitive load for each bus line | - | 400 | - | 400 | pF |

1. Guaranteed by design, not tested in production.
2. f_{PCLK1} must be at least 2 MHz to achieve standard mode I²C frequencies. It must be at least 4 MHz to achieve fast mode I²C frequencies. It must be a multiple of 10 MHz to reach the 400 kHz maximum I²C fast mode clock.
3. The maximum Data hold time has only to be met if the interface does not stretch the low period of SCL signal.

Figure 27. I²C bus AC waveforms and measurement circuit



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

Table 56. SCL frequency ($f_{PCLK1} = 32 \text{ MHz}$, $V_{DD} = 3.3 \text{ V}$)⁽¹⁾⁽²⁾

| f_{SCL} (kHz) | I2C_CCR value |
|-----------------|-----------------------------|
| | $R_p = 4.7 \text{ k}\Omega$ |
| 400 | 0x801B |
| 300 | 0x8024 |
| 200 | 0x8035 |
| 100 | 0x00A0 |
| 50 | 0x0140 |
| 20 | 0x0320 |

- R_p = External pull-up resistance, f_{SCL} = I²C speed.
- For speeds around 200 kHz, the tolerance on the achieved speed is of $\pm 5\%$. For other speed ranges, the tolerance on the achieved speed is $\pm 2\%$. These variations depend on the accuracy of the external components used to design the application.

SPI characteristics

Unless otherwise specified, the parameters given in the following table are derived from tests performed under ambient temperature, f_{PCLKx} frequency and V_{DD} supply voltage conditions summarized in [Table 14](#).

Refer to [Section 6.3.12: I/O current injection characteristics](#) for more details on the input/output alternate function characteristics (NSS, SCK, MOSI, MISO).

Table 57. SPI characteristics⁽¹⁾

| Symbol | Parameter | Conditions | Min | Max ⁽²⁾ | Unit |
|--|----------------------------------|----------------------------|---------------|--------------------|------|
| f_{SCK} $1/t_{c(SCK)}$ | SPI clock frequency | Master mode | - | 16 | MHz |
| | | Slave mode | - | 16 | |
| | | Slave transmitter | - | 12 ⁽³⁾ | |
| $t_{r(SCK)}^{(2)}$ $t_{f(SCK)}^{(2)}$ | SPI clock rise and fall time | Capacitive load: C = 30 pF | - | 6 | ns |
| DuCy(SCK) | SPI slave input clock duty cycle | Slave mode | 30 | 70 | % |
| $t_{su(NSS)}$ | NSS setup time | Slave mode | $4t_{HCLK}$ | - | ns |
| $t_{h(NSS)}$ | NSS hold time | Slave mode | $2t_{HCLK}$ | - | |
| $t_{w(SCKH)}^{(2)}$ $t_{w(SCKL)}^{(2)}$ | SCK high and low time | Master mode | $t_{SCK}/2-5$ | $t_{SCK}/2+3$ | |
| $t_{su(MI)}^{(2)}$ | Data input setup time | Master mode | 5 | - | |
| $t_{su(SI)}^{(2)}$ | | Slave mode | 6 | - | |
| $t_{h(MI)}^{(2)}$ | Data input hold time | Master mode | 5 | - | |
| $t_{h(SI)}^{(2)}$ | | Slave mode | 5 | - | |
| $t_{a(SO)}^{(4)}$ | Data output access time | Slave mode | 0 | $3t_{HCLK}$ | |
| $t_{v(SO)}^{(2)}$ | Data output valid time | Slave mode | - | 33 | |
| $t_{v(MO)}^{(2)}$ | Data output valid time | Master mode | - | 6.5 | |
| $t_{h(SO)}^{(2)}$ | Data output hold time | Slave mode | 17 | - | |
| $t_{h(MO)}^{(2)}$ | | Master mode | 0.5 | - | |

1. The characteristics above are given for voltage range 1.
2. Based on characterization, not tested in production.
3. The maximum SPI clock frequency in slave transmitter mode is given for an SPI slave input clock duty cycle (DuCy(SCK)) ranging between 40 to 60%.
4. Min time is for the minimum time to drive the output and max time is for the maximum time to validate the data.

Figure 28. SPI timing diagram - slave mode and CPHA = 0

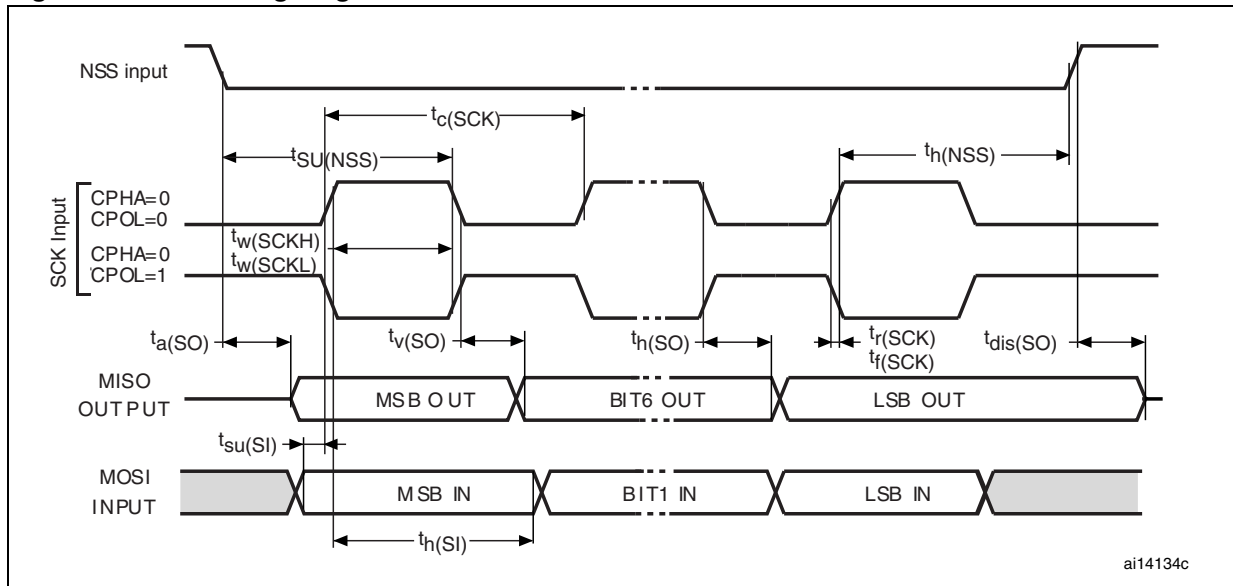
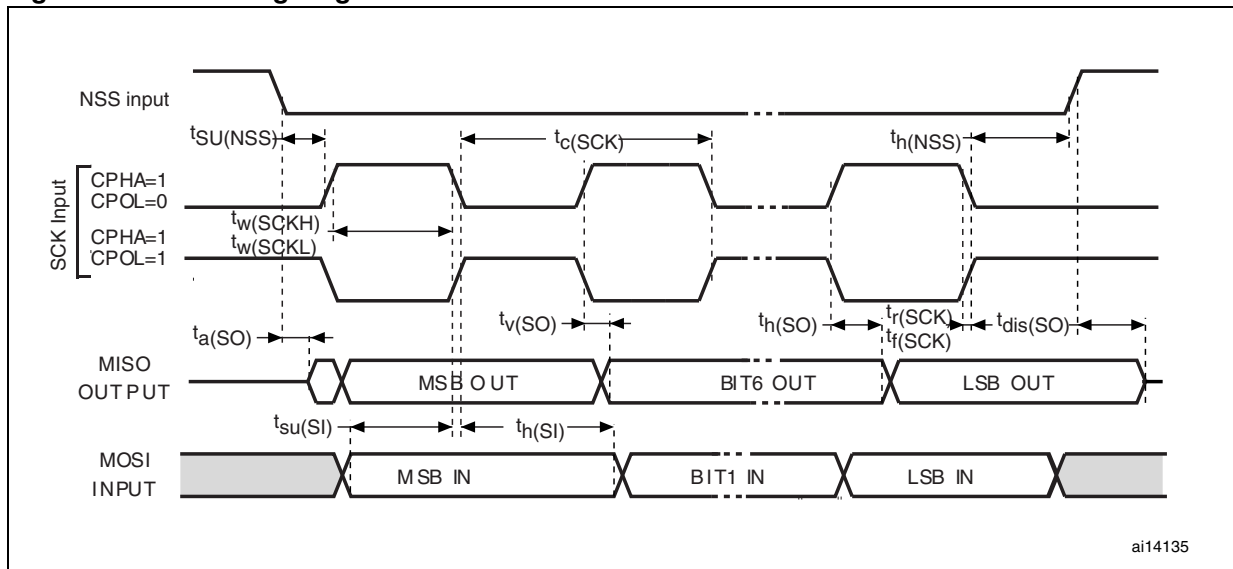
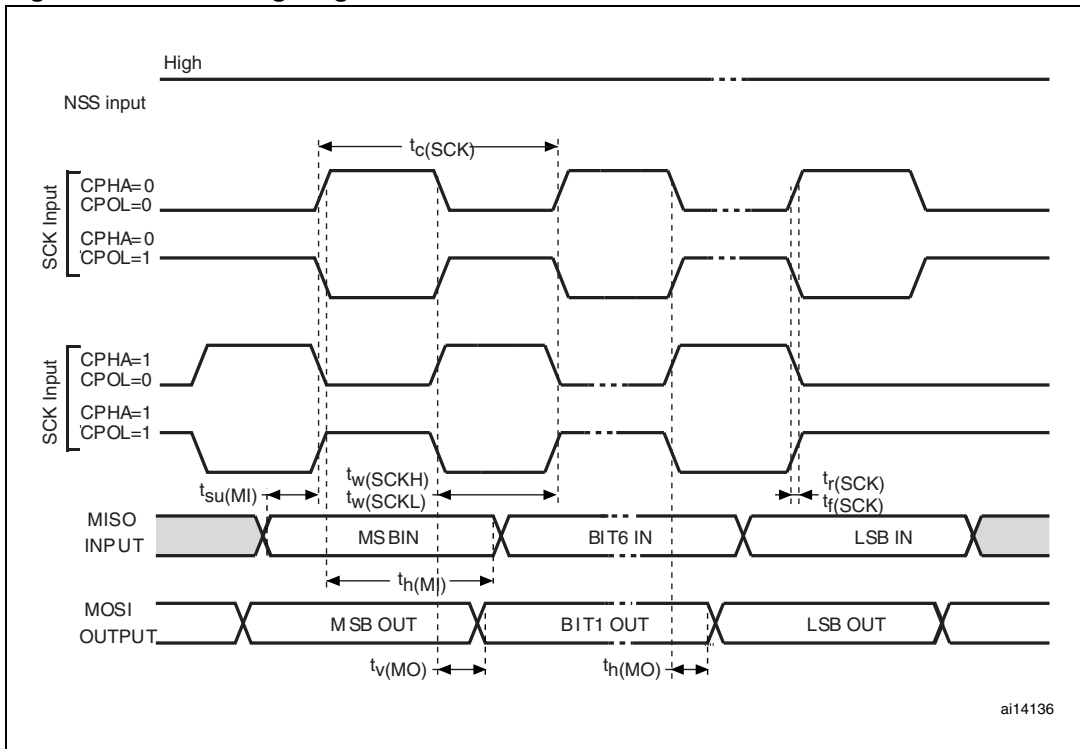


Figure 29. SPI timing diagram - slave mode and CPHA = 1⁽¹⁾



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

Figure 30. SPI timing diagram - master mode⁽¹⁾



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

6.3.17 I2S characteristics

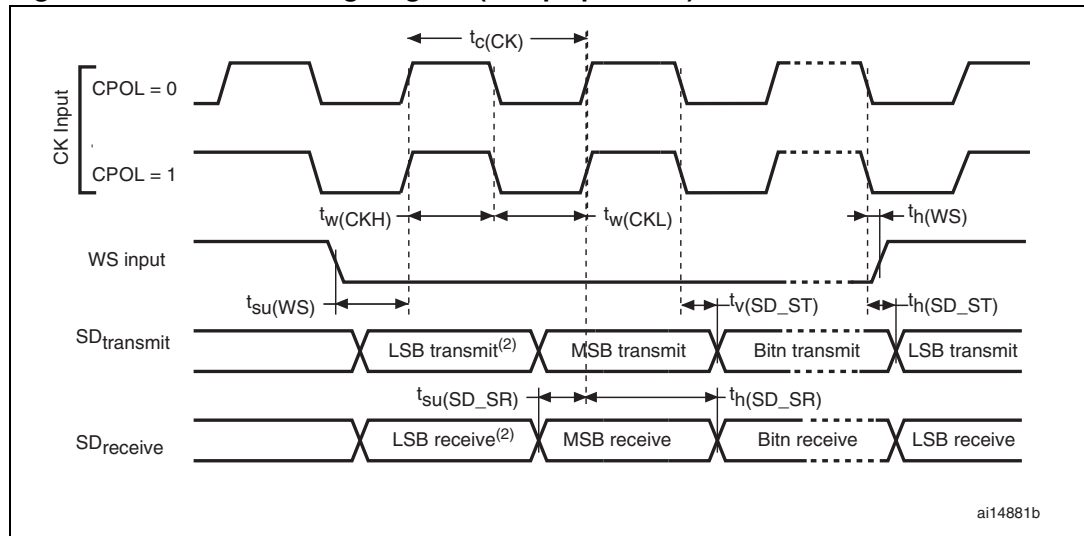
Table 58. I2S characteristics

| Symbol | Parameter | Conditions | Min | Max | Unit |
|------------------|--------------------------------|--|----------|---------------------------|------|
| f_{MCK} | I2S Main Clock Output | | 256 x 8K | 256x F_s ⁽¹⁾ | MHz |
| f_{CK} | I2S clock frequency | Master data: 32 bits | - | 64x F_s | MHz |
| | | Slave data: 32 bits | - | 64x F_s | |
| D_{CK} | I2S clock frequency duty cycle | Slave receiver, 48KHz | 30 | 70 | % |
| $t_{r(CK)}$ | I2S clock rise time | Capacitive load CL=30pF | - | 8 | ns |
| $t_{f(CK)}$ | I2S clock fall time | | | 8 | |
| $t_{v(WS)}$ | WS valid time | Master mode | 4 | 24 | |
| $t_{h(WS)}$ | WS hold time | Master mode | 0 | - | |
| $t_{su(WS)}$ | WS setup time | Slave mode | 15 | - | |
| $t_{h(WS)}$ | WS hold time | Slave mode | 0 | - | |
| $t_{su(SD_MR)}$ | Data input setup time | Master receiver | 8 | - | |
| $t_{su(SD_SR)}$ | Data input setup time | Slave receiver | 9 | - | |
| $t_{h(SD_MR)}$ | Data input hold time | Master receiver | 5 | - | |
| $t_{h(SD_SR)}$ | | Slave receiver | 4 | - | |
| $t_{v(SD_ST)}$ | Data output valid time | Slave transmitter (after enable edge) | - | 64 | |
| $t_{h(SD_ST)}$ | Data output hold time | Slave transmitter (after enable edge) | 22 | - | |
| $t_{v(SD_MT)}$ | Data output valid time | Master transmitter (after enable edge) | - | 12 | |
| $t_{h(SD_MT)}$ | Data output hold time | Master transmitter (after enable edge) | 8 | - | |

1. The maximum for 256x F_s is 8 MHz

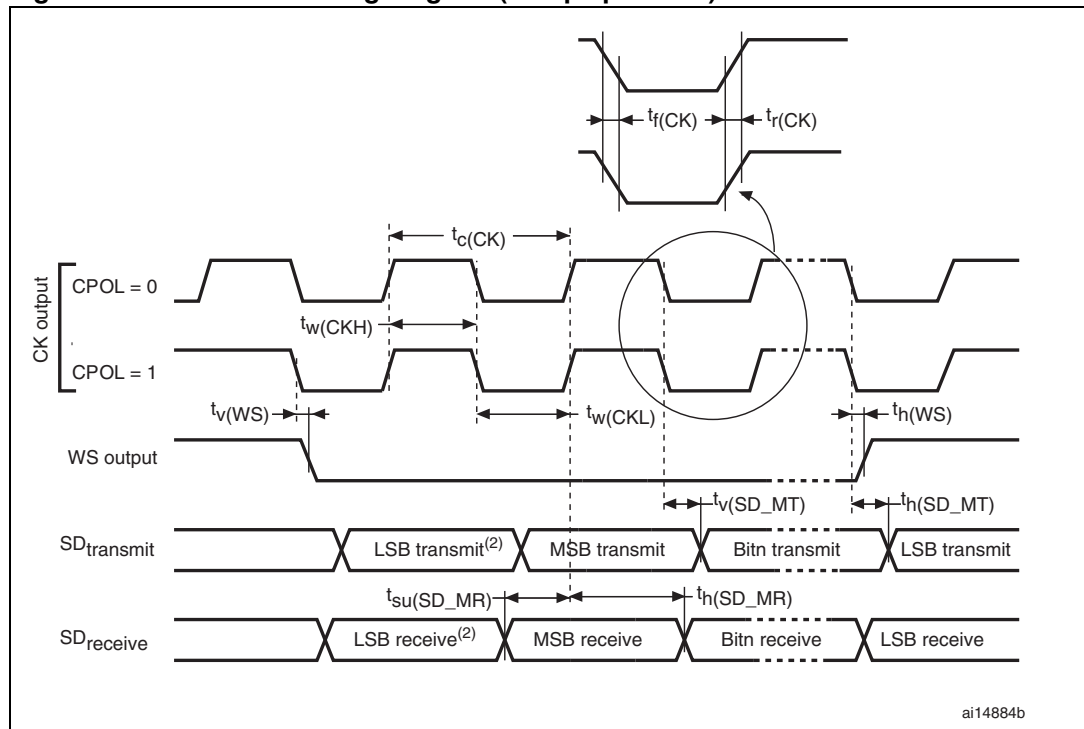
Note: Refer to the I2S section of the product reference manual for more details about the sampling frequency (F_s), f_{MCK} , f_{CK} and D_{CK} values. These values reflect only the digital peripheral behavior, source clock precision might slightly change them. D_{CK} depends mainly on the ODD bit value, digital contribution leads to a min of $(I2SDIV/(2*I2SDIV+ODD))$ and a max of $(I2SDIV+ODD)/(2*I2SDIV+ODD)$. F_s max is supported for each mode/condition.

Figure 31. I²S slave timing diagram (Philips protocol)⁽¹⁾



1. Measurement points are done at CMOS levels: $0.3 \times V_{DD}$ and $0.7 \times V_{DD}$.
2. LSB transmit/receive of the previously transmitted byte. No LSB transmit/receive is sent before the first byte.

Figure 32. I²S master timing diagram (Philips protocol)⁽¹⁾



1. Based on characterization, not tested in production.
2. LSB transmit/receive of the previously transmitted byte. No LSB transmit/receive is sent before the first byte.

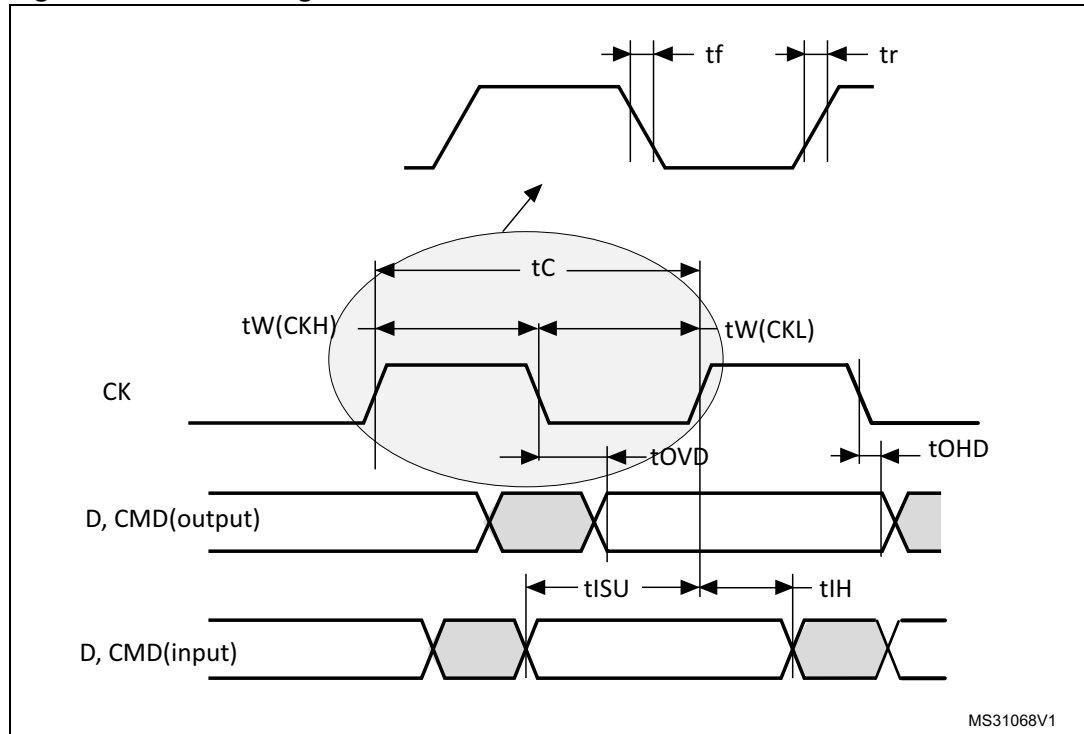
6.3.18 SDIO characteristics

Table 59. SDIO characteristics⁽¹⁾

| Symbol | Parameter | Conditions | Min | Max | Unit |
|--|--|-------------------------|-------------------|-----|------|
| f_{PP} | Clock frequency in data transfer mode | $CL \leq 30 \text{ pF}$ | 0 | 24 | MHz |
| $t_{W(CKL)}$ | Clock low time, $f_{PP} = 24 \text{ MHz}$ | $CL \leq 30 \text{ pF}$ | 20 ⁽²⁾ | - | ns |
| $t_{W(CKH)}$ | Clock high time, $f_{PP} = 24 \text{ MHz}$ | $CL \leq 30 \text{ pF}$ | 18 ⁽²⁾ | - | |
| t_r | Clock rise time, $f_{PP} = 24 \text{ MHz}$ | $CL \leq 30 \text{ pF}$ | - | 5 | |
| t_f | Clock fall time, $f_{PP} = 24 \text{ MHz}$ | $CL \leq 30 \text{ pF}$ | - | 5 | |
| CMD, D inputs (referenced to CK) in SD default mode | | | | | |
| | | | From 2.8 to 3.6 V | | |
| t_{ISU} | Input setup time, $f_{PP} = 24 \text{ MHz}$ | $CL \leq 30 \text{ pF}$ | 2 | - | ns |
| t_{IH} | Input hold time, $f_{PP} = 24 \text{ MHz}$ | $CL \leq 30 \text{ pF}$ | 1.6 | - | |
| CMD, D outputs (referenced to CK) in SD default mode | | | | | |
| t_{OVD} | Output valid default time, $f_{PP} = 24 \text{ MHz}$ | $CL \leq 30 \text{ pF}$ | 0 | 14 | ns |
| t_{OHD} | Output hold default time, $f_{PP} = 24 \text{ MHz}$ | $CL \leq 30 \text{ pF}$ | 0 | - | |

1. Based on characterization, not tested in production.
2. Values measured with a threshold level equal to $V_{DD}/2$.

Figure 33. SDIO timings



USB characteristics

The USB interface is USB-IF certified (full speed).

Table 60. USB startup time

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

1. Guaranteed by design, not tested in production.

Table 61. USB DC electrical characteristics

| Symbol | Parameter | Conditions | Min. ⁽¹⁾ | Max. ⁽¹⁾ | Unit |
|----------------------|---------------------------------|---|---------------------|---------------------|------|
| Input levels | | | | | |
| V_{DD} | USB operating voltage | | 3.0 | 3.6 | V |
| $V_{DI}^{(2)}$ | Differential input sensitivity | I(USB_DP, USB_DM) | 0.2 | - | V |
| $V_{CM}^{(2)}$ | Differential common mode range | Includes V_{DI} range | 0.8 | 2.5 | |
| $V_{SE}^{(2)}$ | Single ended receiver threshold | | 1.3 | 2.0 | |
| Output levels | | | | | |
| $V_{OL}^{(3)}$ | Static output level low | R_L of 1.5 k Ω to 3.6 V ⁽⁴⁾ | - | 0.3 | V |
| $V_{OH}^{(3)}$ | Static output level high | R_L of 15 k Ω to $V_{SS}^{(4)}$ | 2.8 | 3.6 | |

1. All the voltages are measured from the local ground potential.
2. Guaranteed by characterization, not tested in production.
3. Tested in production.
4. R_L is the load connected on the USB drivers.

Figure 34. USB timings: definition of data signal rise and fall time

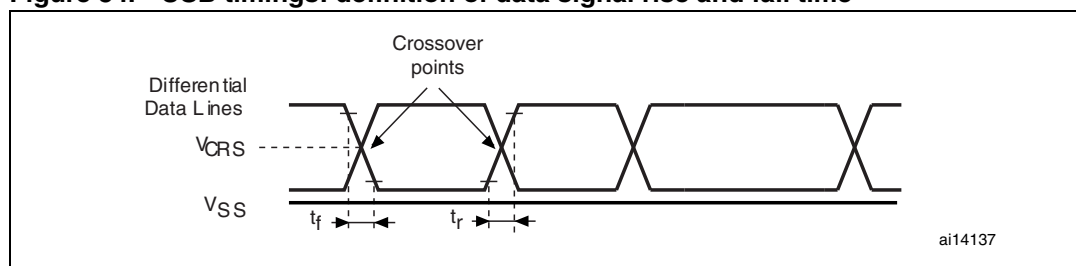


Table 62. USB: full speed electrical characteristics

| Driver characteristics ⁽¹⁾ | | | | | |
|---------------------------------------|---------------------------------|---------------|-----|-----|------|
| Symbol | Parameter | Conditions | Min | Max | Unit |
| t_r | Rise time ⁽²⁾ | $C_L = 50$ pF | 4 | 20 | ns |
| t_f | Fall Time ⁽²⁾ | $C_L = 50$ pF | 4 | 20 | ns |
| t_{rfm} | Rise/ fall time matching | t_r/t_f | 90 | 110 | % |
| V_{CRS} | Output signal crossover voltage | | 1.3 | 2.0 | V |

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

6.3.19 12-bit ADC characteristics

Unless otherwise specified, the parameters given in [Table 64](#) are guaranteed by design.

Table 63. ADC clock frequency

| Symbol | Parameter | Conditions | | Min | Max | Unit | |
|-----------|---------------------|---------------------|---|--|-------|------|-----|
| f_{ADC} | ADC clock frequency | Voltage range 1 & 2 | $2.4\text{ V} \leq V_{DDA} \leq 3.6\text{ V}$ | $V_{REF+} = V_{DDA}$ | 0.480 | 16 | MHz |
| | | | | $V_{REF+} < V_{DDA}$ $V_{REF+} > 2.4\text{ V}$ | | 8 | |
| | | | | $V_{REF+} < V_{DDA}$ $V_{REF+} \leq 2.4\text{ V}$ | | 4 | |
| | | | $1.8\text{ V} \leq V_{DDA} \leq 2.4\text{ V}$ | $V_{REF+} = V_{DDA}$ | | 8 | |
| | | | | $V_{REF+} < V_{DDA}$ | | 4 | |
| | | | | Voltage range 3 | | 4 | |

Table 64. ADC characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|------------------|---|---|--------------------|-----------|------------|---------------|
| V_{DDA} | Power supply | | 1.8 | - | 3.6 | |
| V_{REF+} | Positive reference voltage | $2.4\text{ V} \leq V_{DDA} \leq 3.6\text{ V}$ V_{REF+} must be below or equal to V_{DDA} | 1.8 ⁽¹⁾ | - | V_{DDA} | V |
| V_{REF-} | Negative reference voltage | | - | V_{SSA} | - | |
| I_{VDDA} | Current on the V_{DDA} input pin | | - | 1000 | 1450 | μA |
| $I_{VREF}^{(2)}$ | Current on the V_{REF} input pin | Peak | - | 400 | 700 | |
| | | Average | - | | 450 | |
| V_{AIN} | Conversion voltage range ⁽³⁾ | | 0 ⁽⁴⁾ | - | V_{REF+} | V |
| f_S | 12-bit sampling rate | Direct channels | 0.03 | - | 1 | Msps |
| | | Multiplexed channels | 0.03 | - | 0.76 | |
| | 10-bit sampling rate | Direct channels | 0.03 | - | 1.07 | Msps |
| | | Multiplexed channels | 0.03 | - | 0.8 | |
| | 8-bit sampling rate | Direct channels | 0.03 | - | 1.23 | Msps |
| | | Multiplexed channels | 0.03 | - | 0.89 | |
| | 6-bit sampling rate | Direct channels | 0.03 | - | 1.54 | Msps |
| | | Multiplexed channels | 0.03 | - | 1 | |

Table 64. ADC characteristics (continued)

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|------------------------|--|---|---|-----|---------------------|--------------------|
| t_S | Sampling time | Direct channels $2.4\text{ V} \leq V_{DDA} \leq 3.6\text{ V}$ | 0.25 ⁽⁵⁾ | - | - | μs |
| | | Multiplexed channels $2.4\text{ V} \leq V_{DDA} \leq 3.6\text{ V}$ | 0.56 ⁽⁵⁾ | - | - | |
| | | Direct channels $1.8\text{ V} \leq V_{DDA} \leq 2.4\text{ V}$ | 0.56 ⁽⁵⁾ | - | - | |
| | | Multiplexed channels $1.8\text{ V} \leq V_{DDA} \leq 2.4\text{ V}$ | 1 ⁽⁵⁾ | - | - | |
| | | | 4 | - | 384 | $1/f_{\text{ADC}}$ |
| t_{CONV} | Total conversion time (including sampling time) | $f_{\text{ADC}} = 16\text{ MHz}$ | 1 | - | 24.75 | μs |
| | | | 4 to 384 (sampling phase) + 12 (successive approximation) | | | $1/f_{\text{ADC}}$ |
| C_{ADC} | Internal sample and hold capacitor | Direct channels | - | 16 | - | pF |
| | | Multiplexed channels | - | | - | |
| f_{TRIG} | External trigger frequency Regular sequencer | 12-bit conversions | - | - | $T_{\text{conv}}+1$ | $1/f_{\text{ADC}}$ |
| | | 6/8/10-bit conversions | - | - | T_{conv} | $1/f_{\text{ADC}}$ |
| f_{TRIG} | External trigger frequency Injected sequencer | 12-bit conversions | - | - | $T_{\text{conv}}+2$ | $1/f_{\text{ADC}}$ |
| | | 6/8/10-bit conversions | - | - | $T_{\text{conv}}+1$ | $1/f_{\text{ADC}}$ |
| $R_{\text{AIN}}^{(6)}$ | External input impedance | | - | - | 50 | $\text{k}\Omega$ |
| | | | - | - | 0.5 | |
| t_{lat} | Injection trigger conversion latency | $f_{\text{ADC}} = 16\text{ MHz}$ | 219 | - | 281 | ns |
| | | | 3.5 | - | 4.5 | |
| t_{latr} | Regular trigger conversion latency | $f_{\text{ADC}} = 16\text{ MHz}$ | 156 | - | 219 | ns |
| | | | 2.5 | - | 3.5 | |
| t_{STAB} | Power-up time | | - | - | 3.5 | μs |

- The Vref+ input can be grounded if neither the ADC nor the DAC are used (this allows to shut down an external voltage reference).
- The current consumption through VREF is composed of two parameters:
 - one constant (max 300 μA)
 - one variable (max 400 μA), only during sampling time + 2 first conversion pulses

So, peak consumption is $300+400 = 700\text{ }\mu\text{A}$ and average consumption is $300 + [(4\text{ sampling} + 2) / 16] \times 400 = 450\text{ }\mu\text{A}$ at 1Msps
- $V_{\text{REF+}}$ can be internally connected to V_{DDA} and $V_{\text{REF-}}$ can be internally connected to V_{SSA} , depending on the package. Refer to [Section 4: Pin descriptions](#) for further details.
- V_{SSA} or $V_{\text{REF-}}$ must be tied to ground.
- Minimum sampling and conversion time is reached for maximum $R_{\text{ext}} = 0.5\text{ k}\Omega$.
- For 1 Msps, maximum R_{ext} is 0.5 $\text{k}\Omega$.

Table 65. ADC accuracy⁽¹⁾⁽²⁾

| Symbol | Parameter | Test conditions | Min ⁽³⁾ | Typ | Max ⁽³⁾ | Unit |
|--------|--------------------------------------|---|--------------------|-----|--------------------|------|
| ET | Total unadjusted error | $2.4\text{ V} \leq V_{DDA} \leq 3.6\text{ V}$ $2.4\text{ V} \leq V_{REF+} \leq 3.6\text{ V}$ $f_{ADC} = 8\text{ MHz}$, $R_{AIN} = 50\ \Omega$ $T_A = -40\text{ to }105\text{ }^\circ\text{C}$ | - | 2 | 4 | LSB |
| EO | Offset error | | - | 1 | 2 | |
| EG | Gain error | | - | 1.5 | 3.5 | |
| ED | Differential linearity error | | - | 1 | 2 | |
| EL | Integral linearity error | | - | 1.7 | 3 | |
| ENOB | Effective number of bits | $2.4\text{ V} \leq V_{DDA} \leq 3.6\text{ V}$ $V_{DDA} = V_{REF+}$ $f_{ADC} = 16\text{ MHz}$, $R_{AIN} = 50\ \Omega$ $T_A = -40\text{ to }105\text{ }^\circ\text{C}$ $1\text{ kHz} \leq F_{input} \leq 100\text{ kHz}$ | 9.2 | 10 | - | bits |
| SINAD | Signal-to-noise and distortion ratio | | 57.5 | 62 | - | dB |
| SNR | Signal-to-noise ratio | | 57.5 | 62 | - | |
| THD | Total harmonic distortion | | -74 | -75 | - | |
| ET | Total unadjusted error | | - | 4 | 6.5 | |
| EO | Offset error | $2.4\text{ V} \leq V_{DDA} \leq 3.6\text{ V}$ $1.8\text{ V} \leq V_{REF+} \leq 2.4\text{ V}$ $f_{ADC} = 4\text{ MHz}$, $R_{AIN} = 50\ \Omega$ $T_A = -40\text{ to }105\text{ }^\circ\text{C}$ | - | 2 | 4 | LSB |
| EG | Gain error | | - | 4 | 6 | |
| ED | Differential linearity error | | - | 1 | 2 | |
| EL | Integral linearity error | | - | 1.5 | 3 | |
| ET | Total unadjusted error | | - | 2 | 3 | |
| EO | Offset error | $1.8\text{ V} \leq V_{DDA} \leq 2.4\text{ V}$ $1.8\text{ V} \leq V_{REF+} \leq 2.4\text{ V}$ $f_{ADC} = 4\text{ MHz}$, $R_{AIN} = 50\ \Omega$ $T_A = -40\text{ to }105\text{ }^\circ\text{C}$ | - | 1 | 1.5 | LSB |
| EG | Gain error | | - | 1.5 | 2 | |
| ED | Differential linearity error | | - | 1 | 2 | |
| EL | Integral linearity error | | - | 1 | 1.5 | |
| ET | Total unadjusted error | | - | 2 | 3 | |

1. ADC DC accuracy values are measured after internal calibration.
2. ADC accuracy vs. negative injection current: Injecting a negative current on any analog input pins should be avoided as this significantly reduces the accuracy of the conversion being performed on another analog input. It is recommended to add a Schottky diode (pin to ground) to analog pins which may potentially inject negative currents. Any positive injection current within the limits specified for $I_{INJ(PIN)}$ and $\Sigma I_{INJ(PIN)}$ in [Section 6.3.12](#) does not affect the ADC accuracy.
3. Based on characterization, not tested in production.

Figure 35. ADC accuracy characteristics

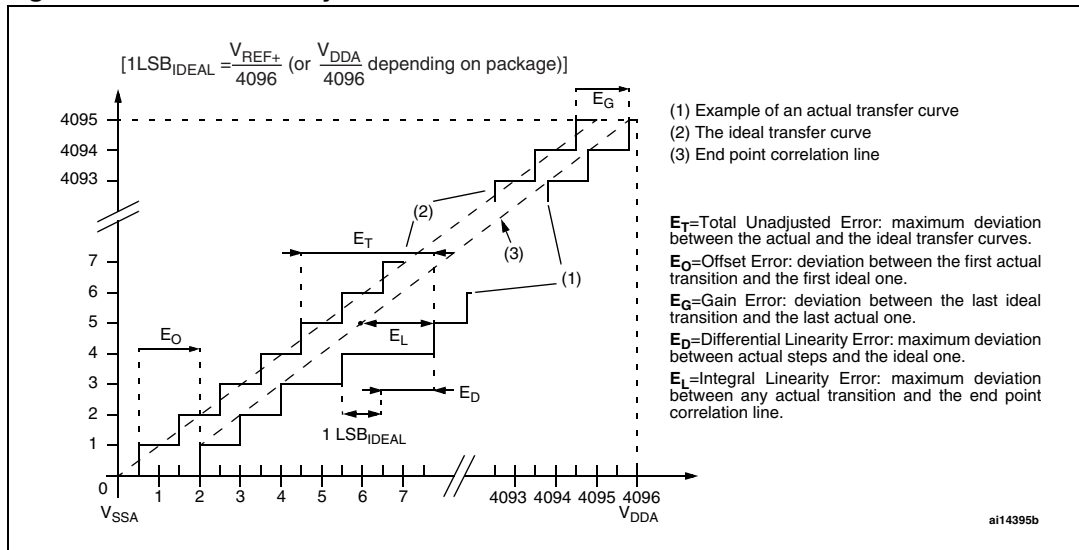
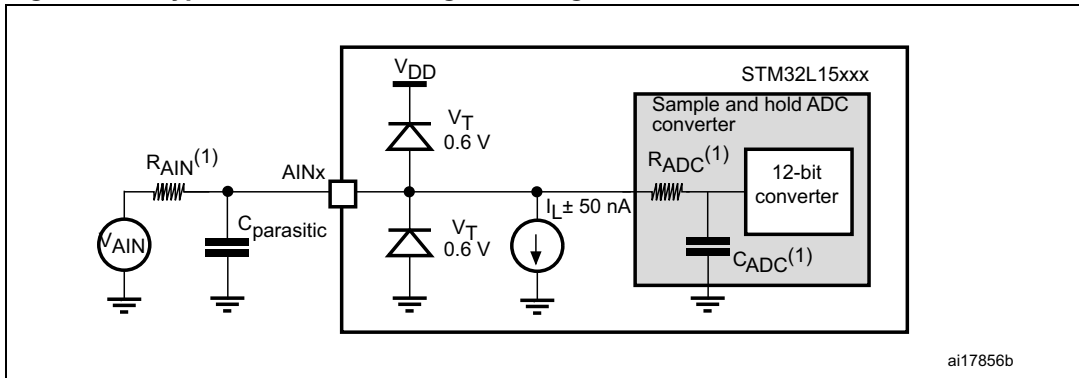


Figure 36. Typical connection diagram using the ADC



1. Refer to [Table 64](#) for the values of R_{AIN} , R_{ADC} and C_{ADC} .
2. $C_{parasitic}$ represents the capacitance of the PCB (dependent on soldering and PCB layout quality) plus the pad capacitance (roughly 7 pF). A high $C_{parasitic}$ value will downgrade conversion accuracy. To remedy this, f_{ADC} should be reduced.

Figure 37. Maximum dynamic current consumption on V_{REF+} supply pin during ADC conversion

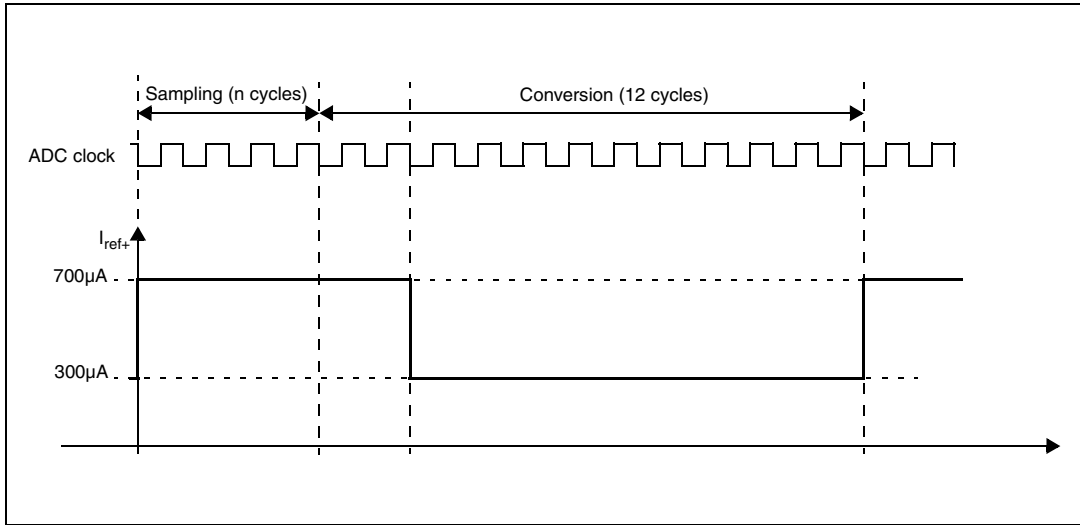


Table 66. R_{AIN} max for f_{ADC} = 16 MHz⁽¹⁾

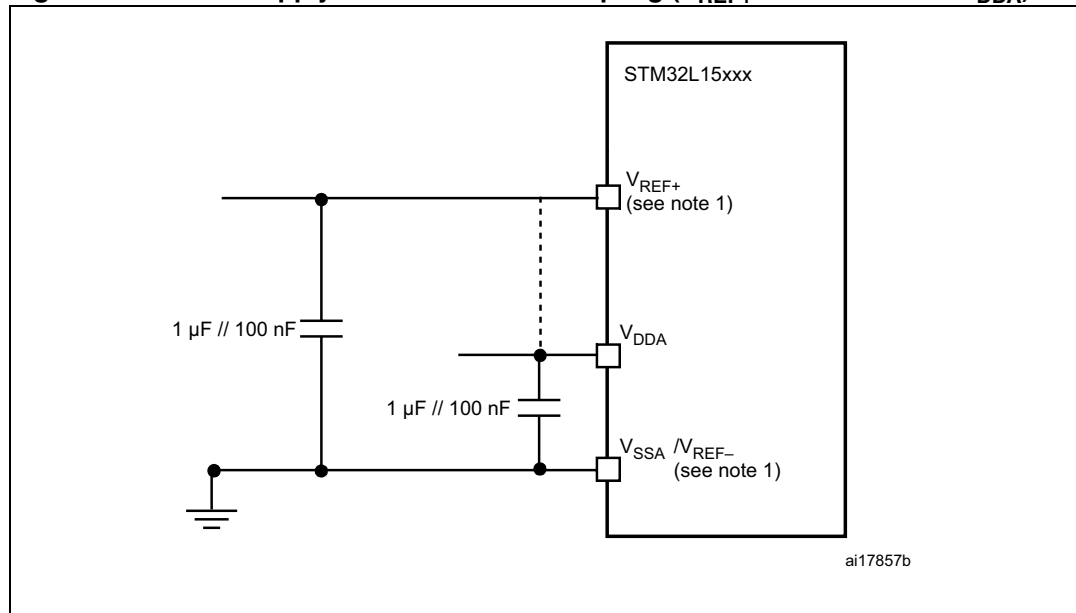
| Ts (cycles) | Ts (µs) | R _{AIN} max (kΩ) | | | |
|-------------|---------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| | | Multiplexed channels | | Direct channels | |
| | | 2.4 V < V _{DDA} < 3.6 V | 1.8 V < V _{DDA} < 2.4 V | 2.4 V < V _{DDA} < 3.3 V | 1.8 V < V _{DDA} < 2.4 V |
| 4 | 0.25 | Not allowed | Not allowed | 0.7 | Not allowed |
| 9 | 0.5625 | 0.8 | Not allowed | 2.0 | 1.0 |
| 16 | 1 | 2.0 | 0.8 | 4.0 | 3.0 |
| 24 | 1.5 | 3.0 | 1.8 | 6.0 | 4.5 |
| 48 | 3 | 6.8 | 4.0 | 15.0 | 10.0 |
| 96 | 6 | 15.0 | 10.0 | 30.0 | 20.0 |
| 192 | 12 | 32.0 | 25.0 | 50.0 | 40.0 |
| 384 | 24 | 50.0 | 50.0 | 50.0 | 50.0 |

1. Guaranteed by design, not tested in production.

General PCB design guidelines

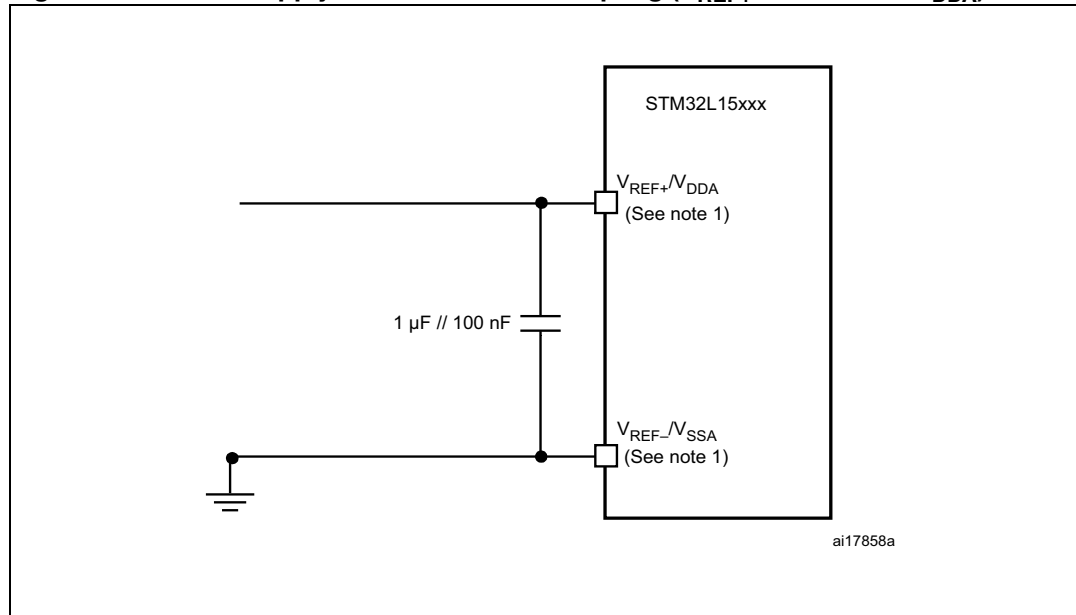
Power supply decoupling should be performed as shown in *Figure 38* or *Figure 39*, depending on whether V_{REF+} is connected to V_{DDA} or not. The 10 nF capacitors should be ceramic (good quality). They should be placed as close as possible to the chip.

Figure 38. Power supply and reference decoupling (V_{REF+} not connected to V_{DDA})



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

Figure 39. Power supply and reference decoupling (V_{REF+} connected to V_{DDA})



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

6.3.20 DAC electrical specifications

Data guaranteed by design, not tested in production, unless otherwise specified.

Table 67. DAC characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|-------------------------------------|--|--|------------------|------|--------------------------|------|
| V _{DDA} | Analog supply voltage | | 1.8 | - | 3.6 | V |
| V _{REF+} | Reference supply voltage | V _{REF+} must always be below V _{DDA} | 1.8 | - | 3.6 | |
| V _{REF-} | Lower reference voltage | | V _{SSA} | | | |
| I _{DDVREF+} ⁽¹⁾ | Current consumption on V _{REF+} supply V _{REF+} = 3.3 V | No load, middle code (0x800) | - | 130 | 220 | μA |
| | | No load, worst code (0x000) | - | 220 | 350 | |
| I _{DDA} ⁽¹⁾ | Current consumption on V _{DDA} supply V _{DDA} = 3.3 V | No load, middle code (0x800) | - | 210 | 320 | |
| | | No load, worst code (0xF1C) | - | 320 | 520 | |
| R _L ⁽²⁾ | Resistive load | DAC output buffer ON | 5 | - | - | kΩ |
| C _L ⁽²⁾ | Capacitive load | | - | - | 50 | pF |
| R _O | Output impedance | DAC output buffer OFF | 6 | 8 | 10 | kΩ |
| V _{DAC_OUT} | Voltage on DAC_OUT output | DAC output buffer ON | 0.2 | - | V _{DDA} - 0.2 | V |
| | | DAC output buffer OFF | 0.5 | - | V _{REF+} - 1LSB | mV |
| DNL ⁽¹⁾ | Differential non linearity ⁽³⁾ | C _L ≤ 50 pF, R _L ≥ 5 kΩ DAC output buffer ON | - | 1.5 | 3 | LSB |
| | | No R _{LOAD} , C _L ≤ 50 pF DAC output buffer OFF | - | 1.5 | 3 | |
| INL ⁽¹⁾ | Integral non linearity ⁽⁴⁾ | C _L ≤ 50 pF, R _L ≥ 5 kΩ DAC output buffer ON | - | 2 | 4 | |
| | | No R _{LOAD} , C _L ≤ 50 pF DAC output buffer OFF | - | 2 | 4 | |
| Offset ⁽¹⁾ | Offset error at code 0x800 ⁽⁵⁾ | C _L ≤ 50 pF, R _L ≥ 5 kΩ DAC output buffer ON | - | ±10 | ±25 | |
| | | No R _{LOAD} , C _L ≤ 50 pF DAC output buffer OFF | - | ±5 | ±8 | |
| Offset1 ⁽¹⁾ | Offset error at code 0x001 ⁽⁶⁾ | No R _{LOAD} , C _L ≤ 50 pF DAC output buffer OFF | - | ±1.5 | ±5 | |

Table 67. DAC characteristics (continued)

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---------------------------|--|---|-----|--------------|--------------|-------|
| dOffset/dT ⁽¹⁾ | Offset error temperature coefficient (code 0x800) | V _{DDA} = 3.3V V _{REF+} = 3.0V T _A = 0 to 50 °C DAC output buffer OFF | -20 | -10 | 0 | μV/°C |
| | | V _{DDA} = 3.3V V _{REF+} = 3.0V T _A = 0 to 50 °C DAC output buffer ON | 0 | 20 | 50 | |
| Gain ⁽¹⁾ | Gain error ⁽⁷⁾ | C _L ≤ 50 pF, R _L ≥ 5 kΩ DAC output buffer ON | - | +0.1 / -0.2% | +0.2 / -0.5% | % |
| | | No R _{LOAD} , C _L ≤ 50 pF DAC output buffer OFF | - | +0 / -0.2% | +0 / -0.4% | |
| dGain/dT ⁽¹⁾ | Gain error temperature coefficient | V _{DDA} = 3.3V V _{REF+} = 3.0V T _A = 0 to 50 °C DAC output buffer OFF | -10 | -2 | 0 | μV/°C |
| | | V _{DDA} = 3.3V V _{REF+} = 3.0V T _A = 0 to 50 °C DAC output buffer ON | -40 | -8 | 0 | |
| TUE ⁽¹⁾ | Total unadjusted error | C _L ≤ 50 pF, R _L ≥ 5 kΩ DAC output buffer ON | - | 12 | 30 | LSB |
| | | No R _{LOAD} , C _L ≤ 50 pF DAC output buffer OFF | - | 8 | 12 | |
| t _{SETTLING} | Settling time (full scale: for a 12-bit code transition between the lowest and the highest input codes till DAC_OUT reaches final value ±1LSB) | C _L ≤ 50 pF, R _L ≥ 5 kΩ | - | 7 | 12 | μs |
| Update rate | Max frequency for a correct DAC_OUT change (95% of final value) with 1 LSB variation in the input code | C _L ≤ 50 pF, R _L ≥ 5 kΩ | - | | 1 | MSPS |
| t _{WAKEUP} | Wakeup time from off state (setting the ENx bit in the DAC Control register) ⁽⁸⁾ | C _L ≤ 50 pF, R _L ≥ 5 kΩ | - | 9 | 15 | μs |
| PSRR+ | V _{DDA} supply rejection ratio (static DC measurement) | C _L ≤ 50 pF, R _L ≥ 5 kΩ | - | -60 | -35 | dB |

1. Data based on characterization results.

2. Connected between DAC_OUT and V_{SSA}.

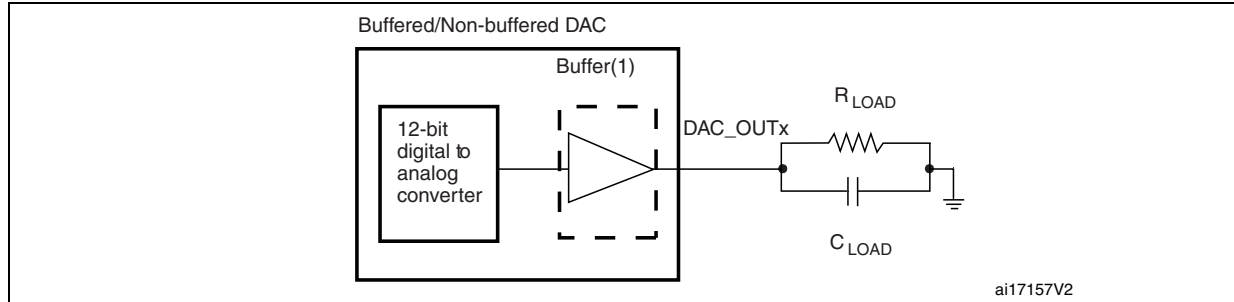
3. Difference between two consecutive codes - 1 LSB.

4. Difference between measured value at Code i and the value at Code i on a line drawn between Code 0 and last Code 4095.

5. Difference between the value measured at Code (0x800) and the ideal value = V_{REF+}/2.

6. Difference between the value measured at Code (0x001) and the ideal value.
7. Difference between ideal slope of the transfer function and measured slope computed from code 0x000 and 0xFF when buffer is OFF, and from code giving 0.2 V and ($V_{DDA} - 0.2$) V when buffer is ON.
8. In buffered mode, the output can overshoot above the final value for low input code (starting from min value).

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.

6.3.21 Operational amplifier characteristics

Table 68. Operational amplifier characteristics

| Symbol | Parameter | | Condition ⁽¹⁾ | Min ⁽²⁾ | Typ | Max ⁽²⁾ | Unit |
|-----------------------------|------------------------------|---------------------------|--------------------------|--------------------|-----|--------------------|------------------------------|
| CMIR | Common mode input range | | | 0 | - | V_{DD} | |
| $V_{I\text{OFFSET}}$ | Input offset voltage | Maximum calibration range | | - | - | ± 15 | mV |
| | | After offset calibration | | - | - | ± 1.5 | |
| $\Delta V_{I\text{OFFSET}}$ | Input offset voltage drift | Normal mode | | - | - | ± 40 | $\mu\text{V}/^\circ\text{C}$ |
| | | Low power mode | | - | - | ± 80 | |
| I_{IB} | Input current bias | Dedicated input | 75 °C | - | - | 1 | nA |
| | | General purpose input | | - | - | 10 | |
| I_{LOAD} | Drive current | Normal mode | | - | - | 500 | μA |
| | | Low power mode | | - | - | 100 | |
| I_{DD} | Consumption | Normal mode | No load, quiescent mode | - | 100 | 220 | μA |
| | | Low power mode | | - | 30 | 60 | |
| CMRR | Common mode rejection ration | Normal mode | | - | -85 | - | dB |
| | | Low power mode | | - | -90 | - | |
| PSRR | Power supply rejection ratio | Normal mode | DC | - | -85 | - | dB |
| | | Low power mode | | - | -90 | - | |

Table 68. Operational amplifier characteristics (continued)

| Symbol | Parameter | | Condition ⁽¹⁾ | Min ⁽²⁾ | Typ | Max ⁽²⁾ | Unit |
|----------------------|---|----------------|---|--------------------|------|--------------------|---------------|
| GBW | Bandwidth | Normal mode | $V_{DD} > 2.4 \text{ V}$ | 400 | 1000 | 3000 | kHz |
| | | Low power mode | | 150 | 300 | 800 | |
| | | Normal mode | $V_{DD} < 2.4 \text{ V}$ | 200 | 500 | 2200 | |
| | | Low power mode | | 70 | 150 | 800 | |
| SR | Slew rate | Normal mode | $V_{DD} > 2.4 \text{ V}$ (between 0.1 V and $V_{DD} - 0.1 \text{ V}$) | - | 700 | - | V/ms |
| | | Low power mode | $V_{DD} > 2.4 \text{ V}$ | - | 100 | - | |
| | | Normal mode | $V_{DD} < 2.4 \text{ V}$ | - | 300 | - | |
| | | Low power mode | | - | 50 | - | |
| AO | Open loop gain | Normal mode | | 55 | 100 | - | dB |
| | | Low power mode | | 65 | 110 | - | |
| R _{LOAD} | Resistive load | Normal mode | $V_{DD} < 2.4 \text{ V}$ | 4 | - | - | k Ω |
| | | Low power mode | | 20 | - | - | |
| C _{LOAD} | Capacitive load | | | - | - | 50 | pF |
| V _{OH} SAT | High saturation voltage | Normal mode | $I_{LOAD} = \text{max or}$ $R_{LOAD} = \text{min}$ | $V_{DD} - 100$ | - | - | mV |
| | | Low power mode | | $V_{DD} - 50$ | - | - | |
| V _{OL} SAT | Low saturation voltage | Normal mode | | - | - | 100 | |
| | | low power mode | | - | - | 50 | |
| ϕ_m | Phase margin | | | - | 60 | - | ° |
| GM | Gain margin | | | - | -12 | - | dB |
| t _{OFFTRIM} | Offset trim time: during calibration, minimum time needed between two steps to have 1 mV accuracy | | | - | 1 | - | ms |
| t _{WAKEUP} | Wakeup time | Normal mode | $C_{LOAD} \leq 50 \text{ pf,}$ $R_{LOAD} \geq 4 \text{ k}\Omega$ | - | 10 | - | μs |
| | | Low power mode | $C_{LOAD} \leq 50 \text{ pf,}$ $R_{LOAD} \geq 20 \text{ k}\Omega$ | - | 30 | - | |

1. Operating conditions are limited to junction temperature (0 °C to 105 °C) when V_{DD} is below 2 V. Otherwise, the operating temperature range is 105 °C to -40 °C.

2. Data based on characterization results, not tested in production.

6.3.22 Temperature sensor characteristics

Table 69. Temperature sensor characteristics

| Symbol | Parameter | Min | Typ | Max | Unit |
|-------------------------------|---|------|---------|---------|------------------------|
| $T_L^{(1)}$ | V_{SENSE} linearity with temperature | - | ± 1 | ± 2 | $^{\circ}\text{C}$ |
| Avg_Slope ⁽¹⁾ | Average slope | 1.48 | 1.61 | 1.75 | mV/ $^{\circ}\text{C}$ |
| V_{110} | Voltage at 110 $^{\circ}\text{C} \pm 5^{\circ}\text{C}^{(2)}$ | 612 | 626.8 | 641.5 | mV |
| $I_{DDA}(\text{TEMP})^{(3)}$ | Current consumption | - | 3.4 | 6 | μA |
| $t_{\text{START}}^{(3)}$ | Startup time | - | - | 10 | μs |
| $T_{\text{S_temp}}^{(4)(3)}$ | ADC sampling time when reading the temperature | 10 | - | - | |

1. Guaranteed by characterization, not tested in production.
2. Measured at $V_{DD} = 3\text{ V} \pm 10\text{ mV}$. V_{110} ADC conversion result is stored in the TSENSE_CAL2 byte.
3. Guaranteed by design, not tested in production.
4. Shortest sampling time can be determined in the application by multiple iterations.

6.3.23 Comparator

Table 70. Comparator 1 characteristics

| Symbol | Parameter | Conditions | Min ⁽¹⁾ | Typ | Max ⁽¹⁾ | Unit |
|-------------------------|--|--|--------------------|---------|--------------------|---------------|
| V_{DDA} | Analog supply voltage | | 1.65 | | 3.6 | V |
| R_{400K} | R_{400K} value | | - | 400 | - | k Ω |
| R_{10K} | R_{10K} value | | - | 10 | - | |
| V_{IN} | Comparator 1 input voltage range | | 0.6 | - | V_{DDA} | V |
| t_{START} | Comparator startup time | | - | 7 | 10 | μs |
| t_d | Propagation delay ⁽²⁾ | | - | 3 | 10 | |
| Voffset | Comparator offset | | - | ± 3 | ± 10 | mV |
| d_{Voffset}/dt | Comparator offset variation in worst voltage stress conditions | $V_{DDA} = 3.6\text{ V}$ $V_{IN+} = 0\text{ V}$ $V_{IN-} = V_{REFINT}$ $T_A = 25\text{ }^{\circ}\text{C}$ | 0 | 1.5 | 10 | mV/1000 h |
| I_{COMP1} | Current consumption ⁽³⁾ | | - | 160 | 260 | nA |

1. Based on characterization, not tested in production.
2. The delay is characterized for 100 mV input step with 10 mV overdrive on the inverting input, the non-inverting input set to the reference.
3. Comparator consumption only. Internal reference voltage not included.

Table 71. Comparator 2 characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max ⁽¹⁾ | Unit |
|--------------------------------|---|--|------|---------|--------------------|-----------------------|
| V_{DDA} | Analog supply voltage | | 1.65 | - | 3.6 | V |
| V_{IN} | Comparator 2 input voltage range | | 0 | - | V_{DDA} | V |
| t_{START} | Comparator startup time | Fast mode | - | 15 | 20 | μs |
| | | Slow mode | - | 20 | 25 | |
| $t_{d\ slow}$ | Propagation delay ⁽²⁾ in slow mode | $1.65\text{ V} \leq V_{DDA} \leq 2.7\text{ V}$ | - | 1.8 | 3.5 | |
| | | $2.7\text{ V} \leq V_{DDA} \leq 3.6\text{ V}$ | - | 2.5 | 6 | |
| $t_{d\ fast}$ | Propagation delay ⁽²⁾ in fast mode | $1.65\text{ V} \leq V_{DDA} \leq 2.7\text{ V}$ | - | 0.8 | 2 | |
| | | $2.7\text{ V} \leq V_{DDA} \leq 3.6\text{ V}$ | - | 1.2 | 4 | |
| V_{offset} | Comparator offset error | | - | ± 4 | ± 20 | mV |
| $\frac{d\text{Threshold}}{dt}$ | Threshold voltage temperature coefficient | $V_{DDA} = 3.3\text{ V}$ $T_A = 0\text{ to }50\text{ }^\circ\text{C}$ $V^- = V_{REF+}, 3/4 V_{REF+}, 1/2 V_{REF+}, 1/4 V_{REF+}$ | - | 15 | 30 | ppm/ $^\circ\text{C}$ |
| I_{COMP2} | Current consumption ⁽³⁾ | Fast mode | - | 3.5 | 5 | μA |
| | | Slow mode | - | 0.5 | 2 | |

1. Based on characterization, not tested in production.
2. The delay is characterized for 100 mV input step with 10 mV overdrive on the inverting input, the non-inverting input set to the reference.
3. Comparator consumption only. Internal reference voltage (necessary for comparator operation) is not included.

6.3.24 LCD controller (STM32L152xD only)

The STM32L152xD embeds a built-in step-up converter to provide a constant LCD reference voltage independently from the V_{DD} voltage. An external capacitor C_{ext} must be connected to the V_{LCD} pin to decouple this converter.

Table 72. LCD controller characteristics

| Symbol | Parameter | Min | Typ | Max | Unit |
|-----------------------|--|------|---------------|-----------|------------------|
| V_{LCD} | LCD external voltage | - | - | 3.6 | V |
| V_{LCD0} | LCD internal reference voltage 0 | - | 2.6 | - | |
| V_{LCD1} | LCD internal reference voltage 1 | - | 2.73 | - | |
| V_{LCD2} | LCD internal reference voltage 2 | - | 2.86 | - | |
| V_{LCD3} | LCD internal reference voltage 3 | - | 2.98 | - | |
| V_{LCD4} | LCD internal reference voltage 4 | - | 3.12 | - | |
| V_{LCD5} | LCD internal reference voltage 5 | - | 3.26 | - | |
| V_{LCD6} | LCD internal reference voltage 6 | - | 3.4 | - | |
| V_{LCD7} | LCD internal reference voltage 7 | - | 3.55 | - | |
| C_{ext} | V_{LCD} external capacitance | 0.1 | | 2 | μF |
| $I_{LCD}^{(1)}$ | Supply current at $V_{DD} = 2.2\text{ V}$ | - | 3.3 | - | μA |
| | Supply current at $V_{DD} = 3.0\text{ V}$ | - | 3.1 | - | |
| $R_{Htot}^{(2)}$ | Low drive resistive network overall value | 5.28 | 6.6 | 7.92 | $\text{M}\Omega$ |
| $R_L^{(2)}$ | High drive resistive network total value | 192 | 240 | 288 | $\text{k}\Omega$ |
| V_{44} | Segment/Common highest level voltage | - | - | V_{LCD} | V |
| V_{34} | Segment/Common 3/4 level voltage | - | $3/4 V_{LCD}$ | - | V |
| V_{23} | Segment/Common 2/3 level voltage | - | $2/3 V_{LCD}$ | - | |
| V_{12} | Segment/Common 1/2 level voltage | - | $1/2 V_{LCD}$ | - | |
| V_{13} | Segment/Common 1/3 level voltage | - | $1/3 V_{LCD}$ | - | |
| V_{14} | Segment/Common 1/4 level voltage | - | $1/4 V_{LCD}$ | - | |
| V_0 | Segment/Common lowest level voltage | 0 | - | - | |
| $\Delta V_{xx}^{(3)}$ | Segment/Common level voltage error $T_A = -40\text{ to }85\text{ }^\circ\text{C}$ | - | - | ± 50 | mV |

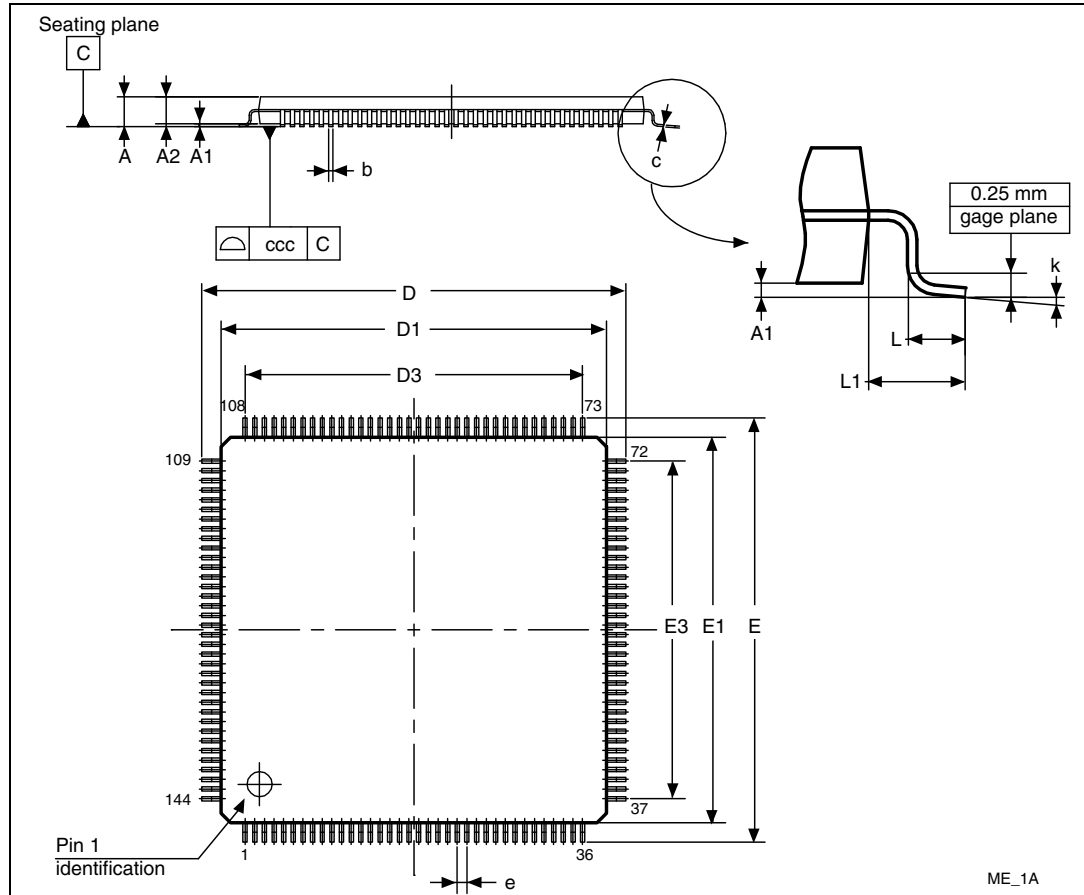
1. LCD enabled with 3 V internal step-up active, 1/8 duty, 1/4 bias, division ratio= 64, all pixels active, no LCD connected.
2. Guaranteed by design, not tested in production.
3. Based on characterization, not tested in production.

7 Package characteristics

7.1 Package mechanical data

In order 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.

Figure 41. LQFP144, 20 x 20 mm, 144-pin low-profile quad flat package outline



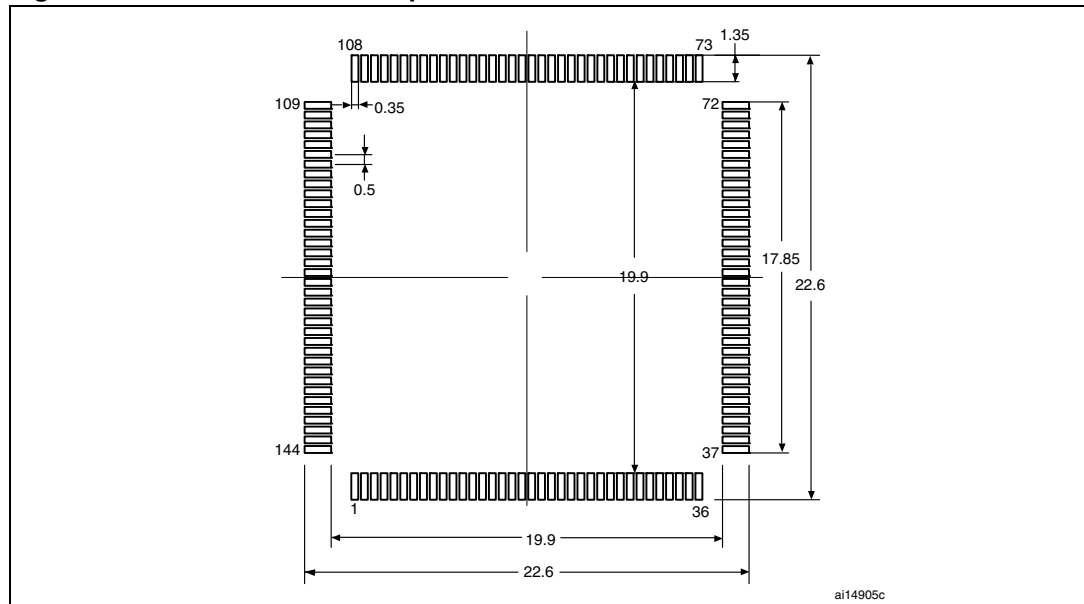
Drawing is not to scale.

Table 73. LQFP144, 20 x 20 mm, 144-pin low-profile quad flat package mechanical data

| Symbol | millimeters | | | inches ⁽¹⁾ | | |
|--------|-------------|--------|--------|-----------------------|--------|--------|
| | Min | Typ | Max | Min | Typ | Max |
| A | | | 1.600 | | | 0.0630 |
| A1 | 0.050 | | 0.150 | 0.0020 | | 0.0059 |
| A2 | 1.350 | 1.400 | 1.450 | 0.0531 | 0.0551 | 0.0571 |
| b | 0.170 | 0.220 | 0.270 | 0.0067 | 0.0087 | 0.0106 |
| c | 0.090 | | 0.200 | 0.0035 | | 0.0079 |
| D | 21.800 | 22.000 | 22.200 | 0.8583 | 0.8661 | 0.8740 |
| D1 | 19.800 | 20.000 | 20.200 | 0.7795 | 0.7874 | 0.7953 |
| D3 | | 17.500 | | | 0.6890 | |
| E | 21.800 | 22.000 | 22.200 | 0.8583 | 0.8661 | 0.8740 |
| E1 | 19.800 | 20.000 | 20.200 | 0.7795 | 0.7874 | 0.7953 |
| E3 | | 17.500 | | | 0.6890 | |
| e | | 0.500 | | | 0.0197 | |
| L | 0.450 | 0.600 | 0.750 | 0.0177 | 0.0236 | 0.0295 |
| L1 | | 1.000 | | | 0.0394 | |
| k | 0° | 3.5° | 7° | 0° | 3.5° | 7° |
| ccc | | | 0.080 | | | 0.0031 |

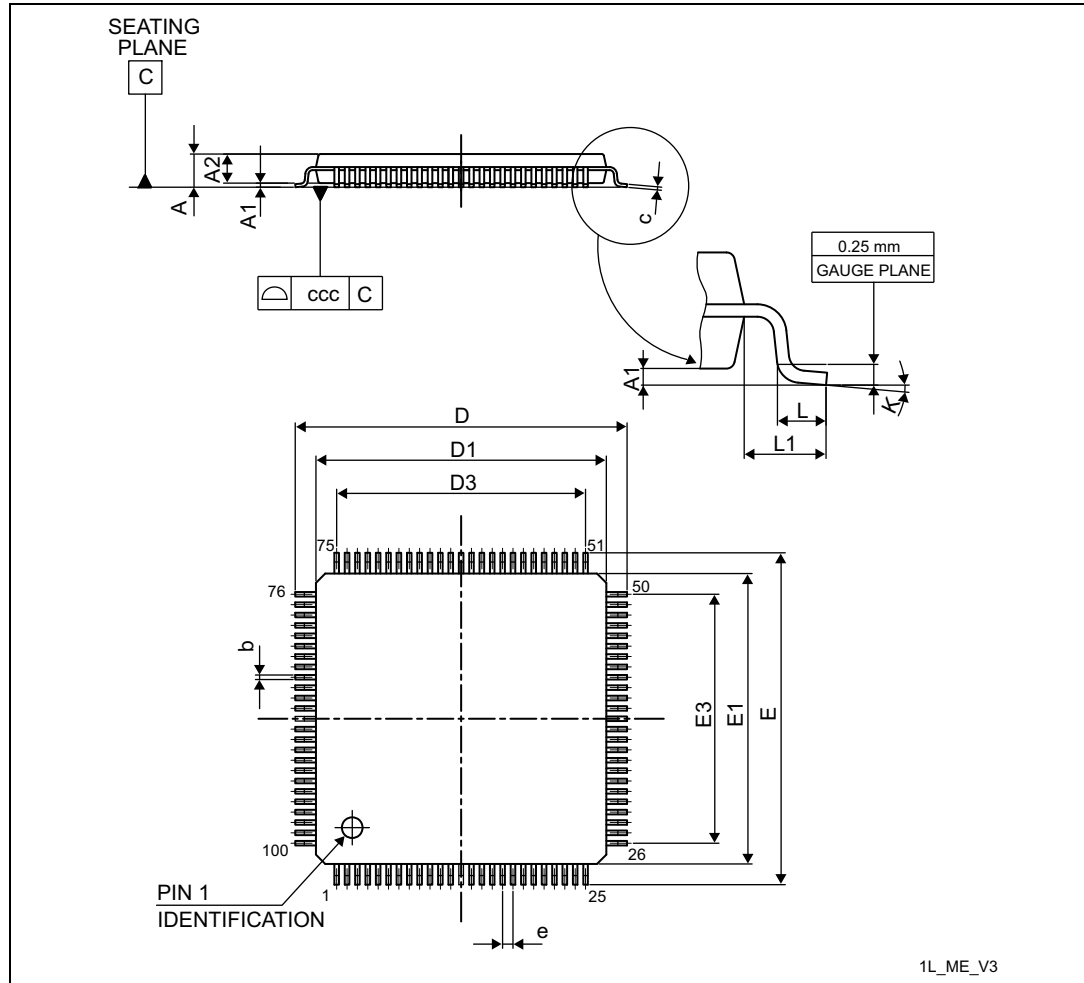
1. Values in inches are converted from mm and rounded to 4 decimal digits.

Figure 42. Recommended footprint



1. Dimensions are in millimeters.

Figure 43. LQFP100, 14 x 14 mm, 100-pin low-profile quad flat package outline



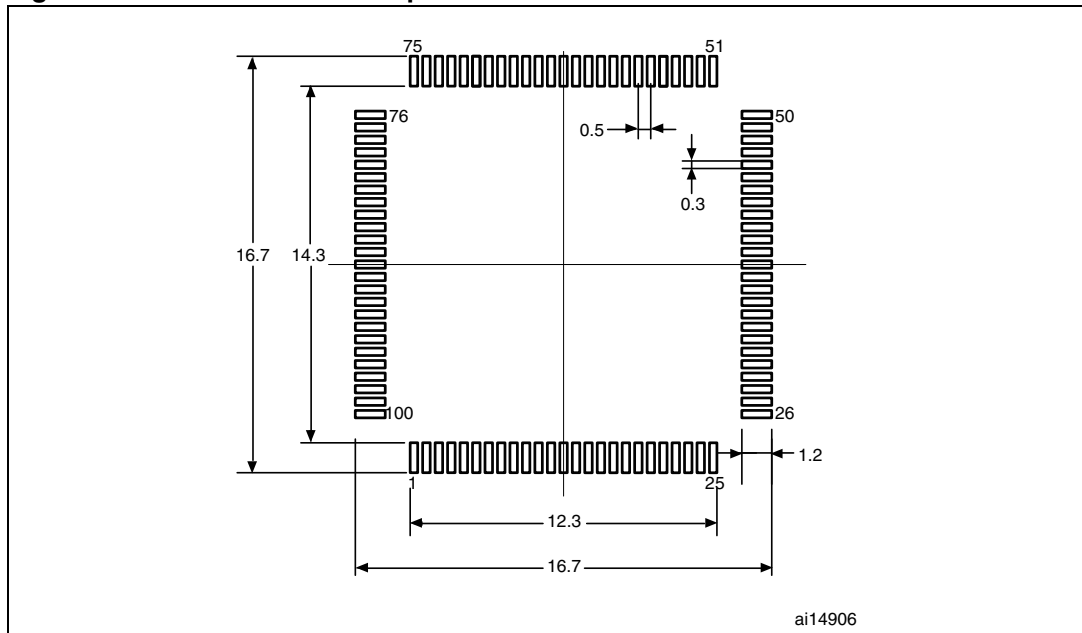
1. Drawing is not to scale.

Table 74. LQPF100, 14 x 14 mm, 100-pin low-profile quad flat package mechanical data

| Symbol | millimeters | | | inches ⁽¹⁾ | | |
|--------|-------------|--------|--------|-----------------------|--------|--------|
| | Min | Typ | Max | Min | Typ | Max |
| A | | | 1.600 | | | 0.0630 |
| A1 | 0.050 | | 0.150 | 0.0020 | | 0.0059 |
| A2 | 1.350 | 1.400 | 1.450 | 0.0531 | 0.0551 | 0.0571 |
| b | 0.170 | 0.220 | 0.270 | 0.0067 | 0.0087 | 0.0106 |
| c | 0.090 | | 0.200 | 0.0035 | | 0.0079 |
| D | 15.800 | 16.000 | 16.200 | 0.6220 | 0.6299 | 0.6378 |
| D1 | 13.800 | 14.000 | 14.200 | 0.5433 | 0.5512 | 0.5591 |
| D3 | | 12.000 | | | 0.4724 | |
| E | 15.800 | 16.000 | 16.200 | 0.6220 | 0.6299 | 0.6378 |
| E1 | 13.800 | 14.000 | 14.200 | 0.5433 | 0.5512 | 0.5591 |
| E3 | | 12.000 | | | 0.4724 | |
| e | | 0.500 | | | 0.0197 | |
| L | 0.450 | 0.600 | 0.750 | 0.0177 | 0.0236 | 0.0295 |
| L1 | | 1.000 | | | 0.0394 | |
| k | 0.0° | 3.5° | 7.0° | 0.0° | 3.5° | 7.0° |
| ccc | | | 0.080 | | | 0.0031 |

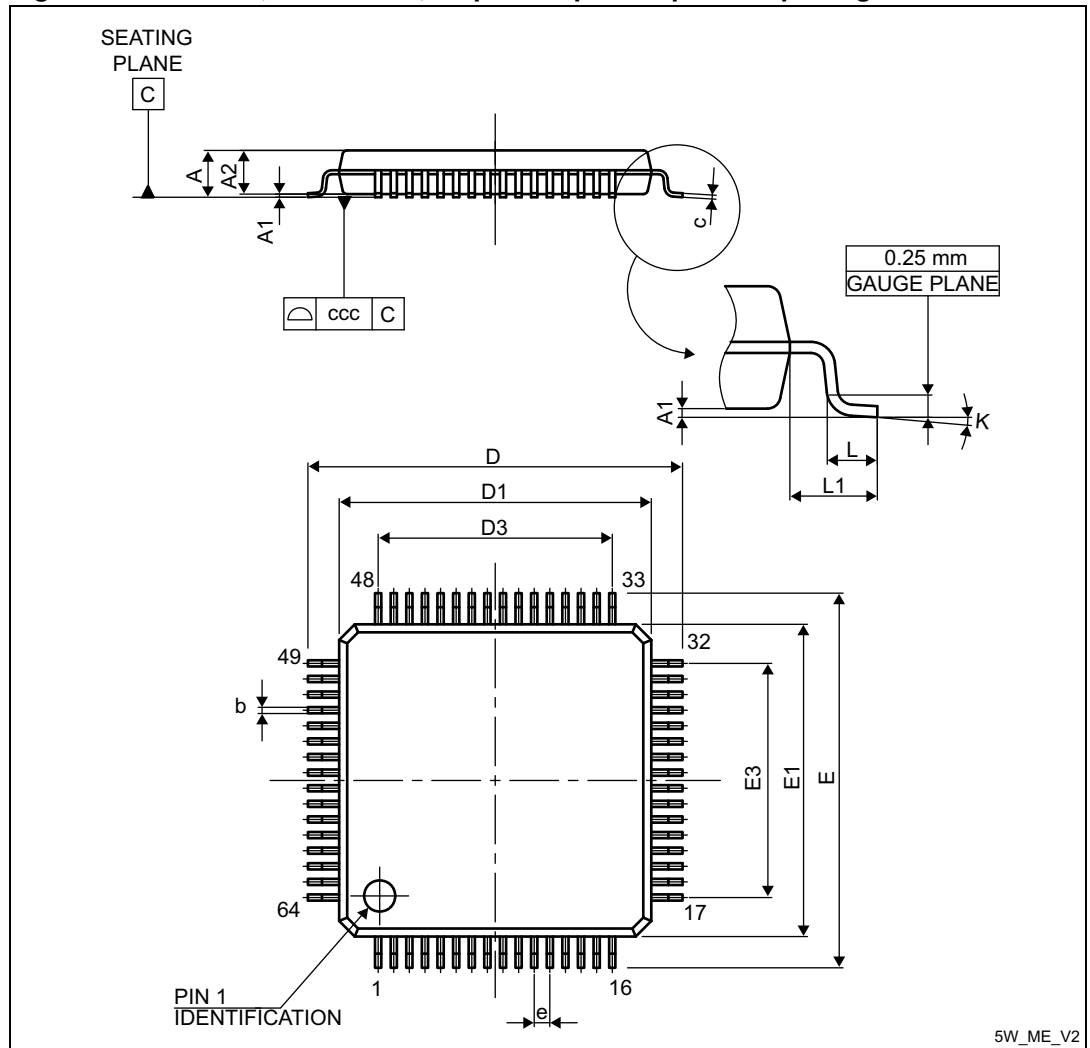
1. Values in inches are converted from mm and rounded to 4 decimal digits.

Figure 44. Recommended footprint



1. Dimensions are in millimeters.

Figure 45. LQFP64, 10 x 10 mm, 64-pin low-profile quad flat package outline



1. Drawing is not to scale.

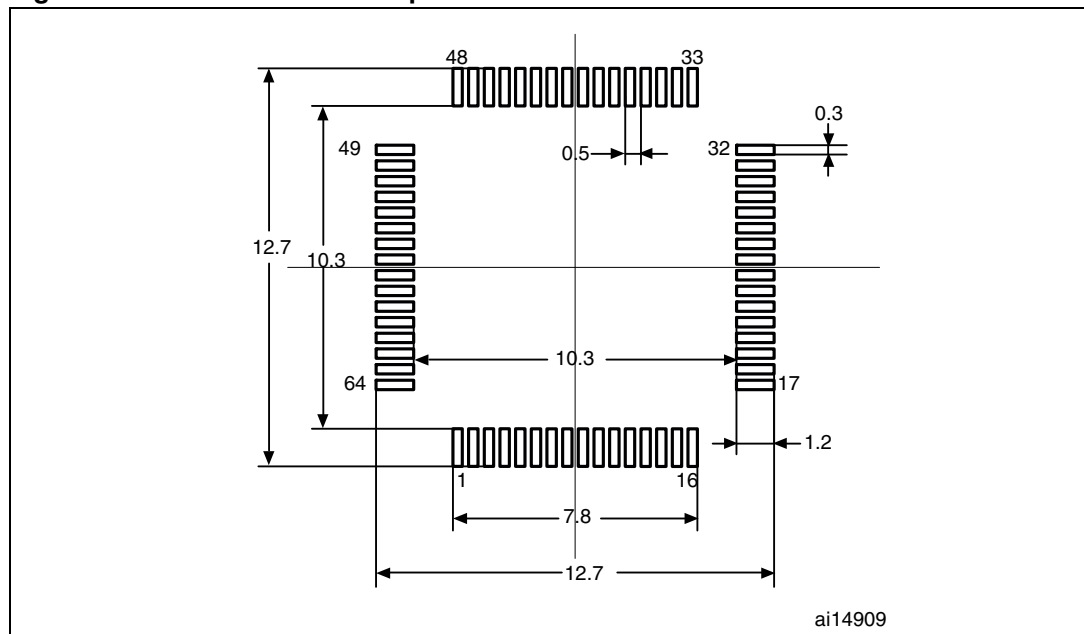
5W_ME_V2

Table 75. LQFP64, 10 x 10 mm 64-pin low-profile quad flat package mechanical data

| Symbol | millimeters | | | inches ⁽¹⁾ | | |
|--------|-------------|--------|--------|-----------------------|--------|--------|
| | Min | Typ | Max | Min | Typ | Max |
| A | | | 1.600 | | | 0.0630 |
| A1 | | 0.050 | 0.150 | | 0.0020 | 0.0059 |
| A2 | 1.400 | 1.350 | 1.450 | 0.0551 | 0.0531 | 0.0571 |
| b | 0.220 | 0.170 | 0.270 | 0.0087 | 0.0067 | 0.0106 |
| c | | 0.090 | 0.200 | | 0.0035 | 0.0079 |
| D | 12.000 | 11.800 | 12.200 | 0.4724 | 0.4646 | 0.4803 |
| D1 | 10.000 | 9.800 | 10.200 | 0.3937 | 0.3858 | 0.4016 |
| D3 | 7.500 | | | 0.2953 | | |
| E | 12.000 | 11.800 | 12.200 | 0.4724 | 0.4646 | 0.4803 |
| E1 | 10.000 | 9.800 | 10.200 | 0.3937 | 0.3858 | 0.4016 |
| E3 | 7.500 | | | 0.2953 | | |
| e | 0.500 | | | 0.0197 | | |
| L | 0.600 | 0.450 | 0.750 | 0.0236 | 0.0177 | 0.0295 |
| L1 | 1.000 | | | 0.0394 | | |
| ccc | | | 0.080 | | | 0.0031 |
| K | 3.5 | 0.0 | 7.0 | 3.5 | 0.0 | 7.0 |

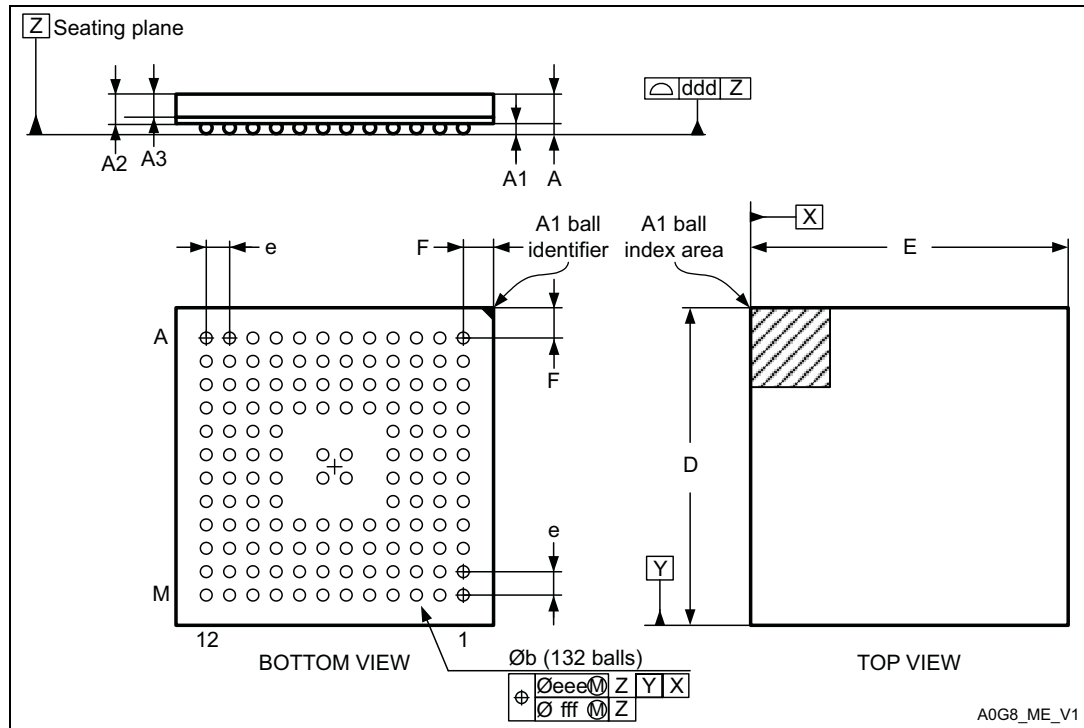
1. Values in inches are converted from mm and rounded to 4 decimal digits.

Figure 46. Recommended footprint



1. Dimensions are in millimeters.

Figure 47. UFBGA132, 7 x 7 mm, 132-ball ultra thin, fine-pitch ball grid array package outline



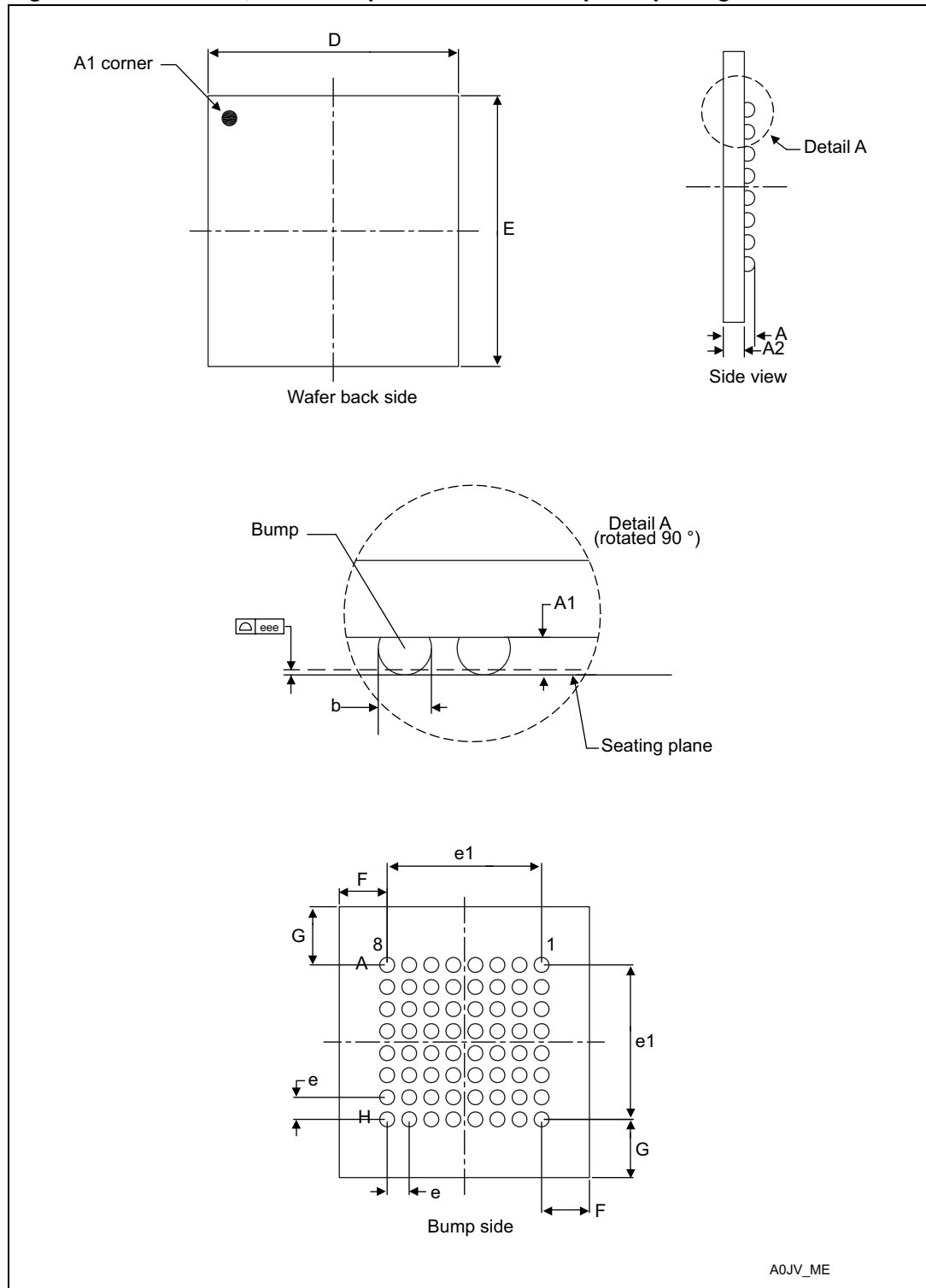
1. Drawing is not to scale.

Table 76. UFBGA132, 7 x 7 mm, 132-ball ultra thin, fine-pitch ball grid array mechanical data

| Symbol | millimeters | | | inches ⁽¹⁾ | | |
|--------|-------------|-------|-------|-----------------------|--------|--------|
| | Min | Typ | Max | Min | Typ | Max |
| A | 0.530 | 0.460 | 0.600 | 0.0209 | 0.0181 | 0.0236 |
| A1 | 0.080 | 0.050 | 0.110 | 0.0031 | 0.0020 | 0.0043 |
| A2 | 0.450 | 0.400 | 0.500 | 0.0177 | 0.0157 | 0.0197 |
| A3 | 0.320 | 0.270 | 0.370 | 0.0126 | 0.0106 | 0.0146 |
| b | 0.280 | 0.170 | 0.330 | 0.0110 | 0.0067 | 0.0130 |
| D | 7.000 | 6.950 | 7.050 | 0.2756 | 0.2736 | 0.2776 |
| E | 7.000 | 6.950 | 7.050 | 0.2756 | 0.2736 | 0.2776 |
| e | 0.500 | | | 0.0197 | | |
| F | 0.750 | 0.700 | 0.800 | 0.0295 | 0.0276 | 0.0315 |
| ddd | | | 0.080 | | | 0.0031 |
| eee | | | 0.150 | | | 0.0059 |
| fff | | | 0.050 | | | 0.0020 |

1. Values in inches are converted from mm and rounded to 4 decimal digits.

Figure 48. WLCSP64, 0.400 mm pitch wafer level chip size package outline



1. Drawing is not to scale.

Table 77. WLCSP64, 0.400 mm pitch wafer level chip size package mechanical data

| Symbol | millimeters | | | inches ⁽¹⁾ | | |
|--------|-------------|-------|-------|-----------------------|--------|--------|
| | Min | Typ | Max | Min | Typ | Max |
| A | 0.540 | 0.570 | 0.600 | 0.0205 | 0.0224 | 0.0244 |
| A1 | | 0.19 | | 0.0067 | 0.0075 | 0.0083 |
| A2 | | 0.380 | | 0.0138 | 0.0150 | 0.0161 |
| b | 0.240 | 0.270 | 0.300 | 0.0094 | 0.0106 | 0.0118 |
| D | 4.504 | 4.539 | 4.574 | 0.1779 | 0.1787 | 0.1795 |
| E | 4.876 | 4.911 | 4.946 | 0.1926 | 0.1933 | 0.1941 |
| e | | 0.400 | | | 0.0157 | |
| e1 | | 2.800 | | | 0.1102 | |
| F | | 0.870 | | | 0.0343 | |
| G | | 1.056 | | | 0.0416 | |
| eee | | | 0.050 | | | 0.0020 |

1. Values in inches are converted from mm and rounded to 4 decimal digits.

7.2 Thermal characteristics

The maximum chip-junction temperature, $T_J \text{ max}$, in degrees Celsius, may be calculated using the following equation:

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

Where:

- $T_A \text{ max}$ is the maximum ambient temperature in °C,
- Θ_{JA} is the package junction-to-ambient thermal resistance, in °C/W,
- $P_D \text{ max}$ is the sum of $P_{INT} \text{ max}$ and $P_{I/O} \text{ max}$ ($P_D \text{ max} = P_{INT} \text{ max} + P_{I/O} \text{ max}$),
- $P_{INT} \text{ max}$ is the product of I_{DD} and V_{DD} , expressed in Watts. This is the maximum chip internal power.

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

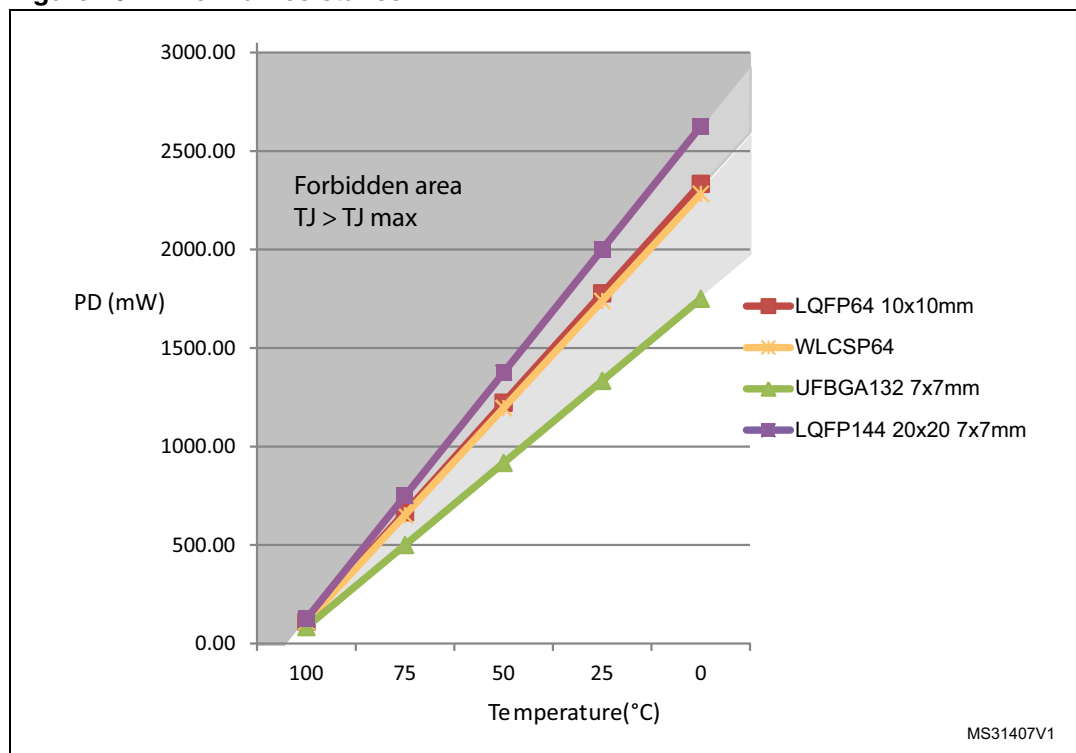
$$P_{I/O} \text{ max} = \Sigma (V_{OL} \times I_{OL}) + \Sigma ((V_{DD} - V_{OH}) \times I_{OH}),$$

taking into account the actual V_{OL} / I_{OL} and V_{OH} / I_{OH} of the I/Os at low and high level in the application.

Table 78. Thermal characteristics

| Symbol | Parameter | Value | Unit |
|---------------|---|-------|------|
| Θ_{JA} | Thermal resistance junction-ambient LQFP144 - 20 x 20 mm / 0.5 mm pitch | 40 | °C/W |
| | Thermal resistance junction-ambient UFBGA132 - 7 x 7 mm | 60 | |
| | Thermal resistance junction-ambient LQFP100 - 14 x 14 mm / 0.5 mm pitch | 43 | |
| | Thermal resistance junction-ambient LQFP64 - 10 x 10 mm / 0.5 mm pitch | 46 | |
| | Thermal resistance junction-ambient WLCSP64 - 0.400 mm pitch | 46 | |

Figure 49. Thermal resistance



7.2.1 Reference document

JESD51-2 Integrated Circuits Thermal Test Method Environment Conditions - Natural Convection (Still Air). Available from www.jedec.org.

8 Ordering information scheme

Table 79. STM32L15xxD ordering information scheme

| Example: | STM32 | L | 151 | R | C | T | 6 | D | xxx |
|---|-------|---|-----|---|---|---|---|---|-----|
| Device family STM32 = ARM-based 32-bit microcontroller | | | | | | | | | |
| Product type L = Low power | | | | | | | | | |
| Device subfamily 151: Devices without LCD 152: Devices with LCD | | | | | | | | | |
| Pin count R = 64 pins V = 100 pins Z = 144 pins Q = 132 pins | | | | | | | | | |
| Flash memory size D = 384 Kbytes of Flash memory | | | | | | | | | |
| Package H = BGA T = LQFP Y = WLCSP64 | | | | | | | | | |
| Temperature range 6 = Industrial temperature range, -40 to 85 °C | | | | | | | | | |
| Options No character = V _{DD} range: 1.8 to 3.6 V and BOR enabled D = V _{DD} range: 1.65 to 3.6 V and BOR disabled | | | | | | | | | |
| Packing TR = tape and reel No character = tray or tube | | | | | | | | | |

For a list of available options (speed, package, etc.) or for further information on any aspect of this device, please contact your nearest ST sales office.

9 Revision history

Table 80. Document revision history

| Date | Revision | Changes |
|-------------|----------|--|
| 03-Oct-2011 | 1 | Initial release. |
| 03-Feb-2012 | 2 | <p>Status of the document changed (datasheet instead of preliminary data).</p> <p>Updated low power features on page 1.</p> <p>Removed references to devices with 256 KB of Flash memory. GPIOF replaced with GIOPH.</p> <p>Added SDIO in Table 2: Ultra-low-power STM32L15xxD device features and peripheral counts on page 11 and in Table 10: Alternate function input/output on page 43 (FSMC/SDIO instead of FSMC).</p> <p>Table 2: Ultra-low-power STM32L15xxD device features and peripheral counts: replaced STM32L15xWx with STM32L15xQx.</p> <p>Figure 1: Ultra-low-power STM32L15xxD block diagram: updated legend.</p> <p>Modified Section 3.4: Clock management on page 21.</p> <p>Table 4: STM32L15xQD UFBGA132 ballout: replaced STM32L15xWC/D with STM32L15xQD.</p> <p>Figure 5, Figure 5, Figure 6: updated titles.</p> <p>Table 9: STM32L15xxD pin definitions: updated title, updated pins PF0, PF1, PH2, PF12, PF13, PF14, PF15, PG0, PG1, PG12, PG15, PD0, and PD1.</p> <p>Table 10: Alternate function input/output: Modified alternate function for PA13 and PA14; removed EVENT OUT for PH2.</p> <p>Figure 8: Memory map: removed the text “APB memory space”.</p> <p>Modified Figure 11: Power supply scheme on page 54.</p> <p>Modified Table 3: Functionalities depending on the operating power supply range on page 16.</p> <p>Table 18: Current consumption in Run mode, code with data processing running from RAM: added footnote 3.</p> <p>Table 19: Current consumption in Sleep mode: updated condition for f_{HSE}; added footnote 3.</p> <p>Table 23: Typical and maximum current consumptions in Standby mode: modified max values.</p> <p>Table 61: USB DC electrical characteristics: removed two footnotes.</p> <p>Modified Table 35: Flash memory and data EEPROM characteristics on page 82.</p> <p>Table 78: Thermal characteristics: updated “TBDs” with values.</p> <p>Modified tables in Section 6.3.4: Supply current characteristics on page 60.</p> |

Table 80. Document revision history (continued)

| Date | Revision | Changes |
|-------------|----------|---|
| 18-Apr-2012 | 3 | <p>Added WLCSP64 package.</p> <p><i>Section 3.1: Low power modes</i>: changed '128 kHz' to '131 kHz' in section "Low power run mode".</p> <p><i>Section 3.17.1: General-purpose timers (TIM2, TIM3, TIM4, TIM5, TIM9, TIM10 and TIM11)</i>: changed 'six' to 'seven' synchronizable general-purpose timers.</p> <p><i>Table 9: STM32L15xxD pin definitions on page 37</i>: updated name of reference manual in footnote 5.</p> <p>I2C updated: footnote 3. from <i>Table 55</i></p> <p>Note about I2C clock updated: footnote 2. from <i>Table 55</i> modified.</p> <p>Note [non-robust] updated: footnote 2. from <i>Table 65</i> modified.</p> <p>GPIOs high current capability updated: <i>Section 3.6: GPIOs (general-purpose inputs/outputs)</i> 'except for analog inputs' was removed.</p> |
| 15-Jun-2012 | 4 | <p>Changed maximum number of touch sensing channels to 34, and updated <i>Table 2: Ultra-low-power STM32L15xxD device features and peripheral counts</i>.</p> <p>Updated <i>Section 3.11: ADC (analog-to-digital converter)</i> to add <i>Section 3.11.1: Temperature sensor</i> and <i>Section 3.11.2: Internal voltage reference (VREFINT)</i>.</p> <p>Removed caution note below <i>Figure 11: Power supply scheme</i>.</p> <p>Added note below <i>Table 4: STM32L15xQD UFBGA132 ballout</i>.</p> <p>Modified <i>Table 7: STM32L15xRD WLCSP64 ballout</i> to match top view.</p> <p>Changed FSMC_LBAR into FSMC_NADV, and I2C1_SMBAL into I2C1_SMBA in <i>Table 9: STM32L15xxD pin definitions</i>.</p> <p>Modified PB10/11/12 for AFIO4 alternate function, and replaced LBAR by NADV for AFIO12 in <i>Table 10: Alternate function input/output</i>.</p> <p>Updated <i>Table 22: Typical and maximum current consumptions in Stop mode</i> and added <i>Note 6</i>. Updated <i>Table 23: Typical and maximum current consumptions in Standby mode</i>. Updated t_{WUSTOP} in <i>Table 24: Typical and maximum timings in Low power modes</i>.</p> <p>Updated <i>Table 25: Peripheral current consumption</i>.</p> <p>Updated <i>Table 57: SPI characteristics</i>, added <i>Note 1</i> and <i>Note 3</i>, and applied <i>Note 2</i> to $t_{r(SCK)}$, $t_{f(SCK)}$, $t_{w(SCKH)}$, $t_{w(SCKL)}$, $t_{su(MI)}$, $t_{su(SI)}$, $t_{h(MI)}$, and $t_{h(SI)}$.</p> <p>Updated I_{DD} maximum value in <i>Table 35: Flash memory and data EEPROM characteristics</i>.</p> |

Table 80. Document revision history (continued)

| Date | Revision | Changes |
|-------------|----------|---|
| 25-Oct-2012 | 5 | <p>Updated <i>Features</i></p> <p>Updated <i>Figure 1: Ultra-low-power STM32L15xxD block diagram</i></p> <p>Added <i>Table 5: Functionalities depending on the working mode (from Run/active down to standby)</i>, and <i>Table 4: CPU frequency range depending on dynamic voltage scaling</i></p> <p>Updated <i>Figure 5: STM32L15xVD LQFP100 pinout</i></p> <p>Updated <i>Table 9: STM32L15xxD pin definitions</i></p> <p>Added <i>Note 2</i> in <i>Table 15: Embedded reset and power control block characteristics</i></p> <p>Replaced TBD values in <i>Table 27: Low-speed external user clock characteristics</i>, <i>Table 35: Flash memory and data EEPROM characteristics</i> and <i>Table 52: I/O AC characteristics</i></p> <p>Added <i>Table 58: I2S characteristics</i>, <i>Figure 31: I2S slave timing diagram (Philips protocol)(1)</i> and <i>Figure 32: I2S master timing diagram (Philips protocol)(1)</i></p> <p>Added <i>Table 59: SDIO characteristics</i></p> <p>Added <i>Figure 33: SDIO timings</i></p> <p>Updated <i>Section 6.3.9: FSMC characteristics</i></p> <p>Updated <i>Table 69: Temperature sensor characteristics</i></p> <p>Added <i>Figure 49: Thermal resistance</i></p> |
| 01-Feb-2013 | 6 | <p>Removed AHB1/AHB2 and corrected typo on APB1/APB2 in <i>Figure 1: Ultra-low-power STM32L15xxD block diagram</i></p> <p>Updated "OP amp" line in <i>Table 5: Functionalities depending on the working mode (from Run/active down to standby)</i></p> <p>Added IWDG and WWDG rows in <i>Table 5: Functionalities depending on the working mode (from Run/active down to standby)</i></p> <p>Added OneNAND support in <i>Section 3.8: FSMC (flexible static memory controller)</i></p> <p>The comment "HSE = 16 MHz(2) (PLL ON for fHCLK above 16 MHz)" replaced by "fHSE = fHCLK up to 16 MHz included, fHSE = fHCLK/2 above 16 MHz (PLL ON)(2)" in table <i>Table 19: Current consumption in Sleep mode</i></p> <p>Updated Stop mode current to 1.5 µA in <i>Ultra-low-power platform</i></p> <p>Replaced BGA132 by UFBGA132 in <i>Table 2: Ultra-low-power STM32L15xxD device features and peripheral counts</i></p> <p>Replaced BGA132 by UFBGA132 in <i>Figure 4: STM32L15xQD UFBGA132 ballout</i></p> <p>Updated entire <i>Section 7: Package characteristics</i></p> |

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